TGD INSPIRED THEORY OF CONSCIOUSNESS

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0.1 Background

T(opological) G(eometro)D(ynamics) is one of the many attempts to find a unified description of basic interactions. The development of the basic ideas of TGD to a relatively stable form took time of about half decade [16]. The great challenge is to construct a mathematical theory around these physically very attractive ideas and I have devoted the last twenty-three years for the realization of this dream and this has resulted in seven online books [1, 2, 4, 5, 3, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [10, 8, 9, 13, 11, 12, 14, 15].

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness have been for last decade of the second millenium the basic three strongly interacting threads in the tapestry of quantum TGD.

For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. The work with Riemann hypothesis made time ripe for realization that the notion of infinite primes could provide, not only a reformulation, but a deep generalization of quantum TGD. This led to a thorough and extremely fruitful revision of the basic views about what the final form and physical content of quantum TGD might be.

The fifth thread came with the realization that by quantum classical correspondence TGD predicts an infinite hierarchy of macroscopic quantum systems with increasing sizes, that it is not at all clear whether standard quantum mechanics can accommodate this hierarchy, and that a dynamical quantized Planck constant might be necessary and certainly possible in TGD framework. The identification of hierarchy of Planck constants whose values TGD "predicts" in terms of dark matter hierarchy would be natural. This also led to a solution of a long standing puzzle: what is the proper interpretation of the predicted fractal hierarchy of long ranged classical electro-weak and color gauge fields. Quantum classical correspondences allows only single answer: there is infinite hierarchy of p-adically scaled up variants of standard model physics and for each of them also dark hierarchy. Thus TGD Universe would be fractal in very abstract and deep sense.

TGD forces the generalization of physics to a quantum theory of consciousness, and represent TGD as a generalized number theory vision leads naturally to the emergence of p-adic physics as physics of cognitive representations. The seven online books [1, 2, 4, 5, 3, 6, 7] about TGD and eight online books about TGD inspired theory of consciousness and of quantum biology [10, 8, 9, 13, 11, 12, 14, 15] are warmly recommended to the interested reader.

0.2 Basic Ideas of TGD

The basic physical picture behind TGD was formed as a fusion of two rather disparate approaches: namely TGD is as a Poincare invariant theory of gravitation and TGD as a generalization of the old-fashioned string model.

0.2.1 TGD as a Poincare invariant theory of gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_+ \times CP_2$, where M^4_+ denotes the interior of the future light cone of the Minkowski space (to be referred as light cone in the sequel) and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [2, 16, 18, 5]. The identification of the space-time as a submanifold [19, 21] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity [Misner-Thorne-Wheeler, Logunov *et al*]. The actual choice $H = M^4_+ \times CP_2$ implies the breaking of the Poincare invariance in the cosmological scales but only at the quantum level. It soon however turned out that submanifold geometry, being considerably richer in structure than the abstract manifold geometry, leads to a geometrization of all basic interactions. First, the geometrization of the elementary particle quantum numbers is achieved. The geometry of CP_2 explains electro-weak and color quantum numbers. The different H-chiralities of H-spinors correspond to the conserved baryon and lepton numbers. Secondly, the geometrization of the field concept results. The

projections of the CP_2 spinor connection, Killing vector fields of CP_2 and of H-metric to four-surface define classical electro-weak, color gauge fields and metric in X^4.

0.2.2 TGD as a generalization of the hadronic string model

The second approach was based on the generalization of the mesonic string model describing mesons as strings with quarks attached to the ends of the string. In the 3-dimensional generalization 3-surfaces correspond to free particles and the boundaries of the 3- surface correspond to partons in the sense that the quantum numbers of the elementary particles reside on the boundaries. Various boundary topologies (number of handles) correspond to various fermion families so that one obtains an explanation for the known elementary particle quantum numbers. This approach leads also to a natural topological description of the particle reactions as topology changes: for instance, two-particle decay corresponds to a decay of a 3-surface to two disjoint 3-surfaces.

0.2.3 Fusion of the two approaches via a generalization of the space-time concept

The problem is that the two approaches seem to be mutually exclusive since the orbit of a particle like 3-surface defines 4-dimensional surface, which differs drastically from the topologically trivial macroscopic space-time of General Relativity. The unification of these approaches forces a considerable generalization of the conventional space-time concept. First, the topologically trivial 3-space of General Relativity is replaced with a "topological condensate" containing matter as particle like 3-surfaces "glued" to the topologically trivial background 3-space by connected sum operation. Secondly, the assumption about connectedness of the 3-space is given up. Besides the "topological condensate" there is "vapor phase" that is a "gas" of particle like 3-surfaces (counterpart of the "baby universies" of GRT) and the nonconservation of energy in GRT corresponds to the transfer of energy between the topological condensate and vapor phase.

0.3 The five threads in the development of quantum TGD

The development of TGD has involved four strongly interacting threads: physics as infinite-dimensional geometry; p-adic physics; TGD inspired theory of consciousness and TGD as a generalized number theory. In the following these five threads are briefly described.

0.3.1 Quantum TGD as configuration space spinor geometry

A turning point in the attempts to formulate a mathematical theory was reached after seven years from the birth of TGD. The great insight was "Do not quantize". The basic ingredients to the new approach have served as the basic philosophy for the attempt to construct Quantum TGD since then and are the following ones:

a) Quantum theory for extended particles is free(!), classical(!) field theory for a generalized Schrödinger amplitude in the configuration space CH consisting of all possible 3-surfaces in H. "All possible" means that surfaces with arbitrary many disjoint components and with arbitrary internal topology and also singular surfaces topologically intermediate between two different manifold topologies are included. Particle reactions are identified as topology changes [23, 31, 25]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \to B + C$. Classically this corresponds to a path of configuration space leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

b) Configuration space is endowed with the metric and spinor structure so that one can define various metric related differential operators, say Dirac operator, appearing in the field equations of the theory.

0.3.2 p-Adic TGD

The p-adic thread emerged for roughly ten years ago as a dim hunch that p-adic numbers might be important for TGD. Experimentation with p-adic numbers led to the notion of canonical identification mapping reals to p-adics and vice versa. The breakthrough came with the successful p-adic mass calculations using p-adic thermodynamics for Super-Virasoro representations with the super-Kac-Moody algebra associated with a Lie-group containing standard model gauge group. Although the details of the calculations have varied from year to year, it was clear that p-adic physics reduces not only the ratio of proton and Planck mass, the great mystery number of physics, but all elementary particle mass scales, to number theory if one assumes that primes near prime powers of two are in a physically favored position. Why this is the case, became one of the key puzzless and led to a number of arguments with a common gist: evolution is present already at the elementary particle level and the primes allowed by the p-adic length scale hypothesis are the fittest ones.

It became very soon clear that p-adic topology is not something emerging in Planck length scale as often believed, but that there is an infinite hierarchy of p-adic physics characterized by p-adic length scales varying to even cosmological length scales. The idea about the connection of p-adics with cognition motivated already the first attempts to understand the role of the p-adics and inspired 'Universe as Computer' vision but time was not ripe to develop this idea to anything concrete (p-adic numbers are however in a central role in TGD inspired theory of consciousness). It became however obvious that the p-adic length scale hierarchy somehow corresponds to a hierarchy of intelligences and that p-adic prime serves as a kind of intelligence quotient. Ironically, the almost obvious idea about p-adic regions as cognitive regions of space-time providing cognitive representations for real regions had to wait for almost a decade for the access into my consciousness.

There were many interpretational and technical questions crying for a definite answer. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *The Physics*? Should one perform p-adicization also at the level of the configuration space of 3-surfaces? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question.

Despite these frustrating uncertainties, the number of the applications of the poorly defined p-adic physics growed steadily and the applications turned out to be relatively stable so that it was clear that the solution to these problems must exist. It became only gradually clear that the solution of the problems might require going down to a deeper level than that represented by reals and p-adics.

0.3.3 TGD as a generalization of physics to a theory consciousness

General coordinate invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [10, 8, 9, 13, 11, 12, 14, 15].

Quantum jump as a moment of consciousness

The identification of quantum jump between deterministic quantum histories (configuration space spinor fields) as a moment of consciousness defines microscopic theory of consciousness. Quantum jump involves the steps

$$\Psi_i \to U\Psi_i \to \Psi_f \quad ,$$

where U is informational "time development" operator, which is unitary like the S-matrix characterizing the unitary time evolution of quantum mechanics. U is however only formally analogous to Schrödinger time evolution of infinite duration although there is *no* real time evolution involved. It is not however clear whether one should regard U-matrix and S-matrix as two different things or not: U-matrix is a completely universal object characterizing the dynamics of evolution by self-organization whereas S-matrix is a highly context dependent concept in wave mechanics and in quantum field theories where it at least formally represents unitary time translation operator at the limit of an infinitely long interaction time. The S-matrix understood in the spirit of superstring models is however something very different and could correspond to U-matrix.

The requirement that quantum jump corresponds to a measurement in the sense of quantum field theories implies that each quantum jump involves localization in zero modes which parameterize also the possible choices of the quantization axes. Thus the selection of the quantization axes performed by the Cartesian outsider becomes now a part of quantum theory. Together these requirements imply that the final states of quantum jump correspond to quantum superpositions of space-time surfaces which are macroscopically equivalent. Hence the world of conscious experience looks classical. At least formally quantum jump can be interpreted also as a quantum computation in which matrix U represents unitary quantum computation which is however not identifiable as unitary translation in time direction and cannot be 'engineered'.

The notion of self

The concept of self is absolutely essential for the understanding of the macroscopic and macro-temporal aspects of consciousness. Self corresponds to a subsystem able to remain un-entangled under the sequential informational 'time evolutions' U. Exactly vanishing entanglement is practically impossible in ordinary quantum mechanics and it might be that 'vanishing entanglement' in the condition for self-property should be replaced with 'subcritical entanglement'. On the other hand, if space-time decomposes into p-adic and real regions, and if entanglement between regions representing physics in different number fields vanishes, space-time indeed decomposes into selves in a natural manner.

It is assumed that the experiences of the self after the last 'wake-up' sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-subselves S_{ij}. Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

Relationship to quantum measurement theory

The third basic element relates TGD inspired theory of consciousness to quantum measurement theory. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

a) The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of configuration space spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

b) Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to a fundamental quantum theory. This reduction is implied by the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. Therefore the reduction is a triumph for quantum TGD and favors TGD against string models.

Standard quantum measurement theory involves also the notion of state preparation which reduces to the notion of self measurement. Each localization in zero modes is followed by a cascade of self measurements leading to a product state. This process is obviously equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given self localized in zero modes (after ordinary quantum measurement) is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement. In p-adic context NMP can be regarded as the variational principle defining the dynamics of cognition. In real context self measurement could be seen as a repair mechanism allowing the system to fight against quantum thermalization by reducing the entanglement for the subsystem for which it is largest (fill the largest hole first in a leaking boat).

Selves self-organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [I1]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

Dissipation can be regarded as the ultimate Darwinian selector of both memes and genes. The mathematically ugly irreversible dissipative dynamics obtained by adding phenomenological dissipation terms to the reversible fundamental dynamical equations derivable from an action principle can be understood as a phenomenological description replacing in a well defined sense the series of reversible quantum histories with its envelope.

Classical non-determinism of Kähler action

The fifth basic element are the concepts of association sequence and cognitive space-time sheet. The huge vacuum degeneracy of the Kähler action suggests strongly that the absolute minimum space-time is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as

volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration and psychological time can be identified as a temporal center of mass coordinate of the cognitive space-time sheet. The gradual drift of the cognitive space-time sheets to the direction of future force by the geometry of the future light cone explains the arrow of psychological time.

p-Adic physics as physics of cognition and intentionality

The sixth basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [E1]. The application this notion at the level of the imbedding space implies that imbedding space has a book like structure with various variants of the imbedding space glued together along common rationals (algebraics). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real imbedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

This view implies also that purely local p-adic physics codes for the p-adic fractality characterizing long range real physics and provides an explanation for p-adic length scale hypothesis stating that the primes $p \simeq 2^k$, k integer are especially interesting. It also explains the long range correlations and short term chaos characterizing intentional behavior and explains why the physical realizations of cognition are always discrete (say in the case of numerical computations). Furthermore, a concrete quantum model for how intentions are transformed to actions emerges.

The discrete real projections of p-adic space-time sheets serve also space-time correlate for a logical thought. It is very natural to assign to p-adic pinary digits a p-valued logic but as such this kind of logic does not have any reasonable identification. p-Adic length scale hypothesis suggest that the $p = 2^k - n$ pinary digits represent a Boolean logic B^k with k elementary statements (the points of the k-element set in the set theoretic realization) with n taboos which are constrained to be identically true.

0.3.4 TGD as a generalized number theory

Quantum T(opological)D(ynamics) as a classical spinor geometry for infinite-dimensional configuration space, p-adic numbers and quantum TGD, and TGD inspired theory of consciousness, have been for last ten years the basic three strongly interacting threads in the tapestry of quantum TGD. For few yeas ago the discussions with Tony Smith generated a fourth thread which deserves the name 'TGD as a generalized number theory'. It relies on the notion of number theoretic compactifiction stating that space-time surfaces can be regarded either as hyper-quaternionic, and thus maximally associative, 4-surfaces in M^8 identifiable as space of hyper-octonions or as surfaces in $M^4 \times CP_2$ [E2].

The discovery of the hierarchy of infinite primes and their correspondence with a hierarchy defined by a repeatedly second quantized arithmetic quantum field theory gave a further boost for the speculations about TGD as a generalized number theory. The work with Riemann hypothesis led to further ideas.

After the realization that infinite primes can be mapped to polynomials representable as surfaces geometrically, it was clear how TGD might be formulated as a generalized number theory with infinite

primes forming the bridge between classical and quantum such that real numbers, p-adic numbers, and various generalizations of p-adics emerge dynamically from algebraic physics as various completions of the algebraic extensions of rational (hyper-)quaternions and (hyper-)octonions. Complete algebraic, topological and dimensional democracy would characterize the theory.

What is especially satisfying is that p-adic and real regions of the space-time surface could emerge automatically as solutions of the field equations. In the space-time regions where the solutions of field equations give rise to in-admissible complex values of the imbedding space coordinates, p-adic solution can exist for some values of the p-adic prime. The characteristic non-determinism of the p-adic differential equations suggests strongly that p-adic regions correspond to 'mind stuff', the regions of space-time where cognitive representations reside. This interpretation implies that p-adic physics is physics of cognition. Since Nature is probably extremely brilliant simulator of Nature, the natural idea is to study the p-adic physics of the cognitive representations to derive information about the real physics. This view encouraged by TGD inspired theory of consciousness clarifies difficult interpretational issues and provides a clear interpretation for the predictions of p-adic physics.

0.3.5 Dynamical quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electroweak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale [31] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [D6].

Already before learning about Nottale's paper I had proposed the possibility that Planck constant is quantized [E9] and the spectrum is given in terms of logarithms of Beraha numbers: the lowest Beraha number B_3 is completely exceptional in that it predicts infinite value of Planck constant. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character and at the transition $n = 4 \to 3$ only the small perturbative correction to $1/\hbar(3) = 0$ remains. This would apply to QCD and to atoms with $Z > 137$ as well.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes. Also a model for the formation of planetary system as a condensation of ordinary matter around quantum coherent dark matter emerges [D6].

Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

a) Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

b) The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [M3].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy and number theoretical arguments suggest a general formula for the allowed values of Planck constant λ depending logarithmically on p-adic prime [C7]. Also the value of $\hbar_0$ has spectrum characterized by Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$, varying by a factor in the range $n > 3$ [C7]. It must be however emphasized that the relation of this picture to the model of quantized gravitational Planck constant h_{gr} appearing in Nottale's model is not yet completely understood.

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass

degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

3. The time span of long term memories as signature for the level of dark matter hierarchy

The simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4\ CP_2$ times so that $2^{127} - 1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k = 127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness [L1]. A more refined guess is that $\tau_p = \sqrt{p}\tau$ gives the dependence of the duration of quantum jump on p-adic prime p. By multi-p-fractality predicted by TGD and explaining p-adic length scale hypothesis, one expects that at least $p = 2$-adic level is also always present. For the higher levels of dark matter hierarchy τ_p is scaled up by $\hbar/\hbar_0$. One can understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ [L2].

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

0.4 Bird's eye of view about the topics of the book

This book tries to give an overall view about TGD inspired theory of consciousness as it stands now. In nutshell TGD based view about consciousness relies following ideas and concepts.

1. The basic notions TGD inspired theory of consciousness are quantum jump identified as a moment of consciousness, self identified as sequence of quantum jumps analogous to bound state of particles, self hierarchy with sub-selves experienced by self as mental images, and sharing and fusion of mental images by quantum entanglement.

2. Dark matter hierarchy, the levels of which are labeled by increasing quantized value of Planck constant, suggests that the geometric durations for the moments of consciousness form defined as the scale of the space-time volume from which conscious experience is about, form an increasing hierarchy so that the highest level associated with a given self would correspond to single moment of consciousness. This would actually eliminate the notion of self and self hierarchy would correspond to a fractal hierarchy of quantum jumps.

3. The anatomy of quantum jumps must be consistent with the notions of state preparation, state function reduction, and unitary evolution and this leads to a detailed view what quantum jump means for quantum states of the Universe identified as classical spinor fields in configuration space, the "world of classical worlds". The zero modes of the configuration space geometry which do not contribute to its metric and thus do not quantum fluctuate, correspond to classical observables. A direct connection with quantum measurement theory emerges.

4. Negentropy Maximization Principle (NMP) defines the basic variational principle of TGD inspired theory of consciousness. NMP states that the negentropy gain in quantum jump is maximal. The allowance of a number theoretic variant of Shannon entropy making sense for rational or algebraic entanglement probabilities implies that quantum jump can also generate or increase the amount of entanglement. A possible interpretation is in terms of bound state entanglement to which conscious information can be assigned.

5. A natural characterization of the fundamental qualia is in terms of quantum number increments associated with the quantum jump. The classical non-determinism of Kähler action (in the usual sense of the world) means that the contents of the conscious experience of a given self comes from a 4-dimensional space-time region rather than representing 3-D snapshot of space-time. This together with the new view about energy and time (negative energies and communications to the geometric past are predicted) leads to a new vision about memory, intentional action, and also metabolism.

6. p-Adic physics as physics of cognition and intentionality is a genuinely new element as compared to the existing theories of consciousness and forces to give up the view that cognition is localized in the sense of real physics. Indeed, p-adic space-time sheets representing intentions have literally infinite size since most p-adic integers, in particular those which are infinitesimally small, have infinitely large as real numbers. Cognition would quite literally see the real cosmos from outside. The transformations of p-adic space-time sheets to real ones in quantum jump define an attractive view about what happens when intention transforms to an action and is consistent with TGD based view about energy (also negative inertial energies are possible and the density of inertial energy vanishes in cosmological length scales). The discrete rational projection of p-adic space-time sheets to the real imbedding space is excellent candidate for the realization of cognitive representations at the level of space-time since p-adic numbers define very naturally a generalization of binary logic and for primes satisfying p-adic length scale hypothesis the resulting logic has also Boolean interpretation as a logic in which certain number of statements are taboos so that the number of allowed statements is reduced from 2^k to $p = 2^k - n$.

7. The new view about the relationship between experienced and geometric time inspires a general model of memory, intentional action, and metabolism. In this model time mirror mechanism meaning communications with geometric past using negative energy (phase conjugate photons) is in central role. Also time-like entanglement plays a key role in the model of memories. A precise conceptualization for this vision is provided by zero energy ontology in which M-matrix

generalizes S-matrix. M-matrix is identifiable as the "square" root of density matrix defines time like entanglement coefficients between positive and negative energy parts of the zero energy state located at past and future boundaries of the causal diamond defined by the intersection of future and past directed light-cones.

The topics of the book are organized in the following manner.

1. In the first part of the book TGD inspired theory of consciousness is discussed at general level. There are three summarizing chapters give a view about how ideas have evolved. Besides this there are chapters devoted to Negentropy Maximization Principle, to a detailed exposition of the notion of self, and to a model of sensory representations.

2. The second part of the book contains two chapters about the relationship between experienced and geometric time. The first one is more than decade old. The second one - inspired by zero energy ontology and written quite recently - provides a rather detailed vision about how the arrow of geometric time correlating with the arrow of experienced time and the localization of the contents of sensory experience to a narrow time interval emerge. The chapter explaining TGD based view about long term memory is also included.

3. The third part of the book summarizes roughly decade old view about intelligence and cognition. p-Adic physics as physics of cognition and intentionality and many-fermion states as representations of Boolean statements are the key notions. In zero energy ontology also quantal versions of logical rules $A \to B$ realized as quantum variants of Boolean functions emerge at the fundamental level. A chapter about the role of dark matter hierarchy, in particular about topological quantum computation as a universal information processing tool, would be needed to make the picture more complete.

4. The fourth chapter is devoted to remote mental interactions. The theoretical motivation for taking remote mental interactions seriously is that exactly the same mechanisms which are involved with the interaction between magnetic body and biological body apply also to remote mental interactions in TGD Universe. One could also understand why these phenomena are rare: a kind of immune system making it impossible for foreign magnetic bodies to control and communicate with the biological body possessed by a particular magnetic body would be a highly probable (but perhaps not unavoidable) outcome of evolutionary process.

The seven online books about TGD [1, 2, 4, 5, 3, 6, 7] and eight online books about TGD inspired theory of consciousness and quantum biology [10, 8, 9, 13, 11, 12, 14, 15] are warmly recommended for the reader willing to get overall view about what is involved.

0.5 The contents of the book

0.5.1 Part I: Basic ideas of TGD inspired theory of consciousness

TGD inspired quantum theory of consciousness and of biosystems: an overall view

Matter, Mind, Quantum

The chapter is devoted to the TGD inspired theory of consciousness, which can be also regarded as a generalization of quantum measurement theory. The basic elements of the theory are following.

1. Physical realities correspond to quantum histories, configuration space spinor fields, which can be regarded as generalized Schrödinger amplitudes in the world of classical worlds identified as space-time surfaces. The quantum jump between deterministic quantum histories is identified as a moment of consciousness. Quantum jump begins with the step $\Psi_i \to U\Psi_i$, where U is informational "time development" operator defining S-matrix. There is actually no real time development involved. The requirement that quantum jump involves a state function reduction in the sense of quantum field theories implies that the unitary time development is followed by a localization in zero modes: $U\Psi_i \to \Psi_{f_0}$. Hence Ψ_{f_0} corresponds to a quantum superposition of space-time surfaces which are perceptively equivalent, and the world of conscious experience looks classical in space-time degrees of freedom.

The localization in zero modes is followed by a cascade of self measurements $\Psi_{f_0} \to ....\Psi_f$ leading to a minimimally entangled product state: this sequence affects the state only in quantum fluctuating degrees of freedom. Only bound state entanglement is stable against self measurements. This process is equivalent with the state preparation process. Self measurement is governed by the so called Negentropy Maximization Principle (NMP) stating that the information content of conscious experience is maximized. In the self measurement the density matrix of some subsystem of a given su-bsystem is measured. The self measurement takes place for that subsystem of self for which the reduction of the entanglement entropy is maximal in the measurement.

Also p-adic-real (or cognitive) entanglement makes sense if entanglement coefficients are algebraic numbers. In this case a number theoretical definition of the entanglement entropy is possible. The number-theoretical entanglement entropy can be also negative, and in this case self measurement cannot reduce entanglement. A very attractive identification for the cognitive entanglement with positive entanglement negentropy is as a correlate for the experience of understanding.

2. The concept of self is absolutely essential for the understanding of the macroscopic aspects of consciousness. Self corresponds to a subsystem able to not generate bound state entanglement during quantum jumps. It is assumed that the experiences of the self after the last 'wake-up' sum to single average experience. This means subjective memory identifiable as a conscious short term memory. Selves form infinite hierarchy with entire Universe, God, at the top.

   A natural hypothesis is that self X experiences the experiences of its subselves as kind of abstracted experience: the experiences of subselves X_i are not experienced as such but represent kind of averages $\langle X_{ij} \rangle$ of sub-subselves X_{ij}. Entanglement between selves, most naturally realized by the formation of join along boundaries bonds between the space-time sheets, provides a mechanism building wholes from parts at the level of mental images represented by subselves. The fusion of mental images gives rise to what might be called stereo consciousness (stereo vision is the basic example of this). The notion of sub-system motivated by the many-sheeted space-time concept allows the sub-selves of un-entangled selves to entangle. This makes possible fusion and telepathic sharing of mental images. Self can be regarded as a statistical ensemble consisting of quantum jumps and various qualia are identified as statistical averages for the increments of quantum numbers and zero modes over the sequence of the quantum jumps defining self.

3. The quantum theory of self-organization is based on the identification of quantum jump as the basic iterative step of self-organization. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of slaving hierarchy. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. The possibility of the reversal of the arrow of geometric time (negative energy space-time sheets) below p-adic time scales means that the second law of thermodynamics is broken below p-adic time scale with respect to the geometric time although it still holds true with respect to subjective time. There are good reasons to expect that the temporal reversal of the arrow of geometric time in various p-adic time scales is a crucial element in the function of living matter and identifiable as a universal healing mechanism.

4. p-Adic physics provides the physics cognition and intentionality. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic space-time regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by glueing together regions for which integration constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. p-Adic spacetime sheets are also correlates of intentionality and the transformation of p-adic space-time sheet to a real one in the quantum jump has interpretation as a transformation of intention to action. The freedom of imagination is basically due to the p-adic non-determinism. p-Adic regions perform mimicry

and make possible for the Universe to form cognitive representations about itself. Real resp. p-adic space-time sheets are interpreted as symbolic resp. cognitive space-time correlates for conscious experience.

5. Quantum-classical correspondence is absolutely essential for the interpretation of the theory and understanding of how psychological time emerges. The classical non-determinism of Kähler action makes it possible to interpret space-time surfaces as symbolic representations for the contents of consciousness (not faithful). In particlar, the concepts of association sequence and mindlike space-time sheet are made possible by the classical non-determinism. Association sequences relate closely with the mindlike space-time sheets defined as space-time sheets having finite time duration and psychological time can be identified as a temporal center of mass coordinate of the mindlike space-time sheet. The gradual drift of the mindlike space-time sheets to the direction of future force by the geometry of the future lightcone explains the arrow of psychological time. Simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4\ CP_2$ times so that $2^{127} - 1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k = 127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness. Psychological time can be also interpreted as a temporal coordinate for the front of a p-adic-to-real phase transition proceeding to the direction of the geometric future and representing the transformation of intentions to actions.

6. The new view about space-time is crucial for the understanding of brain consciousness. Biosystems are identified as macroscopic quantum systems and the quantum criticality of TGD Universe predicts the existence of quantum systems in all length scales and fractality. The notion of many-sheeted space-time provides several mechanisms making bio-systems macroscopic quantum systems. The generation of bound state entanglement makes possible macrotemporal quantum coherence implying that decoherence time increases from CP_2 time to a macrotemporal time interval. An essential prequisite of the macrotemporal quantum coherence is the quantum spin glass degeneracy of TGD Universe and classical gravitation is essentially involved with the mechanism. Macrotemporal quantum coherence implies a genuine breaking of the second law of thermodynamics since dissipation is effectively absent in quantum coherent degrees of freedom, and processes analogous to quantum computation become possible in the time scales relevant to human consciousness. From the point of view of consciousness this means that a sequence of moments of consciousness effectively integrates to a single moment of consciousness of macrotemporal duration, and that various qualia defined as subjectotemporal averages for the increments of quantum numbers and zero modes stay sharp.

   Topological field quantization forces to assign to any material system also a field body, in particular magnetic and Z^0 magnetic bodies. The notion of the magnetic body plays a pivotal role in the understanding of how sensory representations, long term memories, and motor actions are realized. Living organisms become in TGD Universe essentially objects of astrophysical size.

   The fractal hierarchy of massless extremals (MEs) represents genuinely quantum gravitational states at a more abstract level of existence than ordinary quantum states. MEs interacting with fractal hierarchy of magnetic flux tube structures in many-sheeted ionic flow equilibrium with ordinary bio-matter at the atomic space-time sheets provide the hardware of bio-consciousness. The sign of energy depends in TGD Universe on the time orientation of the space-time sheet. Negative energy MEs serve as space-time correlates for bound state entanglement, and allow to understand an amazing variety of phenomena related to consciousness and biocontrol. The models of long term memory, sensory experience, and motor actions rely crucially on negative energy MEs serving as quantum entanglers and positive energy MEs serving as tools of precisely targeted classical communications.

Negentropy Maximization Principle

In TGD Universe the moments of consciousness are associated with quantum jumps between quantum histories. The localization in zero modes guarantees that the world of conscious experience looks classical. Together with the assumption that the unitary operator U acts effectively as a flow in zero modes, this implies standard quantum measurement theory with zero modes playing the role of

macroscopic effectively classical variables and quantum fluctuating degrees of freedom correspond to quantum degrees of freedom. Contrary to original belief there is however no need to assume that this localization occurs in each quantum jump and might also be governed by Negentropy Maximization Principle, whose formulation is the basic topic of this chapter.

The localization in zero modes (state function reduction) is assumed be followed by a sequence of self measurements in quantum fluctuating degrees of freedom. Self measurement is repeated again and again and eventually leads to a product state: only bound state entanglement is stable against this process. Obviously the process is equivalent with state preparation. Negentropy Maximization Principle provides the dynamical law governing state preparation and, as is has turned out, also state function reduction.

1. Consider a given unentangled system S. The basic assumption is that the density matrix of the subsystem of S, or equivalently, of its complement, is the fundamental observable measured in self measurement. NMP applies separately inside each system of this kind and states that for given system the quantum measurement occurs for that subsystem-complement pair for which the reduction of the entanglement entropy in self measurement is largest.

2. The original belief was that self measurement leads to an un-entangled state. It is however possible to assign a negative entanglement entropy to an entanglement characterized by entanglement probabilities in finite extension of rationals. Thus NMP allows also a reduction to this kind of state. The natural interpretation of this kind of state is as a bound state. The density matrix must be unit matrix for the outcome if one requires that a measurement of density matrix is in question.

There are important technicalities involved with the formulation of NMP.

1. The definition of sub-system concept remains a highly nontrivial challenge for TGD. The reason is the classical non-determinism of Kähler action. A 3-surface acting as a causal determinant of Kähler action is the most general definition of the sub-system at space-time level. Causal determinants can can be light like surfaces $X_l^3 \subset H$ (elementary particle horizons) or space-like 3-surfaces inside light like 7-surfaces $X_l^3 \times CP_2 \subset M_+^4 \times CP_2$ analogous to the boundary $\delta M_+^4 \times CP_2$ of H. The reason is that these surface act as quantum holograms and representations of super-canonical and quaternion conformal algebras.

2. The many-sheeted space-time concept forces to modify the naive definition of subsystem as a tensor factor: two un-entangled systems can have sub-systems, which are entangled. The length scale dependent notion of subsystem allows to see this kind of entanglement as an entanglement invisible in the length scale resolution of the un-entangled systems.

3. Concerning the precise definition of negentropy there are three cases to be discussed.
   i) In the situation in which entanglement probabilities reduce to a finite extension of rationals (discrete number field) a purely number theoretic definition of the entanglement entropy is possible using a p-adic variant of logarithm with argument replaced by its p-adic norm. Entanglement entropy can be defined as the maximally negative entanglement entropy S_p resulting in this manner: this assigns a unique p-adic prime p to the entanglement. The resulting real-valued entanglement entropy is negative and the entanglement is stable against self measurements and NMP. This negentropic entanglement could be identified as a correlate for the experience of understanding.
   ii) In the second case entanglement probabilities are genuinely real or p-adic numbers. For real entanglement Shannon entropy works. The modification of p-based logarithm preserving the additivity of negentropy allows to define in p-adic case a p-adic valued entanglement entropy, which can be mapped to a non-negative real number by canonical identification.

4. The highly non-trivial observation is that the entanglement between systems belonging to different number fields is possible provided the states are orthonormalized. Furthermore, entanglement coefficients can belong to any number field. This means that the character of entanglement does not depend at all on the character of the entangled systems and is thus a typical category theoretic notion (relationship or "arrow" in the slang of category theory).

These findings lead to the idea state function reduction and preparation are number theoretic necessities. Unitary process U creates a formal superposition of states with entanglements in various number fields. State function reduction and preparation realized as a sequence of self measurements reduce the entanglement to a finitely extended rational entanglement interpreted as an information carrying bound state entanglement. Quantum jump can therefore be regarded as an elementary act of cognition in which unitary process is followed by analysis yielding as an outcome bound state entanglement giving rise to an experience of understanding. State function reduction and preparation can also occur in quantum parallel manner in various scales. This view modifies dramatically the interpretation of what de-coherence means. De-coherence removes only the entropic non-bound entanglement and preserves and even generates bound state entanglement. This obviously forces totally new view about second law of thermodynamics.

There are good reasons to expect that finitely extended rational entanglement is a basic characteristic of living and intelligent systems and crucial for the understanding of the information theoretic aspects of life. Negentropic bound state entanglement due to the quantum spin glass degeneracy provides mechanisms of macro-temporal quantum coherence making possible quantum computation type processes. The possibility of quantum parallel dissipation also forces to generalize quantum computation paradigm so that quantum parallel classical computations become possible.

Self and Binding

The quantum notion of self solved some long standing problems of TGD inspired theory of consciousness and led to a breakthrough in quantum theory of consciousness. Self is identified as a sub-system able to not generate bound state entanglement during quantum jumps. Generation of bound state entanglement leads to a loss of consciousness.

Subjective memory is assumed to correspond to an average of conscious experiences of quantum jumps occurred after the last wake-up of self. This leads to the identification of qualia as averages of the increments of quantum numbers and zero modes in the ensemble of quantum jumps defining self. Summation hypothesis states that self X experiences the experiences of its subselves as abstracted experiences, averages X_{ij} about sub-subselves X_{ij}. Subselves of un-entangled selves can entangle (this is due to the many-sheeted sub-system concept) and this allows fusion and sharing of mental images.

Selves are called irreducible if they possess no subselves, otherwise reducible. Subselves correspond to mental images so that irreducible subselves possess no mental images and are in a state of pure self-awareness: it is not clear whether this kind of states are possible in practice. When the subselves of self fuse to single subself, a state of "one-ness" results. This mode of consciousness can be identified as "whole-body" consciousness and differs from ordinary consciousness during which self has large number of mental images. These modes could naturally explain emotional/holistic and rational modes of mind. These two modes could make it possible to understand various dichotomies like brain/left brain, emotional/analytic, religous/rational, Eastern/Western,...

One could understand linear cognitive processes like thinking and language as self cascades in which self decomposes into subselves, which in turn decompose into subselves, which ... and self hierarchy implies connection with computationalism. Quantum entanglement provides a mechanism leading also to formation of irreducible wholes at the level of mental images.

In TGD framework it is not at all obvious that the highest levels of our personal self hierarchy should correspond to the size of the physical body. Various empirical facts, in particular the observations related to the special effects of excitations of geomagnetic fields and ELF em fields in EEG frequency range on brain, inspire the hypothesis that our selves correspond to topological field quanta of em fields associated with EEG frequencies and thus by Uncertainty Principle have size scale of Earth. This leads to a rather radical modification of the brain centered views about consciousness, and one can quite seriously consider the questions like what physical death means from the point of view of consciousness: it could be that electromagnetic part of self hierarchy could survive after the physical death as a 'soul'.

Quantum model for sensory representations

One of the toughest challenges of quantum theories of consciousness is to understand how sensory representations are constructed at quantum level. It became as a surprise that the vision about sensory representation which resulted from a long lasting thought experimentation is actually very much what

the original, fifteen year old, experience about myself as a computer sitting at its own terminal, when taken very literally in some aspects, actually suggests. This vision adds to the standard view about brain an additional layer responsible for the sensory representations and brings in the quantum level of control so that nerve pulse patterns are only part of the control loop. In fact, it has turned out that the same basic theory applies to both geometric memories, precognition, sensory perception, and motor actions.

1. As far as our consciousness is considered, primary sensory organs are the seats of sensory qualia and brain only constructs cognitive and symbolic representations. Various objections against this hypothesis can be circumvented by assuming that sensory organs entangle with the brain and by the mirror mechanism of the long term memory. The question how imagination differs from the sensory experience becomes trivial, and dreams and hallucinations can be understood as resulting via the back-projection of the imagined mental images to the primary sensory organs.

2. Libet's findings about passive aspects of consciousness lead to the view that sensory percept can be regarded as a geometric memory in time scale of .5 seconds involving entanglement with the geometric past mediated by negative energy MEs. Libet's experiments about the active aspects of consciousness in turn lead to realization that motor actions and sensory perceptions are in a well-defined sense time-reversals of each other: pre-cognition is a definite aspect of motor action. One can say that motor action at the level of negative energy MEs is initiated from the level of muscles rather than brain and motor imagination is just a motor action starting from some level higher than muscles. The transformation of a p-adic ME to negative energy ME realizes the transformation of intention to action in a precisely targeted manner and the emission of negative energy makes possible extreme flexibility by buy now-let others pay mechanism of remote metabolism. This process is the basic step initiating motor action, neural activity leading to imagery, and active memory recall. This picture also explains why geometric memories occur more or less spontaneously whereas precognition is a rare phenomenon (pre-cognizer must *receive* negative energy MEs).

3. In TGD framework one can assign to any material structure a magnetic body having much large size. The closed flux loops composing magnetic bodies allow an elegant realization of the long term memories in terms of negative and positive energy MEs. A stronger hypothesis is that various magnetic bodies define sensory canvases at which various sensory representations are realized. Motor action can be seen as a geometric time reversal of sensory perception. Cortex can be seen as a collection of pre-existing symbolic and cognitive features possibly entangled with sensory mental images at sensory organs, and activated when they appear in the perceptive field or form a part of motor action. The basic task of the central nervous system is to identify these features from the sensory input. The mental images associated with various parts of the physical body are entangled with the points of the corresponding magnetic bodies representing objects of the perceptive field by sharing of mental images and in this manner define attributes of these objects. There is an entire hierarchy of representations corresponding to the hierarchy of magnetic bodies, and also sensory perception involves active selections by entangling a sequences of mental images defining paths along the tree-like structure defined by the hierarchy of magnetic bodies beginning from the personal magnetic body and ending at the roots defined by magnetic bodies of sensory organs. This explains phenomena like sensory rivalry.

4. The decomposition of the perceptive field to objects is one of the basic aspects of sensory experiencing and TGD provides a mechanism generating these objects as mindlike space-time sheets: the boundaries of these objects correspond to regions of strong Kähler electric field whose strength is assumed to correlate with the intensity of the neural input. It might be that even the objects of perceptive field or thoughts could be regarded as features.

5. The computational activities associated with the construction of the sensory representations (say estimating distances and directions of the objects of perceptive field) and virtual sensory representations representing the goals of motor action are presumably realized as iterated processes in which virtual sensory inputs characterizing the expected experiences are compared with the real world sensory input. In a similar manner the goal of the motor action is compared with the sensory representation resulting from effect of a virtual motor action on the representation of

the recent state of world and body. This comparison does not necessarily require sensory representation at any level of the self hierarchy and could be based on comparison circuits defined by parallel supra currents in which the inputs which are sufficiently near to each other generate constructive interference giving rise to a large Josephson current.

New Developments in TGD and Their Implications for TGD Inspired Theory of Consciousness

The conflict between the non-determinism of state function reduction and determinism of time evolution of Schrödinger equation is serious enough a problem to motivate the attempt to extend physics to a theory of consciousness by raising the observer from an outsider to a key notion also at the level of physical theory. Further motivations come from the failure of the materialistic and reductionistic dogmas in attempts to understand consciousness in neuroscience context.

There are reasons to doubt that standard quantum physics could be enough to achieve this goal and the new physics predicted by TGD is indeed central in the proposed theory. The developments in quantum TGD during last years have led to a fusion of real and p-adic physics by using generalization of number concept, to the realization of the crucial role of hyper-finite factors of type II_1 for quantum TGD, to the generalization of the imbedding space implying hierarchy of quantized values of Planck constant, to so called zero energy ontology, and to the reduction of quantum TGD to parton level with parton understand as 2-D surface whose orbit is light-like 3-surface, and to the realization that quantum TGD can be formulated as almost topological quantum field theory using category theoretical framework.

These developments have considerably simplified the conceptual framework behind both TGD and TGD inspired theory of consciousness and provided justification for various concepts of consciousness theory deduced earlier from quantum classical correspondence and properties of many-sheeted space-time.

The notions of quantum jump and self can be unified in the recent formulation of TGD relying on dark matter hierarchy characterized by increasing values of Planck constant. Negentropy Maximization Principle serves as a basic variational principle for the dynamics of quantum jump and must be modified to the case of hyper-finite factors of type II_1 The new view about the relation of geometric and subjective time together with zero energy ontology leads to a new view about memory and intentional action. The quantum measurement theory based on finite measurement resolution and realized in terms of hyper-finite factors of type II_1 justifies the notions of sharing of mental images and stereoconsciousness deduced earlier on basis of quantum classical correspondence. A new element is finite resolution of quantum measurement and cognitive and sensory experience. Qualia reduce to quantum number increments associated with quantum jump. Self-referentiality of consciousness can be understood from quantum classical correspondence implying a symbolic representation of contents of consciousness at space-time level updated in each quantum jump. p-Adic physics provides space-time correlates for cognition and intentionality.

0.5.2 Part II: Time and Consciousness

Time and consciousness

In moments of consciousness as quantum jumps between quantum histories picture the basic challenge is to explain how psychological time arises: why the contents of at least sensory experiences are concentrated around definite value of geometric time and what is the origin of the arrow of psychological time. It has become gradually clear that TGD cannot reproduce the common sense conception of time and that one can only require that the generalized view is consistent with our restricted conscious experiences and shows our position in the hierarchy of consciousness.

The long sought-for solution to the puzzle of psychological time and its arrow was surprisingly simple. Psychological time corresponds to center of mass coordinate for mindlike space-time sheet and is zero mode so that its value is precisely defined for each state of quantum jump by the localization in zero modes associated with quantum jump. The geometry of future lightcone in turn implies the gradual drift of the mindlike space-time sheet to the direction of the future.

Much later came the realization that this picture leads to several paradoxes unless one assumes that psychological time labels the zone of volition corresponding to a p-adic-to-real phase transition proceeding towards the geometric future. Furthermore, the value of the psychological time must be

assumed to be common for the selves at the same level of the self hierarchy, perhaps for the entire bio-sphere. This gives very strong first principle support for the view that entire bio-sphere is conscious being and gives justification for very speculative ideas such as sensory representations realized on the magnetic sensory canvas having size much larger than the physical body. Rather concrete vision about the character of consciousness after the physical death emerges and throws light to various religious concepts (saints and sinners, heaven and hell).

The concept of self led to the understanding of the subjective memory as an average over experiences of self experienced after its "wake-up". Subjective memories are always about past. Geometric memories are predictions for the future/past assuming that no quantum jumps would occur after/had occurred before the one giving rise to the geometric memory. Pre-cognitions can be seen as geometric memories about future. Intentions are p-adic variants of precognitions. It seems that long term memories must correspond to geometric memories: this hypothesis, when combined with the spin glass model of brain, the notion of quantum self-organization, and some key aspects of many-sheeted physics, allows to understand the basic aspects of the long term memory and avoids the basic difficulties of the neural net models.

"Ontogeny recapitulates phylogeny" principle suggests that the structure of the many-sheeted space-time represents the structure of the cosmology of consciousness. This heuristic principle together with the concept of self, the hypothesis that also infinite primes are present in the topological condensate and association sequence concept, leads to a Grand Scenario for the cosmology of consciousness. There is no need to assume that different irreducible sub-experiences associated with given moment of consciousness correspond to a common value of the psychological time. Most naturally, the values of psychological time extending from zero to strictly infinite values of time and beyond(!) are present. This means that cosmology of consciousness has fractal like structure: there are sub-cosmologies which know nothing about each other's existence except in quantum jumps involving entanglement with larger space-time sheets: in this case the conscious experience could be regarded as a religious or mystic experience. Both future and past civilizations participate in each quantum jump. The allowance of infinite primes suggested strongly by various arguments, means that conscious intelligences which are God like as compared to us, participate in each quantum jump.

An especially important general consequence is the paradigm of 4-dimensional brain.

1. This paradigm trivializes the problem of long term memory. The desire to remember would be quantum communicated from the geometric now to the geometric past by sharing of mental images made possible by time-like quantum entanglement of sub-selves. In the case of episodal memories the sharing of mental images gives already rise to the memory. For non-episodal memories the memory is communicated classically to the geometric future. An essential element of the mechanism are negative energy MEs ("massless extremals") which are ideal for generating time-like quantum entanglement with the geometric past. Positive energy MEs are in turn involved with classical communications.

2. Second consequence is a model of cognition relying on the concept of cognitive neutrino pair: cognitive neutrino pair has almost vanishing total energy and consists of neutrino and antineutrino residing at different space-time sheets. The cornerstone of the model is the negative energy of the condensed matter neutrinos deriving from the classical Z^0 interaction with nuclear Z^0 charges. Thus one can say that TGD predicts that $k = 169$ space-time sheet ($L(169) \simeq 5$ microns) is the length scale in which cognitive consciousness emerges.

Quantum jumps between quantum histories concept explains the peculiar time delays of consciousness revealed in the experiments relating to active and passive roles of consciousness and the causal anomalies revealed by the experiments of Radin and Bierman. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

Quantum model for memory

The neural realization of long term memories has remained to a high extent a mystery in the framework of the standard brain science. The TGD based quantum model for memory have developed gradually from the basic realization that in TGD framework the identification of quantum states as quantum histories makes it un-necessary to store information about the geometric past to the geometric now. This has deep implications.

1. It is possible to separate genuine geometric memory recall from apparent memory recalls such as feature recognition, associations, and implicit and procedural memories. There are no memory storages in brain and only memory representations abstracting the essential aspects of experience are needed.

2. The models of long term memory based on the assumption that information about the geometric past is stored in the recent state of the system predict that the new memories should mask the old ones. It is however known that childhood memories are the stablest ones. In TGD framework this ceases to be a problem.

Mirror mechanism provides a very general mechanism of long term memory. To remember something at a temporal distance T in the geometric past is to look at a mirror at a distance $cT/2$. If the mirror is quantum mirror only a timelike entanglement (allowed by the non-determinism of Kähler action) of the mental image of the geometric past with a mental image in brain now is needed. The un-necessity to communicate memories classically implies extreme generality of the mechanism: all kinds of memories: sensory, cognitive, verbal,.... can be recalled in this manner. Even the mechanism of memory recall by cue can be generalized since the notion of tele association makes in principle sense.

The basic objections against this over-simplified picture is that there is no guarantee that the reflected ME returns to the brain and that there is no control over the time span of long term memories. The notion of magnetic body allows a more realistic formulation. Brain or the personal magnetic body generates spontaneously negative energy MEs with all fundamental frequencies. These MEs can be also curved and are parallel to the closed flux tubes defining the personal magnetic body and connect geometric now with the brain of the geometric past: multiple reflections are probably required to achieve this. The length of the closed magnetic loop defines the time span of the corresponding long term memory. The sharing of mental images by timelike entanglement allows to communicate the desire to remember to the geometric past, and gives rise to the memory recall in the case of episodal memories. In the case of non-episodal/declarative memories the memory is communicated from the brain of the geometric past by classical communications using positive positive energy MEs which propagate with an effective phase velocity much lower than light velocity along closed magnetic flux tubes and generate in the receiving end symbolic representation of the memory.

Macrotemporal quantum coherence is further important piece of the model. The understanding of how macrotemporal quantum coherence is made possible by the spin glass degeneracy led to a concrete realization of the mirror model and also provided a connection with the ideas of Hameroff and Penrose. When a bound state is formed the zero modes of the bound state entangled subsystems become quantum fluctuating degrees of freedom. This means that state function reduction and state preparation cease to occur in these degrees of freedom. The bound state is in a kind of long-lasting multiverse state, or state of 'oneness' experientially, and the sequence of quantum jumps defined by the duration of the bound state behaves effectively as a single quantum jump. Macrotemporal quantum coherence making possible supercomputer like activities becomes possible.

The spin glass degeneracy associated with the join along boundaries bonds (the space-time correlates for the bound state formation) lengthens the lifetimes of the bound states dramatically and solves thus the basic objections against quantum consciousness. The spin glass degeneracy is due to classical gravitational energy of the system. The quantum jumps between different classical gravitational configurations involve the emission of gravitational (equivalently Z^0) MEs and the intention to remember is realized as a transformation of p-adic ME to negative energy gravitational ME. The fact that classical gravitational fields couple to classical gauge fields with a coupling which is about 10^8 stronger than the ordinary gravitational coupling, could play an important role too. Water clusters and macromolecules with sizes in the range of cell membrane thickness and cell size are good candidates for generating gravitonic MEs responsible for all geometric memories. Also classical Z^0 interaction might be involved since gravitonic MEs can be regarded also as Z^0 MEs.

A rather detailed neuro level model of long term memory is developed and the model conforms nicely with the basic facts known about the relationship of hippocampus and long term memory.

About the Nature of Time

The identification of the experienced time t_e and geometric time t_g involves well-known problems. Physicist is troubled by the reversibility of t_g contra irreversibility of t_e, by the conflict between

determinism of Schrödinger equation and the non-determinism of state function reduction, and by the poorly understood the origin of the arrow of t_g. In biology the second law of thermodynamics might be violated in its standard form for short time intervals. Neuroscientist knows that the moment of sensory experience has a finite duration, does not understand what memories really are, and is bothered by the Libet's puzzling finding that neural activity seems to precede conscious decision. These problems are discussed in the framework of Topological Geometrodynamics (TGD) and TGD inspired theory of consciousness constructed as a generalization of quantum measurement theory. In TGD space-times are regarded as 4-dimensional surfaces of 8-dimensional space-time $H = M^4 \times CP_2$ and obey classical field equations. The basic notions of consciousness theory are quantum jump and self. Subjective time is identified as a sequence of quantum jumps. Self has as a geometric correlate a fixed volume of H- "causal diamond"-defining the perceptive field of self. Quantum states are regarded as quantum superpositions of space-time surfaces of H and by quantum classical correspondence assumed to shift towards the geometric past of H quantum jump by quantum jump. This creates the illusion that perceiver moves to the direction of the geometric future. Self is curious about the geometric future and induces the shift bringing it to its perceptive field. Macroscopic quantum coherence and the identification of space-times as surfaces in H play a crucial role in this picture allowing to understand also other problematic aspects in the relationship between experienced and geometric time.

0.5.3 Part III: Intelligence, information, and consciousness

Conscious information and intelligence

In this chapter the notions of information and intelligence are discussed in TGD framework. The discussion reflects the chronological development of ideas towards increasing realism. Definitions for the information measures of the configuration space spinor field and information gain of conscious experience as well as the information theoretic interpretation of Kähler action are discussed in detail the first sections of the chapter.

1. Information content of conscious experience associated with single quantum jump can be defined as the difference of the informations associated with initial and initial quantum histories, which are well defined geometric objects and to which classical information theory applies. One can assign separate information measures to both the state function reduction stage (localization in zero modes) and state preparation stage (cascade of self measurement leading to unentangled state) of the quantum jump. The requirement that information gain of conscious experience reduces to information gains associated with irreducible sub-experiences implies that information measures are local in zero modes.

2. The information content of the conscious experience associated with self is more interesting practically. Since self defines a statistical ensemble, it is straightforward to define entropies associated with the increments of quantum numbers and zero modes defining non-geometric and geometric qualia. These entropies characterize the fuzziness of the quale and are 'negative' information measures. Genuine information measures can be defined as differences of the entropies associated with the asymptotic thermal self (if indeed defined) and self. Also information measures for single quantum jump generalize to the case of self.

3. Information theoretic interpretation of the Kähler function is discussed in detail. With certain hypothesis about the degeneracy of the absolute minima as function of Kähler action, the negative of the Kähler function can be interpreted as an entropy type measure for the information content of the space-time surface. Absolute minimization of the Kähler action can be interpreted as a maximization of the information content of the space-time surface and quantum criticality makes TGD universe maximally interesting and maximizes its intelligence. A concrete prediction is that generation of Kähler electric fields generates cognitive resources: indeed, the presence of strong electric fields is the characteristic feature of living systems.

4. Quantum entanglement between real and p-adic degrees of freedom makes sense if entanglement coefficients are algebraic numbers. In this case one can define entanglement entropy using the p-adic variant of the logarithm. p-Adic entropy can be also negative, and the states for which the entropy is negative are stable against self measurements (NMP) and define macrotemporally quantum coherent states. The number-theoretic entropy serves as an an information measure for

cognitive entanglement, and positive entanglement negentropy can be interpreted as a correlate for the experience of understanding. An open question is whether bound states with algebraic entanglement coefficients are sufficiently generic also in the real context to justify the use of the p-adic entanglement negentropy with the value of p fixed uniquely by the requirement that the negentropy is maximal. The number-theoretic definition of information could clearly pave the way towards the understanding of conscious information in the living systems.

Concerning the modelling of conscious intelligence the following aspects are important.

1. Association sequences represent geometric memories, simulations for time development whereas selves represent subjective memories and conscious experience involves always the comparison of geometric and subjective memories telling whether expectations were realized. Quantum theory of self-organization applies also to the evolution of consciousness understood as self-organization in the ensemble of association sequences/selves and implies Darwinian selection also at the level of selves and conscious experiences.

2. TGD Universe is quantum computer in a very general sense and one can understand intelligent system as a quantum computer like system performing one quantum computation per CP_2 time about 10^4 Planck times. Quantum computationalism is shown to reproduce the relevant aspects of computationalism and connectionism without reducing conscious brain to a deterministic machine. Holographic brain is also one of the dominating ideas of neuroscience. TGD based realization of memory allows to reduce hologram idea to its essentials: what matters is that piece of hologram is like a small window giving same information as larger window but in less accurate form. This inspires the concept of neuronal window: each neuron has small window to the perceptive landscape and is typically specialized to detect particular feature in the landscape. Coherent photons emitted by mindlike space-time sheets and propagating along axonal microtubules serving as wave guides, realize neuronal windows quantum physically. Massless extremals allow rather precise definition for the notion of quantum hologram.

   A more refined formulation of these ideas is based on the notion of conscious hologram. Many-sheeted space-time is essentially a fractal Feynmann diagram with lines thicknened to 4-surfaces. The lines are like wave guides carrying laser beams and vertices are like nodes where these laser beams interfere and generate the points of the hologram. The 3-dimensionality of the ordinary hologram generalizes to stereo consciousness resulting in the fusion of mental images associated with various nodes of the conscious hologram. An essential element is the possibility of negative energy space-time sheets analogous to the past directed lines of the Feynmann diagram: negative energy MEs are the crucial element of sensory perception, motor action, and memory.

3. An important element is effective four-dimensionality of brain making possible to understand long term memories, planning and motor activities in a completely new manner. Further important ideas are music metaphor already described and the vision about brain as an associative net. The memetic code, with codewords consisting 126 bit sequences and represented in terms of nerve pulse sequences or membrane oscillations and time varying antineutrino magnetization, is the key essential element of brain as cognitive system. Codewords can be interpreted either as elements of a Boolean algebra or as bits in the binary expansion of an integer in the range $(0, 2^{126})$ so that memetic code makes brain able to assign numbers with qualia. An attractive and testable identification for the memetic codewords is as phonemes of language.

p-Adic physics as physics of cognition and intention

TGD as a generalized number theory vision forces the interpretation of the p-adic physics as a physics of cognitive representations so that matter-mind dichotomy corresponds to real–p-adic dichotomy at the level of the geometric correlates of mind. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. Cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that cognition and intention are present even at this level. In this chapter these implications are studied from the point of view of cognitive consciousness.

p-Adic space-time sheets are identified as the counterparts of cognitive representations: one could also assign them with memes, morphic fields, or analogous notions used by parapsychologists. The possibility to identify the inherent non-determinism of the p-adic field equations as the non-determinism

of imagination makes this identification so attractive. The 'phase transition' of a p-adic space-time sheet to a real space-time sheet taking place in quantum jump between quantum histories corresponds to the transformation of a thought into action or sensory experience (during dreams and hallucinations) whereas the reverse transformation corresponds to the transformation of the sensory input into cognition. One possible view is that p-adic memes are everywhere waiting for their materialization by p-adic-to-real phase transition and that biological systems are only a special class of cognitive systems. The identification of the psychological time as the value of the geometric time associated with the front of volition (identified as p-adic-to-real phase transition) proceeding towards geometric future has very strong implications and allows to consider even questions like 'What after physical death?'.

p-Adic teleportation for the massless extremals (MEs) is a basic mechanism making in principle possible the replication and transmission of memes with an effective velocity which can be superluminal. Time reversed cognition is a basic implication of the teleportation mechanism. Basic cognitive functions are dicussed in this this conceptual framework. Time reverse reference waves generate time reversed holograms, which suggests an extremely general and simple model of healing using the phase conjugate of the reference wave inducing the 'disease program' hologram and thus forcing the program to run backwards. DNA strand and its conjugate strand have interpretation as represention of a command and its time reversal coded to holograms by MEs scanning DNA like reading head and coding nucleotide sequence to a lightlike vacuum current.

The realization of p-adic–real phase transitions at brain level is suggested: the appearence of the millisecond rhytm behind neuronal synchronization would correspond to p-adic-to-real transition for MEs carrying classical Z^0 fields.

The obvious question is how to test p-adic physics empirically. First of all, thinking is p-adic sensory experiencing. Hence the reduction of theories–experimental science dichotomy to p-adic–real dichotomy seems natural: just like experimental science is an extension of everyday real sensory experience, theories represent an extension of everyday p-adic sensory experience (common sense thinking). Thus the basic test is how well p-adic physics based theories describe cognition. Secondly, the p-adic models for physical systems are strictly speaking models for cognitive models for real physics. The successes of these highly predictive models (consider only p-adic elementary particle mass calculations involving only very few integer valued parameters) supports the vision about p-adic physics as physics of cognition. p-Adic–real phase transitions as models for how thought is transformed to action and sensory input to thought provide a further testing ground for the new paradigm.

p-Adic–real phase transitions as models for how thought is transformed to action and sensory input to thought provide a further testing ground for the new paradigm. This forces the allowance of finite-dimensional extensions of p-adic numbers involving real transcendentals like π and e. The outcome is a series of number theoretical conjectures and a considerable generalization of the previously developed insights about how to understand and prove Riemann hypothesis. The zeros of Riemann Zeta can be identified as a universal number theoretically quantized spectrum of scaling momenta characterizing various conformally invariant critical systems.

0.5.4 Part IV: Paranormal Phenomena

Quantum model for paranormal phenomena

The general quantum model for bio-systems leads to a general model for electromagnetic bio-control which applies to a very wide variety of hard-to-understand bio-chemical phenomena such as molecular recognition mechanisms, water memory, and homeopathy and leads to a generalization of genetic code explaining the mystery of introns. The same model generalizes to a model of paranormal phenomena such as psychokinesis, remote sensing, remote healing, telepathy, communications with deceased, and instrumental transcommunications.

1. Magnetic mirrors (ME-magnetic flux tube pairs) connecting the sender and receiver make possible a universal mechanism for the transfer of intent and action. p-Adic MEs represent the transfer of a mere intent and real MEs represent a transfer of action. p-Adic ME can be transformed to real ME either by receiver or some higher level magnetic self.

2. The transfer of intent gives rise to mechanism of remote interaction which can act both endo- and exogenously. Magnetic mirrors characterized by their fundamental frequencies make possible bridges between sender and receiver (say healer and healee) and allow a resonant interaction

in which healer can initiate various control commands acting as 4-dimensional templates represented as holograms. Also smaller MEs can be send along the MEs serving as bridges (this is like throwing balls with light velocity!).

3. The ME-magnetic flux tube pair connecting sender and receiver acts as a reference wave which can initiate an arbitrarily complex hologram representing biological program. Sender has the ability to generate and amplify the frequencies which induce holograms representing the control commands. In particular, sender can initiate complex biological programs without knowing anything about their functioning.

4. Magnetic mirrors make possible also feedback and this feedback could make possible learning. For instance, in psychokinesis (especially so in micro PK), this learning would be crucial and analogous to that what occurs when we learn to drive a car. In healing this kind of feedback might help to find the healing frequency by trial and error.

5. It is quite possible that also multibrained and -bodied higher level magnetic selves actively participate in the process. This makes possible coherent amplification effects (TEM, prayer groups) and also makes available information resources of all brains involved with the group. This could for instance explain the ability of a remote viewer to see an object on basis of data which need not have any meaning for her. Fast amplitude modulation of alpha waves introducing higher harmonics to the carrier wave is a good candidate for mediating communication between brains and higher level multibrained selves. Mesoscopic 'features' in brain involve precisely this kind of amplitude modulation and might represent just this kind of messages. Interestingly, also speech is produced by fast amplitude modulation of 10 Hz basic vibration frequency of speech organs.

Model for OBEs

Out-of-body experiences (OBEs) are often understood as experience of seeing oneself from a position outside of the body. OBEs are poorly understood in the framework of neuro science and pose a challenge for the reductionistic world view.

In TGD framework the notion of magnetic body provides an attractive starting point in attempts to understand what OBEs and related experiences are. The basic idea is that magnetic body serves effectively as a mirror defining a third person view as a cognitive representation also in ordinary wake-up state and that during OBEs this representation becomes sensory representation. Magnetic body need not always be a personal magnetic body but could correspond to a magnetic body receiving information from several brains (collective consciousness), magnetic body of another person, or be even associated with "dead" matter.

The progress in identifying dark matter as a phase of matter with large value of Planck constant making possible macroscopic quantum coherence has led to the vision about dark matter at magnetic flux quanta as quantum controller of ordinary matter in living systems. The Bose-Einstein condensates of dark photons decaying via decoherence to ordinary photons mediate interactions between ordinary and dark matter and the hypothesis is that dark photon "laser" beams from body and brain reflected at magnetic flux quanta give rise to third person aspect of consciousness which in OBEs and related experiences are realized as sensory representations. The identification of bio-photons as end products of the de-coherence of dark photon beams is natural.

The model leads also to a model for dreams, hallucinations, sensory feedback from brain to sensory organs, and directed attention. Concrete models for how dark photons can give rise to experiences in various sensory modalities such as vision, hearing, olfaction, and tactile senses, are proposed.

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Part I

BASIC IDEAS OF TGD INSPIRED THEORY OF CONSCIOUSNESS

Chapter 1

TGD Inspired Quantum Theory of Consciousness and of Bio-systems: an Overall View

1.1 Introduction

In this chapter I will discuss TGD based view about time and space-time. The discussion of the many-sheeted space-time concept explaining the basic notions once again is included because I feel that this is in order since the understanding of "topological light rays" (massless extremals, briefly MEs), and of magnetic and electric flux quanta has developed vigorously since the articles published in the last issue of JNLRMI [16]. I have not even attempted to include all essential aspects since this would simply lead both me and the reader to despair. I consider those aspect that I feel especially relevant just now. To be honest, the act of writing the article generated a lot of new insight s and ideas so that the boring duty to summarize something already done transformed once again to an active process of thinking and identifying weak points in the existing scenario and trying to see the idea landscape from a more general perspective. The 8 online books [10, 8, 9, 13, 11, 12, 14, 15] at my home page provide a comprehensive unavoidably out of date summary TGD inspired theory of consciousness.

A brief summary of what might be called basic principles is in order to facilitate the reader to assimilate the basic tools and rules of intuitive thinking involved.

1.1.1 Quantum-classical correspondence

The fundamental metalevel guiding principle is quantum-classical correspondence (classical physics is an exact part of quantum TGD). The principle states that all quantum aspects of the theory, which means also various aspects of consciousness such as volition, cognition, and intentionality, should have space-time correlates. Real space-time sheets provide kind of symbolic representations whereas p-adic space-time sheets provide correlates for cognition and intentions. All that we can symbolically communicate about conscious experience relies on quantal space-time engineering to build these representations.

1.1.2 Classical physics as exact part of quantum theory

Classical physics corresponds to the dynamics of space-time surfaces determined by the absolute minimization of so called Kähler action. This dynamics have several unconventional features basically due to the possibility to interpret the Kähler action as a Maxwell action expressible in terms of the induced metric defining classical gravitational field and induced Kähler form defining a non-linear Maxwell field not as such identifiable as electromagnetic field however.

Classical weak and color fields as signature for a fractal hierarchy of copies standard model physics

The geometrization of classical fields means that various classical fields are expressible in terms of imbedding space-coordinates and are thus not primary dynamical variables. This predicts the presence of long range Z^0 and color (gluon) fields not possible in standard physics context. It took 26 years to end up with a convincing interpretation for this puzzling prediction.

What seems to be the correct interpretation is in terms of an infinite fractal hierarchy of copies of standard models physics with appropriately scaled down mass spectra for quarks, leptons, and gauge bosons. Both p-adic length scales and the values of Planck constant predicted by TGD [C7] label various physics in this hierarchy. Also other quantum numbers are predicted as labels. This means that universe would be analogous to an inverted Mandelbrot fractal with each bird's eye of view revealing new long length scale structures serving also as correlates for higher levels of self hierarchy.

Exotic dark weak forces and their dark variants are consistent with the experimental widths for ordinary weak gauge bosons since the particles belonging to different levels of the hierarchy do not have direct couplings at Feynman diagram level although they have indirect classical interactions and also the de-coherence reducing the value of $\hbar$ is possible. Classical long ranged weak fields play a key role in quantum control and communications in living matter [M3, L6]. Long ranged classical color force in turn is the backbone in the model of color vision [K3]: colors correspond to the increments of color quantum numbers in this model. The increments of weak isospin in turn could define the basic color like quale associated with hearing (black-white $\leftrightarrow$ to silence-sound [K3, M5, M6]).

Topological field quantization and the notion of many-sheeted space-time

The compactness of CP_2 implies the notions of many-sheeted space-time and field quantization. Topological field quantization means that various classical field configurations decompose into topological field quanta. One can see space-time as a gigantic Feynman diagram with lines thickened to 4-surfaces. Absolute minimization of Kähler action implies that only selected field configurations analogous to Bohr's orbits are realized physically so that quantum-classical correspondence becomes very predictive. An interpretation as a 4-D quantum hologram is a further very useful picture [K2] but will not be discussed in this chapter in any detail.

Topological field quantization implies that the field patterns associated with material objects form extremely complex topological structures which can be said to belong to the material objects. The notion of field body, in particular magnetic body, typically much larger than the material system, differentiates between TGD and Maxwell's electrodynamics, and has turned out to be of fundamental importance in the TGD inspired theory of consciousness. One can say that field body provides an abstract representation of the material body.

One implication of many-sheetedness is the possibility of macroscopic quantum coherence. By quantum classical correspondence large space-time sheets as quantum coherence regions are macroscopic quantum systems and therefore ideal sites of the quantum control in living matter.

1. The original argument was that each space-time sheet carrying matter has a temperature determined by its size and the mass of the particles residing at it via de Broglie wave length $\lambda_{dB} = \sqrt{2mE}$ assumed to define the p-adic length scale by the condition $L(k) < \lambda_{dB} < L(k_>)$. This would give very low temperatures when the size of the space-time sheet becomes large enough. The original belief indeed was that the large space-time sheets can be very cold because they are not in thermal equilibrium with the smaller space-time sheets at higher temperature.

2. The assumption about thermal isolation is not needed if one accepts the possibility that Planck constant is dynamical and quantized and that dark matter corresponds to a hierarchy of phases characterized by increasing values of Planck constant [C7, J6]. From $E = hf$ relationship it is clear that arbitrarily low frequency dark photons (say EEG photons) can have energies above thermal energy which would explain the correlation of EEG with consciousness. This vision allows to formulate more precisely the basic notions of TGD inspired theory of consciousness and leads to a model of living matter giving precise quantitative predictions. Also the ability of this vision to generate new insights to quantum biology provides strong support for it [M3].

Many-sheeted space-time predicts also fundamental mechanisms of metabolism based on the dropping of particles between space-time sheets with an ensuing liberation of the quantized zero point

kinetic energy. Also the notion of many-sheeted laser follows naturally and population inverted many-sheeted lasers serve as storages of metabolic energy [K6].

Space-time sheets topologically condense to larger space-time sheets by wormhole contacts which have Euclidian signature of metric. This implies causal horizon at which the signature of the induced metric changes from Minkowskian to Euclidian. This forces to modify the notion of subsystem. What is new is that two systems represented by space-time sheets can be unentangled although their subsystems bound state entangle with the mediation of the join along boundaries bonds connecting the boundaries of sub-system space-time sheets. This is not allowed by the notion of subsystem in ordinary quantum mechanics. This notion in turn implies the central concept of fusion and sharing of mental images by entanglement.

The possibility of negative energies

A further prediction derives from the fact that space-time is 4-surface rather than an abstract manifold. Energy momentum tensor of general relativity is replaced by a collection of conserved energy and momentum currents, which are 4-vector fields. This makes the notions of energy and momentum precisely defined but also implies that the sign of energy and momentum depend on the time-orientation of the space-time sheet. Negative energies become therefore possible somewhat like in the lines of a Feynman diagram. Negative energy topological light rays have phase conjugate laser waves [20] as the most plausible standard physics counterparts, and play a fundamental role in quantum metabolism as a kind of quantum credit card [K6]. They generate also time like entanglement which corresponds to a formation of new kind of bound states.

Negative energies might be possible even for ordinary particles and could mean dramatic deviation from the standard quantum theory. The roles of annihilation and creation operators have changed for negative energy space-time sheets. This would mean that operator combinations involving both annihilation and creation operators would generate states involving positive and negative energy space-time sheets. One can even imagine that a intentional action could create states with vanishing net quantum numbers and that positive and negative energy particles could be separated from each other.

TGD Universe is quantum spin glass

Since Kähler action is Maxwell action with Maxwell field and induced metric expressed in terms of $M^4_+ \times CP_2$ coordinates, the gauge invariance of Maxwell action as as a symmetry of the vacuum extremals (this implies is a gigantic vacuum degeneracy) but not of non-vacuum extremals. Gauge symmetry related space-time surfaces are not physically equivalent and gauge degeneracy transforms to a huge spin glass degeneracy. Spin glass degeneracy provides a universal mechanism of macro-temporal quantum coherence and predicts degrees of freedom called zero modes not possible in quantum field theories describing particles as point-like objects. Zero modes are identifiable as effectively classical variables characterizing the size and shape of the 3-surface as well as the induced Kähler field.

Classical and p-adic non-determinism

The vacuum degeneracy of Kähler action implies classical non-determinism, which means that space-like 3-surface is not enough to fix the space-time surface associated with it uniquely as an absolute minimum of action, and one must generalize the notion of 3-surface by allowing sequences of 3-surfaces with time like separations to achieve determinism in a generalized sense. These "association sequences" can be seen as symbolic representations for the sequences of quantum jumps defining selves and thus for contents of consciousness. Not only speech and written language define symbolic representations but all real space-time sheets of the space-time surfaces can be seen in a very general sense as symbolic representations of not only quantum states but also of quantum jump sequences. An important implication of the non-determinism is the possibility to have conscious experiences with contents localized with respect to geometric time. Without this non-determinism conscious experience would have no correlates localized at space-time surface, and there would be no psychological time.

p-Adic non-determinism follows from inherent non-determinism of p-adic differential equations for any action principle and is due to the fact that integration constants, which by definition are functions with vanishing derivatives, are not constants but functions of the pinary cutoffs x_N defined as $x = \sum_k x_k p^k \rightarrow x_N = \sum_{k<N} x_k p^k$ of the arguments of the function. In p-adic topology one can therefore fix the behavior of the space-time surface at discrete set of space-time points *above*

some length scale defined by p-adic concept of nearness by fixing the integration constants. In the real context this corresponds to the fixing the behavior *below* some time/length scales since points p-adically near to each other are in real sense faraway. This is a natural correlate for the possibility to plan the behavior and p-adic non-determinism is assumed to be a classical correlate for the non-determinism of intentionality, and perhaps also imagination and cognition.

These two non-determinisms allow to understand the self-referentiality of consciousness at a very general level. In a given quantum jump a space-time surface can be created with the property that it represents symbolically or cognitively something about the contents of consciousness before the quantum jump. Thus it becomes possible to become conscious about being conscious of something. This is very much like mathematician expressing her thoughts as symbol sequences which provides feedback to go the next abstraction level.

Classical and p-adic non-determinisms force also the generalization of the notion of entanglement. Time-like entanglement, crucial for understanding long term memory and precognition becomes possible. The notion of many-sheeted space-time forces also to modify the notion of subsystem, which implies that unentangled systems can have entangled subsystems. One can partially understand this in terms of length scale dependent notion of entanglement (the entanglement of subsystems is not seen in the length scale resolution defined by the size of unentangled systems) but only partially. The formation of join along boundaries bonds between subsystem space-time sheets and the fact that topologically condensed space-time sheets are separated by "elementary particle horizons" from larger space-time sheets, provide the deeper topological motivation for the generalization of subsystem concept.

p-Adic fractality of life and consciousness

p-Adic fractality of biology and consciousness has become an increasingly important guide line in the construction of the theory. This notion allows to relate phenomena occurring in the molecular level to phenomena like remote viewing and psychokinesis and it leads also to the view that topological field quanta of various fields of astrophysical size are crucial for the functioning of bio-systems. If one accepts p-adic fractality, the theory can be tested in unexpected manners, in particular in molecular and cellular length scales where the systems are much simpler. Sensory perception, long term memory, remote mental interactions, metabolism: all these phenomena rely on the same basic mechanisms. p-Adic length scale hypothesis allows to quantify the hypothesis with testable quantitative predictions.

1.1.3 Some basic ideas of TGD inspired theory of consciousness and quantum biology

The following ideas of TGD inspired theory of consciousness and of quantum biology are the most relevant ones for what will follow.

1. "Everything is conscious and consciousness can be only lost" is the briefest manner to summarize TGD inspired theory of consciousness. Quantum jump as moment of consciousness and the notion of self are key concepts of the theory. Self is a system able to avoid bound state entanglement with environment and can be formally seen as an ensemble of quantum jumps. The contents of consciousness of self are defined by the averaged increments of quantum numbers and zero modes (sensory and geometric qualia). Moments of consciousness can be said to be the counterparts of elementary particles and selves the counterparts of many-particle states, both bound and free. The selves formed by macro-temporal quantum coherence are in turn the counterparts of atoms, molecules and larger structures. Macro-temporal quantum coherence effectively binds a sequence of quantum jumps to a single quantum jump as far as conscious experience is considered. The idea that conscious experience is about changes amplified to macroscopic quantum phase transitions, is the key philosophical guideline in the construction of various models, such as the model of qualia, the capacitor model of sensory receptor, the model of cognitive representations, and declarative memories.

2. Macro-temporal quantum coherence is a second consequence of the spin glass degeneracy [K2]. It is essentially due to the formation of bound states and has as a topological correlate the formation of join along boundaries bonds connecting the boundaries of the component systems. During macro-temporal coherence quantum jumps integrate effectively to single long-lasting

quantum jump and one can say that system is in a state of oneness, eternal now, outside time. Macro-temporal quantum coherence makes possible stable non-entropic mental images. Negative energy MEs are one particular mechanism making possible macro-temporal quantum coherence via the formation of bound states, and remote metabolism and sharing of mental images are other facets of this mechanism. The real understanding of the origin of macroscopic quantum coherence requires the generalization of quantum theory allowing dynamical and quantized Planck constant [J6, M3].

3. p-Adic physics as physics of intentionality and possily also of cognition is a further key idea of TGD inspired theory of consciousness. p-Adic space-time sheets as correlates for intentions and p-adic-to-real transformations of them as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. Negative energy MEs are absolutely essential for the understanding of how precisely targeted intentionality is realized.

1.2 Many-sheeted space-time, magnetic flux quanta, electrets and MEs

TGD inspired theory of consciousness and of living matter relies on space-time sheets carrying ordinary matter, topological light rays (massless extremals, MEs), and magnetic and electric flux quanta. There are some new results which motivate a separate discussion of them.

1.2.1 Dynamical quantized Planck constant and dark matter hierarchy

By quantum classical correspondence space-time sheets can be identified as quantum coherence regions. Hence the fact that they have all possible size scales more or less unavoidably implies that Planck constant must be quantized and have arbitrarily large values. If one accepts this then also the idea about dark matter as a macroscopic quantum phase characterized by an arbitrarily large value of Planck constant emerges naturally as does also the interpretation for the long ranged classical electroweak and color fields predicted by TGD. Rather seldom the evolution of ideas follows simple linear logic, and this was the case also now. In any case, this vision represents the fifth, relatively new thread in the evolution of TGD and the ideas involved are still evolving.

Dark matter as large $\hbar$ phase

D. Da Rocha and Laurent Nottale have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

Nottale and Da Rocha believe that their Schrödinger equation results from a fractal hydrodynamics. Many-sheeted space-time however suggests astrophysical systems are not only quantum systems at larger space-time sheets but correspond to a gigantic value of gravitational Planck constant. The gravitational (ordinary) Schrödinger equation would provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [D6].

Dark matter as a source of long ranged weak and color fields

Long ranged classical electro-weak and color gauge fields are unavoidable in TGD framework. The smallness of the parity breaking effects in hadronic, nuclear, and atomic length scales does not however seem to allow long ranged electro-weak gauge fields. The problem disappears if long range classical electro-weak gauge fields are identified as space-time correlates for massless gauge fields created by dark matter. Also scaled up variants of ordinary electro-weak particle spectra are possible. The identification explains chiral selection in living matter and unbroken $U(2)_{ew}$ invariance and free color in bio length scales become characteristics of living matter and of bio-chemistry and bio-nuclear

physics. An attractive solution of the matter antimatter asymmetry is based on the identification of also antimatter as dark matter.

1.2.2 p-Adic length scale hypothesis and the connection between thermal de Broglie wave length and size of the space-time sheet

Also real space-time sheets are assumed to be characterized by p-adic prime p and assumed to have a size determined by primary p-adic length scale L_p or possibly n-ary p-adic length scale $L_p(n)$. More generally, each space-time dimension could correspond to its own p-adic length scale and even several p-adic primes could be associated with single dimension.

The possibility to assign a p-adic prime to the real space-time sheets is required by the success of the elementary particle mass calculations and various applications of the p-adic length scale hypothesis. Rationals are common to reals and all p-adic number fields. The p-adic-to-real transition transforming intentions to actions is made possible by a large number of common rational points between p-adic and real space-time surfaces, which supports the view that real space-time sheets obeys effective p-adic topology as an approximate topology in some resolution and below some length scale. p-Adic prime thus characterizes the classical non-determinism of the Kähler action.

Parallel space-time sheets with distance about 10^4 Planck lengths form a hierarchy. Each material object (...,atom, molecule, ..., cell,...) corresponds to this kind of space-time sheet. The p-adic primes $p \simeq 2^k$, k prime or power of prime, characterize the size scales of the space-time sheets in the hierarchy. The p-adic length scale $L(k)$ can be expressed in terms of cell membrane thickness as

$$L(k) = 2^{(k-151)/2} \times L(151) \ , \tag{1.2.1}$$

$L(151) \simeq 10$ nm. These are so called primary p-adic length scales but there are also n-ary p-adic length scales related by a scaling of power of $\sqrt{p}$ to the primary p-adic length scale. Quite recent model for photosynthesis [K6] gives additional support for the importance of also n-ary p-adic length scales so that the relevant p-adic length scales would come as half-octaves in a good approximation but prime and power of prime values of k would be especially important.

1.2.3 Topological light rays (massless extremals, MEs)

I have described MEs, or "topological light rays", in previous articles of JNLRMI [18] and in [J4, J7], and describe here only very briefly the basic characteristics of MEs and concentrate on new idea about their possible role for consciousness and life.

What MEs are?

MEs can be regarded as topological field quanta of classical radiation fields [J4, J7]. They are typically tubular space-time sheets inside which radiation fields propagate with light velocity in single direction without dispersion. The simplest case corresponds to a straight cylindrical ME but also curved MEs, kind of curved light rays, are possible. The initial values for a given moment of time are arbitrary by light likeness. Therefore MEs are ideal for precisely targeted communications. What distinguishes MEs from Maxwellian radiation fields in empty space is that light like vacuum 4-current is possible: ordinary Maxwell's equations would state that this current vanishes. Quite generally, purely geometric vacuum charge densities and 3-currents are purely TGD based prediction and could be seen as a classical correlate of the vacuum polarization predicted by quantum field theories.

MEs are fractal structures containing MEs within MEs. The so called scaling law of homeopathy predicts that the high frequency MEs inside low frequency MEs are in a ratio having discrete values [K5]. One can indeed justify this relationship. As ions drop from smaller space-time sheets to magnetic flux tubes, zero point kinetic energy is liberated as high frequency MEs, and the ions dropped to magnetic flux quanta generate cyclotron radiation, and the ratio of the fundamental frequencies is constant not depending on particle mass and being determined solely by p-adic length scale hypothesis. The model for the radio waves induced by the irradiation of DNA by laser light [31] gives support for this picture [K2].

Two basic types of MEs

MEs have 2-dimensional CP_2 projection which means that electro-weak holonomy group is Abelian (color holonomy is always Abelian which suggests that physical states in TGD Universe correspond to states of color multiplets with vanishing color hypercharge and isospin rather than color singlets). If CP_2 projection belongs to a homologically non-trivial geodesic sphere, only em and Z^0 fields and Abelian color gauge fields are present. In the homologically trivial case only classical W fields are non-vanishing.

1. Neutral MEs can be assigned to various kinds of communications from biological body to the magnetic body and fractal hierarchy of EEGs and ZEGs represent the basic example in this respect [M3].

2. Dark W MEs serving as correlate for dark W exchanges induce an exotic ionization of atomic nuclei [F8, F9, M3]. This induces charge entanglement between magnetic body and biological body generating dark plasma oscillation patterns inducing nerve pulse patterns and ion waves at the space-time sheets occupied by the ordinary matter. The mechanism is based on many-sheeted Faraday law inducing electromagnetic fields at ordinary space-time sheet in turn giving rise to ohmic currents. State function reduction selects one of the exotically ionized configurations. This mechanism is the most plausible candidate for how magnetic body as an intentional agent controls biological body.

Negative energy MEs

MEs can have either positive or negative energy. The understanding of negative energy MEs has increased considerably. Phase conjugate laser waves [20] are the most plausible standard physics counterparts of negative energy MEs since they can be interpreted as time reversed laser beams and do not possess direct Maxwellian analog. By quantum-classical correspondence one can interpret the frequencies associated with negative energy MEs as energies. One can also assume that the Bose-Einstein condensed photons associated with negative energy MEs and with the coherent light generated by the light like vacuum current have negative energies.

For frequencies which are above thermal energy there is no system which could interact with negative energy MEs or absorb negative energy photons. Therefore negative energy MEs and corresponding photons should propagate through matter practically without any interaction. Feinberg has demonstrated that phase conjugate laser beams behave similarly: for instance, one can see through chickens using these laser beams [21]. This means that negative energy MEs do not respect Faraday cages and thus represent an attractive candidate for the hypothetical Psi field. Note that MEs are not a mere classical correlate for photons, as is clear from the fact that in the case of Z^0 MEs there are no Z^0 photons.

Negative energy MEs have many applications.

1. Negative energy MEs ideal for generating time like entanglement. Since negative energies are involved, this entanglement can be seen as a correlate for the bound state entanglement leading to a macro-temporal quantum coherence. Negative energy MEs make thus possible telepathic sharing of mental images. Negative energy MEs are involved with both sensory perception, long term memory, and motor action.

2. Negative energy MEs are ideal for a precisely targeted realization of intentions. p-Adic ME having a large number of common rational points with negative energy ME is generated and transformed to a real ME in quantum jump. The system receives positive energy and momentum as a recoil effect and the transition is not masked by ordinary spontaneously occurring quantum transitions since the energy of the system increases. One can say that negative energy ME represents the desires communicated to the geometric past and inducing as a reaction the desired action realized as say neuronal activity and generation of positive energy MEs.

3. The generation of negative energy MEs is also in a key role in remote metabolism and MEs serve as quantum credit cards implying an extreme flexibility of the metabolism. During the writing of this article one new and important aspect of remote metabolism became obvious. If the system receiving negative energy MEs is a population inverted laser or its many-sheeted

counterpart, then quite a small field intensity associated with negative energy MEs (intensity of negative energy photons) can lead to the amplification of the time reflected positive energy signal. The reason is that the rate for the induced emission is proportional to the number of particles dropped to the ground state from the excited state. Therefore even negative energy bio-photons might serve as quantum controllers of metabolism and induce much more intense beams of positive energy photons, say when interacting with mitochondria.

1.2.4 Magnetic flux quanta and electrets

Magnetic flux tubes and electrets are extremals of Kähler action dual to each other. Also layer like magnetic flux quanta and their electric counterparts are possible. The magnetic/electric field is in a good approximation of constant magnitude but has varying direction.

Magnetic fields and life

The magnetic field associated with any material system is topologically quantized, and one can speak about magnetic body. An attractive idea is that the relationship of the magnetic body to the material system is to some degree that of the manual to an electronic instrument. Magnetic body would thus allow to realize both sensory and abstract symbolic representations about the material body. Magnetic body would in this case serve as a kind of computer screen at which the data items processes in say brain are communicated either classically (positive energy MEs) or by sharing of mental images (negative energy MEs).

Magnetic body is also an active intentional agent: motor actions are controlled from magnetic body and proceed as cascade like processes from long to short length and time scales as quantum communications of desires at various levels of hierarchy of magnetic bodies. Communication occurs backwards in geometric time by negative energy MEs. Motor action as a response to these desires occurs by classical communications by positive energy MEs and as neural activities. This explains the coherence and synchrony of motor actions difficult to understand in neuroscience framework. The sizes of flux tubes are astrophysical: for instance, EEG frequency of 7.8 Hz corresponds to a wave length defined by Earth's circumference. The non-locality in the length scale of magnetosphere, and even in length scales up to light life, is forced by Uncertainty Principle alone, if taken seriously in macroscopic length scales.

The leakage of supra currents of ions and their Cooper pairs from magnetic flux tubes of the Earth's magnetic field to smaller space-time sheets and their dropping back involving liberation of the zero point kinetic energy defines one particular metabolic "Karma's cycle". The dropping of protons from $k = 137$ atomic space-time sheet involved with the utilization of ATP molecules is only a special instance of the general mechanism involving an entire hierarchy of zero point kinetic energies defining universal metabolic currencies. This leads to the idea that the topologically quantized magnetic field of Earth defines the analog of central nervous system and blood circulation present already during the pre-biotic evolution and making possible primitive metabolism. This has far reaching implications for the understanding of how pre-biotic evolution led to living matter as we understand it [L6].

For instance, it has recently become clear that the dropping of atoms and molecules from $k = 131$ space-time sheets creates photons at visible and near infrared wave lengths. The hot $k = 131$ space-time sheets (with temperatures above 1000 K) could have served as a source of metabolic energy for life-forms at cool $k = 137$ sheets. Photosynthesis could have developed in the circumstances where solar radiation was replaced with these photons. The correct prediction is that chlorophylls should be especially sensitive to these wave lengths. In particular, it is predicted that also IR wave lengths 700-1000 nm should have been utilized. There indeed are bacteria using only this portion of solar radiation. This leads to a scenario making sense only in TGD universe. Pre-biotic life could have developed at the cool space-time sheets in the hot interior of Earth below crust, where $k = 131$ space-time sheets are possible and this life could still be there [L6]. Also the life as we know it, could involve hot spots generated by the cavitation of water inside cell. The classical repulsive Z^0 force causes a strong acceleration during final stages of bubble collapse creating high temperatures, and could explain also sono-luminescence [22] as suggested in [F9].

Magnetic Mother Gaia could also form sensory and other representations receiving input from several brains via negative energy EEG MEs entangling magnetosphere with brains. The multi-brained magnetospheric selves could be responsible for the third person aspect of consciousness and for the

evolution of social structures. Some aspects of remote viewing very difficult to understand if remote viewing involves only the target and viewer [26], the successful healing by prayer and meditation groups [27], and the experiments of Mark Germine [46] support the view that multi-brained possibly magnetospheric selves are involved. Magnetic flux tubes could function as wave guides for MEs and this aspect is crucial in the model of long term memory.

Electrets and bio-systems

Bio-systems are known to be full of electrets and liquid crystals [38]. Perhaps the most fundamental electret structure is cell membrane. In particular, the water inside cells tends to be in gel phase which is liquid crystal phase. There are many good reasons for why water should be in ordered phase. One very fundamental reason is that bio-polymers are stable in liquid crystal/ordered water phase since there are no free water molecules available for the depolymerization by hydration. In fact, only a couple of years ago it was experimentally discovered that bio-polymers can be stabilized around ice.

The capacitor model for sensory receptor is one very important application of the electret concept (see the article "Quantum model of sensory receptor" in [17] and [K3]). Sensory qualia result in the flow of particles with given quantum numbers from the plate to another one in quantum discharge. This kind of amplification of quantum number *resp.* zero mode increments would give rise to both geometric *resp.* non-geometric qualia [K3].

Also micro-tubuli are electrets. Sol-gel transition, as any phase transition, is an good candidate for the representation of a conscious bit and controlled local sol-gel transitions between ordinary and liquid crystal water could be a basic control tool making possible cellular locomotion, changes of protein conformations, etc... The tubulin dimers of micro-tubuli could induce sol-gel transformations by generating negative energy MEs, and micro-tubular surface could provide bit maps of their environment somewhat like sensory areas of brain provide maps of body. If gel→sol transition around tubulin inducing conformational change induces sol→gel transformation in some point of environment as would be the case for the seesaw mechanism to be discussed below, a one-one correspondence would result. By this one-one correspondence micro-tubules would automatically generate kind of conscious log files about the control activities which could have evolved to micro-tubular declarative memory representations about what happens inside cell [K6].

1.3 TGD inspired theory of consciousness very briefly

In the following the basic concepts and ideas of TGD inspired theory of consciousness are briefly summarized.

1.3.1 Quantum jumps between quantum histories as moments of consciousness

The individual quantum jump between quantum histories has a complex anatomy which has become obvious only gradually. Quantum jump consists of the unitary, informational "time evolution"

$$\Psi_i \rightarrow U\Psi_i$$

of the initial quantum history Ψ_i described by the unitary operator U (essentially S-matrix), followed by the step

$$U\Psi_i \rightarrow \Psi_{f_0} \quad ,$$

in which a localization in zero modes occurs. This step is the counterpart of the state function reduction process and gives rise to the ordinary quantum measurement with zero modes playing the role of classical variables.

This step is followed by a sequence of self measurements

$$\Psi_{f_0} \rightarrow \Psi_{f_1} \rightarrow ....\Psi_f$$

leading to a state Ψ_f in which only bound state entanglement remains. This process is the counterpart of the state preparation. In a given self measurement sub-system decomposes into two unentangled

parts and the decomposition is fixed by the requirement that the reduction of the entanglement entropy is maximal (Negentropy Maximization Principle) and the density matrix serves as a universal observable in the self measurement.

It should be emphasized that the operator U, or equivalently S-matrix, is only the formal counterpart of the Schrödinger time evolution lasting infinite time: there is no actual Schrödinger equation involved and U has nothing to do with geometric time development[1]. U codes all the statistical predictions of quantum TGD and is the counterpart of S-matrix of quantum field theories.

Subjective time development understood as a sequence of quantum jumps occurs outside the realm of the geometric space-time. It could be regarded as a non-deterministic hopping in the space of the configuration space spinor fields. Individual quantum jump is however fundamentally irreducible in the sense that one cannot model it by any dynamical time development. The identification of quantum jump as a moment of consciousness defines what might be called microscopic theory of consciousness. The subjective time development presumably obeys some variational principle consistent with the quantum measurement theory, in particular, with its non-determinism[2]. This principle dictates which systems for given initial quantum history can perform quantum jumps and have moments of consciousness. This variational principle will be discussed in section [2.2.2].

Standard quantum measurement theory

The assumption that a localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies standard quantum measurement theory as the following arguments demonstrate.

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory.

2. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m-M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

3. Unitarity is consistent with the localization in zero modes if the unitary time evolution operator U acts effectively as a flow in zero mode degrees. This means that in some incoming state basis $|n,z\rangle$, where z refers to zero modes, the outgoing states are of form $S^\dagger_{nm}|m,z_1(z,n)\rangle$. The effective flow property means a 1-1 mapping of the outgoing quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field). The final state is an eigenstate of the density matrix for the measured system identified as quantum fluctuating degrees of freedom and zero mode degrees of freedom identified as measuring system.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to basic quantum theory. This reduction involves crucially the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. The reduction is a triumph for quantum TGD and favours TGD against string models.

[1] From TGD point of view the identification of the geometric time and the time coordinate appearing in the general Schrödinger equation of quantum field theories quantized using Hamiltonian formalism is wrong. Schrödinger equation is not even needed. The identification of the time coordinate of the Dirac equation as a geometric time however makes sense from TGD point of view.

[2] This means that the variational principle in question must be more akin to the second law of thermodynamics rather than to the ordinary variational principles of physics.

Also self measurements are possible

TGD allows also second type of quantum measurement following ordinary quantum measurement reducing entanglement in quantum fluctuating degrees of freedom for some sub-system-complement pair inside self which corresponds to a state localized in zero modes. This measurement can be regarded as a self measurement and there is entire cascade of them reducing the state to a completely classical product state. The process is obviously the counterpart of the phenomenological state preparation process in quantum physics. The only universal observable is the *density matrix* of the sub-system, which should be thus measured in the quantum jump. Negentropy Maximization Principle (NMP) governs the dynamics of self measurement and states that the the density matrix of a sub-system of self for which the reduction of entanglement entropy is maximal, is measured in self measurement. In the real context self measurement means a reduction of the entanglement and provides a mechanism of self-repair: NMP [H2] says that the biggest hole in the leaking boat is filled first. In p-adic context NMP becomes the basic dynamical principle of cognition.

It is however far from obvious what the notion of quantum measurement means when quantum states are quantum histories. For instance, the precise definition of the sub-system concept involves nontrivial delicacies caused by the classical non-determinism of Kähler action. In absence of this non-determinism, all self measurements could be assigned to the boundary of the future light cone (big bang) in accordance with the quantum holography principle. The fact that the lightlike boundaries of (MEs) allow superconformal and supercanonical symmetries crucial for construction of quantum TGD and act as quantum holograms, leads to the hypothesis that non-determinism of Kähler action induces a fractal hierarchy of MEs in inside MEs and to the identification of the geometric correlates of selves as lightlike boundaries of MEs. MEs can have also finite time duration (virtual MEs) and define also what might be called mindlike space-time sheets.

State preparations induce a tendency opposite to the second law of thermodynamics which follows from the non-determinism of Kähler action implying the generation of MEs inside MEs inside future lightcone. This in turn means that one cannot predict the future from the knowledge of the quantum state at the boundary of the future lightcone using general coordinate invariance as the most stringent form of quantum holography would predict.

Quantum jump as quantum computation like process

The Universe according to TGD is a quantum computer in an extremely general sense of the word. Every quantum jump involves unitary informational "time development" U (quantum computation) and state function reduction involving a localization in the zero modes (halting of the computation) and a sequence of self measurements giving rise to state preparation. It is neither possible nor necessary to assign Schrödinger equation with U. U is however completely analogous to the time evolution operator $U(-t,t)$, $t \to \infty$, defining the S-matrix in quantum field theories. It is important to notice that also in quantum field theories one is interested only in the S-matrix so that new interpretation brings in nothing new at practical level.

There are thus three time developments in TGD:

1. The geometric time development of the space-time surface determined by the absolute minimization of the Kähler action, which also via general coordinate invariance defines in what sense quantum histories are histories;

2. the informational "time development" U analogous to quantum computation (hence the attribute 'informational') represented by S-matrix;

3. the subjective time development by quantum jumps taking outside the realm of the space-time.

These three notions of time development fuse to single "holy trinity" of informational, subjective and geometric time evolutions. This "holy trinity" of time evolutions corresponds to the "holy trinity" of

1. matter in the sense of res extensa identified as 3-surfaces,

2. ideas/objective realities (logos= cosmos) identified as quantum histories (physics= mathematics)[3].

3. and the world of subjective experiences defined by the quantum jump sequences for selves (mathematician exists subjectively in the quantum jumps between mathematical ideas).

Tri-partism allows to overcome the basic difficulties of the monistic and dualistic world pictures. In particular, the theory-reality dualism disappears.

It should be emphasized that in this framework the standard physics identification of the time parameter of Schrödinger evolution with geometric time is wrong. The big problem, to be discussed later, is how the value of geometric time associated with the contents of conscious experience is determined.

How the world of conscious experience can look classical?

If quantum histories (/states) are quantum superpositions over a huge number of classical space-time surfaces, it is very difficult to understand how the world of conscious experience manages to look classical. The solution of the problem comes out from the requirement that quantum jumps in a well defined sense reduce to quantum measurements performed in a space-time with a fixed macroscopic geometry as in quantum field theory. The macroscopic aspects of the space-time surface are determined completely by the zero modes of the configuration space characterizing the induced Kähler field and geometric size and shape of the four-surface totally. Thus, if each quantum measurement involves a localization in zero modes, then the classicality of the universe of subjective experience is achieved automatically, and as noticed, standard quantum measurement theory follows from quantum TGD proper. In p-adic space-time degrees of freedom complete localization must occur in every quantum jump for purely mathematical reasons, and the interpretation is that intentionality and cognition are completely classical.

During macrotemporal quantum coherence due to the formation of bound state half of the zero modes of two space-time sheets connected by join along boundaries bonds become macroscopic quantum fluctuating degrees of freedom, and in these states consciously experienced world looks non-classical. These states correspond to states of "one-ness" at the level of conscious experience.

There are counter arguments against complete localization. First of all, one can imagine that the reduction could occur to a sub-space of zero modes consisting of a discrete points. Rational bound state entanglement in discrete sub-spaces of zero modes would be stable against state function reduction. Even more generally, the existence of symplectic structure in zero modes allows to consider a hierarchy of 2n-dimensional sub-manifolds in the space of zero modes with volume element defined by the n:th power of the symplectic form. State function reduction could occur to this kind of sub-manifold since at least the transition amplitude would be well-defined. Preferred sub-manifolds of this kind are sub-manifolds closed with respect to the action of $SO(3) \times SU(3)$ isometries such that only the coordinates associated with a finite number of super-canonical generators are non-constant.

1.3.2 Quantum self

In the following the notion of self is introduced. To avoid confusions it must be emphasised that the notion of self is completely general and by no means restricted to brain. Brain consciousness is in this framework only a special form of consciousness.

The notions of self and subjective memory

The simplest hypothesis is that the contents of consciousness are determined by single quantum jump. There are several objections to this view.

1. The idea about self as a continuous stream of consciousness is very attractive and it seems difficult to believe that our consciousness could be actually a sequence of moments of consciousness with gaps between.

[3]Quantum histories can be regarded as superpositions of Boolean statements represented by many fermion Fock states (fermion number=1↔true, fermion number =0↔ false), hence logos=cosmos identification.

2. Furthermore, if the contents of consciousness are determined completely by the initial and final states of single quantum jump, we cannot have any memories about our previous conscious experiences. Hence subjective memories should be only pseudo memories perhaps resulting from the simulations of the subjective past.

It took quite a long time to realize the real strength of these objections and to discover that a proper quantum definition of the concept of self provides a manner to overcome these obstacles.

1. Entanglement is one of the basic non-classical notions of quantum theory. Un-entangled sub-system, as opposed to an entangled one, behaves as its own sub-universe and can be regarded as a pure quantum state. The natural guess is that self should be identified as a sub-system able to remain unentangled in subsequent quantum jumps. The self lasting only single quantum jump can be also regarded formally as self. This kind of a definition looks intuitively very satisfactory since me-external world separation is a basic characteristic of consciousness. The problem is to formulate precisely what are the characteristics of sub-system defining self, which must remain invariant in quantum jump. It seems that the p-adic prime characterizing the system might be the basic and perhaps only invariant of this kind.

2. The absence of entanglement between space-time regions belonging to different number fields (real and p-adic) would automatically imply the decomposition of the space-time surface to regions identifiable as selves. The entanglement between real and p-adic space-time regions is however possible if entanglement coefficients for orthonormalized state basis are algebraic numbers [H2], and has an interpretation as giving rise to a correlation between cognitive quantum states and the states of the material system. For a negative entanglement entropy the reduction of the entanglement would be in a conflict with NMP: hence a cognitive bound state is in question. This means a period of macrotemporal cognitive quantum coherence during which a sequence of quantum jumps is effectively fused to a single quantum jump. The state decays in what might be called a cognitive measurement. Cognitive bound state entanglement is possible only in configuration space spin degrees of freedom, that is in basically fermionic degrees of freedom (elementary bosons can be regarded as antifermion-fermion bound states).

3. The hypothesis that the experiences of self associated with the quantum jumps occurred after the "wake-up" (the quantum jump during which U made sub-system unentangled or created unentangled sub-system) sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore the self becomes an extended object with respect to the subjective time and has a well defined "personal history". Subjective memory has a natural identification as a short term memory with a duration of order second.

4. If the temporal binding of experiences involves some kind of averaging, that is, if quantum statistical determinism generalizes to the level of the subjective experience, the total experience defined by the heap of the experiences associated with individual quantum jumps is reliable.

5. Self can have sub-selves: this corresponds geometrically to a space-time sheet having smaller space-time sheets glued to it. An irreducible self is defined as a self having no sub-selves. Reducible and irreducible selves give rise to two modes of consciousness identifiable as ordinary and "whole-body" consciousness.

6. The sub-selves of two selves can entangle if one allows the definition of sub-system concept based on p-adic length scale cutoff. Essentially this means that because of the p-adic length scale cutoff, the entanglement of sub-systems is not 'seen' at the level of systems so that they can remain unentangled. p-Adic length scale cutoff is natural since the wormhole contacts associated with topologically condensed space-time sheets are surrounded by 'elementary particle horizons' analogous to blackhole horizons. Therefore the larger space-time sheet 'sees' about topologically condensed space-time sheet only some quantum numbers like mass, spin and charge. The entanglement of sub-systems makes possible fusion and sharing of mental images crucial for quantum communications. For instance, receiver can understand the message by sharing the mental image of the sender representing the understanding of the message.

7. Sub-system can wake-up (become conscious self) in several manners. The phase transitions $R \leftrightarrow R_p$ inside real/p-adic self generate new p-adic/real sub-selves. In fact, real–p-adic phase

transitions correspond to the transformation of sensory input into cognition and thought into action. Also the transitions $R_{p_1} \to R_{p_2}$ inside p_1-adic self generate new p_2-adic sub-selves.

Negentropy Maximization Principle

As already explained, TGD reduces the state function reduction of the standard quantum measurement theory to the localization in zero modes. Besides this, it is postulated that the localization in zero modes is followed by a cascade of self measurements giving rise to an unentangled product state and thus state preparation. NMP governs the dynamics of self measurement.

1. NMP applies to each un-entangled sub-system resulting in self measurement cascase separately, and is therefore in a well-defined sense a local principle. Every un-entangled sub-system X in Ψ_{f_0} participates in quantum jump $\Psi_{f_0} \to \Psi_{f_1}$, which means that the density matrix for some sub-system of X is quantum measured.

2. A quantum jump for a given unentangled sub-system X corresponds to a measurement of the density matrix for some sub-system Y of X. In this measurement sub-system Y goes to an eigenstate of the density matrix and Y becomes unentangled. Same happens to the complement of Y inside X. The amount of entanglement is measured by entanglement entropy S and S vanishes for the final state of the quantum jump. Thus S can be regarded as negentropy gain having interpretation as some kind of conscious information, or rather, reduction of dis-information. The conscious experience must be assigned with X. One cannot associate it with the measured sub-system or its complement inside$X$ since they are in completely symmetric position since diagonalized density matrices are identical. Hence there is no manner to tell which is the measured system and which the measuring sub-system. Thus one must define self measurement as a measurement creating an unentangled sub-system-complement pair inside X and identify X as the conscious measurer.

3. NMP states that the entanglement entropy reduction associated with the conscious experience of the sub-system X is maximal. Interpreting entanglement negentropy gain as conscious information, on can say that we live in (or create) the best possible world. Only the quantum jumps giving rise to maximum information content of conscious experience occur. It must be noticed however that one can assign several types of information measures with conscious experience. This requirement fixes the quantum measured sub-system Y of given self uniquely unless there are several sub-systems giving rise to same maximum negentropy gain: in this case any of the quantum jumps occurs with same probability.

The precise formulation of NMP involves delicate issues. In the purely real standard physics context NMP need not make sense since in the generic case the entire universe could be the only unentangled system after state function reduction and entanglement entropies for candidate sub-systems would be infinite. In TGD space-time decomposing into both real and p-adic space-time sheets, an elegant formulation of NMP with sensical predictions is possible, since universe decomposes to subselves possessing finite entanglement entropies. NMP reduces to a local principle applying separately to each unentangled system.

In p-adic context entanglement negentropy gain is defined as the real counterpart of the p-adic negentropy gain with p-adic prime p characterizing the sub-system in question. The definition of the negentropy concept in p-adic framework involves quite interesting delicacies. For instance, entanglement with a vanishing entanglement entropy is possible [H3, H5]. One must also define the concept of sub-system very carefully since quantum states are identified as quantum histories in TGD framework and here MEs turn out to be crucial element because their lightlike boundaries have quantum hologram property meaning the reduction the physics inside ME to conformally invariant physics at the boundary of ME. It has been already mentioned that number theoretic entanglement entropies emerge naturally in case of real-p-adic entanglement and can be negative.

Summation hypothesis and binding of experiences

The self X behaves essentially as a separate sub-Universe. Also the sub-selves of X_i of X have their own experiences. The question is: how the experience of X and experiences of X_i are related? The following basic hypothesis provides a possible answer to this question.

1. X experiences the sub-selves X_i as separate mental images superposed to the pure self experience of X: this is natural since sub-selves are unentangled and hence behave like separate sub-Universes.

2. The experiences of self X about the experiences of its sub-selves X_i are abstractions. Sub-self X_i experiences its sub-selves X_{ij} as separate mental images. X however experiences them as a single mental image representing what it is to be a sub-self of X_i, that is the average $\langle X_{ij} \rangle$ of the mental images X_{ij}. Thus the mental images of sub-sub-...selves of X are smoothed out to an average mental image and become effectively unconcious to X. Averaging hypothesis generalizes quantum statistical determinism to the level of subjective experience and is analogous to the hypothesis about averaging related to temporal binding.

Temporal binding with averaging implies that the experiences of the individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles. The inability to perceive the flickering of light when the frequency of the flickering is larger than about one Hz is consistent with the hypothesis that subjective sensory memory has duration of order .1 seconds and that temporal averaging indeed occurs. Time averaging could involve weighting such that the conscious experiences associated with the last quantum jumps have the largest weight. This would allow our self to have duration much longer than .1 seconds. For instance, the duration of the ordinary wake-up period could determine the duration of our self. The duration could be even longer: sleep could actually involve awareness and the lack of the sensory memories from sleep period could create the illusion about sleep as an unconscious state.

Summation hypothesis and temporal binding imply a hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is the entire universe, God, enjoying eternal self-consciousness since it cannot entangle with with any larger system. Also we are mental images of some higher level self. This hierarchy obviously has far-reaching consequences.

Binding of the experiencers by entanglement

The binding of experiencers is also possible. The binding of selves by quantum entanglement however means they lose their consciousness. This process naturally corresponds to the formation of wholes from their parts at the level of conscious experiences. The formation of a mental image (sub-self) representing word from the mental images representing letters is example of this process. Also the fusion of the left and right visual fields to a single visual field could occur via the entanglement of the corresponding sub-selves. Note however that right–left entanglement might occur already at neuronal level. Entanglement mechanism provides also a possible mechanism of "enlightment" experiences envolving extension of self [H3, H5]. Quantum entanglement could make possible communication between selves belonging to different levels of the self hierarchy.

Binding and quantum metabolism as different sides of the same coin

Quantum jump involves also a state preparation process and only bound state entanglement is stable against the state preparation. Hence the fusion of the mental images implicates the formation of a bound state. This process is expected to involve a liberation of the binding energy as a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and binding are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enchanced oxidative metabolism [29]. A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

How to understand evolution and self-organization?

One could argue that since the quantum jump is random (not actually since selection between the eigenstates of the density matrix occurs), quantum jump as a moment of consciousness identification cannot explain evolution. In standard physics it is difficult to circumvent this objection. Even worse, heat death seems to be the ultimate fate of the universe according to standard physics.

The fact that quantum jump involves localization in zero modes and thus localization into a definite sector D_P of configuration space labelled by infinite prime P, implies evolution as a statistical increase of P. Since infinite primes are in well-defined sense composites of finite primes, this in turn implies that the finite p-adic prime associated with a given sub-system tends to increase and that new space-time sheets labelled by finite primes emerge during the time evolution by quantum jumps.

This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies (MEs inside MEs inside...). Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (or even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favoured self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The proposed realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [H7]. TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism.

How to understand morally responsible free will?

One could argue that the randomness of the quantum jump means that moral choices are impossible. The essence of volition is intentionality. p-Adic space-time sheets are excellent candidates for the correlates of intentions because of the inherent non-determinism of the p-adic differential equations. p-adic-to-real transformation of a p-adic space-time sheet in quantum jump is the geometric correlate for the transformation of intention to action. At configuration space level one cannot assign any (at least p-adic probabilities to p-adic localizations so that randomness is not in question. System can therefore intend, that is perform a particular localization in p-adic degrees of freedom very many times.

p-Adic evolution defines the fundamental value of the quantum ethics. The selections which tend to increase the value of the p-adic prime represent good deeds since they mean evolution. The values of this ethics are not in the physical world but in the quantum jumps defining the subjective reality.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and gives rise to a "prophecy", a prediction for the future and past, which would be reliable if the world were completely classical). As a matter fact, it is p-adic space-time sheets which correspond to intentions and plans and act of volition transforms p-adic space-time sheet to a real one. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents if they can experience directly that increase of p is good and decrease of p is bad.

1.3.3 Space-time correlates of matter and mind

Mindlike and material space-time sheets

In TGD space-time surfaces decompose into real and p-adic regions. p-Adic regions are identified as cognitive representations for real regions. The basic motivation for this identification is the inherent non-determinism of the p-adic field equations making possible imagination and simulation.

The classical non-determinism of Kähler action makes possible also real space-time sheets of finite temporal duration. These space-time sheets are identified as mindlike space-time sheets serving as ge-

ometric correlates of sensory experience. Thus matter-mind duality is realized geometrically although space-time as such is not conscious. The notion of mindlike space-time sheets (referred to as cognitive space-time sheets in earlier writings) has turned out to be crucial for the understanding of cognition and sensory experience.

Mindlike space-time sheets provide a simulation of geometric history and explain the intentional aspects of consciousness (planning, expectations, desires,...), the localization of contents to finite time interval, and give rise to what might be called "geometric memory". Each quantum jump involves naturally comparison of the expected time development provided by "geometric memory" and the actual subjective time development stored in subjective memory. This comparison should give rise to those emotions involving comparison of some kind.

One can understand the arrow of psychological time very simply. The center of mass time coordinate for a given mindlike space-time sheet is zero mode so that each quantum jump involves localization to a superposition of space-time surfaces for which the values of the psychological time for all mindlike space-time sheets involved are identical. Since there is much more room in the future of a given point of the future lightcone than in its past, mindlike space-time sheets are expected to gradually drift in the direction of future so that the arrow of psychological time results.

p-Adic–real phase transitions as a transformation of thought to action and of sensory input to cognition

Basic hypothesis is that sensory experiences resp. thoughts have real resp. p-adic space-time sheets as their geometric correlates. A fundamental model for the transformation of thought into action is as a p-adic-to-real phase transition for the topology of a mindlike space-time sheet induced by quantum jump. TGD as a generalized number theory vision suggests that this kind of phase transition can be induced by a variation of the parameters in the polynomial $P(p, q)$ of two quaternionic imbedding space coordinates defining the space-time surface changing a p-adic root to a real one or viceversa. The reverse of this phase transition corresponds to the transformation of sensory experiences to cognition.

In principle it is enough that very simple and possibly standardized p-adic–real transformations occur at some level, say neuronal level or at the level of topological field quanta of em field ("massless extremals"). The reason is that simple transformations can serve as symbols inducing macrocopic action in an initial value sensitive system (single push of button can induce nuclear war). The commands given using written or spoken language are typical examples of the emergence of this kind symbol function.

1.3.4 Dynamical quantized Planck constant,dark matter hierarchy, and consciousness

Dark matter hierarchy has far reaching implications for TGD inspired theory of consciousness since it makes possible the realization of macroscopic and macro-temporal coherence. It also allows to make more precise the idea about hierarchy of quantum jumps with increasing durations with respect to the geometric time.

p-Adic and dark matter hierarchies and hierarchy of moments of consciousness

Dark matter hierarchy assigned to a spectrum of Planck constant having arbitrarily large values brings additional elements to the TGD inspired theory of consciousness.

1. Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

2. The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta with field magnitude near to that for Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [M3].

For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest a general formula for the allowed values of λ [C9] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [C7]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \to h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \to nL(k)$ and $B \to B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 25$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [E9].

The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$. Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. The quantum parallel dissipation at the lower levels would give rise to the experience of flow of time. For instance, hadron as a macro-temporal quantum system in the characteristic time scale of hadron is a dissipating system at quark and gluon level corresponding to shorter p-adic time scales. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

The time span of long term memories as signature for the level of dark matter hierarchy

The simplest dimensional estimate gives for the average increment τ of geometric time in quantum jump $\tau \sim 10^4\ CP_2$ times so that $2^{127} - 1 \sim 10^{38}$ quantum jumps are experienced during secondary p-adic time scale $T_2(k = 127) \simeq 0.1$ seconds which is the duration of physiological moment and predicted to be fundamental time scale of human consciousness [L1]. A more refined guess is that $\tau_p = \sqrt{p}\tau$ gives the dependence of the duration of quantum jump on p-adic prime p. By multi-p-fractality predicted by TGD and explaining p-adic length scale hypothesis, one expects that at least $p = 2$-adic level is also always present. For the higher levels of dark matter hierarchy τ_p is scaled up by $\hbar/\hbar_0$. One can understand evolutionary leaps as the emergence of higher levels at the level of individual organism making possible intentionality and memory in the time scale defined τ [L2].

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

1.3.5 About the arrow of psychological time and notion of self: once again!

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic. I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation [E10] has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which come into my mind first.

The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - began to look very elegant during last night. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. The simplest assumption is that evolution in a reasonable approximation means shifting of the field patterns backwards in geometric time by some amount per quantum jump. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the perceiver space-time sheet and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-atronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

Can one choose between the two variants for the notion of self?

I have considered two different notions of "self" and it is interesting to see whether this picture might allow to choose between them.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labelled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the notion of self hierarchy to that of fractal quantum jump in the sense of dark matter hierarchy but there is an objection. Does this concept really make sense? Fractality is a geometric notion and subjective time does not reduce to the geometry. It is also not quite clear whether the reasonable looking idea about the role of entanglement can be kept.

The older variant of self looks more attractive if one accepts the new model for the arrow of psychological time.

1. Entire Universe performs the quantum jump and there is an infinite fractal hierarchy of scales associated with quantum jump and state function reduction/state preparation part of quantum jump proceeds as a sequence from long to short scales. One cannot assign any finite geometric duration to a given step in this sequence since the geometric duration assignable to the entire quantum jump would in this case be automatically infinite. In this framework our life cycle would most naturally correspond to a sequence of quantum jumps.

2. The simplest guess for the interval of geometric time assignable to single quantum jump is as CP_2 time. p-Adic time scales define alternative and perhaps more attractive identification. The larger the value of p-adic prime p, the faster the psychological time would flow and faster the experienced rate of evolution would be. Also the hierarchy of Planck constants suggests a hierarchy of these times and the concentration of attention to to dark matter levels would make the flow of psychological time much faster. The model of tqc suggests that each period of EEG rhythm corresponds to single quantum jump for corresponding "me" in un-entangled self-state.

3. The ability to avoid entanglement with environment would be essential for the original notion of self. One can of however ask whether the assumption about the loss of consciousness in entanglement - that is during sleep - is really necessary. One could however argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday. Furthermore, during topological quantum computation entanglement is absent and thus this state should correspond to conscious experience. Night time is however the best time for tqc since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at some level during sleep and perform quite a long tqc. Perhaps we are!

Could it be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with some system means only diving into the ocean of consciousness as someone has expressed it. We would be Gods as also quantum classical correspondence in the reverse direction requires (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions). This would be the most optimistic view that one can imagine.

This arguments look nice but more arguments are needed to exclude the model of self as single quantum jump.

What after biological death?

Could the new option allow to speculate about the course of events at the moment of death? Certainly this particular sensory "me" would effectively meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape brings in a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what might she might call enlightment.

1.4 Local p-adic physics and the p-adic fractality of the real physics and p-adic-to-real transition as a space-time correlate for the transformation of intention to action

This section provides the recent view about transformation of intentions to actions and the presence of this a motivation for its presence of p-adic cognitive neutrino pair. The interpretation of the p-adic as physics of cognition and the vision about reduction of physics to rational physics continuable algebraically to various extensions of rationals and p-adic number fields is an attractive general framework

allowing to understand how p-adic fractality could emerge in real physics. In this section it will be found that this vision provides a concrete tool in principle allowing to construct global solutions of field equations by reducing long length scale real physics to short length scale p-adic physics. Also p-adic length scale hypothesis can be understood and the notion of multi-p p-fractality can be formulated in precise sense in this framework. This vision leads also to a concrete quantum model for how intentions are transformed to actions and the S-matrix for the process has the same general form as the ordinary S-matrix.

1.4.1 p-Adic physics and the construction of solutions of field equations

The number theoretic vision about physics relies on the idea that physics or, rather what we can know about it, is basically rational number based. One interpretation would be that space-time surfaces, the induced spinors at space-time surfaces, configuration space spinor fields, S-matrix, etc..., can be obtained by algebraically continuing their values in a discrete subset of rational variant of the geometric structure considered to appropriate completion of rationals (real or p-adic). The existence of the algebraic continuation poses very strong additional constraints on physics but has not provided any practical means to solve quantum TGD.

In the following it is however demonstrated that this view leads to a very powerful iterative method of constructing global solutions of classical field equations from local data and at the same time gives justification for the notion of p-adic fractality, which has provided very successful approach not only to elementary particle physics but also physics at longer scales. The basic idea is that mere p-adic continuity and smoothness imply fractal long range correlations between rational points which are very close p-adically but far from each other in the real sense and vice versa.

The emergence of a rational cutoff

For a given p-adic continuation only a subset of rational points is acceptable since the simultaneous requirements of real and p-adic continuity can be satisfied only if one introduces ultraviolet cutoff length scale. This means that the distances between subset of rational points fixing the dynamics of the quantities involved are above some cutoff length scale, which is expected to depend on the p-adic number field R_p as well as a particular solution of field equations. The continued quantities coincide only in this subset of rationals but not in shorter length scales.

The presence of the rational cutoff implies that the dynamics at short scales becomes effectively discrete. Reality is however not discrete: discreteness and rationality only characterize the inherent limitations of our knowledge about reality. This conforms with the fact that our numerical calculations are always discrete and involve finite set of points.

The intersection points of various p-adic continuations with real space-time surface should code for all actual information that a particular p-adic physics can give about real physics in classical sense. There are reasons to believe that real space-time sheets are in the general case characterized by integers n decomposing into products of powers of primes p_i. One can expect that for p_i-adic continuations the sets of intersection points are especially large and that these p-adic space-time surfaces can be said to provide a good discrete cognitive mimicry of the real space-time surface.

Adelic formula represents real number as product of inverse of its p-adic norms. This raises the hope that taken together these intersections could allow to determine the real surface and thus classical physics to a high degree. This idea generalizes to quantum context too.

The actual construction of the algebraic continuation from a subset of rational points is of course something which cannot be done in practice and this is not even necessary since much more elegant approach is possible.

Hierarchy of algebraic physics

One of the basic hypothesis of quantum TGD is that it is possible to define exponent of Kähler action in terms of fermionic determinants associated with the modified Dirac operator derivable from a Dirac action related super-symmetrically to the Kähler action.

If this is true, a very elegant manner to define hierarchy of physics in various algebraic extensions of rational numbers and p-adic numbers becomes possible. The observation is that the continuation to various p-adic numbers fields and their extensions for the fermionic determinant can be simply

done by allowing only the eigenvalues which belong to the extension of rationals involved and solve field equations for the resulting Kähler function. Hence a hierarchy of fermionic determinants results. The value of the dynamical Planck constant characterizes in this approach the scale factor of the M^4 metric in various number theoretical variants of the imbedding space $H = M^4 \times CP_2$ glued together along subsets of rational points of H. The values of $\hbar$ are determined from the requirement of quantum criticality [C7] meaning that Kähler coupling strength is analogous to critical temperature.

In this approach there is no need to restrict the imbedding space points to the algebraic extension of rationals and to try to formulate the counterparts of field equations in these discrete imbedding spaces.

p-Adic short range physics codes for long range real physics and vice versa

One should be able to construct global solutions of field equations numerically or by engineering them from the large repertoire of known exact solutions [D1]. This challenge looks formidable since the field equations are extremely non-linear and the failure of the strict non-determinism seems to make even in principle the construction of global solutions impossible as a boundary value problem or initial value problem.

The hope is that short distance physics might somehow code for long distance physics. If this kind of coding is possible at all, p-adicity should be crucial for achieving it. This suggests that one must articulate the question more precisely by characterizing what we mean with the phrases "short distance" and "long distance". The notion of short distance in p-adic physics is completely different from that in real physics, where rationals very close to each other can be arbitrary far away in the real sense, and vice versa. Could it be that in the statement "Short length scale physics codes for long length scale physics" the attribute "short"/"long" could refer to p-adic/real norm, real/p-adic norm, or both depending on the situation?

The point is that rational imbedding space points very near to each other in the real sense are in general at arbitrarily large distances in p-adic sense and vice versa. This observation leads to an elegant method of constructing solutions of field equations.

1. Select a rational point of the imbedding space and solve field equations in the real sense in an arbitrary small neighborhood U of this point. This can be done with an arbitrary accuracy by choosing U to be sufficiently small. It is possible to solve the linearized field equations or use a piece of an exact solution going through the point in question.

2. Select a subset of rational points in U and interpret them as points of p-adic imbedding space and space-time surface. In the p-adic sense these points are in general at arbitrary large distances from each and real continuity and smoothness alone imply p-adic long range correlations. Solve now p-adic field equations in p-adically small neighborhoods of these points. Again the accuracy can be arbitrarily high if the neighborhoods are choose small enough. The use of exact solutions of course allows to overcome the numerical restrictions.

3. Restrict the solutions in these small p-adic neighborhoods to rational points and interpret these points as real points having arbitrarily large distances. p-Adic smoothness and continuity alone imply fractal long range correlations between rational points which are arbitrary distant in the real sense. Return to 1) and continue the loop indefinitely.

In this manner one obtains even in numerical approach more and more small neighborhoods representing almost exact p-adic and real solutions and the process can be continued indefinitely.

Some comments about the construction are in order.

1. Essentially two different field equations are in question: real field equations fix the local behavior of the real solutions and p-adic field equations fix the long range behavior of real solutions. Real/p-adic global behavior is transformed to local p-adic/real behavior. This might be the deepest reason why for the hierarchy of p-adic physics.

2. The failure of the strict determinism for the dynamics dictated by Kähler action and p-adic non-determinism due to the existence of p-adic pseudo constants give good hopes that the construction indeed makes it possible to glue together the (not necessarily) small pieces of space-time surfaces inside which solutions are very precise or exact.

3. Although the full solution might be impossible to achieve, the predicted long range correlations implied by the p-adic fractality at the real space-time surface are a testable prediction for which p-adic mass calculations and applications of TGD to biology provide support.

4. It is also possible to generalize the procedure by changing the value of p at some rational points and in this manner construct real space-time sheets characterized by different p-adic primes.

5. One can consider also the possibility that several p-adic solutions are constructed at given rational point and the rational points associated with p-adic space-time sheets labelled by $p_1, ..., p_n$ belong to the real surface. This would mean that real surface would be multi-p p-adic fractal.

I have earlier suggested that even elementary particles are indeed characterized by integers and that only particles for which the integers have common prime factors interact by exchanging particles characterized by common prime factors. In particular, the primes $p = 2, 3, ..., 23$ would be common to the known elementary particles and appear in the expression of the gravitational constant. Multi-p p-fractality leads also to an explanation for the weakness of the gravitational constant. The construction recipe for the solutions would give a concrete meaning for these heuristic proposals.

This approach is not restricted to space-time dynamics but is expected to apply also at the level of say S-matrix and all mathematical object having physical relevance. For instance, p-adic four-momenta appear as parameters of S-matrix elements. p-Adic four-momenta very near to each other p-adically restricted to rational momenta define real momenta which are not close to each other and the mere p-adic continuity and smoothness imply fractal long range correlations in the real momentum space and vice versa.

p-Adic length scale hypothesis

Approximate p_1-adicity implies also approximate p_2-adicity of the space-time surface for primes $p \simeq p_1^k$. p-Adic length scale hypothesis indeed states that primes $p \simeq 2^k$ are favored and this might be due to simultaneous $p \simeq 2^k$- and 2-adicity. The long range fractal correlations in real space-time implied by 2-adicity would indeed resemble those implied by $p \simeq 2^k$ and both $p \simeq 2^k$-adic and 2-adic space-time sheets have larger number of common points with the real space-time sheet.

If the scaling factor λ of $\hbar$ appearing in the dark matter hierarchy is in good approximation $\lambda = 2^{11}$ also dark matter hierarchy comes into play in a resonant manner and dark space-time sheets at various levels of the hierarchy tend to have many intersection points with each other.

There is however a problem involved with the understanding of the origin of the p-adic length scale hypothesis if the correspondence via common rationals is assumed.

1. The mass calculations based on p-adic thermodynamics for Virasoro generator L_0 predict that mass squared is proportional to $1/p$ and Uncertainty Principle implies that L_p is proportional to $\sqrt{p}$ rather than p, which looks more natural if common rationals define the correspondence between real and p-adic physics.

2. It would seem that length $d_p \simeq pR$, R or order CP_2 length, in the induced space-time metric must correspond to a length $L_p \simeq \sqrt{p}R$ in M^4. This could be understood if space-like geodesic lines at real space-time sheet obeying effective p-adic topology are like orbits of a particle performing Brownian motion so that the space-like geodesic connecting points with M^4 distance r_{M^4} has a length $r_{X^4} \propto r_{M^4}^2$. Geodesic random walk with randomness associated with the motion in CP_2 degrees of freedom could be in question. The effective p-adic topology indeed induces a strong local wiggling in CP_2 degrees of freedom so that r_{X^4} increases and can depend non-linearly on r_{M^4}.

3. If the size of the space-time sheet associated with the particle has size $d_p \sim pR$ in the induced metric, the corresponding M^4 size would be about $L_p \propto \sqrt{p}R$ and p-adic length scale hypothesis results.

4. The strongly non-perturbative and chaotic behavior $r_{X^4} \propto r_{M^4}^2$ is assumed to continue only up to L_p. At longer length scales the space-time distance d_p associated with L_p becomes the unit of space-time distance and geodesic distance r_{X^4} is in a good approximation given by

$$r_{X^4} = \frac{r_{M^4}}{L_p} d_p \propto \sqrt{p} \times r_{M^4} \quad , \tag{1.4.1}$$

and is thus linear in M^4 distance r_{M^4}.

Does cognition automatically solve real field equations in long length scales?

In TGD inspired theory of consciousness p-adic space-time sheets are identified as space-time correlates of cognition. Therefore our thoughts would have literally infinite size in the real topology if p-adics and reals correspond to each other via common rationals (also other correspondence based on the separate canonical identification of integers m and n in $q = m/n$ with p-adic numbers).

The cognitive solution of field equations in very small p-adic region would solve field equations in real sense in a discrete point set in very long real length scales. This would allow to understand why the notions of Universe and infinity are a natural part of our conscious experience although our sensory input is about an infinitesimally small region in the scale of universe.

The idea about Universe performing mimicry at all possible levels is one of the basic ideas of TGD inspired theory of consciousness. Universe could indeed understand and represent the long length scale real dynamics using local p-adic physics. The challenge would be to make quantum jumps generating p-adic surfaces having large number of common points with the real space-time surface. We are used to call this activity theorizing and the progress of science towards smaller real length scales means progress towards longer length scales in p-adic sense. Also real physics can represent p-adic physics: written language and computer represent examples of this mimicry.

1.4.2 A more detailed view about how local p-adic physics codes for p-adic fractal long range correlations of the real physics

The vision just described gives only a rough heuristic view about how the local p-adic physics could code for the p-adic fractality of long range real physics. There are highly non-trivial details related to the treatment of M^4 and CP_2 coordinates and to the mapping of p-adic H-coordinates to their real counterparts and vice versa.

How real and p-adic space-time regions are glued together?

The first task is to visualize how real and p-adic space-time regions relate to each other. It is convenient to start with the extension of real axis to contain also p-adic points. For finite rationals $q = m/n$, m and n have finite power expansions in powers of p and one can always write $q = p^k \times r/s$ such that r and s are not divisible by p and thus have pinary expansion of in powers of p as $x = x_0 + \sum_1^N x_n p^n$, $x_i \in \{0, p\}$, $x_0 \neq 0$.

One can always express p-adic number as $x = p^n y$ where y has p-adic norm 1 and has expansion in non-negative powers of p. When x is rational but not integer the expansion contains infinite number of terms but is periodic. If the expansion is infinite and non-periodic, one can speak about *strictly p-adic* number having infinite value as a real number.

In the same manner real number x can be written as $x = p^n y$, where y is either rational or has infinite non-periodic expansion $y = r_0 + \sum_{n>0} r_n p^{-n}$ in negative powers of p. As a p-adic number y is infinite. In this case one can speak about strictly real numbers.

This gives a visual idea about what the solution of field equations locally in various number fields could mean and how these solutions are glued together along common rationals. In the following I shall be somewhat sloppy and treat the rational points of the imbedding space as if they were points of real axis in order to avoid clumsy formulas.

1. The p-adic variants of field equations can be solved in the strictly p-adic realm and by p-adic smoothness these solutions are well defined also in as subset of rational points. The strictly p-adic points in a neighborhood of a given rational point correspond as real points to infinitely distant points of M^4. The possibility of p-adic pseudo constants means that for rational points of M^4 having sufficiently large p-adic norm, the values of CP_2 coordinates or induced spinor fields can be chosen more or less freely.

2. One can solve the p-adic field equations in any p-adic neighborhood $U_n(q) = \{x = q + p^n y\}$ of a rational point q of M^4, where y has a unit p-adic norm and select the values of fields at different points q_1 and q_2 freely as long as the spheres $U_n(q_1)$ and $U_n(q_2)$ are disjoint (these spheres are either identical or disjoint by p-adic ultra-metricity).

   The points in the p-adic continuum part of these solutions are at an infinite distance from q in M^4. The points which are well-defined in real sense form a discrete subset of rational points of M^4. The p-adic space-time surface constructed in this manner defines a discrete fractal hierarchy of rational space-time points besides the original points inside the p-adic spheres. In real sense the rational points have finite distances and could belong to disjoint real space-time sheets. The failure of the strict non-determinism for the field equations in the real sense gives hopes for gluing these sheets partially together (say in particle reactions with particles represented as 3-surfaces).

3. All rational points q of the p-adic space-time sheet can be interpreted as real rational points and one can solve the field equations in the real sense in the neighborhoods $U_n(q) = \{x = q + p^n y\}$ corresponding to real numbers in the the range $p^n \leq x \leq p^{n+1}$. Real smoothness and continuity fix the solutions at finite rational points inside $U_n(q)$ and by the phenomenon of p-adic pseudo constants these values can be consistent with p-adic field equations. Obviously one can can continue the construction process indefinitely.

p-Adic scalings act only in M^4 degrees of freedom

p-Adic fractality suggests that finite real space-time sheets around points $x + p^n$, $x = 0$, are obtained as by just scaling of the M^4 coordinates having origin at $x = 0$ by p^n of the solution defined in a neighborhood of x and leaving CP_2 coordinates as such. The known extremals of Kähler action indeed allow M^4 scalings as dynamical symmetries.

One can understand why no scaling should appear in CP_2 degrees of freedom. CP_2 is complex projective space for which points can be regarded as complex planes and for these p-adic scalings act trivially. It is worth of emphasizing that here could lie a further deep number theoretic reason for why the space S in $H = M^4 \times S$ must be a projective space.

What p-adic fractality for real space-time surfaces really means?

The identification of p-adic and real M^4 coordinates of rational points as such is crucial for p-adic fractality. On the other hand, the identification rational real and p-adic CP_2 coordinates as such would not be consistent with the idea that p-adic smoothness and continuity imply p-adic fractality manifested as long range correlations for real space-time sheets

The point is that p-adic fractality is not stable against small p-adic deformations of CP_2 coordinates as function of M^4 coordinates for solutions representable as maps $M^4 \to CP_2$. Indeed, if the rational valued p-adic CP_2 coordinates are mapped as such to real coordinates, the addition of large power p^n to CP_2 coordinate implies small modification in p-adic sense but large change in the real sense so that correlations of CP_2 at p-adically scaled M^4 points would be completely lost.

The situation changes if the map of p-adic CP_2 coordinates to real ones is continuous so that p-adically small deformations of the p-adic space-time points are mapped to small real deformations of the real space-time points.

1. Canonical identification $I : x = \sum x_n p^n \to \sum x_n p^{-n}$ satisfies continuity constraint but does not map rationals to rationals.

2. The modification of the canonical identification given by

$$I(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{1.4.2}$$

   is uniquely defined for rational points, maps rationals to rationals, has a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$.

3. The form of this map is not general coordinate invariant nor invariant under color isometries. The natural requirement is that the map should respect the symmetries of CP_2 maximally. Therefore the complex coordinates transforming linearly under U(2) subgroup of SU(3) defining the projective coordinates of CP_2 are a natural choice. The map in question would map the real components of complex coordinates to their p-adic variants and vice versa. The residual $U(2)$ symmetries correspond to rational unitary 2×2-matrices for which matrix elements are of form $U_{ij} = p^k r/s$, $r < p, s < p$. It would seem that these transformations must form a finite subgroup if they define a subgroup at all. In case of $U(1)$ Pythagorean phases define rational phases but sufficiently high powers fail to satisfy the conditions $r < p, s < p$. Also algebraic extensions of p-adic numbers can be considered.

4. The possibility of pseudo constant allows to modify canonical identification further so that it reduces to the direct identification of real and p-adic rationals if the highest powers of p in r and s ($q = p^n r/s$) are not higher than p^N. Write $x = \sum_{n \geq 0} x_n p^n = x^{N)} + p^{N+1} y$ with $x^{N)} = \sum_{n=0}^{N} x_n p^n$, $x_0 \neq 0$, $y_0 \neq 0$, and define $I_N(x) = x^{N)} + p^{N+1} I(y)$. For $q = p^n r/s$ define $I_N(q) = p^n I_N(r)/I_N(s)$. This map reduces to the direct identification of real and p-adic rationals for $y = 0$.

5. There is no need to introduce the imaginary unit explicitly. In case of spinors imaginary unit can be represented by the antisymmetric 2×2-matrix ϵ_{ij} satisfying $\epsilon_{12} = 1$. As a matter fact, the introduction of imaginary unit as number would lead to problems since for $p \ mod \ 4 = 3$ imaginary unit should be introduced as an algebraic extension and CP_2 in this sense would be an algebraic extension of RP_2. The fact that the algebraic extension of p-adic numbers by $\sqrt{-1}$ is equivalent with an extension introducing $\sqrt{p-1}$ supports the view that algebraic imaginary unit has nothing to do with the geometric imaginary unit defined by Kähler form of CP_2. For $p \ mod \ 4 = 1$ $\sqrt{-1}$ exists as a p-adic number but is infinite as a real number so that the notion of finite complex rational would not make sense.

Preferred CP_2 coordinates as a space-time correlate for the selection of quantization axis

Complex CP_2 coordinates are fixed only apart from the choice of the quantization directions of color isospin and hyper charge axis in SU(3) Lie algebra. Hence the selection of quantization axes seems to emerge at the level of the generalized space-time geometry as quantum classical correspondence indeed requires.

In a well-defined sense the choice of the quantization axis and a special coordinate system implies the breaking of color symmetry and general coordinate invariance. This breaking is induced by the presence of p-adic space-time sheets identified as correlates for cognition and intentionality. One could perhaps say that the cognition affects real physics via the imbedding space points shared by real and p-adic space-time sheets and that these common points define discrete coordinatization of the real space-time surface analogous to discretization resulting in any numerical computation.

Relationship between real and p-adic induced spinor fields

Besides imbedding space coordinates also induced spinor fields are fundamental variables in TGD. The free second quantized induced spinor fields define the fermionic oscillator operators in terms of which the gamma matrices giving rise to spinor structure of the "world of classical worlds" can be expressed.

p-Adic fractal long range correlations must hold true also for the induced spinor fields and they are in exactly the same role as CP_2 coordinates so that the variant of canonical identification mapping rationals to rationals should map the real and imaginary parts of of real induced spinor fields to their p-adic counterparts and vice versa at the rational space-time points common to p-adic and real space-time sheets.

Could quantum jumps transforming intentions to actions really occur?

The idea that intentional action corresponds to a quantum jump in which p-adic space-time sheet is transformed to a real one traversing through rational points common to p-adic and real space-time sheet is consistent with the conservation laws since the sign of the conserved inertial energy can be

also negative in TGD framework and the density of inertial energy vanishes in cosmological length scales [D5]. Also the non-diagonal transitions $p_1 \to p_2$ are in principle possible and would correspond to intersections of p-adic space-time sheets having a common subset of rational points. Kind of phase transitions changing the character of intention or cognition would be in question.

1. Realization of intention as a scattering process

The first question concerns the interpretation of this process and possibility to find some familiar counterpart for it in quantum field theory framework. The general framework of quantum TGD suggests that the points common to real and p-adic space-time sheets could perhaps be regarded as arguments of an n-point function determining the transition amplitudes for p-adic to real transition or $p_1 \to p_2$-adic transitions. The scattering event transforming an p-adic surface (infinitely distant real surface in real M^4) to a real finite sized surface (infinitely distant p-adic surface in p-adic M^4) would be in question.

2. Could S-matrix for realizations of intentions have the same general form as the ordinary S-matrix?

One might hope that the realization of intention as a number theoretic scattering process could be characterized by an S-matrix, which one might hope of being unitary in some sense. These S-matrix elements could be interpreted at fundamental level as probability amplitudes between intentions to prepare a define initial state and the state resulting in the process.

Super-conformal invariance is a basic symmetry of quantum TGD which suggests that the S-matrix in question should be constructible in terms of n-point functions of a conformal field theory restricted to a subset of rational points shared by real and p-adic space-time surfaces or their causal determinants. According to the general vision discussed in [C1], the construction of n-point functions effectively reduces to that at 2-dimensional sections of light-like causal determinants of space-time surfaces identified as partonic space-time sheets.

The idea that physics in various number fields results by algebraic continuation of rational physics serves as a valuable guideline and suggests that the form of the S-matrices between different number fields (call them non-diagonal S-matrices) could be essentially the same as that of diagonal S-matrices. If this picture is correct then the basic differences to ordinary real S-matrix would be following.

1. Intentional action could transform p-adic space-time surface to a real one only if the exponent of Kähler function for both is rational valued (or belongs to algebraic extension of rationals).

2. The points appearing as arguments of n-point function associated with the non-diagonal S-matrix are a subset of rational points of imbedding space whereas in the real case, where the integration over these points is well defined, all values of arguments can be allowed. Thus the difference between ordinary S-matrix and more general S-matrices would be that a continuous Fourier transform of n-point function in space-time domain is not possible in the latter case. The inherent nature of cognition would be that it favors localization in the position space.

3. Objection and its resolution

Exponent of Kähler function is the key piece of the configuration space spinor field. There is a strong counter argument against the existence of the Kähler function in the p-adic context. The basic problem is that the definite integral defining the Kähler action is not p-adically well-defined except in the special cases when it can be done algebraically. Algebraic integration is however very tricky and numerically completely unstable.

The definition of the exponent of Kähler function in terms of Dirac determinants or, perhaps equivalently, as a result of normal ordering of the modified Dirac action for second quantized induced spinors might however lead to an elegant resolution of this problem. This approach is discussed in detail in [B4, D1]. The idea is that Dirac determinant can be defined as a product of eigenvalues of the modified Dirac operator and one ends up to a hierarchy of theories based on the restriction of the eigenvalues to various algebraic extensions of rationals identified as a hierarchy associated with corresponding algebraic extensions of p-adic numbers. This hierarchy corresponds to a hierarchy of theories (and also physics!) based on varying values of Kähler coupling constant and Planck constant. The elegance of this approach is that no discretization at space-time level would be needed: everything reduces to the generalized eigenvalue spectrum of the modified Dirac operator.

4. A more detailed view

Consider the proposed approach in more detail.

1. Fermionic oscillator operators are assigned with the generalized eigenvectors of the modified Dirac operator defined at the light-like causal determinants:

$$\begin{aligned} \Psi &= \sum_n \Psi_n b_n \ , \\ D\Psi_n &= \Gamma^\alpha D_\alpha \Psi_n = \lambda_n O \Psi_n \ , \ O \equiv n_\alpha \Gamma^\alpha \ . \end{aligned} \tag{1.4.3}$$

   Here $\Gamma^\alpha = T^{\alpha k}\Gamma_k$ denote so called modified gamma matrices expressible in terms of the energy momentum current $T^{\alpha k}$ assignable to Kähler action [B4]. The replacement of the ordinary gamma matrices with modified ones is forced by the requirement that the super-symmetries of the modified Dirac action are consistent with the property of being an extremal of Kähler action. n_α is a light like vector assignable to the light-like causal determinant and $O = n_\alpha\Gamma^\alpha$ must be rational and have the same value at real and p-adic side at rational points. The integer n labels the eigenvalues λ_n of the modified Dirac operator, and b_n corresponds to the corresponding fermionic oscillator operator.

2. The condition that the p-adic and real variants Ψ if the Ψ are identical at common rational points of real and p-adic space-time surface (the same applies to 4-surfaces corresponding to different p-adic number fields) poses a strong constraint on the algebraic continuation from rationals to p-adics and gives hopes of deriving implications of this approach.

3. Ordinary fermionic anti-commutation relations do not refer specifically to any number field. Super Virasoro (anti-)commutation relations involve only rationals. This suggest that fermionic Fock space spanned by the oscillator operators b_n is universal and same for reals and p-adic numbers and can be regarded as rational. Same would apply to Super Virasoro representations. Also the possibility to interpret configuration space spinor fields as quantum superpositions of Boolean statements supports this kind of universality. This gives good hopes that the contribution of the inner produces between Fock states to the S-matrix elements are number field independent.

4. Dirac determinant can be defined as the product of the eigenvalues λ_n restricted to a given algebraic extension of rationals. The solutions of the modified Dirac equation correspond to vanishing eigen values and define zero modes generating conformal super-symmetries and are not of course included.

5. Only those operators b_n for which λ_n belongs to the algebraic extension of rationals in question are used to construct physical states for a given algebraic extension of rationals. This might mean an enormous simplification of the formalism in accordance with the fact that configuration space Clifford algebra corresponds as a von Neumann algebra to a hyper-finite factor of type II_1 for which finite truncations by definition allow excellent approximations [C7]. One can even ask whether this hierarchy of algebraic extensions of rationals could in fact define a hierarchy of finite-dimensional Clifford algebras. If so then the general theory of hyper-finite factors of type II_1 would provide an extremely powerful tool.

1.4.3 Infinite primes, cognition and intentionality

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented

by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether configuration space degrees of freedom and configuration space spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionic) primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling super-generators to the finite primes. One must also remember that the infinite primes considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

Precise space-time correlates of cognition and intention

The best manner to end up with the proposal about how p-adic cognitive representations relate bosonic representations of intentions and actions and to fermionic cognitive representations is through the following arguments.

1. In TGD inspired theory of consciousness Boolean cognition is assigned with fermionic states. Cognition is also assigned with p-adic space-time sheets. Hence quantum classical correspondence suggests that the decomposition of the space-time into p-adic and real space-time sheets should relate to the decomposition of the infinite prime to bosonic and fermionic parts in turn relating to the above mention decomposition of physical states to bosonic and fermionic parts.

   If infinite prime defines an association of real and p-adic space-time sheets and this association could serve as a space-time correlate for the Fock state defined by configuration space spinor for given 3-surface. Also spinor field as a map from real partonic 3-surface would have as a space-time correlate a cognitive representation mapping real partonic 3-surfaces to p-adic 3-surfaces obtained by algebraic continuation.

2. Consider first the concrete interpretation of integers m_B and n_B. The most natural guess is that the primes dividing $m_B = \prod_i p^{m_i}$ characterize the effective p-adicities possible for the real 3-surface. m_i could define the numbers of disjoint partonic 3-surfaces with effective p_i-adic topology and associated with with the same real space-time sheet. These boundary conditions would force the corresponding real 4-surface to have all these effective p-adicities implying multi-p-adic fractality so that particle and wave pictures about multi-p-adic fractality would be mutually consistent. It seems natural to assume that also the integer n_i appearing in $m_B = \prod_i q_i^{n_i}$ code for the number of real partonic 3-surfaces with effective q_i-adic topology.

3. Fermionic statistics allows only single genuinely q_i-adic 3-surface possibly forming a pair with its real counterpart from which it is obtained by algebraic continuation. Pairing would conform with the fact that n_F appears both in the finite and infinite parts of the infinite prime (something absolutely essential concerning the consistency of interpretation!).

   The interpretation could be as follows.

   i) Cognitive representations must be stable against intentional action and fermionic statistics guarantees this. At space-time level this means that fermionic generators correspond to pairs of real effectively q_i-adic 3-surface and its algebraically continued q_i-adic counterpart. The quantum jump in which q_i-adic 3-surface is transformed to a real 3-surface is impossible since one would obtain two identical real 3-surfaces lying on top of each other, something very singular and not allowed by geometric exclusion principle for surfaces. The pairs of boson and fermion surfaces would thus form cognitive representations stable against intentional action.

   ii) Physical states are created by products of super algebra generators. Bosonic generators can have both real or p-adic partonic 3-surfaces as space-time correlates depending on whether they correspond to intention or action. More precisely, m_B and n_B code for collections of real and p-adic partonic 3-surfaces. What remains to be interpreted is why m_B and n_B cannot have common prime factors (this is possible if one allows also infinite integers obtained as products of finite integer and infinite primes).

   iii) Fermionic generators to the pairs of a real partonic 3-surface and its p-adic counterpart obtained by algebraic continuation and the pictorial interpretation is as fermion hole pair. Unrestricted quantum super-position of Boolean statements requires that many-fermion state is accompanied by a corresponding many-antifermion state. This is achieved very naturally if real and corresponding p-adic fermion have opposite fermion numbers so that the kicking of negative energy fermion from Dirac sea could be interpreted as creation of real-p-adic fermion pairs from vacuum.

   If p-adic space-time sheets obey same algebraic expressions as real sheets (rational functions with algebraic coefficients), the Chern-Simons Noether charges associated with real partons defined as integrals can be assigned also with the corresponding p-adic partons if they are rational or algebraic numbers. This would allow to circumvent the problems related to the p-adic integration. Therefore one can consider also the possibility that p-adic partons carry Noether charges opposite to those of corresponding real partons sheet and that pairs of real and p-adic fermions can be created from vacuum. This makes sense also for the classical charges associated with Kähler action in space-time interior if the real space-time sheet obeying multi-p p-adic effective topology has algebraic representation allowing interpretation also as p-adic surface for all primes involved.

   iv) This picture makes sense if the partonic 3-surfaces containing a state created by a product of super algebra generators are unstable against decay to this kind of 3-surfaces so that one could regard partonic 3-surfaces as a space-time representations for a configuration space spinor field.

4. Are alternative interpretations possible? For instance, could $q = m_B/n_B$ code for the effective q-adic topology assignable to the space-time sheet. That q-adic numbers form a ring but not a number field casts however doubts on this interpretation as does also the general physical picture.

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Chapter 2

Matter, Mind, Quantum

2.1 Introduction

Topological Geometro-Dynamics (TGD) is a unified theory of fundamental interactions. TGD involves a quite far-reaching generalization of the space-time concept and, apart from the notion of quantum jump, reduces quantum theory to infinite-dimensional geometry. Quantum TGD requires the introduction of several new mathematical tools and concepts, in particular p-adic numbers. TGD-based theory of consciousness has developed gradually during the last fifteen years side by side with TGD based quantum measurement theory. For a summary of TGD and p-adic aspects of TGD see [1, 6]. The basic concepts and ideas of TGD based theory of consciousness can be summarized as follows.

2.1.1 Identification of quantum states as quantum histories

General coordinate invariance forces the identification of the quantum states as quantum histories rather than time=constant snapshots of single quantum history. Quantum history can be regarded as a classical spinor field in the space of all possible classical worlds so that rather abstract concept is in question. This identification has several important consequences.

1. The possibility to regard state function collapse as a quantum jump between quantum histories solves the basic paradox posed by the determinism of the Schrödinger equation contra non-determinism of the state function collapse[1].

2. A radical reconsideration of the concepts of psychological time and observer becomes necessary and forces a profound generalization of the standard views about time.

2.1.2 Quantum notion of self

An important step in the development of the theory was the discovery of the quantum level definition of the concept of self. Self can be identified as a subsystem able to not generate bound state entanglement during subsequent quantum jumps. A subsystem possessing self behaves thus like its own independent sub-Universe. The quantum notion of self together with some natural assumptions about how the contents of consciousness are determined, leads to an understanding of the phenomenology of the everyday consciousness and to some rather dramatic and often testable predictions. One of the newest ideas related to the notion of self is that the sub-selves of two unentangled selves can entangle although selves remain unentangled. This is possible by the modification of the subsystem concept forced by the p-adic length scale cutoff. The entanglement of sub-selves means fusion and sharing of mental images providing a universal telepathy like quantum communication mechanism and presumably making possible both molecular, cellular, and human societies.

[1]The notion of quantum jump is more general than the notion of state function collapse which suggests a localization of wave packet

2.1.3 Generalization of quantum measurement theory

One must reformulate quantum measurement theory. The hypothesis that each quantum jump involves localization in the so called zero modes having interpretation as classical variables characterizing the observable geometric properties of the space-time surface, and thus of external macroscopic observer, together with an additional condition guaranteing that the density matrix characterizing the entanglement between quantum fluctuating degrees of freedom and zero modes is diagonal, implies standard quantum measurement theory. Needless to emphasize, the reduction of the standard quantum measurement theory to fundamental quantum physics is a triumph of TGD approach.

This is however not the whole story. The standard quantum measurement is followed by a cascade self measurements inside self, which reduces entanglement between some subsystem and its complement in quantum fluctuating degrees of freedom: again a measurement of the density matrix is in question. This cascade is equivalent with the process of state preparation which is a phenomenological notion in the standard quantum measurement theory. The dynamics of self measurement is governed by Negentropy Maximization Principle (NMP), which specifies which subsystems are subject to quantum measurement in a given quantum jump. NMP can be regarded as a basic law for the dynamics of quantum jumps and states that the information content of the conscious experience is maximized. In p-adic context NMP dictates the dynamics of cognition.

2.1.4 Quantum criticality

The systems possessing self correspond to macroscopic quantum phases. In standard physics context the existence of the required macroscopic quantum phases is not at all obvious whereas the new physics implied by TGD predicts their existence. The point is that the Universe according to TGD is a quantum critical system. Quantum criticality is mathematically very similar to thermodynamical criticality and implies long range quantum correlations in all length scales. This in turn implies the existence of macroscopic quantum phases. TGD Universe is also quantum spin glass with state degeneracy broken only by the classical gravitational energy of the space-time sheets having same induced Kähler field. This degeneracy makes it possible to have quantum coherence over time periods longer than CP_2 time of order 10^{-39} seconds characterizing the duration of single quantum jump so that biosystems can act as quantum computers in macroscopic time scales.

2.1.5 TGD based space-time concept and the existence of macroscopic quantum phases

TGD implies a radical generalization of the space-time concept in all length and time scales. The concept of many-sheeted space-time leads to fresh proposals for how biosystems manage to be macroscopic quantum systems. Examples of these mechanisms are so called wormhole superconductivity, electronic high T_c super-conductivity, neutrino super-conductivity, ionic and a mechanism for generating coherent light and gravitons [J1, J2, J2, J4]. The notion of many-sheeted ionic equilibrium summarizes the basic vision about quantum control and coordination according to which the space-time sheets associated with the superconducting magnetic flux tube structures control ordinary biomatter at the atomic space-time sheets.

The so called massless exremals (MEs), which can be regarded as 'topological light rays', are carriers of especially important exmple of macroscopic quantum states. The lightlike boundaries of MEs act as quantum holograms and carry representations of the superconformal and supercanonical algebras. These states have gigantic almost-degeneracies, and are genuine quantum gravitational states (state functionals in the configuration space of 3-surfaces, 'the world of worlds') and thus correspond to higher abstraction level than ordinary quantum states. MEs can control the supercurrents at superconducting magnetic flux tube structures by magnetic interactions, act as Josephson junctions, and induce magnetic quantum phase transitions. Therefore the quantum holograms associated with MEs are excellent candidates for quantum correlates of higher level consciousness.

2.1.6 p-Adic numbers and consciousness

p-Adic number fields R_p (one number field for each prime $p = 2, 3, 5, ...$) are analogous to real numbers but differ from them in that p-adic numbers are not well-ordered. p-Adic numbers play an absolutely

essential role in the formulation of quantum TGD and of TGD inspired theory of consciousness. The inherent non-determinism of p-adic differential equations motivates the identification of the p-adic space-time sheets as cognitive representations of ordinary matter with p-adic non-determinism identified as non-determinism of imagination. Mind-matter duality is realized at the level of space-time geometry and mind stuff corresponds to p-adic regions of space-time. TGD Universe performs self mimicry in all length scales. Besides p-adic nondeterminism there is nondeterminism of Kähler action: these two nondeterminisms allow to represent some aspects of quantum jump sequences, that is contents of consciousness of selves, at space-time level cognitively and symbolically (languaging). This in turn makes possible self referentiality of consciousness: it is possible to become conscious about being conscious about...

2.1.7 Implications of dynamical Planck constant and dark matter hierarchy for TGD inspired theory of consciousness

The identification of dark matter as a phase characterized by large value of quantized Planck constant led to a vigorous evolution of ideas still continuing while I am writing this. An entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [C7]. Also a good educated guess for the spectrum of Planck constants emerges. The hierarchy with $\hbar = \lambda^k \hbar_0$, $\lambda \simeq 2^{11}$, $k = 0, 1, ...$, seems to be especially important for living matter.

The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Dark matter hierarchy has implications also for the basic theory by giving justification for the earlier vision about hierarchy of moments of consciousness analogous to hierarchy elementary particles-hadrons-nuclei-atoms...characterized by their average geometric duration identifiable as the typical duration of the memory span. Also the notion of quantum parallel dissipation emerges: self at the highest level of dark matter hierarchy assignable to it correspond to single moment of consciousness experiencing the quantum jumps sequences at lower level as sub-selves.

This onion-like structure of self helps to answer more convincingly the question how the experienced continuous stream of consciousness can be consistent with the notion of quantum jump. What fuses the lower level quantum jumps to a longer sequence is the presence of higher level self containing this sequence as a mental image.

The developments related to the dark matter hierarchy are added to the end of the chapter together with the newest view about p-adic physics as physics of cognition and intentionality.

2.2 TGD inspired theory of consciousness

Before continuing some comments about the definition of quantum history concept are in order. In TGD quantum states corresponds to Diff^4 invariant configuration space spinor fields defined in the space of 3-surfaces. By general coordinate invariance the value of the configuration space spinor field is same for all 3-surfaces $X^3 \subset X^4(Y^3)$ related by diffomorphisms, especially by time translations of $X^4(Y^3)$. This means that configuration space spinor field cannot be localized temporally unless $X^4(Y^3)$ has finite time duration and is therefore vacuum 4-surface. Hence it is natural to speak of quantum history. Note that 'quantum history' in this sense does not refer to Schrödinger time evolution (since the Schrödinger evolution operator is generalized by TGD) nor evolution by quantum jumps (since, in TGD, these are jumps between entire quantum histories) but is quantum history with respect to the geometric time of $X^4(Y^3)$ and determined by the requirement of general coordinate invariance. Quantum history is defined in the world of all possible clasical worlds (3-surfaces or equivalently allowed space-time surfaces).

Quantum histories can be also regarded as superpositions of classical space-time surfaces since the definition of the configuration space geometry assigns to each 3-surface Y^3 a unique space-time surface $X^4(Y^3)$ and since configuration space spinor field is invariant under general coordinate transformations. As a consequence, classical TGD becomes an exact part of quantum TGD.

2.2.1 Quantum jumps between quantum histories as moments of consciousness

The individual quantum jump between quantum histories has a complex anatomy which has become obvious only gradually. Quantum jump consists of the unitary, informational "time evolution"

$$\Psi_i \to U\Psi_i$$

of the initial quantum history Ψ_i described by the unitary operator U (essentially S-matrix), followed by the step

$$U\Psi_i \to \Psi_{f_0} \ ,$$

in which a localization in zero modes occurs. This step is the counterpart of the state function reduction process and gives rise to the ordinary quantum measurement with zero modes playing the role of classical variables.

This step is followed by a sequence of self measurements

$$\Psi_{f_0} \to \Psi_{f_1} \to ....\Psi_f$$

leading to a state Ψ_f in which only bound state entanglement remains. This process is the counterpart of the state preparation. In a given self measurement sub-system decomposes into two unentangled parts and the decomposition is fixed by the requirement that the reduction of the entanglement entropy is maximal (Negentropy Maximization Principle) and the density matrix serves as a universal observable in the self measurement.

It should be emphasized that the operator U, or equivalently S-matrix, is only the formal counterpart of the Schrdinger time evolution lasting infinite time: there is no actual Schrödinger equation involved and U has nothing to do with geometric time development[2]. U codes all the statistical predictions of quantum TGD and is the counterpart of S-matrix of quantum field theories.

Subjective time development understood as a sequence of quantum jumps occurs outside the realm of the geometric space-time. It could be regarded as a non-deterministic hopping in the space of the configuration space spinor fields. Individual quantum jump is however fundamentally irreducible in the sense that one cannot model it by any dynamical time development. The identification of quantum jump as a moment of consciousness defines what might be called microscopic theory of consciousness. The subjective time development presumably obeys some variational principle consistent with

[2]From TGD point of view the identification of the geometric time and the time coordinate appearing in the general Schrödinger equation of quantum field theories quantized using Hamiltonian formalism is wrong. Schrödinger equation is not even needed. The identification of the time coordinate of the Dirac equation as a geometric time however makes sense from TGD point of view.

the quantum measurement theory, in particular, with its non-determinism[3]. This principle dictates which systems for given initial quantum history can perform quantum jumps and have moments of consciousness. This variational principle will be discussed in section [2.2.2].

Standard quantum measurement theory

The assumption that a localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It also implies standard quantum measurement theory as the following arguments demonstrate.

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory.

2. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field,...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m-M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

3. Unitarity is consistent with the localization in zero modes if the unitary time evolution operator U acts effectively as a flow in zero mode degrees. This means that in some incoming state basis $|n,z\rangle$, where z refers to zero modes, the outgoing states are of form $S^{\dagger}_{nm}|m,z_1(z,n)\rangle$. The effective flow property means a 1-1 mapping of the outgoing quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field). The final state is an eigenstate of the density matrix for the measured system identified as quantum fluctuating degrees of freedom and zero mode degrees of freedom identified as measuring system.

This simple prediction is of utmost theoretical importance since the black box of the quantum measurement theory is reduced to basic quantum theory. This reduction involves crucially the replacement of the notion of a point like particle with particle as a 3-surface. Also the infinite-dimensionality of the zero mode sector of the configuration space of 3-surfaces is absolutely essential. The reduction is a triumph for quantum TGD and favours TGD against string models.

Also self measurements are possible

TGD allows also second type of quantum measurement following ordinary quantum measurement reducing entanglement in quantum fluctuating degrees of freedom for some sub-system-complement pair inside self which corresponds to a state localized in zero modes. This measurement can be regarded as a self measurement and there is entire cascade of them reducing the state to a completely classical product state. The process is obviously the counterpart of the phenomenological state preparation process in quantum physics. The only universal observable is the *density matrix* of the sub-system, which should be thus measured in the quantum jump. Negentropy Maximization Principle (NMP) governs the dynamics of self measurement and states that the the density matrix of a sub-system of self for which the reduction of entanglement entropy is maximal, is measured in self measurement. In the real context self measurement means a reduction of the entanglement and provides a mechanism of self-repair: NMP [H2] says that the biggest hole in the leaking boat is filled first. In p-adic context NMP becomes the basic dynamical principle of cognition.

It is however far from obvious what the notion of quantum measurement means when quantum states are quantum histories. For instance, the precise definition of the sub-system concept involves nontrivial delicacies caused by the classical non-determinism of Kähler action. In absence of this non-determinism, all self measurements could be assigned to the boundary of the future light cone (big

[3]This means that the variational principle in question must be more akin to the second law of thermodynamics rather than to the ordinary variational principles of physics.

bang) in accordance with the quantum holography principle. The fact that the lightlike boundaries of (MEs) allow superconformal and supercanonical symmetries crucial for construction of quantum TGD and act as quantum holograms, leads to the hypothesis that non-determinism of Kähler action induces a fractal hierarchy of MEs in inside MEs and to the identification of the geometric correlates of selves as lightlike boundaries of MEs. MEs can have also finite time duration (virtual MEs) and define also what might be called mindlike space-time sheets.

State preparations induce a tendency opposite to the second law of thermodynamics which follows from the non-determinism of Kähler action implying the generation of MEs inside MEs inside future lightcone. This in turn means that one cannot predict the future from the knowledge of the quantum state at the boundary of the future lightcone using general coordinate invariance as the most stringent form of quantum holography would predict.

Quantum jump as quantum computation like process

The Universe according to TGD is a quantum computer in an extremely general sense of the word. Every quantum jump involves unitary informational "time development" U (quantum computation) and state function reduction involving a localization in the zero modes (halting of the computation) and a sequence of self measurements giving rise to state preparation. It is neither possible nor necessary to assign Schrödinger equation with U. U is however completely analogous to the time evolution operator $U(-t,t)$, $t \to \infty$, defining the S-matrix in quantum field theories. It is important to notice that also in quantum field theories one is interested only in the S-matrix so that new interpretation brings in nothing new at practical level.

There are thus three time developments in TGD:

1. The geometric time development of the space-time surface determined by the absolute minimization of the Kähler action, which also via general coordinate invariance defines in what sense quantum histories are histories;

2. The informational "time development" U analogous to quantum computation (hence the attribute 'informational') represented by S-matrix;

3. The subjective time development by quantum jumps taking outside the realm of the space-time.

These three notions of time development fuse to single "holy trinity" of informational, subjective and geometric time evolutions. This "holy trinity" of time evolutions corresponds to the "holy trinity" of

1. matter in the sense of res extensa identified as 3-surfaces,

2. ideas/objective realities (logos= cosmos) identified as quantum histories (physics= mathematics)[4].

3. and the world of subjective experiences defined by the quantum jump sequences for selves (mathematician exists subjectively in the quantum jumps between mathematical ideas).

Tri-partism allows to overcome the basic difficulties of the monistic and dualistic world pictures. In particular, the theory-reality dualism disappears.

It should be emphasized that in this framework the standard physics identification of the time parameter of Schrödinger evolution with geometric time is wrong. The big problem, to be discussed later, is how the value of geometric time associated with the contents of conscious experience is determined.

How the world of conscious experience can look classical?

If quantum histories (/states) are quantum superpositions over a huge number of classical space-time surfaces, it is very difficult to understand how the world of conscious experience manages to look classical. The solution of the problem comes out from the requirement that quantum jumps in a well defined sense reduce to quantum measurements performed in a space-time with a fixed macroscopic

[4]Quantum histories can be regarded as superpositions of Boolean statements represented by many fermion Fock states (fermion number=1↔true, fermion number =0↔ false), hence logos=cosmos identification.

geometry as in quantum field theory. The macroscopic aspects of the space-time surface are determined completely by the zero modes of the configuration space characterizing the induced Kähler field and geometric size and shape of the four-surface totally. Thus, if each quantum measurement involves a localization in zero modes, then the classicality of the universe of subjective experience is achieved automatically, and as noticed, standard quantum measurement theory follows from quantum TGD proper. In p-adic space-time degrees of freedom complete localization must occur in every quantum jump for purely mathematical reasons, and the interpretation is that intentionality and cognition are completely classical.

During macrotemporal quantum coherence due to the formation of bound state half of the zero modes of two space-time sheets connected by join along boundaries bonds become macroscopic quantum fluctuating degrees of freedom, and in these states consciously experienced world looks non-classical. These states correspond to states of "one-ness" at the level of conscious experience.

There are counter arguments against complete localization. First of all, one can imagine that the reduction could occur to a sub-space of zero modes consisting of a discrete points. Rational bound state entanglement in discrete sub-spaces of zero modes would be stable against state function reduction. Even more generally, the existence of symplectic structure in zero modes allows to consider a hierarchy of 2n-dimensional sub-manifolds in the space of zero modes with volume element defined by the n:th power of the symplectic form. State function reduction could occur to this kind of sub-manifold since at least the transition amplitude would be well-defined. Preferred sub-manifolds of this kind are sub-manifolds closed with respect to the action of $SO(3) \times SU(3)$ isometries such that only the coordinates associated with a finite number of super-canonical generators are non-constant.

Information gain of the conscious experience

Quantum jump cannot be described by any model obeying deterministic dynamics. Thus one can claim that it is impossible to write any formula for the contents of the conscious experience in terms of, say, final quantum history: qualities are not in the world but in the no-where-land between the initial and final worlds of the quantum jump. This might indeed be the case at least when the component of the conscious experience is not about quantities as sensory experiences might be.

Despite this it is possible to assign well-defined information measures for the contents of conscious experience associated with single quantum jump. The idea is simple: interpret conscious systems as "information eaters" in the sense that information gain[5] ΔI in conscious experience is difference for the information measures for the initial and final states $U\Psi_i$ and Ψ_f respectively:

$$\Delta I = I(U\Psi_i) - I(\Psi_f) \quad .$$

Since one can write a formula for a quantum history (quantities are in the world), it is possible to assign well defined information measures to them.

In real context these information measures would be typically infinite by the mere reason that universe is infinite. A crucial role is played by the unique pinary cutoff associated with any mapping of a real geometric object to its p-adic counterpart and by the fact that the real counterpart of integer n regarded as p-adic integer is finite even in the case that n is infinite as ordinary integer. p-Adicization and pinary cutoff suggest a universal manner to characterize the finiteness of the mental capacity of particular self caused by its finite size (information gains are bounded by $p \times log(p)$). One could perhaps call the p-adic image of the reality with pinary cutoff as "personal p-adicity" of self characterized by p-adic prime p.

The assumption that information measures are local with respect to configuration space together with the fact that configuration space spinors are analogous to ordinary single particle Schrödinger amplitudes, makes it possible to assign unique measure to a given type of information. These kind of measures are not possible in quantum field theory [H7].

One can question the claim that a formula for the contents of conscious experience is not possible[6]. In particular, one could claim that sensory experiences are exceptional since they represent basically quantities. Indeed, a working hypothesis worth of studying is that the values of the zero modes (which are same for all the macroscopically equivalent space-time surfaces present in the final quantum history,) determine the contents of the sensory experience. If this is the case, then the p-adic information

[5] Information gain can be also negative.

[6] I am grateful for Philip van Loocke for representing this objection.

measures $I(\Psi_f)$ for the final state of the quantum jump provide measures for the information contents of the sensory experience. Pinary cutoff would automatically take care of the finite resolution of the sensory experience caused by the finite size of the experiencer.

The information measures characterizing single quantum jump are not practical. The work done with the formulation of the Negentropy Maximization Principle (NMP) however led to the discovery that one can and must introduce number-theoretic information measures. p-Adic-real entanglement is possible if the entanglement coefficients are algebraic numbers so that they can be interpreted as belonging to any number field (algebraic extensions of p-adics are allowed). In this case a modification of the logarithm function ($Log_p(x) = log_p(|x|_p)$) allows an infinite series of real-valued entropies labelled by primes p. These entropies can be also negative and therefore serve as genuine information measures. For instance, the experience of understanding has as a correlate p-adic-real cognitive entanglement with negative entanglement entropy. These information measures could mean a revolution in the understanding of the information theoretic aspects of conscious experience. These information measures make sense also in the case of real-real bound state entanglement if it reduces to an algebraic entanglement, and a unique prime p can be assigned to the information measure by maximizing it.

2.2.2 Quantum self

In the following the notion of self is introduced. To avoid confusions it must be emphasised that the notion of self is completely general and by no means restricted to brain. Brain consciousness is in this framework only a special form of consciousness.

The notions of self and subjective memory

The simplest hypothesis is that the contents of consciousness are determined by single quantum jump. There are several objections to this view.

1. The idea about self as a continuous stream of consciousness is very attractive and it seems difficult to believe that our consciousness could be actually a sequence of moments of consciousness with gaps between.

2. Furthermore, if the contents of consciousness are determined completely by the initial and final states of single quantum jump, we cannot have any memories about our previous conscious experiences. Hence subjective memories should be only pseudo memories perhaps resulting from the simulations of the subjective past.

It took quite a long time to realize the real strength of these objections and to discover that a proper quantum definition of the concept of self provides a manner to overcome these obstacles.

1. Entanglement is one of the basic non-classical notions of quantum theory. Un-entangled subsystem, as opposed to an entangled one, behaves as its own sub-universe and can be regarded as a pure quantum state. The natural guess is that self should be identified as a sub-system able to remain unentangled in subsequent quantum jumps. The self lasting only single quantum jump can be also regarded formally as self. This kind of a definition looks intuitively very satisfactory since me-external world separation is a basic characteristic of consciousness. The problem is to formulate precisely what are the characteristics of sub-system defining self, which must remain invariant in quantum jump. It seems that the p-adic prime characterizing the system might be the basic and perhaps only invariant of this kind.

2. The absence of entanglement between space-time regions belonging to different number fields (real and p-adic) would automatically imply the decomposition of the space-time surface to regions identifiable as selves. The entanglement between real and p-adic space-time regions is however possible if entanglement coefficients for orthonormalized state basis are algebraic numbers [H2], and has an interpretation as giving rise to a correlation between cognitive quantum states and the states of the material system. For a negative entanglement entropy the reduction of the entanglement would be in a conflict with NMP: hence a cognitive bound state is in question. This means a period of macrotemporal cognitive quantum coherence during which a sequence of quantum jumps is effectively fused to a single quantum jump. The state decays in what might be called a cognitive measurement. Cognitive bound state entanglement is possible

only in configuration space spin degrees of freedom, that is in basically fermionic degrees of freedom (elementary bosons can be regarded as antifermion-fermion bound states).

3. The hypothesis that the experiences of self associated with the quantum jumps occurred after the "wake-up" (the quantum jump during which U made sub-system unentangled or created unentangled subystem) sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore the self becomes an extended object with respect to the subjective time and has a well defined "personal history". Subjective memory has a natural identification as a short term memory with a duration of order second.

4. If the temporal binding of experiences involves some kind of averaging, that is, if quantum statistical determinism generalizes to the level of the subjective experience, the total experience defined by the heap of the experiences associated with individual quantum jumps is reliable.

5. Self can have sub-selves: this corresponds geometrically to a space-time sheet having smaller space-time sheets glued to it. An irreducible self is defined as a self having no sub-selves. Reducible and irreducible selves give rise to two modes of consciousness identifiable as ordinary and "whole-body" consciousness.

6. The sub-selves of two selves can entangle if one allows the definition of sub-system concept based on p-adic length scale cutoff. Essentially this means that because of the p-adic length scale cutoff, the entanglement of sub-systems is not 'seen' at the level of systems so that they can remain unentangled. p-Adic length scale cutoff is natural since the wormhole contacts associated with topologically condensed space-time sheets are surrounded by 'elementary particle horizons' analogous to blackhole horizons. Therefore the larger space-time sheet 'sees' about topologically condensed space-time sheet only some quantum numbers like mass, spin and charge. The entanglement of sub-systems makes possible fusion and sharing of mental images crucial for quantum communications. For instance, receiver can understand the message by sharing the mental image of the sender representing the understanding of the message.

7. Sub-system can wake-up (become conscious self) in several manners. The phase transitions $R \leftrightarrow R_p$ inside real/p-adic self generate new p-adic/real sub-selves. In fact, real–p-adic phase transitions correspond to the transformation of sensory input into cognition and thought into action. Also the transitions $R_{p_1} \to R_{p_2}$ inside p_1-adic self generate new p_2-adic sub-selves.

Negentropy Maximization Principle

As already explained, TGD reduces the state function reduction of the standard quantum measurement theory to the localization in zero modes. Besides this, it is postulated that the localization in zero modes is followed by a cascade of self measurements giving rise to an unentangled product state and thus state preparation. NMP governs the dynamics of self measurement.

1. NMP applies to each un-entangled sub-system resulting in self measurement cascase separately, and is therefore in a well-defined sense a local principle. Every un-entangled sub-system X in Ψ_{f_0} participates in quantum jump $\Psi_{f_0} \to \Psi_{f_1}$, which means that the density matrix for some sub-system of X is quantum measured.

2. A quantum jump for a given unentangled sub-system X corresponds to a measurement of the density matrix for some sub-system Y of X. In this measurement sub-system Y goes to an eigenstate of the density matrix and Y becomes unentangled. Same happens to the complement of Y inside X. The amount of entanglement is measured by entanglement entropy S and S vanishes for the final state of the quantum jump. Thus S can be regarded as negentropy gain having interpretation as some kind of conscious information, or rather, reduction of dis-information. The conscious experience must be assigned with X. One cannot associate it with the measured sub-system or its complement inside$X$ since they are in completely symmetric position since diagonalized density matrices are identical. Hence there is no manner to tell which is the measured system and which the measuring sub-system. Thus one must define self measurement as a measurement creating an unentangled sub-system-complement pair inside X and identify X as the conscious measurer.

3. NMP states that the entanglement entropy reduction associated with the conscious experience of the sub-system X is maximal. Interpreting entanglement negentropy gain as conscious information, on can say that we live in (or create) the best possible world. Only the quantum jumps giving rise to maximum information content of conscious experience occur. It must be noticed however that one can assign several types of information measures with conscious experience. This requirement fixes the quantum measured sub-system Y of given self uniquely unless there are several sub-systems giving rise to same maximum negentropy gain: in this case any of the quantum jumps occurs with same probability.

The precise formulation of NMP involves delicate issues. In the purely real standard physics context NMP need not make sense since in the generic case the entire universe could be the only unentangled system after state function reduction and entanglement entropies for candidate sub-systems would be infinite. In TGD space-time decomposing into both real and p-adic space-time sheets, an elegant formulation of NMP with sensical predictions is possible, since universe decomposes to subselves possessing finite entanglement entropies. NMP reduces to a local principle applying separately to each unentangled system.

In p-adic context entanglement negentropy gain is defined as the real counterpart of the p-adic negentropy gain with p-adic prime p characterizing the sub-system in question. The definition of the negentropy concept in p-adic framework involves quite interesting delicacies. For instance, entanglement with a vanishing entanglement entropy is possible [H3, H5]. One must also define the concept of sub-system very carefully since quantum states are identified as quantum histories in TGD framework and here MEs turn out to be crucial element because their lightlike boundaries have quantum hologram property meaning the reduction the physics inside ME to conformally invariant physics at the boundary of ME. It has been already mentioned that number theoretic entanglement entropies emerge naturally in case of real-p-adic entanglement and can be negative.

Summation hypothesis and binding of experiences

The self X behaves essentially as a separate sub-Universe. Also the sub-selves of X_i of X have their own experiences. The question is: how the experience of X and experiences of X_i are related? The following basic hypothesis provides a possible answer to this question.

1. X experiences the sub-selves X_i as separate mental images superposed to the pure self experience of X: this is natural since sub-selves are unentangled and hence behave like separate sub-Universes.

2. The experiences of self X about the experiences of its sub-selves X_i are abstractions. Sub-self X_i experiences its sub-selves X_{ij} as separate mental images. X however experiences them as a single mental image representing what it is to be a sub-self of X_i, that is the average $\langle X_{ij} \rangle$ of the mental images X_{ij}. Thus the mental images of sub-sub-...selves of X are smoothed out to an average mental image and become effectively unconcious to X. Averaging hypothesis generalizes quantum statistical determinism to the level of subjective experience and is analogous to the hypothesis about averaging related to temporal binding.

Temporal binding with averaging implies that the experiences of the individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles. The inability to perceive the flickering of light when the frequency of the flickering is larger than about one Hz is consistent with the hypothesis that subjective sensory memory has duration of order .1 seconds and that temporal averaging indeed occurs. Time averaging could involve weighting such that the conscious experiences associated with the last quantum jumps have the largest weight. This would allow our self to have duration much longer than .1 seconds. For instance, the duration of the ordinary wake-up period could determine the duration of our self. The duration could be even longer: sleep could actually involve awareness and the lack of the sensory memories from sleep period could create the illusion about sleep as an unconscious state.

Summation hypothesis and temporal binding imply a hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is the entire universe, God, enjoying eternal self-consciousness since it cannot entangle with with any larger system. Also we are mental images of some higher level self. This hierarchy obviously has far-reaching consequences.

Binding of the experiencers by entanglement

The binding of experiencers is also possible. The binding of selves by quantum entanglement however means they lose their consciousness. This process naturally corresponds to the formation of wholes from their parts at the level of conscious experiences. The formation of a mental image (sub-self) representing word from the mental images representing letters is example of this process. Also the fusion of the left and right visual fields to a single visual field could occur via the entanglement of the corresponding sub-selves. Note however that right–left entanglement might occur already at neuronal level. Entanglement mechanism provides also a possible mechanism of "enlightment" experiences envolving extension of self [H3, H5]. Quantum entanglement could make possible communication between selves belonging to different levels of the self hierarchy.

Binding and quantum metabolism as different sides of the same coin

Quantum jump involves also a state preparation process and only bound state entanglement is stable against the state preparation. Hence the fusion of the mental images implicates the formation of a bound state. This process is expected to involve a liberation of the binding energy as a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and binding are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enchanced oxidative metabolism [29]. A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

How to understand evolution and self-organization?

One could argue that since the quantum jump is random (not actually since selection between the eigenstates of the density matrix occurs), quantum jump as a moment of consciousness identification cannot explain evolution. In standard physics it is difficult to circumvent this objection. Even worse, heat death seems to be the ultimate fate of the universe according to standard physics.

The fact that quantum jump involves localization in zero modes and thus localization into a definite sector D_P of configuration space labelled by infinite prime P, implies evolution as a statistical increase of P. Since infinite primes are in well-defined sense composites of finite primes, this in turn implies that the finite p-adic prime associated with a given sub-system tends to increase and that new space-time sheets labelled by finite primes emerge during the time evolution by quantum jumps.

This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies (MEs inside MEs inside...). Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (or even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favoured self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The proposed realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [H7]. TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism.

How to understand morally responsible free will?

One could argue that the randomness of the quantum jump means that moral choices are impossible. The essence of volition is intentionality. p-Adic space-time sheets are excellent candidates for the correlates of intentions because of the inherent non-determinism of the p-adic differential equations. p-adic-to-real transformation of a p-adic space-time sheet in quantum jump is the geometric correlate for the transformation of intention to action. At configuration space level one cannot assign any (at least p-adic) probabilities to p-adic localizations so that randomness is not in question. System can therefore intend, that is perform a particular localization in p-adic degrees of freedom very many times.

p-Adic evolution defines the fundamental value of the quantum ethics. The selections which tend to increase the value of the p-adic prime represent good deeds since they mean evolution. The values of this ethics are not in the physical world but in the quantum jumps defining the subjective reality.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and gives rise to a "prophecy", a prediction for the future and past, which would be reliable if the world were completely classical). As a matter fact, it is p-adic space-time sheets which correspond to intentions and plans and act of volition transforms p-adic space-time sheet to a real one. Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps. Thus selves are genuine moral agents if they can experience directly that increase of p is good and decrease of p is bad.

Implications of the dark matter hierarchy for the notion of self

The identification of dark matter as phases having large value of Planck constant [D6, J6, C7] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [C7]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3]. The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the basic

hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^{11}$ is integer. Also sub-harmonics and integer valued sub-harmonics of λ are possible [C7]. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests also a slight modification of the notion of self. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

2.2.3 About geometric correlates of selves

Space-time sheets with a finite time duration serve as geometric correlates for selves. There are several questions to answer. For instance, one should understand how the conscious experiences associated with the p-adic and real space-time sheets differ. Also one should understand how psychological time and its arrow emerge in this picture.

Cognition, imagination and p-adic physics

The problem about geometric correlates of cognition is not yet completely resolved. An important problem is what one understands with cognition and loose definitions might generate additional confusion. Intuitively it is clear that cognition should correspond to thinking. The simplest model for logical thinking is based on Boolean algebra: one could however argue that 'this is true' experiences are actually much like ordinary sensory experiences. Besides true/false dichotomy there are also beatiful/ugly and right/wrong dichotomies which suggests that aesthetics, moral, and logic might correspond to various aspects of some Boolean structure having physical interpretation and that cognition involves logic as one aspect only. Imagination is an important aspect of thinking and one could also consider the identification of the most fundamental aspect of cognition as imagination and perhaps even identify cognition as imagination.

The notion of the many-sheeted space-time decomposing into real and p-adic space-time sheets, and the classical non-determinism of the Kähler action making possible experiences with temporally localized information contents, are the key elements of TGD based model of consciousness.

The notions of mindlike space-time sheet (space-time sheet with a finite temporal duration) and association sequence were originally identified as geometric correlates of thoughts quite generally. On the other hand, the inherent non-determinism of p-adic differential equations means that the solutions of p-adic counterparts of field equations consist of pieces which are characterized by ordinary integration constants glued together. This is very much like the non-determinism of imagination and dreams, and inspires the hypothesis that p-adic space-time sheets serve as cognitive representations.

Real mindlike space-time would be the geometric correlates of sensory mental images rather than cognition. The difference between real and imagined experiences would correspond to real–p-adic distinction. One must be however very cautious here: one cannot exclude the possibility that also cognition is one aspect of sensory experience and that the notion of imagined cognition makes sense. It is also somewhat a convention, what is counted as cognition.

What we regard as imagination presumably involves p-adic–to–real transitions giving rise to initial values determining nerve pulse patterns generating almost motor actions and almost sensory perceptions Also cell membrane oscillation patterns could represent imagination whereas nerve pulses give rise to sensory experiences. Thus p-adic physics would represent the core element of imagination and

cognition. There are still unclear points: what seems certain that p-adic physics represents intentionality but one can debate about whether it represents also imagination and cognition.

What space-time surfaces look like?

The notion of the space-time surface appears often in the sequel and deserves some explaining. Mathematician's notion of the space-time surface is more general than the intuitive notion about it. For instance, space-time surface can be union of disjoint surfaces (2-D visualization: 2-surface can consist of several disjoint 2-surfaces: sphere here and piece of plane there,..). Space-time sheet is near to what one intuitively would understand with a space-time surface.

The TGD based notion of space-time surface is roughly the following.

1. One obtains piece of Minkowski space as a 4-surface defined by putting CP_2 coordinates constant: this is simplest kind of a vacuum extremal. By suitably deforming one obtains infinitely many vacuum extremals. Vacuum extremals can have finite time duration: in this case they correspond to mindlike space-time sheets.

2. Allowing several values for CP_2 coordinates one obtains several 'parallel' pieces of Minkowski space which can be deformed to more general vacuum extremals. These sheets can be glued together by wormhole contacts and deformed so that they are not vacua anymore.

3. By gluing extremely small surfaces representing elementary particles to this complex one obtains a rough view about what TGD space-time surface looks like.

4. Besides real regions there are also p-adic regions but these look like fractal dust in real topology. p-Adic and real regions are glued together at rational points of imbedding space.

Two-dimensional visualization might also help. Put z-coordinate constant in 3-space and allow several values of z-coordinate: you get several parallel pieces of plane. Deform them and glue them together by wormhole contacts. Glue elementary particle like surfaces, represented by, say, extremely tiny spheres and tori.

Association sequences and mindlike space-time sheets

The concepts of mindlike space-time sheet and association sequence are crucial for TGD based quantum model of intelligent system [H7].

Mindlike space-time sheets are geometric correlates of selves (see Fig. 2). They are made possible by the huge vacuum degeneracy of the Kähler action, TGD and more standard theories of physics. By gluing vacuum extremals to nonvacuum space-time surfaces and suitably deforming, one obtains new degenerate absolute minima. One manner to see mindlike space-time sheets is as the classical counterparts of the virtual particles of the quantum field theories (in TGD particles are 3-surfaces!) created from vacuum and returning to it. By definition material space-time sheets have infinite temporal extension whereas mindlike space-time sheets have *finite* temporal extension. Finite temporal extension is possible since classical conserved quantities like energy can flow to mindlike space-time sheet begins and flow back to a material space-time sheet when mindlike space-time sheet ends. The finite temporal extension implies that the information contents of the conscious experiences for selves associated with the mindlike space-time sheets are temporally localized. Thus a rough idea about the origin of the psychological time emerges. Mindlike space-time sheets provide cognitive representations for the material space-time sheets to which they are glued by wormhole contacts and/or join along boundaries contacts. Since the sign of the classical energy in TGD correlates with the time orientation of the space-time sheet, pairs of mindlike space-time sheets with vanishing net energy are possible. Direct mimicry is the simplest possible cognitive representation and this kind of a two-sheeted structure makes it possible! If this is indeed true, TGD universe would be physicist's version of the computer scientist's universe populated by computers emulating each other.

The original belief was that association sequence provides a model for thought understood as a simulation of the classical time development. This model does not necessitate p-adicity and one can ask whether all cognition is p-adic or whether also real cognition based on the classical non-determinism of Kähler action is possible. It is quite possible that the classical non-determinism of

Kähler action provides sensory rather than cognitive simulation of the classical time development in the real context. This simulation could be naturally regarded as a symbolic representation whereas p-adic nondeterminism would make possible cognitive representations. Thus real association sequences would make possible language as symbolic representation of thoughts rather than thoughts as believed originally.

1. The original motivation of the association sequence concept is the vacuum degeneracy of the Kähler action. p-Adic non-determinism gives also rise to association sequences. This degeneracy implies classical non-determinism in the sense that the absolute minimum $X^4(Y^3)$ of the Kähler action associated with a given spacelike 3-surface Y^3 on lightcone boundary $\delta M^4_+ \times CP_2$ is not unique in general. In order to get rid of this non-determinism one must generalize the concept of 3-surface. "Association sequences", defined as 3-surfaces consisting of unions of some minimal number of disjoint 3-surfaces with timelike(!) separations, must be allowed (see Fig. 1) in order to fix uniquely which degenerate absolute minimum is in question.

2. A simple model for association sequence is obtained by considering a non-deterministic motion of a point in, say, plane. Suppose that there are N bifurcations. One can clearly fix single branch by fixing $N + 1$ points on the orbit. The union of these points, which have time like distances and are not clearly unique, defines association sequence. Non-determinism brings in finite number of degrees of freedom characterized by a sequence of N binary digits.

3. Association sequence provides a simulation of the classical time evolution and gives rise to what might be called "geometric memory" involved with the intentional aspects of consciousness (planning, expectations, desires,...). Geometric memory can be regarded as a "prophecy" for what will happen and what must have happened earlier provided the world were classical (no quantum jumps replacing the macroscopic classical space-time with a new one). Each quantum jump involves naturally a comparison of the expected time development provided by the "geometric memory" and the actual subjective time development stored in the subjective memory.

4. Association sequences of ... of association sequences are also possible and the average spatial and temporal distances ΔL and ΔT between fundamental building blocks of the association sequence give measures for the temporal and spatial resolutions of the cognitive/sensory representation provided by the association sequence.

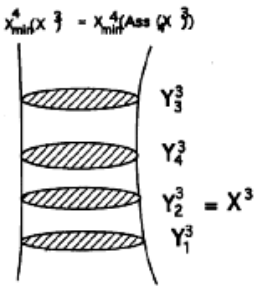

Figure 2.1: 'Association sequence': a geometric model for cognitive/sensory simulation as a sequence of disjoint 3-surfaces with timelike separations.

The notions of mindlike space-time sheet and association sequence are frustratingly abstract concepts. It has however become clear that MEs (massless extremals) provide very general, if not even universal, identification for the geometric correlates of selves. The lightlike boundaries of MEs carry representations of superconformal and supercanonical algebras and act as quantum holograms. The general concepts of quantum information theory, the notion of quantum hologram in the sense of both quantum information theory and quantum gravity, and perhaps even quantum computation (in

a suitably generalized sense) at the lightlike boundaries of MEs, seem to emerge as basic aspects of TGD inspired theory of conscious information processing.

A genuinely TGD based aspect is the possibility of negative time orientations making possible MEs carrying negative energies and representing classical signals proceeding into the direction of the geometric past, and the communication to the direction of the geometric past distinguishes TGD based and ordinary quantum information theory. This is especially interesting from the viewpoint of lightlike quantum computation since the classical restrictions coming from the huge length of MEs for reasonable computation times can be circumvented.

How to understand psychological time and its arrow?

If quantum states are entire quantum histories, it is not at all obvious how the contents of our everyday consciousness can be concentrated around a definite moment of the geometric time. One must show that the theory predicts the emergence of selves with the property that the information contents of their conscious experiences are concentrated around a definite value of the geometric time or possibly several of them. One must also understand why the value of this time parameter increases in a statistical sense.

The classical non-determinism of the Kähler action gives excellent hopes that the time localization for the information contents of the conscious experience takes place. Mindlike space-time sheets are the geometric correlates of selves and psychological time can be identified as the average center of mass time coordinate for the mindlike space-time sheet, which has finite time duration. This coordinate is naturally a zero mode and therefore has the same value for all space-time surfaces appearing in the superposition of the macroscopically equivalent space-time surfaces defined by the final quantum history Ψ_f. Since there is much more room in the future of a given point of the future lightcone than in its past and since the presence of the lightcone boundary is felt in each quantum jump (the magnitude for the increase of the psychological time can be arbitrarily large whereas the magnitude for the decrease is bounded by the presence of the lightcone boundary), the average increase of the psychological time in quantum jump is non-negative. Thus the evolution by quantum jumps is analogous to diffusion in the presence of a future directed drift force and leads to a drift of the mindlike space-time sheet to the direction of future. Therefore a local arrow of psychological time results (see Fig. 2).

The simplest guess is that the average increment of the psychological time in a single quantum jump does not depend on properties of the self and is of the order of CP_2 time about 10^4 Planck times. This means that consciousness in biological length scales is in a well defined sense macroscopic phenomenon and that single quantum jump corresponds to a microscopic building block of self. A natural assumption is that self hierarchy starts already from selves having duration of few quantum jumps (elementary particles?).

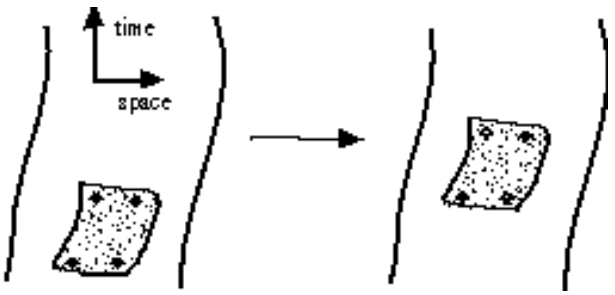

Figure 2.2: The mechanism giving rise to the arrow of psychological time

If the space-time sheet is not in self state, it is part of a larger self. Thus space-time sheets drift towards the geometric future irrespective of whether they are in self state or not. The simplest possibility is that the drifting velocity is constant so that the increment of the geometric time, most naturally identifiable as the lightcone proper time a, is given by

$$\Delta a = k\tau \ ,$$

where k is some numerical constant and τ is some fundamental time scale, most naturally of the order of CP_2 time τ_{CP_2} is CP_2 time about 10^4 Planck times.

Drifting rate could in principle depend on the p-adic length scale associated with the self and also on the gradient of the total entropy of self with respect to subjective time. For instance, one could have

$$\frac{dn}{da} = \frac{k}{\tau}\frac{dS}{dn} \ ,$$

where k is a dimensionless constant. The idea that self which approaches thermal equilibrium begins to drift towards geometric future with arbitrary high rate does not certainly make sense. The only sensical interpretation is that the gradient of entropy with respect to subjective time tells the fraction of time spent by the system in self state. When the entropy gradient is small, geometric time is experienced to flow very fast, very few moments of consciousness per geometric time. The approach of 'our' self to thermal equilibrium could thus explain why old people feel that time flows fast. When the entropy gradient is large, as it perhaps is in a very emotional situation like car accident, the flow of the geometric time would be experienced to stop since the number of moments of consciousness per geometric time is very high.

The new concept of the psychological time means a dramatic generalization of the standard view about subjective existence. mindlike space-time sheets are distributed everywhere around material space-time sheets of infinite time duration and all of them can participate in a given quantum jump. Therefore one can say that the entire space-time is a conscious, living being. Civilizations of the geometric past and future exist simultaneously with us. We are members of a four-dimensional society in the sense that our actions affect the life of selves of both geometric past and future since each quantum jump performed by us changes the macroscopic space-time in both past and future. It is quite possible that there are new versions of me in the geometric past represented by mindlike space-time sheets drifting in future time direction along the material space-time sheet describing "material me". Therefore this particular life of mine is only one among very many ones. p-Adic evolution implies that in the statistical sense the quality of these lives tends to get better. We in our youth now experience in slightly more deeper manner and live in a society having slightly higher level of moral.

What distinguishes 'now' from memories and plans?

The new notion of psychological time leads to a very elegant mechanism of long term memory and memories in general: to remember something at temporal distance T in the past is to look at a mirror with length $L = cT/2$. There is no need to store the memories of the geometric past in the geometric now. The conscious experience contains contributions from both the geometric past, from the geometric now, and probably also from the geometric future (plans, dreams, expectations). This raises an obvious question: what distinguishes so dramatically the geometric now from memories and plans so that the illusion about reality as a time=constant snapshot of the geometric time development is created?

The most plausible answer is based on the identification of the p-adic physics as physics of cognition. p-Adic space-time regions represent thoughts, intentions, plans, etc. and quantum jumps in which a p-adic region is transformed to a real region correspond to the transformations of intentions to actions. Psychological now corresponds to a a front of a phase transition in which p-adic space-time sheets (perhaps massless extremals (MEs) which are topological counterparts of light rays) transform to real ones. Psychological now corresponds to the front of enhanced volition. In the geometric future intentions are still intentions represented by p-adic MEs whereas in the geometric past they have transformed to actions. Of course, also the reverse transformation, during which the arrow of psychological time presumably changes and things get undone (a possible mechanism of healing), might occur but should occur with a low probability.

If the front of the p-adic-to-real phase transition is common to the entire biosphere, one avoids many paradoxes. Consider only a situation in which the friends living at different psychological times participate to the funeral of a common friend. This picture implies that the geometric past is relatively stable as is required by the fact that our personal identities do not suffer sudden changes (consider only the situation in which the me of my geometric past decides to choose differently in some turning point

of life!). The stability below a given time scale holds true above certain length scale. For instance, the very fact that our memories are surprisingly unstable suggests that geometric memories which result from the information processing at brain level are not stable against quantum jumps.

How selves wake-up and fall asleep?

If the impossibility of entanglement between different number fields is what makes selves possible, the wake-up of the mental image most probably means generation of space-time region with topology different from that of surrounding space-time region. For instance, p-adic space-time regions surrounding real regions with different p could serve as shields allowing real space-time sheets to stay in self state and vice versa. Topologically the death of the mental image would mean a phase transition in which the topology of the mental image becomes that of the surrounding space-time region or a fusion with a larger region when it forms an extrusion through the shielding region. If our sensory mental images are real (as opposed to p-adic), this could be one of the mechanisms involved. For instance, falling asleep could involve either phase transition or fusion mechanism.

Sleep would have obvious function: when mental image ages, its entropy grows and it becomes fuzzy. One manner to avoid this is a temporary death and re-incarnation as a brisk and young mental image. Of course, also we are mental images and the reason for why we die physically might be precisely this. This would encourage to believe that our bodily sub-self (also mental image!) has a duration determined by our lifetime. Second manner to achieve this is to somehow reduce the entropy growth rate or change its sign. Very probably biosystems are full of mechanisms tending to achieve this kind of state. For instance, de-differentiation of cells to stem cell stage would be an example of this mechanism. The basic function of metabolism would be to help this fight against second law. Note however that this war against second law could occur both at the level of mental images and the matter at atomic space-time sheets and it might be that a neglilible fraction of metabolic energy is needed to to keep our mental images sharp.

Estimate for the "wake-up time" of sensory selves from p-adic length scale hypothesis

The basic question relates to the age of selves representing sensory mental images and also to the age of our own self which at least apparently seems to be of order of our wake-up period. The question is not trivial.

1. It is not at all clear whether the wake-up state is continuous: also our self could exist only a fraction of time and memories could create the illusion about continuity of self.

2. Maximally entropic long-aged sub-selves in thermal equilibrium need not contribute to conscious experience and their disappearance from our consciousness need not mean that they die: they could simply give rise to a background sensory and cognitive noise which is certainly present.

Consider first some arguments supporting a short wake-up time.

1. The identification of subjective memory as a short term memory and the fact that sensory sub-selves with too long age cannot provide the needed time resolution of sensory experience encourages the idea that sensory sub-selves have a short wake-up period of order .1 seconds. Since sensory sub-selves seem to have finite wake-up time also our self should have.

2. The duration of short term memory seems to be of order second so that the periods of, at least, sensory wake-up should be of order second. On the other hand, memory sub-selves of sufficiently short duration can give rise to sensory memory with sufficient resolution even if our self has much longer wake-up period.

3. A good guess seems to be that the duration of our self is not longer than wake-up period. But again it could be that we simply do not remember what we experience during sleep: to remember what happened during sleep we must perhaps be in sleep state! It is known that dreams experienced during some period of time for logical stories. Thus it seems that at least dreaming involves memories about previous dreams.

The fact that the entropy of an ageing sub-self tends to increase means that mental image gets fuzzy. This allows the possibility that our sensory mental images are rather quite long-lived but get rapidly fuzzy so that only the youngest sensory mental images would dominate our consciousness.

p-Adic length scale hypothesis suggests that the typical duration of a self characterized by p-adic prime p is given by the p-adic time scale $T_p = L_p/c$, where $L_p \simeq 10^4\sqrt{p}$ Planck lengths is the p-adic length scale. The duration of our immediate sensory memory of about .1 second would correspond to a p-adic length scale of the order of the circumference of the Earth! Either the estimate is wrong or our picture about brain as a seat of consciousness is quite not correct! TGD predicts entire self-hierarchy so that it is not all obvious which option is correct.

One could also adopt a purely formal approach and try to estimate the wake-up time using p-adic length scale hypothesis. The time scale of .1 seconds corresponds to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of Earth size. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies [38] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and neural instabilities [60]. Furthermore, the estimate for the thickness of the magnetic flux tubes of Earth's magnetic field based on the quantization of the magnetic flux is about cell size. These observations raise the question whether our "physical" body is only a tip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures[I3].

Our self hierarchy could contain also higher levels and the fact that we experience continuity of personal existence suggests that this is the case. This consistent with the basic assumptions about conscious experience if the temporal averaging involved with the temporal binding is weighted so that only the most recent experiences are present with large weight. An interesting possibility is that entire fractal hierarchy of magnetic flux tube structures carrying superconducting BE condensates of ions is involved so that also a hierarchy of cyclotron time scales defining a hierarchy of durations for selves (mental images) is involved. Same is true for MEs and Uncertainty Principle suggest that MEs with size of order light life time are involved with our long term memories.

How fast subjective time runs?

An interesting challenge is to understand the relation of the subjectively experienced time to the psychological time (essentially geometric time). In order to experience time self must have a clock. The simplest assumption is that the sequence of quantum jumps defines the sequence of ticks for the clock. Therefore subjective time would be measured as the number n of quantum jumps occurred after the wake-up of the self. The rate for the running of subjective time would be dn/da and just the inverse for the rate of running for psychological time and same for all systems if the average duration of chronon is of order of CP_2 time: this is certainly not consistent with the fact subjectively experienced time can run faster or even stop. One could also kill this naive hypothesis by noticing that self should be able to distinguish between the ticks of the clock: obviously we cannot experience quantum jumps as separate events.

A more realistic model is based on the idea that the average time interval Δa between two wake-ups of a 'clock' sub-self, which exists periodically in a wake-up state defines a natural unit of subjective time. The number N of ticks for the clock is given by the age of self divided by the duration of single wake-up period for the 'clock' self

$$N(a) = \frac{a}{\Delta a} \quad .$$

N would naturally define a measure of subjectively experienced time. Slowing down of subjective time would correspond to the slowing down of the internal clock in the sense that Δa increases.

Consider now whether this simple model can explain basic facts about experienced rate of subjectively experienced time.

1. Experienced time is said to run slowly, when we get bored and drowsy. Actually the situation is just the opposite since the number of ticks of the internal clock per unit of psychological time must be large. In order to understand what might be involved, assume that also the internal clock gets drowsy so that the average wake-up period Δa_W for the internal clock gets shorter.

If internal clock wakes up spontaneously, one can assume that the average duration Δa_S for the sleeping periods for clock self is not changed. Hence $\Delta = \Delta a_W + \Delta a_S$ is reduced so that $N(a) \propto 1/\Delta a$ increases and geometric time is experienced as longer.

2. Quite different situation is encountered, when person is in the state of whole-body-consciousness. In this kind of situation there is no internal clock and one can indeed say that there is no time! This would explain the reports of meditators about state of 'timelessness' [34] Oliver Sacks has described in his book 'Awakenings' patients who have lived for years in 'no-time' state with frozen contents of conscious experience, which presumably meant that everything in the external world seemed to happen extremely slowly. It would be natural to assume that the lifetime Δa of the 'clock' self was very long in this kind of situation or even that person was in the state of whole-body-consciousness. The only clock is person itself and the entire experience corresponds to single tick of this clock. There are also reports that when person is in dramatic situation like traffic accident, time is experienced to stop. One explanation is that person experiences state of whole-body consciousness. Second possibility is that in this kind of situation involving very high level of alertness Δa becomes very short so that all motions seem to occur very slowly: in this manner person gets a lot of subjective time to react to the situation.

One could also try to understand why persons at older age feel that time runs faster. This statement is clearly not about what person immediately experiences but impression about what has happened. One possible explanation is however that the period Δa of the internal clock indeed gets longer at older age. This could be caused by the increase of the period Δa_S of the sleeping period of the internal clock. This is consistent with the previous idea that the wake-up time of mental images gets shorter, which also explains why old people experience that geometric time flows faster. Thus, if the total fraction of geometric time spend by the person and his/her sub-selves in wake-up state decreases when person gets older, one can understand why the time is experienced to run faster at the older age.

Time delays of consciousness and other anomalies

TGD based concept of time has rather dramatic implications and it is important to show that the new time concept indeed solves the conceptual problems and anomalies of the standard physics. One should also device experiments to test the new time concept.

1. Dissipation is the black sheep in the family of theoretical physics and quantum jump between quantum histories concept explains dissipation in an elegant manner. The ad hoc addition of various parameters characterizing dissipation to the reversible fundamental equations of the classical physics can be understood as a phenomenological model for the subjective time evolution as a sequence of macroscopic space-times defined by the final states of the quantum jumps. Dissipative space-time is kind of an envelope for a sequence of non-dissipative space-times. Dissipation is a signature of quantum jumps which, by the basic assumptions related to the formulation of NMP, correspond to a sequence of quantum measurements and can occur only inside selves. Hence dissipation gives direct evidence for consciousness. TGD predicts the possibility of whole-body consciousness with anomalously low dissipation and this spectacular effect provides a test of TGD approach [I3].

2. Quantum jumps between quantum histories concept together with the notion of self explains also the peculiar time delays of consciousness revealed in the experiments [45, 28] relating to the active and passive roles of consciousness and described by Penrose in his book [25]. The basic observation is that quantum jump replaces macroscopic space-time with a new one and that both the geometric past and future change. For instance, the EEG activity preceding the conscious decision to raise the index finger in experiments of Libet related to the active aspects of consciousness [28] can be interpreted as classical electromagnetic fields present in the geometric past of the new macroscopic space-time generated by the decision to raise the finger.

3. It is also possible to explain the causal anomalies revealed by the experiments of Radin and Bierman [35, 36, 41]. In these experiences pictures with emotionally provocative content generated galvanic skin responses already before they were seen. A natural looking assumption about the contents of conscious experience is that the change of the geometric past is larger for emotional than for non-emotional quantum jumps (e-motion!): this is also consistent with the

important role of emotion as a motivator and with the fact that neural transmitters involved with the emotion induce long term synaptic changes. With this assumption the change of the past recordings about galvanic skin response is predicted to be larger for the emotional pictures than for the non-emotional ones. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept [H5].

2.2.4 Biosystems as macroscopic quantum systems

The empirical fact that energy conservation holds true holds true in space-time assumed to be single sheeted requires that the energy transfer between atomic and non-atomic space-time sheets must be very small. Thus there are good hopes that non-atomic space-time sheets can be in extremely low temperatures and are indeed superconducting. Also self measurements governed by NMP allow macroscopic quantum systems to fight against thermalization.

In the standard physics context there are not many candidates for the macroscopic quantum systems required. In the TGD framework the situation is different since quantum criticality predicts long range quantum correlations in all length scales.

1. Coherent photons and coherent gravitons created by vacuum electromagnetic currents and vacuum energy density are a phenomenon characteristic for TGD and might be crucial for the functioning of biosystems as macroscopic quantum systems [J4].

2. Wormhole contacts feeding gauge fluxes between space-time sheets behave like bosons and form BE condensates.

3. Neutrino super conductivity, made possible by the presence of the classical long range Z^0 fields, might provide the realization of thinking systems as magnetized defects in type I super conductors near criticality. The geometric form of the cellular and endoplasma membranes and chiral selection support this picture.

4. A new form of electronic super conductivity is made possible by the many-sheeted space-time concept: what happens is that electrons drop to a larger space-time sheet at which there is cold, dry and silent. The new form of electron superconductivity is a good candidate for the mechanism behind high T_c super conductivity. Also ionic superconductivity for the ions dropped to larger space-time sheets from the atomic space-time sheet is possible. Ordinary atoms and ions can be regarded as fully ionized Z^0 ions and similar mechanism allows also Z^0 super conductivity. Thus an entire zoo of bio-superconductors associated with magnetic flux tube structures in turn forming a fractal hierarchy, is predicted [J1, J2, J3].

5. The states of supercanonical representations at the lightlike boundaries of MEs define a hierarchy of genuinely quantum gravitational states in the sense that these states genuine state functionals in the space of 3-surfaces (world of worlds) and therefore correspond to a higher abstraction level than ordinary quantum states for which orbital configuration space degrees of freedom are not excited. This suggests strongly that 'our' consciousness corresponds more or less to that associated with MEs and that the consciousness associated with, say, the magnetic quantum phase transitions at superconducting magnetic flux tubes corresponds to more primitive chemical senses not directly conscious to us.

The recent view about biosystems as macroscopic systems boils down to fractal hierarchies of MEs and superconducting magnetic flux tube structures living in symbiosis with ordinary biomatter at atomic space-time sheets. The basic control mechanism is many-sheeted ionic flow equilibrium allowing to amplify extremely small superconducting ion densities to large ion densities at the atomic space-time sheets. The magnetic interaction of MEs with the magnetic flux tubes can induce both supracurrents and quantum coherent phase transitions making possible biochemical control. For instance, protein conformations could be quantum controlled by electronic super currents at protein space-time sheets in turn being controlled by MEs which are at the top of the hierarchy.

This picture explains naturally the observed effects of ELF em fields on living matter at multiples of magnetic cyclotron frequencies [44], the observed DC current circuits [43] and collagen circuitry [38] as parts of this circuitry, and the strange findings challenging the notions of ionic channels and pumps [21].

2.3 Various types of conscious experiences

In the following the general structure and classication of conscious experiences is discussed. Most predictions are brain independent. Assuming that zero modes of the configuration space, characterizing the geometry of macroscopic classical space-time, determine the geometric information contents of conscious experience and identifying macroscopic quantum phases as quantum correlates of various sensory modalities, one can make rather far reaching predictions about basic aspects of, say, sensory experience of any experiencer, be it human brain or some strange life form in distant galaxy.

2.3.1 Basic structure of conscious experience

Before continuing, it is perhaps useful to recall the basic anatomy of the quantum jump: $\Psi_i \to U\Psi_i \to \Psi_{f_0} \to ....\Psi_f$, where the final quantum history Ψ_f is a superposition of space-time surfaces, which are macroscopically equivalent and only bound state entanglement is present. Every space-time surface of the superposition consists of parallel space-time sheets (connected by wormhole contacts). Some of these space-time sheets have infinite time extension and some have not. The latter ones are 'mindlike space-time sheets'. One must make a clear distinction between the quantum superposition of the space-time surfaces and the decomposition of the space-time surface to space-time sheets.

Real and imagined experiences

The assumption that p-adic physics is physics of imagination means division of qualia to real qualia and imagined qualia. There are good arguments based on mathematical consistency that in p-adic configuration space degrees of freedom complete localization occurs in each quantum jump (see Appendix). This means that there are no quantum fluctuations in p-adic degrees of freedom and since non-geometric sensory qualia like color correspond to quantum number increments in quantum fluctuating degrees of freedom, there are no p-adic non-geometric qualia. This however leaves p-adic geometric qualia determined by the increments of p-adic configuration space coordinates. This view is certainly consistent with intuitive notion that cognitive qualia are only about the geometric aspects, like shape and size, of the objects of the external world.

One could debate about whether cognition can be identified as imagination but this is the working hypothesis made. The tranformations of thoughts into actions or sensory experiences and of sensory inputs into thoughts correspond to p-adic–real phase transitions for mindlike space-time sheets so that one can speak about matter-mind interaction in a well-defined sense. Cognition is predicted to be present already at elementary particle length scales and this assumption is crucial for understanding the success of the p-adic length scale hypothesis works and p-adic mass calculations.

One can identify p-adic space-time sheets as memes [32] and relate them to the morphic fields of Sheldrake. The p-adic vision about cognition is discussed in [H8].

Whole-body consciousness and ordinary consciousness

TGD predicts two basic modes of consciousness.

1. Reducible self is the state in which sub-selves are "falling asleep" and "waking up" all the time, corresponds naturally to the ordinary state of consciousness. Sub-selves represent mental images which pop out and dissappear all the time.

2. In case of irreducible self quantum jumps do not lead to a generation of sub-selves. Thus the sub-systems of irreducible self have only bound state entanglement and self measurement cascade stops at irreducible self. This state is presumably accompanied by the experience of "oneness" and could therefore be called a state of "whole-body consciousness". The absence of the sub-selves means the absence of mental images so that the identification as a state of pure self awareness without any contents is natural. Less ideal situation is that sub-selves are generated but are very short lived and represent short flashes against background awareness. "Whole-body-consciousness" presumably means abnormally low metabolism since dissipation inside sub-selves is not present.

Active and passive aspects of conscious experience

Conscious experience involves two fundamental contributions.

1. The "non-classical" contribution from the quantum measurement reducing quantum entanglement associated with the fermionic degrees of freedom and with the quantum fluctuating configuration space degrees of freedom (as opposed to zero modes).

2. The "classical" contribution determined by the localization in zero modes and by the selection between different degenerate absolute minimum space-time surfaces having different decompositions into p-adic regions.

The natural guess is that the experienced free will corresponds to the non-determinism of the quantum jump somehow. The standard objection is that the non-determinism of the quantum measurement gives rise to randomness rather than volition. Quantum numbers relate to microscopic aspects of the quantum jump and the average quantum numbers measured in quantum jumps probably sum up to zero in the presence of energy feed and external perturbations. Indeed, if temporal binding for the experiences of self involves averaging, this component of experience need not give rise to an experience of volition since it is expected to average out for large number of quantum jumps (10^{38} per second by the argument for the arrow of psychological time). Therefore the time averaging involved with the temporal binding smooths out this non-determinism.

Here the special features of TGD however come in rescue.

1. The first candidate for the quantum correlate of volition is the localization in zero modes. This localization corresponds to the spontaneous symmetry breaking of quantum field theories which selects one classical configuration among many degenerate ones. Spontaneous symmetry breaking has been suggested to be a basic aspect of the quantum jump also by Joel Henkel [19]. Asymptotic localization in zero modes seems to be however determined statistically by the self-organization process taking the system to the bottom of some valley of the spin glass energy landscape. Hence volition need not be in question.

2. The second candidate for volition is classical non-determinism of Kähler action (which gives rise to the geometric model of thought as "association sequence"). The selection between the different degenerate alternative classical time evolutions, that is different degenerate absolute minima $X^4(Y^3)$ going through a given 3-surface Y^3, is an excellent candidate for the volitional act. The reason is that absolute minima differ macroscopically so that the choice between degenerate minima dramatically affects the entire geometric future. Note also that the selection between branches of a multifurcation of macroscopic space-time is in question, the choice can be done only when mindlike space-time sheet is located in a narrow time interval around multifurcation and is hence irreversible. The identification of the classical non-determinism as a geometric correlate of the volitional non-determinism is in nice accordance with the "ontogeny recapitulates phylogeny" principle stating that the geometric time evolution at the level of the space-time surface reflects the time evolution by quantum jumps at the level of the configuration space. One can however argue that this kind of volition is still passive in that it is only a selection between given alternatives rather than a transformation of an intention to action. The second objection is that there are actually infinite number of options between which to select in the state function reduction: why do we not experience these alternatives consciously?

3. The third candidate for volition is a quantum jump in which p-adic-to-real transformation for a p-adic space-time sheet representing cognitively intention occurs so that it becomes an action. This identification of the volitional act seems to be the most realistic one and indeed allows to understand how the notion of psychological time emerges. Since complete localization occurs in p-adic degrees of freedom in the state function reduction stage, there is no selection between infinite number of alternatives but only a selection of the p-adic space-time sheet which is transformed to a real one and induces the self-organization process possibly leading to the desired goal.

An interesting possibility is that the zero modes characterizing the macroscopic features of the macroscopically equivalent space-time surfaces present in the *final* quantum state of quantum jump

determine the contents of at least sensory experiences. This would be in accord with the idea that pure sensory experiences represent quantities which indeed 'are in the world', the world being identified as the macroscopic space-time associated with the final quantum history of the quantum jump. One could however argue that it is only *the increments of zero modes* in quantum jump, which are perceived directly consciously: this claim is consistent with the fact that insects are able to see only the motion and that also human visual consciousness is crucially dependent on saccadic motion. Localization in the zero modes involves the fixing of the parameters characterizing the shape and size of the 3-surface X^3 as well as the Kähler field of $X^4(X^3)$. Kähler field can reduce to a purely electromagnetic or Z^0 type classical gauge field and is in general also accompanied by a classical color field. The spatio-temporal patterns of the induced Kähler field should correlate strongly with the contents of the conscious experience.

2.3.2 Cognition and p-adic physics

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that a unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

If one accepts the idea that real and p-adic space-time regions are correlates for matter and cognitive mind, one encounters the question how matter and mind interact. A good candidate for this interaction is the phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations can take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or to an action. The reverse phase transition might relate to the transformation of the sensory experience to cognition. Sensory experiences could be also transformed to cognition by initial values realized as common rational points of a real space-time sheet representing sensory input and a p-adic space-time sheet representing the cognitive output. In this case the cognitive mental image is unique only in case that p-adic pseudo constants are ordinary constants.

The identification of p-adic physics as physics of cognition satisfies quite a number of consistency constraints.

1. Consistency constraints force to assume that p-adic regions of 3-surface do not contribute to the line element of the configuration space. This means that p-adic degrees of freedom are zero modes and thus completely classical in the sense that a localization occurs in p-adic configuration space degrees of freedom in each quantum jump. Thus the word of cognition is completely classical.

2. Classicality of cognition implies that there are no non-geometric cognitive qualia determined by the increments of quantum numbers in quantum jumps but only geometric cognitive qualia determined by the increments of zero modes. Thoughts are indeed non-colored. Same applies to emotions if emotions correspond to rates of the entropies associated with various non-geometric sensory qualia. Since it is not possible to talk about the sign of the p-adic entropy gradient (p-adic numbers are not well-ordered), one cannot classify possible geometric p-adic emotions to positive and negative. p-Adic Boolean mind is however possible and should represent what we call rational mind.

Various identifications for the quantum correlate of volition were already discussed and it was found that the most realistic option is the identification of volition as associated with a quantum jump in which a p-adic space-time sheet representing an intention is transformed to a real region representing action. This identification leads also to the assignment of the psychological time with the phase transition front at which intentions transform to action proceeding to the direction of the geometric future. The difference between intentions and memories would be that intentions are p-adic whereas memories are real.

2.3.3 Reflective- and proto-levels of consciousness and Boolean mind

The decomposition into proto consciousness and reflective consciousness (consciousness about being conscious) is one of the fundamental features of conscious experience. Logical thinking is also a fundamental component of conscious mind and probably also the mind unconscious-to-us, in fact so fundamental one that is has inspired the computationalistic approach to consciousness. One can consider two alternative identifications for the reflective level of consciousness.

Boolean mind as reflective mind?

The state basis of the Fock space generated by N fermionic creation operators is isomorphic with the Boolean algebra consisting of 2^N possible statements about N basic statements. This follows from the simple observation that by Pauli exclusion principle the fermion number associated with a given fermion state can have only two values: 0 (false) or 1 (true). This observation leads to the idea that many fermion states give representation for what might be called reflective consciousness in the sense that the information contents for experiences about conscious experiences could correspond to the quantum jumps in the fermionic sector.

A more convincing interpretation is in terms of Boolean mind. In p-adic case only quaternion conformal degrees of freedom are possible for configuration space spinors (see appendix) and since pure cognition involves no emotions and no values it must correspond to logic (true/false). In real case the spin associated with the configuration space metric correlates with the sensory experience and naturally corresponds to the logic of aesthetics (beautiful/ugly) whereas real quaternion conformal degrees of freedom having no correlation with the sensory experience correspond naturally to the logic of ethics (right/wrong), or more generally the true/false logic of belief system having strong right/wrong emotional coloring. Thus the Goodness-Truth-Beauty trinity would thus have a reduction to the Boolean algebra defined by the Fock basis for the configuration space spinors.

TGD based model of abstraction process involves a hierarchy of statements about statements about.... starting from 2 basic statements such that the statement represented by empty set in the set theoretic realization of Boolean algebra is thrown away at each step. The model predict besides the genetic code also a memetic code consisting of 127-bit code words such that 126-bit statements form a maximal number of mutually consistent statements. In case of genetic code 7-bit code words represent all possible statements and 64-bit codewords represent mutually consistent statements.

In real context, 6-bit code words for the genetic code and 126 bit code words for the memetic code code form a maximal number of mutually consistent 'this is right thing to do' beliefs. 7-bit resp. 127-bit code words can be interpreted as coding these statements and their negations: all bits must be realized in p-adic case since formal logic requires also the negations of the basic statements. Lying is a cognitive skill. Genetic code would represent in case of the molecular society the moral and social rules whereas memetic code would represent these rules in case of the ordinary society. DNA would provide a symbolic representation for the 64 fundamental truths, kind of a legal code.

Symbolic and cognitive representations as means of becoming conscious about beng conscious about?

An alternative identification of the reflective mind is in terms of language and cognitive representations made possible by the nondeterminism of Kähler action and inherent nondeterminism of p-adic differential equations. These nondeterminisms allow to represent contents of consciousness of self (quantum jump sequence) cognitively and symbolically and to become conscious these representations: this is nothing but becoming conscious about being conscious about...

The (inconvincing) Boolean identification of reflective mind predicts a single directly experienced reflective level. In the second case given quantum jump allows the emergence of only single new reflective level. Indeed, it is easy to become conscious about seeing red but one cannot have direct experience of being conscious about being conscious about seeing red. It is also easy to build theorems about theorems (or imagine what happens under given circumstances) but deriving theorems about theorems about theorems looks impossible without paper and pencil.

2.3.4 Boolean mind and neutrinos

Recall that Boolean mind means more than just ordinary logic in TGD framework. In case of p-adic antineutrinos Boolean mind means logical mind without any emotional aspects whereas real antineutrinos would represent beliefs as right/wrong type statements if the proposed general identification for the correlates of ethical/aesthetical/logical statements makes sense. As already noticed, real neutrinos could represent belief system which includes moral statements as a special case. Obviously the notion of cognitive neutrino is somewhat misleading since it refers to both real and p-adic neutrinos: I apologize for the use this term.

Zero energy neutrino-antineutrino pairs

Very low energy neutrino physics a la TGD differs from that predicted by standard model dramatically because TGD predicts the presence of classical Z^0 fields coupling to neutrinos. Even more, classical Z^0 fields become important above cell length scale.

One ends up with a rather concrete quantum model for Boolean mind based on neutrinos by

1. combining the concept of association sequence with the fermionic realization of Boolean algebra ;

2. requiring that fermionic states exist only in a finite time interval defined by the duration of the mindlike space-time sheets;

3. assuming that timelike entanglement is possible for many-fermion states.

Ordinary fermions cannot reside on mindlike space-time sheets unless they are created as pairs with vanishing total quantum numbers (in particular energy!). In p-adic case there should be no obstacle for this but in the real case this is presumably not possible unless negative energy fermions are allowed.

Real neutrinos are however exceptional [F9, J2]. Neutrinos are an ideal for consciousness since they do not couple to electromagnetic interactions and, having couplings only to the classical Z^0 fields, dissipate extremely weakly. TGD based model of condensed matter predicts that the classical Z^0 binding energy of neutrino with condensed matter makes neutrino energy in condensed matter negative and large [F9, M6]. Thus neutrino pairs can have vanishing total quantum numbers. The creation of zero energy neutrino pairs by the decay of a wormhole contact connecting material and mindlike space-time sheet is indeed possible. Boolean statement and its negation correspond naturally to Fock sates of antineutrinos (resp. neutrinos) condensed to mindlike (matter) like space-time sheets. Fermion number could be also fixed and spin direction could code the Boolean truth values.

Zero energy neutrino pairs could reside in the defect regions of neutrino super conductor which is superconductor of type I having complicated stripe like defect regions near criticality. TGD based model for the interaction of neutrinos with condensed matter predicts that the thickness of the defect regions is of order 10^{-8} meters. Hence cell membranes are excellent candidates for the defect regions. One indeed ends up to a detailed quantitative model of Boolean mind and memetic code by combining this idea with the observation about magnetic and Z^0 magnetic transitions as a fundamental element of our consciousness [L1].

Quantum-classical correspondence (or "ontogeny recapitulates phylogeny" principle as I have used to call it) suggests that it is localization in zero modes, in fact the conscious selection between degenerate absolute minima of Kähler action, which selects beween various configurations of the classical Z^0 field. If the pattern of zero energy neutrino pairs is fixed by the classical Z^0 field, the premises and conclusions of the logical deductions are represented in terms of cognitive neutrinos. This assumption is also in accordance with the hypothesis that the exponent of the Kähler action provides a measure

for the cognitive resources of 3-surface defined as the number of degenerate absolute minima of Kähler action associated with the 3-surface [H7].

Possible realizations of genetic and memetic code using zero energy neutrino pairs

From the previous picture it is still a long way to concrete models and one can make only educated guesses for the concrete realizations of belief systems.

1. "Moral codes", or more generally, belief systems, seem to be represent an evolutionary newcomer and should be related to the neuronal dynamics of neocortex and frontal lobes. The full realization of the memetic code requires precise temporal coding: the 126-bit memetic code word as a temporal sequence of cognitive neutrinos has duration $\sim .1$ seconds so that single bit would have duration about 1/1260 seconds, which is slightly below the duration of a single nerve pulse. The realization of the full memetic code in terms of nerve pulse patterns would requires temporally precise nerve pulse patterns with a maximal firing rate and it is not clear whether this is possible. Also neuronal membrane oscillations realize memetic code. Nerve pulse patterns with frequency coding could represent more primitive form of cognition than cell membrane oscillations. The evolution of moral codes, belief systems, and social structures, and of cognition should have as a correlate increasing number of significant bits of memetic code meaning gradual increase of the maximal firing rate. The p-adic memetic code words could also represent intentions and the value of the 127:th binary digit would tell whether the intention represents right or wrong deed.

2. Also chromosomes (having same thickness as cell membranes) could be identified as defect regions of neutrino super conductor. Very simple model for the abstraction process as a hierarchy of Boolean statements about Boolean statements about... starting from two basic statements explains the basic numbers of the genetic code [H7]. It is difficult to believe that this could be a mere accident. Zero energy neutrino pairs indeed allow to construct a model of a many-sheeted DNA realizing gene level Boolean mind using 64 basic statements and possibly explaining the mystery of introns [34] and the role of zero energy neutrino pairs is very similar to that in cell membrane cognition. Since real neutrinos are in question the interpretation would be that DNA neutrino pairs represent kind of rules of behaviour for an individual of cell society.

3. Microtubules are cylindrical surfaces with inner and outer radii of 15 nm $= 1.5 \times L(151)$ and 25 nm respectively. The diameter of the microtubule interior corresponds therefore to the magic p-adic length scale common to cell membrane and chromosomes. This suggests that also microtubules or microtubule interiors are defects of neutrino super conductor and carriers of axial or helical, Z^0 magnetic fields generated by spontaneously magnetized cognitive antineutrinos. An interesting possibility is that 3 neutrino generations could correspond to three types of cognition associated with DNA, microtubules and axonal membrane.

2.3.5 General model for sensory experiences

The concept of self provides considerable insight to the model of sensory experiencing.

1. If temporal binding involves averaging over the experiences occurred after the wake-up, experiences are reliable.

2. Also the averaging over the experiences of separate sensory subsub-selves implied by the summation hypothesis could be involved.

3. Sensory experiences can involve more than the direct experiencing: also a comparison with the earlier sensory data could quite well be involved and is made possible by subjective and geometric memories. Sensory experiences certainly involve computational aspects.

In the following the general model of sensory experiencing is discussed only briefly [H3].

Macroscopic quantum phases are needed

Self must be able to remain unentangled in subsequence quantum jumps. The presence of the macroscopic quantum condensate means usually energy gap between ground state and excited states. This can make the generation of real entanglement very slow process and self can exist.

The fact that macroscopic quantum phases have coupling to the classical gauge fields, suggests that the order parameters of the macroscopic quantum phases are compeletely determined by the localization in the zero modes. Thus the contents of the sensory experience should correlate with these order parameters. This motivated the original attempt to identify macroscopic quantum phases as quantum correlates of the sensory qualia. A more refined approach identifies quantum phase transitions of the macroscopic quantum phases as correlates of sensory qualia so that the increments of quantum numbers in the phase transition label various qualia. This identification is completely general and almost brain independent (cell length scale turns however be crucially important p-adic length scale).

Many-sheeted space-time concept makes possible large number of macroscopic quantum phases not possible in standard physics context. In particular, the so called massless extremals (MEs) representing 'topological light rays' provide a model for how linear structures such as DNA and microtubules could act as quantum antennae emitting and absorbing coherent photon distribution fixed completely by localization in zero modes. Coherent photons could realize the concept of global workspace [44] and could make possible "mass media" at neural level. Also the concept of "neural window" abstracting the notion of hologramic brain suggests itself [H7, K3]. MEs form a fractal hierarchy and are carriers of supercanonical representations for which states are genuine functionals in the space of 3-surfaces ('world of worlds') and thus correspond to higher abstraction level than ordinary quantum states. Supercanonical states have also gigantic almost degenaries. MEs act also as quantum holograms.

For these reasons MEs are ideal candidates for a hierarchy of life forms [K3]. In particular, the assignment of *'our'* sensory qualia with supercanonical quantum transitions looks reasonable whereas magnetic quantum phase transitions might well correspond to more primitive chemical qualia not directly conscious to us.

The functions of nerve pulses

The identification of the sensory qualia in terms of the quantum phase transitions associated with macroscopic quantum phases is in conflict with the general belief that neuronal activity determines completely the contents of the sensory experiences. In TGD framework one can understand the role of the nerve pulse activity differently. Brain is quantum spin glass and the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape. The contents of the sensory experiences are determined by the zero modes which in turn determine the ground state patterns of the order parameters of various macroscopic quantum phases.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. One role of the nerve pulses is to provide this metabolic energy feed. This suggests that the axons are seats of the self-organization patterns coding at least part of the neuronal experience. Brain seems to systematically maximize the length of the axons feeding sensory data (for instance, right ear feed its sensory input to the left hemisphere). Brain anatomy seems also to favour long pyramidal axons. This phenomenon, which seems to be in conflict with the principles of good metabolic economy, is consistent with the maximization of the expressive power of the sensory pathways. Microtubule conformations are excellent candidates for realizers of declarative memory and this would also explain why the lengths of sensory axons tend to be maximized. Myelin sheets guarantee that external perturbations do not affect the self-organization patterns. It is also possible that myelin sheets form together with the axon Josephson junctions for various super conductors predicted by TGD and are thus essential for the generation of neuronal sensory experiences.

Nerve pulses affect also the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is that the incoming nerve pulses push and pull the postsynaptic cell in different directions and in this manner cause frustrations typical for spin glass like systems. The assumption that neural transmitters give rise to some kind of chemical senses at neuronal level as well as neuronal emotions is in accordance with this. Also frequency coding is consistent with the identification of the nerve pulse activity as a control function.

Of course, spatio-temporal patterns of nerve pulses might also code information about sensory experience. There is indeed evidence that various odours are coded into spatio-temporal nerve pulse patterns [55]. For instance, for the neurons of the associative regions of cortex receiving inputs from several sensory modalities this kind of discrimination is obviously highly desirable. One can even consider the possibility that nerve pulse patterns, in some parts of brain at least (in output axons of association regions), provide a precise naming for axonal experiences.

The notion of memetic code encourages to consider this idea quite seriously and the physical model of the memetic code [L1]. realizes a precise coding of the nerve pulse patters to 126 bit temporal sequences represented in terms of time-varying Z^0 magnetization direction of cognitive anti-neutrinos. Bits could correspond to Boolean truth values or bits in a binary expansion of a integer providing measure for the intensity of the net presynaptic sensory experience represented by the cognitive neutrino pairs of the postsynaptic axon: this would be essentially a mapping of experience to its symbol. This naming would serve also as the basis of our language and duration of a phoneme could correspond to the predicted duration of codeword of order .1 seconds. A degenerate form of memetic code would be based on nerve pulses an realize frequency coding whereas full memetic code would be based on neuronal membrane oscillations.

The model for sensory qualia and sensory representations [K3, M1] assumes that nerve pulse patterns generate EEG MEs (massless extremals) entangling brain with the sensory magnetic canvas. The question where the mental images responsible for the sensory qualia are located, still lacks a convincing answer. Primary qualia could even correspond to mental images associated with the sensory receptors and sensory pathways could serve as cortex-receptor entanglers. Brain would give names for sensory inputs and percepts rather than creating the primary qualia. This would require feedback from brain to the sensory organs.

Frequency coding is not the only manner to code information to nerve pulse patterns and delicate temporal coding mechanisms exist. For instance, frequencies can be coded to peaks of the spike interval distribution by stochastic resonance [17]. Also the coding of spike interval distribution to EEG frequencies is possible (a kick to a harmonic oscillator at the correct half period leads to a resonant amplification [M5]).

How qualia are associated with neural pathways?

Since TGD predicts entire hierarchy of selves, it is important to specify whose sensory experience one is talking about. In TGD framework nerve pulse patterns as such need not give rise to our sensory exerience and it is quite possible that also primary sensory organs have sensory experiences.

Frustratinly, the question about the seat of quale mental images remains unanswered.

1. The assumption that primary qualia are somehow associated with or determined by the sensory receptors would resolve a difficult question about how sensory pathways, which do not seem to have any obvious differences at the level of brain, give rise to qualia. The entanglement of the sensory receptors with brain in turn entangled with the magnetic body would give rise to the sensory representations. Our sensory experience would not be localizable to what happens in the brain region: indeed, MEs in EEG frequency region have size of order Earth size.

   Various objections (hallucinations, experiences generated by the stimulation of the sensory pathways, phantom leg phenomenon, dreams) against this view can be circumvented if there is a feedback between brain and sensory organs (as there indeed is), and if sensory experiences can also correspond to geometric memories (say in case of phantom leg experience). If sensory receptors are the experiencers of the primary sensory qualia, then conscious experience can precede the neural activity in the cortex, as observed by Libet in his classical experiements concerning the timing of the sensory experiencing [28].

2. A more general view is that the neuronal receptors (also "field receptors" responsible for neuronal vision and hearing can be present) along the sensory pathway are specialized to experience only special sensory qualia characterizing the sensory pathway.

How the primary and possible also secondary sensory receptors or sensory pathways could then give rise to particular qualia? Quite generally qualia correspond to average increments of quantum numbers for the quantum jump sequence defining sub-self. In the case of color qualia one has a partial answer. For MEs supercanonical quantum transitions are characterized by configuration space

Hamiltonians carrying spin and color ($SU(3)$) quantum numbers. For configuration space photons state functional in configuration space degrees of freedom is nontrivial and characterized by configuration space Hamiltonian with quantum numbers characterizing a particular quale. This suggests that somehow neural pathway or sensory receptor should be able to generate 'configuration space photons' (MEs) BE condensing on larger MEs and inducing visual color qualia at least. This would mean that configuration space photons would in a well-defined sense carry qualia: the photons generated by sensory receptors and brain could be colored after all!

The educated guess is that the EEG transition frequencies coded the spike interval distributions associated with the sensory pathway characterize the sensory pathway partially. EEG frequencies in turn determine partially the quantum phase transitions which can be stimulated by that particular sensory pathway. The miminal option is that these transitions relate only with what parts of magnetic body the sensory pathway is entangled with. This would make possible very high functional flexibility in accordance with the observed plasticity of brain.

Only changes are perceived

One of the basic laws about sensory experiencing is that only changes and novelties are perceived. For instance, totally monochromatic illumination is experienced as darkness. The zero modes characterizing the macroscopic space-time associated with the final quantum history of the quantum jump should determine the contents of the sensory experience. Part of the zero modes corresponds to the induced Kähler of CP_2 which is nonlinear Maxwell field closely related to the classical electromagnetic and Z^0 fields. There are also zero modes representing the size and shape of 3-surface: these might be related to the discriminative sense of touch. A possible generalization of the law is that sensory stimulus generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go in this kind of situation?

The solution of the problem might be very simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts. Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images already at the level of the sensory organ or the sensory pathway leading to thalamus.

The extreme generality of the mechanism suggests that it could be at work also at the level of brain. Understanding of the computational aspects of sensory experience (say stereovision) is not possible unless one assumes that mindlike space-time sheets in sensory pathway combine with the primary sensory organs to form coherent quantum systems. "Ontogeny recapitulates phylogeny" principle requires that these space-time sheets are connected by join along boundaries bonds most naturally associated with axons leading from sensory organ to brain.

Are the ultimate sensory representations realized outside brain?

One of the dramatic almost predictions of TGD inspired theory of consciousness is that our physical body is accompanied by a hierarchy of field bodies, in particular magnetic body. A given field body provides abstract representations about quantum aspects of the physical body, kind of a manual. This prediction plus some general arguments lead to the view that sensory representations are most naturally realized outside the physical body at the personal magnetic body (first person aspect of consciousness) and at the magnetic body of Earth (third person aspect of consciousness).

This vision leads to the interpretation of EEG as being involved with MEs projecting sensory data to the magnetic body. EEG ME would generate quantum entanglement between two mental images: a feature inside brain and a 'simple feeling of existence' mental image at the magnetic body and representing a point of the external world. Thus the main function of brain would be the construction of features and sensory representations would be completely separated from their construction. Note that also in the case of computers the representation of the data is separated from the generation of the data.

2.3.6 Emotions

TGD suggests several visions about emotions and it is not yet completely clear whether these views are really mutually consistent.

Emotions and comparisons

The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. Subjective and geometric memories make it possible to compare the expectations with what really occurred during the time interval since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. Many higher emotions such as sorrow, depression, frustration, desire, happiness, feeling of relief, pain, fear, anger, envy, hatred, etc... clearly involve comparison of expectations and reality. This could perhaps mean that these emotions are created by the comparison of the predicted or desired geometric time history and subjective time history (what really happened). This would mean that at least higher emotions differ from the sensory qualia, which seem to be determined solely by the localization into zero modes representing the non-quantum fluctuating aspects of space-time geometry.

One might however argue that very primitive emotions such as rage without any object and involving only the activity of the limbic brain could be quale like and that hormones are the quantum correlates of these emotions. These emotions involve however a change of behaviour (e-motion!) so that one could argue that also now there is a simple comparison involved. Perhaps changes in the hormone concentrations could be regarded as consequences of the change of the emotional state. Or vice versa, if hormones are messangers telling to very simple selves of limbic brain whether the real course of events was the desired one or not, then hormones indeed effectively control the emotional state and can be regarded as quantum correlates of emotions.

It is difficult to assign any comparison to an emotion like deep love since it involves a complete acceptance of the object of love and is free of desires. Perhaps the claim of mystics that deep experience of love means that subject and object of love cease to exist as separate objects, makes sense. Lovers quantum entangle and die as separate selves (for some fraction of time only, of course!) and the higher self consisting of lovers experiences whole-body consciousness. Perhaps more mundane love means that my sub-selves representing me and the loved one entangle to form a sub-self experiencing whole-body consciousness. Perhaps also feelings like empathy belong to this class of emotions.

Emotions and entropy

The concrete model of qualia to be developed in [K3] provides an alternative general vision about emotions which allows to understand the difference between comparison type emotions and other emotions as well as the role of emotions in control.

1. The statistical physics approach to qualia leads to the hypothesis that emotions correspond to rates for the generation of various type of entropies for the sub-selves of self. The sign of the rate tells whether emotion is positive or negative. Negative emotions would thus be conscious control variables warning self when some sub-system is generating entropy. The holistic nature of the emotions can be understood easily in this picture and also the fact that they are not directly related to sensory input. One could perhaps also understand higher level emotions like sorrow as reflecting the growing disorder of the virtual world of brain resulting from the primary cause of sorrow.

2. It is known that peptides correlate strongly with emotions and moods [35] and they are even called molecules of emotions. Peptides are also regarded as information molecules. This connection between information and emotions fits nicely with the fact that peptides and other important biomolecules certainly induce strong entropy gradients with respect to subjective time.

3. Sensory qualia can be divided to geometric and non-geometric ones. One can classify also emotions in this manner. Emotions corresponding to the localization in zero modes would perhaps correspond to 'higher level emotions' about external world (say, aesthetic qualia) whereas the

non-geometric emotions associated with the state preparation would correspond to 'self-centered' emotions about the state of body (pain, physical pleasure,...).

4. Also pure emotions which seem to involve no obvious comparison (love, joy, excitement,..) are possible. For instance, the emotions produced by music might represent this kind of emotions. The view about emotions as entropy gradients allows to understand also emotions of this kind. In state of deep love, self enters into very low-entropy state and mental images (not necessarily even present in 'enlightened states') become very pure.

5. An interesting question is whether the entropy growth of our sensory sub-selves is only sensory representation for the entropy growth occurring at the level of atomic space-time sheets or corresponds directly to it. The enormous difference of the temperatures associated with the atomic space-time sheets (ordinary matter) and superconducting magnetic flux tube structures would suggest that the growth rates for these entropies are of totally different order of magnitude and our emotions serve have the role of conscious control variables telling whether things are going well at the atomic space-time sheets.

Consider now the comparison type emotions and the relation of emotions to control in more detail.

1. Many emotions are comparison type emotions. These emotions tend to be negative (say envy). The first option is that comparison type emotions result from the comparison of geometric and subjective memories occurring automatically in any quantum jump and thus to some degree with any quale. Unfortunately, it is very difficult to imagine how to concretely test this kind of hypothesis and it is also difficult to see how the connection with entropy gradient could emerge.

2. One must also seriously consider the possibility that emotions result from the comparison of remembered/anticipated experience and real experience rather than the fundamental comparison involved with anticipation and memory: kind of quasi-computerized version of geometric memory would be in question. The result of comparison would be coded to the sign of the growth rate of some entropy variable. The comparison could perhaps be realized in such a manner that subsequent quantum jumps for comparing sub-system could represent either the anticipated or real quale. If this were the case, the difference between anticipated and real would automatically induce growth of entropy and negative emotion would result. This would be the basic mechanism of dissappointment. In this picture comparison type emotions could be seen as a system of rewards and punishments used to control the self (the controller could be higher level self (conscience) or higher levels selves which also want to survive (the emotions generated by hunger, first, and physical pain). Punish/reward mechanisms could basically involve negentropy/entropy feed to some sub-self.

3. One could also regard emotion as induced by generalized sensory qualia giving information about CNS itself rather than external world or the boundary between external world and body. The regulation involved with the homeostasis involves comparison in an essential manner so that one could perhaps regard emotions as analogous to control variables representing consciously the result of comparison of expected and desired forcing the organism to behave in a manner to reduce this difference and end up to a rest and digest state. This aspect is consistent with the statistical interpretation since the entropy gradients associated with the organism are stronger than those associated with the surrounding world. Also amplification mechanisms exaggerating the entropy gradients might have developed. For instance, our reactions to some odours or tastes could involve this kind of amplification.

4. A hypothesis consistent with these views is that emotional component is involved with all sensory experiences and that we are used to call generalized sensory experiences emotions when they are about body. The emotionality of qualia indeed increases in the sequence of perceptive fields external world – CNS-world boundary – body. The degree of emotionality of experience should be characterized by the deviation of real from expected or desired and this suggests that the emotional component is much stronger for sensory experiences about CNS itself, since the system in question is much less predictable than the external world consisting of dead objects. Interpretation of emotion as measure for entropy gradient explains also this hierarchy.

5. Depression could be seen as a lost ability to experience emotions, be they positive or negative. Depression indeed involves emotional flatness. This state results when mental images become maximally entropic (emotional counterpart of heat death). That depression can follow deep sorrow is natural since negative emotions tend to increase the entropy of the mental images. It is known that depression involves over-activity of the amygdala and under-activity of some forebrain regions and an abnormally small population of glial cells known to be closely involved with metabolism and 'cleansing activities' at brain level. This supports the view that glial cells might be warriors in the war against second law at the level of atomic space-time sheets and the loss of this war is sensorily mapped to the level of mental images and leads to depression. One function of serotonin, dopamin and various other neuropharmaca tending to produce pleasant experiences could be a reduction of entropy either at atomic space-time sheets or, less probably, directly at the level of our sensory sub-selves.

2.3.7 Directed attention

The possibility to interpret self as a statistical ensemble suggests that the entropy of the mental image measures its fuzziness. Thus both attentiveness, alertness and level of arousal should relate very closely to the entropy of the mental images. Attention to a mental image could mean fight against second law to keep the mental image in a low entropy state and this requires metabolism (the icons on the computer screen provide a good example of this). Also alertness means mental images with low entropy content. 7 ± 2 rule of cognitive science suggests that the maximum number of our cognitive sub-selves which can be awake simultaneously, is rather limited. The rule might be based on the metabolic limitations: sub-selves can have low entropy content only in the presence of an external negentropy feed and metabolism must provide the needed negentropy feed. Note however that the needed metabolic energy might be extremely low.

Directed attention is one of the basic processes of consciousness occurring continually. Directed attention seems to involve free choice but focusing of attention could also occur spontaneously. One can imagine several models for the focusing of attention.

1. One possibility is that subsub-self inside sub-self representing mental image (say 'monitor screen' as average over subsub-selves representing the visual objects) somehow pops up one level higher in the self hierarchy so that it becomes mental image. Geometrically this could correspond to the re-gluing of the corresponding space-time sheet to the space-time sheet of self instead of that of sub-self. In this case attended object would not pre-exist.

2. A further aspect of the focused of attention is as a wake-up of sub-self and keeping it in wake-up state and hence in short term memory. This could occur at the expense of the other sub-selves, which would be in wake-up state for only short times. A possible mechanism of selection is a phase transition changing the topology of chosen region (say from p-adic to real or from p_1-adic to p_2-adic) so that a new sub-self pops up from the background.

3. Self directs automatically its attention only to sub-systems immediately below it in the hierarchy. It seems however possible to direct attention to lower levels of the self hierarchy. For instance, I can direct my attention to the entire sentence, which I am writing here or to some word of this sentence or to individual letters of this word. The phenomenon of bio-feedback demonstrates that it is possible to learn to direct the attention to even single neuron. This suggests that selves are able to modify the hierarchy of selves by raising some sub...sub-self to the role of sub-self temporarily and thus experience the former sub...sub-self as a direct mental image. Formation of the join along boundaries bonds between mindlike space-time sheets at various levels of the self hierarchy provides a general geometric mechanism making possible temporary changes of the structure of the self hierarchy. Also the learning taking place during sleep [53] migh involve interaction between different levels of the self-hierarchy.

2.3.8 Four-dimensional brain and long term memories

Four-dimensionality of brain is crucial for the understanding long term memories as multitime experiences receiving contributions from several moments of geometric time. This identification makes it unnecessary to have any memory storage mechanisms. Rather, the activities of the memory circuits

can be seen as increasing the probability that memory recall occurs. Reverberating memory circuits in which experience is echoed indeed do this by extending the deep memory valley in spin glass landscape to a long canyon in time direction. This increases the probability that mindlike space-time sheets enter in the region of four-dimensional spin glass landscape representing the memory. The deepness of the spin glass valley correlates with the emotionality of the memory. Childhood memories are especially emotional and therefore stable. Memories are result of creative action and memory circuit involving hippocampus seem to be active in carving out the art works representing geometric memories worth of remembering. TGD based approach solves the basic problems of the neural net approach resulting from the fact that the formation of new memories destroys old memories and from the fact that it is difficult to understand how the component of experience is known to be a memory.

Long term memories and memories in general can be understood as resulting from a very simple mechanism. When I remember something that happened, say two years ago, I look at a mirror at distance of one light year and see myself in mirror as I am at a distance of two geometric years in the geometric past. Massless extremals (MEs) representing topological light (and graviton) rays and carrying the classical information about the memory are reflected in some kind of a mirror structure. Mirrors could correspond end points, branching points, curved parts or cross sections of magnetic flux tubes and MEs or in case of gravitonic rays to curved parts of the background spatetime surface.

The reflected ME could be seen as topological counterpart of self-energy diagram involving emission and absorption of massless virtual particle such photon or graviton. At quantum level timelike entanglement, which is possible by the non-determinism of the fundamental variational principle, binds the mental images 'now' and 'then' to a single mental image. MEs could be generated in the transitions between almost degenerate quantum spin glass states. Since the energy difference corresponds to the classical gravitational energy, topological gravitonic rays, which also interact very weakly with the external world, are good candidates for MEs responsible for long term memories. The interpretation of these MEs as gravitonic $1/f$ noise suggest itsef strongly.

Note that the continual occurrence of quantum jumps between quantum histories explains why our long term memories are unstable. It seems however that it is probably only sensory and cognitive representations which are altered appreciabely. In human time scales geometric past should be relatively stable in macroscopic length scales: otherwise dramatic changes of the recent reality induced by macroscopic quantum jumps in the geometric past would occur. Four-dimensional brain provides a completely new view about how gemeralized sensory experiences are generated, how generalized motor actions are planned and how memories are constructed. This process is like creating an artwork. *Four*-dimensional spin glass landscape representing a rough scetch is gradually refined by adding details and corrections in increasingly shorter time scales: this corresponds to neural activities of four-dimensional brain generating motion leading to the desired part of spin glass energy landscape. This picture is consistent with the observed $1/f$ noise and fractality of nerve pulse patterns. Absolutely essential is self-organization and related dissipation forcing the Darwinian selection leading to end product which is charicature rather than photo.

2.3.9 Altered states of consciousness

The proposed concept of self provides allows rather rich a palette of altered states of consciousness and one cannot avoid the temptation to a concrete modelling of various altered states of consciousness.

Whole-body consciousness and ordinary consciousness

Krishnamurti has described in his books states of consciousness having natural identification as states of 'whole-body consciousness'. For instance, according to Krishamurti, one can achieve this state only if one is able to stop thinking entirely. If thoughts correspond to cascades of selves decomposing into sub-selves, then this is just what is required. The characteristic of this state of consciousness is the experience of one-ness and the absence of all separations: this is certainly true in the sense that there is only single irreducible self present. Also 'timelessness' characterizes these experiences: the explanation is that internal clock is provided by some sub-self waking up periodically and since there are no sub-selves there can be no time.

I have personally experienced states of whole-body consciousness and also states in which whole-body consciousness is limited to some part of body. These states begin with a sudden fall of silence: all the usual 'noise' from the body disappears suddenly although ordinary physical sounds are still

heard. This could be interpreted as disappearance of sub-selves from body. There is experience like thrill in spine going through the entire body. Interesting experience of this kind occurred when my cat was sleeping over my breast: I woke up and realized that my breast was in the state of whole-body consciousness. Could this mean that sleeping cat was also in this state and that my breast had entangled with the quantum state of cat? Could this in turn mean that during sleep we indeed are in a state of whole-body consciousness or even that our entire body is entangled with some large self? Could the absence of neuronal quantum jumps explain why we do not remember anything about these states? Are remembered states of whole-body-consciousness always such that at least some part of brain is awake?

Possession of self means dissipation, aging and eventual physical death (note however that self lives as a conscious memory realized as a sub-self of higher level self providing kind of summary about the lifetime of self). The absence of neuronal and cell level dissipation during states of whole-body consciousness provides a possible test for the phenomenonon. Test persons could be trained meditators and test should involve the measurement of neural or cellular dissipation occurred during the state of whole-body consciousness. Reduced rate of metabolism could be a measurable signature of whole-body consciousness. Dissipation should be absent or should be very small during this state at least if it is present for sufficiently large fraction of time. The absence of dissipation means that all changes suffered by the cells during whole-body consciousness are reversible and curable. This could explain various miraculous healings. Whole-body consciousness, if possible to arrange artificially, could provide medical means of saving the lifes of victims of accidents (say of victim of heart attack or bleed in brain).

Second signature is the liberation of the binding energy when bound state entanglement leading to whole-body consciousness is generated. This energy could be used for metabolic purposes at some level of the self hierarchy. The anomalously low value of neuronal oxidative metabolism could be due to the binding energy liberated when synchronously firing neuron group forming many neuron bound state is generated .

Whole-body consciousness could explain some spectacular phenomena (not of course taken seriously by skeptics).

1. The claimed ability of yogis to survive for months without eating anything and even without oxygen could have explanation in terms of whole-body consciousness. Oxygen consumption compensates the loss of chemical energy caused by the quantum jumps in biochemical length scales. These quantum jumps occur only if neuronal and lower level chemical selves exist. Under usual circumstances the continuous supply of oxygen makes the ageing of cells slow and the lack of oxygen leads to rapid dissipation and neuronal death. The situation is analogous to Benard flow: if heat feed is stopped, the beautiful flow pattern rapidly dissipates away. If all cells are entangled during whole-body consciousness, no dissipation occurs and the lack of the oxygen supply does not have any irreversible effects and possible effects might be cured automatically. An alternative explanation for the the mystery of yogis who need not eat is that the generation of bound state entanglement involves the liberation of the binding energy as a usable energy possibly compensating for the ordinary metabolic energy.

2. In certain cultures people in trance are able to dance with their bare feet on burning charcoals without any disastrous effects. The disastrous effects of the interaction of heat from burning charcoals with cells in soles of foot must be irreversible changes. If these persons are in a state of whole-body consciousness, then the changes of the invididual cells are reversible.

That-which-is experiences

Irreducible self does not possess any sub-selves. This requires that the sub-systems of self have only bound state entanglement stable against the state preparation process. The absence of sub-selves in turn means the absence of mental images. This kind of situation could correspond to that-which-is experience. The reports of Buddhist meditators about pure awareness with discrete twinkles of consciousness identifiable as short-lived sub-selves are in accord with this view.

In principle meditation could make possible to silence higher sub-selves and make it possible to directly experience quantum jumps occurring at elementary particle level! In this speculative spirit one could even consider the possibility that the abstract theories of elementary particle physics result basically as a summation of the experiences of matter-mind sub-systems entangled with elementary

particles! The state function collapses occurring in particle physics probably result from the entanglement of the states of elementary particles with macroscopic states of matter which in turn entangle with our mindlike space-time sheets.

Interestingly, irreducible selfness is a necessary prequisite of quantum computation since it guarantees that state preparation process has no effect in the state so that in quantum fluctuating degrees of freedom one can approximate the sequence of quantum jumps as a single quantum jump. As a consequence, in these degrees of freedom time evolution can be approximated by a power of unitary operator U and system indeed behaves effectively as a quantum computer for times much longer than CP_2 time of order 10^{-39} seconds. Thus the total emptiness of mind would make possible quantum computation and immense information processing capacities by computation in parallel universes. Perhaps this is why the emptiness of mind is paradoxically associated with a source of infinite wisdom in eastern philosophies.

The formation of bound states essential for the state of irreducible selfness is accompanied by the formation of join along boundaries bonds between space-time sheets representing binding sub-systems. In this process only 'center of mass' zero modes of join along boundaries-condensing space-time sheets are expected to remain zero modes so that in very many particle bound state most of the zero modes become quantum fluctuating degrees of freedom. State function reduction does not occur in these degrees of freedom anymore, macroscopic quantum coherence is preserved from quantum jump to quantum jump, and the system behaves as macroscopic multiverse with new macroscopic degrees of freedom making possible macroscopic quantum computation. This might be the mechanism for how water, DNA, protein, tubulin,... molecules and even neurons bind to quantum computing macroscopic multiverses.

Zen type experiences and $S = 0$ cognitive entanglement

$S = 0$ entanglement between sub-systems is possible only in p-adic context and results when p-adic entanglement probabilities have p-adic norm equal to one. $S = 0$ cognitive system can be defined as a p-adic system for which all sub-systems have $S = 0$ entanglement. NMP does not say anything about state preparation of $S = 0$ p-adic systems. The simplest interpretation is that $S = 0$ entanglement represents the p-adic variant of bound state entanglement so that self measurements reducing the entanglement are not possible and there is conscious analysis yielding separations in these states. Kind of generalization for that-which-is states in which there are no real mental images to states in which there are only $S = 0$ cognitive mental images stable against state preparation suggests itself. Note that $S = 0$ sub-self could act as a p-adic quantum computer in spin degrees of freedom with quantum computation lasting as long as $S = 0$ state lasts. Thus cognitive $S = 0$ mental images provide huge cognitive resources.

The possible identification as states of oneness for cognitive consciousness reported by Zen Buddhists suggests itself. $S = 0$ property means absence of entropy and this could be interpreted as absence of illusions. For ordinary quantum jumps NMP forces a complete selection of final state even when the density matrix is degenerate: this has interpretation as a necessity to select between logically inconsistent alternatives. In quantum jumps to entangled state this kind of choice is not performed: final state is like the famous superposition of dead and living Schrödinger cat. Therefore $S = 0$ entanglement would provide loophole allowing to cognitively experience what it is to be entangled. In real context bound state entanglement between all sub-systems of self makes possible similar experience. Zen Buddhists experiences are often characterized as states of consciousness in which no selection is made between mutually exclusive alternatives. Hofstadter has described this aspect of Zen in hilarious manner in his book 'Gödel, Escher, Bach'.

The absence of desires is one characterization of that-which-is and Zen type experiences. Desires are particular kind of intentions and thus represented by p-adic sub-selves. If p-adic sub-self has subsystem pair for which entanglement is not bound state entanglement ($S > 0$), NMP implies that this sub-self decomposes into sub-selves in state prepartion process so that the state of cognitive oneness is lost. Thus one could say that $S > 0$ cognitive mental images represent desires whereas $S = 0$ p-adic sub-selves represent intentions free of desire. Prediction (in the sense of plan or expectation) is represented as p-adic space-time sheet. The comparison of p-adic expectation with the real subjective memory of what happened would cause the frustration if p-adic expectation represents desire.

The absence of external-world-me separation is also reported to be one characteristic feature of that-which-is and Zen type experiences. This can be understood as absence of cognitive mental images

representing both world and me. This is indeed the case if self possesses only single $S = 0$ cognitive sub-self. If there are several such sub-selves with same value of the p-adic prime, they can develop $S > 0$ mutual entanglement if they correspond to same p-adic prime. Thus it is possible to have single $S = 0$ sub-self corresponding to each p-adic prime.

Extended states of consciousness

Extended states of consciousness seem to be the exact opposite of that-which-experiences. Psi experiments concern subtle connections between subjects removed in space, and occasionally also in time. These experiments are reviewed in [40] and the following representation follows this review closely. The pioneering work related with card and dice-guessing was done by J. B. Rhine in 1930s.

Sharing and fusion of mental images provides an attractive explanation for extended states of consciousness. The sharing can occur only by the entanglement of sub-selves characterized by the same value of p-adic prime. One can also consider the possibility that the process is preceided by a phase transition in which the p-adic prime of experiencer increases: this would make it possible to share mental images of very advanced selves.

The notions of geometric memory and electromagnetic self allow also to understand basic features of these experiences. For instance, the notion of geometric memory allows to understand memories about previous lives and prenatal experiences in which the the contents of consciousness is time shifted. The model for sensory representations leads to the conclusion that the topological field quanta of ELF fields, having frequencies in EEG range and by Uncertainty Principle having size of Earth, are crucial element of our sensory experience. The formation of join along boundaries contacts between topological field quanta associated with different selves could explain a large variety of paranormal experiences.

1. The experiments of Russel Targ and Harold Puthoff

The experiments of Russel Targ and Harold Puthoff [43] were carried in the 1970's some of the best known experiments on subtle connections among distant subjects in regard to the transference of thoughts and images. Both sender and receiver were closed in a sealed, opaque, electrically shielded chamber so that no sensory communication was possible. Sender was subjected to light flashes at regular intervals. This caused a characteristic pattern in the EEG of the sender. In some cases also the receiver exhibited these rhytms.

In remote vision experiments sender served as a beacon. Receiver tried to describe verbally or by scetches what the beacon saw. Independent judges matched on the average 66 per cent of time with what was actually seen by the beacon. There are also remote viewing experiments from other laboratories. The distances between sender and receiver vary from miles to thousands of miles and it seems that distance does not matter.

Distance independence supports the interpretation of both experiments in terms of fusion and sharing of mental images.

2. The experiments of Stanley Krippner

In the experiments of Stanley Krippner [39] image transmission was studied while receiver was asleep. Experimenter, sender and volunteer met each other in the beginning of the experiment. Sender spent the night concentrating on an art print, which he/she had received in the beginning of the experiment in a closed envelope. The brain waves and eye movements of the volunteer were recorded. The experimenter woke the volunteer at the end of the REM period by intercom and the volunteer described the dream.

A correlation between the contents of the dream and of the art print was observed. The score was higher on nights, when there were few or no electric storms in the area and sunspot activity was lowest.

The simplest interpretation is again in terms of fusion of mental images of the subject persons. These mental images are perhaps represented at the personal magnetic sensory canvas. Electric storms and sunspot activity affect directly Earth's magnetic field and should affect the communication mechanism since the experiments of Blackman and other suggest that em selves could correspond to magnetic transition frequencies associated with magnetic field of .2 Gauss which is near to the nominal value .5 Gauss of the Earth's magnetic field. In fact, there exists independent evidence for a general correlation of geomagnetic activity with psi experiences [20].

3. The experiments of J. Grinberg-Zylverbaum

In the experiments of J. Grinberg-Zylverbaum [33] the transfer of EEG potentials was studied. Two subject persons were involved. They were closed in Faraday cages. The sender was meditating. Another subject person was subject to a stimulus in random intervals; not even the experimenter knew, when they were applied. Non-stimulated subject person was in a relaxed state. Stimulus was sudden, short light or sound or short electric shock to index and ring fingers of the right hand causing a characteristic pattern in the EEG of the stimulated person.

The EEG's of the subject persons were synchroninized. The possible presence of transferred potentials in the EEG of nonstimulated subject was studied. Transferred potentials were detected in 25 percent of all cases *provided* persons had met before the experiment. A dramatic example was young couple, deeply in love, whose EEGs remained synchronized throughout the experiment.

The fusion of ELF selves means synchronization of ELF em fields and since ELF selves correspond directly to EEG frequencies, synchronization of EEGs is an immediate consequence and can transfer the synchronous firing in brain circuit of the sender to corresponding brain circuit of the receiver. The personal contact before the experiment certainly enchanges the probablity for the fusion of ELF selves. Also quantum entanglement between sub-selves of subject persons might be involved.

It is known that the EEGs of right and left brain are synchronized in deep meditation. There are also experiments of synchronization of EEGs for different subjects in group meditation [29]. The explanation is same as in above case. Also quantum entanglement might be involved. For instance, quantum entanglement is crucial for the fusion of left and right perceptive fields to single perceptive field.

4. Telesomatic effects

Also the tansfer of actual bodily effects from subject person to another has been studied: references to these experiments can be found in [40]. Physiological changes are found to be triggered in the targeted person by the mental process of another. Distance makes little of no difference. Thus the interpretation in terms of quantum entanglement suggests itself.

There are also countless reports of the transference of pain between persons having very close mutual relationship. Identical twins, mothers and their sons or daughers, couples in love, etc,. Also the relationship between psychiatrist and patient provides example of this kind and is known as projective identification. The general rule seems to the that the relationship between inviduals is always involved with psi effects. This is in accordance with the hypothesis about sharing of mental images having ELF em fields and field bodies as physical correlates. For instance, the field bodies of persons in an intimate relationhip might develop gradually direct contacts (say magnetic flux tubes connecting physical bodies).

5. Grof's experience with altered states of consciousness

Findings of modern psychotherapists, especially the work of Stanislav Grof [38, 40] suggest that besides the ordinary 'biographic-recollective' domain of psyche also perinatal and transpersonal domains of psyche exist. Transpersonal domain can mediate connection between our mind and practically any part or aspect of the phenomenal world. Grof studied for several decades altered states of consciousness induced by psychedelic drugs or holotropic breathing.

In the experience of *'dual unity'*, loosening and melting of the boundaries of the body ego happens but in the merging with another person, own identity is not lost. In the *identification* with another person loss of own identity occurs. Body image, physical sensations, emotional reactions and attitudes, thought processes, memories, facial expressions, typical gestures and mannerisms, postures, movement and even the inflection of the voice become those of the second person. The other can be someone in the presence or absent. Identification involving time shift is also possible. Part of an experience can come from subject's childhood, his or her ancestry or even of a previous lifetime.

Also group identification and group consciousness is possible. Person can identify with an entire group of people having some racial, cultural, national, ideolological, religional, political or professional characteristics. People may experience the totality of suffering of all the soldiers or tenderness of all lovers and dedication of all mothers in regard to their babies.

Identification with animals is possible. This involves body image, specific physiological sensations, instinctual drives, unique perceptions of the environment, emotional reactions, etc.. Person can identify with plants and botanical processes. Also identification with inorganic world can occur. People

can identify with rivers, storms, tornadoes, mountains,.... Or stones, quartz crystals, minerals.... Even the identification with structures of atomic and sub-atomic world is claimed to be possible. At the second end of spectrum are racial and collective experiences and identification with entire human species and the experiences in which one identifies with the whole Earth or even entire cosmos. Also out of body experiences, clairvoyance, clairaudience and telepathy are common. Displacement in time is possible. Patient can have embryonical and fetal experiences and even ancestral experiences as well as past incarnation experiences.

Identification experiences can be generally understood as sharing and fusion of mental images. The fusion of mental images can occur between very many inviduals, say members of a species and would give rise to kind of stereo consciousness analogous to the stereo vision resulting in the fusion of left and right visual fields. We could also share this stereoconsciousness: for instance, shamanist could share the mental images of animal species.

Perinatal experiences and memories extending beyond the lifetime of individual could be explained in terms of geometric memory and the notion of 4-dimensional body: actually these experiences do not in any significant manner differ from ordinary memories. The content of the conscious experience is multilocal both in subjective and geometric time in the sense that the experience contains contributions from several moments of geometric time simultaneously.

Our personal self hierarchy could actually contain higher levels than the levels represented by ELF emf fields associated with EEG. This hypothesis makes sense if the contribution of the higher levels of our self hierarchy to our conscious experience under normal circumstances is only some kind of general awareness ('silent observer'). These higher levels could actually explain the experienced continuity of self. For instance, during sleep there there would be some kind of basic awareness present: the lack of memories about sleep state would lead to, in this framework, erraneous conclusion that sleep state is unconscious.

The assumption that we are doomed to have selves characterized by the same p-adic prime forever, looks rather disconsolate. Also the notion of p-adic evolution suggests that it can change or that the self hierarchy contains always arbitrarily large primes but that they do not contribute to our conscious experience much more than some kind of general awareness.

2.4 Quantum correlates of qualia

The basic theoretical ingredients described above lead to the following general vision about qualia described in detail in [K3]. In the following the latest view about theory is summarized. The notion of quale is understood in an extremely general sense: 'primary attribute of conscious experience' might serve as a synonym for 'quale' in the sense as it is used in the following.

2.4.1 Development of ideas

To achieve something which would deserve to be called a general theory of qualia required almost a decade. During the first years, and in lack of any general theory of qualia, I could only make educated guesses, which were doomed to be wrong.

1. A connection between qualia and EEG MEs emerged, when I learned about the effects of classical electromagnetic fields on brain at frequencies which are cyclotron frequencies or amplitude modulated by cyclotron frequencies [59, 48].

2. The discovery that p-adic physics is physics of cognition (or at least imagination, one should be very cautious in order to avoid over generalizations!) clarified the views about the relationship between cognition and sensory experience [H8].

3. The notion of the many-sheeted ionic flow equilibrium was a further important breakthrough [J1, J2, J3]. It allowed to realize that MEs, superconducting magnetic flux tubes, and ordinary biomatter at atomic space-time sheets form a three-levelled master-slave hierarchy.

4. The realization that MEs carrying supercanonical representations at their lightlike boundaries are excellent candidates for the carriers of at least some of our qualia, gave a totally new perspective to the problem of qualia [J4]. It seems however that MEs are not all that is needed: our qualia involve both supercanonical and magnetic quantum phase transitions.

5. The work with the problems related to the precise formulation of Negentropy Maximization Principle led to the realization that each quantum jump defines a quantum measurement followed by a state preparation leading to an unentangled product state. This means the reduction of the quantum measurement theory to basic quantum TGD. The next realization was that the quantum jump sequence defining self defines a statistical ensemble of prepared states. One can identify the fundamental statistical ensembles of statistical physics as selves and implied a deep and precise connection between thermodynamics and the theory of qualia allowing a general classification of qualia and an identification of their thermodynamical correlates.

6. The last breakthrough in development, which is still continuing, was the realization that very general arguments lead to the view that ultimate (conscious-to-us) sensory representations are realized outside the body on the magnetic canvas provided by the magnetic flux tube structures associated with brain and having most plausibly size for which Earth size as a natural unit. One can see cortex as a collection of standard features some of which are associated to the objects of the perceptive field represented as magnetic sub-selves. Frequency place coding (MEs generate magnetic quantum phase transitions) plays a key role in this association.

Music metaphor at axonal level

Music metaphor has been one philosophical quideline behind the identification of the quantum correlates of the sensory qualia.

1. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas and the variation of these frequencies could code for the distance to the object of the perceptive field.

   A stronger interpretation of the metaphor is that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a sensory modality associated with the sensory pathway. Nerve pulse patterns determine the experience as chords from from the notes of various instruments in the same sense as the musician produces the music. This leads to a generalization of the idea about brain as an associative net.

   More concretely, postsynaptic receptors act as neuronal sensory receptors and transmitters emitted and MEs generated by the presynaptic neuron induce neuronal sensory experiences in the postsynaptic neuron. The specialization of the neuronal receptors would be same for the entire sensory pathway and determine the qualia associated with it.

2. Resonance is an essential aspect of music instrument as is resonant frequency modulation which can involve several levels. The frequencies characterizing the hierarchical modulation provides a partial characterization of the sensory representations. Quantum mechanically resonance corresponds to a harmonic perturbation with frequency which is difference of energies for the states of some sub-system. In this kind of situation quantum jumps can be amplified to quantum phase transitions and sub-self representing mental image wakes up.

Unfortunately, music metaphor is only a metaphor and has led to a plethora of various models for qualia.

ME's and qualia

The identification of MEs as building blocks of sensory and cognitive structures leads to a rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other, magnetic flux tube structures, and the matter at atomic space-time sheets. The realization that MEs serve as quantum holograms and the properties of the supercanonical stats gave the final justification for this identification. The model allows to understand EEG as a direct physical correlate of mindlike space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also what might be called RF (radiofrequency) and MW (microwave) MEs representing our mental images are crucial for the model.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our radiation body. Also the notion of magnetic body is needed. It took a long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; or with self having literally infinite size. The last two options seems to be more plausible than the first two: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body. The simplest option is that the relevant magnetic flux tube structures have same sizes as ELF MEs. During sleep our attention might be directed to transpersonal levels of consciousness.

MEs, magnetic superconductors, and many-sheeted ionic flow equilibrium

The lack of clearcut empirical evidence for the predicted supra phases has been a stumbling block for the quantitative development of the theory for a long time. The situation changed dramatically when I learned about the effects of ELF em fields on living matter[7]. This article provided the ingredients making possible a general quantitative model of quantum control and coordination in which self hierarchy has as its dynamical correlate hierarchy of weakly coupled super conductors and massless extremals (MEs) interacting with the ordinary matter at atomic space-time sheets. MEs indeed provide a model of Josephson junction and an explanation for the amplitude windows observed in the experiments of Blackman and others [48, 44].

Later the experimental findings challenging the notions of ionic channels and pumps [21] led to the identification of homeostasis as many-sheeted ionic flow equilibrium in which the ionic concentrations at atomic space-time sheets are controlled by much smaller ionic concentrations at superconducting magnetic flux tubes. MEs control superconducting magnetic flux tubes via magnetic induction, by inducing magnetic phase transitions and by acting as Josephson junctions between magnetic flux tubes.

Magnetic transitions at superconducting magnetic flux tubes serve as seeds for phase transitions in quantum critical quantum spin glass type phase of macroscopic super conductor leading to generation of a region of new kind of phase whose quantum numbers differ from old one by the quantum numbers associated with magnetic transition frequency. Thus quantum transitions are amplified to macroscopic quantum transitions and Bose-Einstein condensation (analogous to induced emission) is the basic mechanism behind the process.

The first natural guess was that magnetic quantum phase transitions correspond to our qualia. That transition frequencies are involved is indeed in nice accordance with quantum jumps between histories as moment of consciousness identification. However, the fact that magnetic states correspond to a lower level of abstraction than supercanonical states associated with MEs, suggests that magnetic qualia do not correspond to our qualia directly. Rather primitive chemical qualia experienced by cell level selves might be in question.

The role of supercanonical algebra

An important step in the development of the theory of qualia was the realization of the importance of supercanonical symmetries. The answer to this question might have been guessed by taking quantum measurement theory as a starting point.

1. Basic geometric objects is the configuration space of all possible three-surfaces in $M^4_+ \times CP_2$. In absence of non-determinism of Kähler action everything would reduce to the boundary of the future lightcone ($\delta M^4_+ \times CP_2$) carrying representations of supercanonical and superconformal algebra localized with respect to the ligthlike radial coordinate of the lightcone boundary. These symmetries are obviously cosmological. Also quaternion conformal symmetries are possible and these can be identified as the TGD counterparts of string model conformal symmetries responsible for elementary particle quantum numbers.

2. The non-determinism of Kähler action forces to introduce supercanonical representations at the lightlike boundaries X^3 of MEs acting as quantum holograms. Thus superconformal and supercanonical symmetries become macroscopic symmetries and must be crucial for consciousness.

[7] I am grateful for Gene Johnson for sending me the popular article of Yarrow [59] about bio-electromagnetism.

3. There are two kinds of configuration space degrees of freedom: quantum fluctuating non-zero modes and zero modes which can be regarded as classical, non-quantum fluctuating degrees of freedom in complete consistency with the reduction of standard quantum measurement theory to the localization in zero modes occurring in each quantum jump. Zero mode algebra cointains the generators of supercanonical algebra with even conformal weight. In particular, zero modes contain the points of an infinite-dimensional flag-manifold extended to contain the radial Virasoro algebra of the lightlike boundary of ME localized with respect to CP_2. Radial coordinate corresponds to the lightlike coordinate of the the lightlike boundary of ME. This flag-manifold parametrizes all possible choices of the quantization axes for the canonical Lie-algebra.

2.4.2 Qualia and thermodynamics

The connection between thermodynamics and qualia was the real breakthrough in the development of ideas. In some sense this finding is not a news: the close connection between pressure sense and temperature sense and thermodynamics is basic facts of psychophysics. In TGD framework the contents of consciousness is determined as some kind of average over the sequence of very large number of quantum jump and this suggests strongly that non-geometric qualia allow statistical description generalizing ordinary thermodynamical ensemble to the ensemble formed by the prepared states in the sequence of quantum jumps after the last 'wake-up' of self. This picture allows to see the ageing of self with respect to subjective time as an approach to thermal equilibrium.

1. There are geometric qualia corresponding to zero modes expressing the result of quantum measurement in each quantum jump. All geometric information about space-time surface should reduce to geometric qualia. For instance, geometric data given by visual, auditory, and tactile senses should reduce to conscious information about zero modes or about increments of zero modes in quantum jump.

2. The sequence of the prepared states can be modelled as a statistical ensemble of Fock states, which suggests that thermodynamics is basically part of theory of consciousness. The ensemble of prepared states gives rise to a large number of statistical qualia. The relationship $dE = TdS - PdV + \mu dN + B \cdot dM...$ generalizes to TGD context: note however that in case of ME selves energy is replaced with the Super Virasoro generator L_0 associated with the lightcone boundary of ME. Each intensive-extensive variable pair in the differential should correspond to a non-geometric quale, which results only when there is gradient (flow) of the extensive variable in the direction of the subjective time. Supercanonical thermodynamics should obviously map ordinary thermodynamics to the level of conscious experience.

3. Since subjective experience corresponds to quantum jumps, it is natural to assume that only the increments of zero modes and quantum numbers are experienced consciously. Statistical interpretation also suggests that an averaging over increments occurs. The possibility of subselves makes possible to have mental images of finite time duration and this makes possible structured subjective memories (for instance, it becomes possible to remember the digits of phone number). A further working hypothesis is universality: qualia associated with quantum phase transitions depend only on the quantum number increments. In particular, the increments of Poincare and color and electroweak quantum numbers define what might be called universal kinestetic qualia.

The thermodynanical expression for dE suggests a general classification of qualia consistent with the 'holy trinity' of existences implied by TGD.

1. Emotions as order-disorder qualia

$T - S$ pair correspond subjective existence and generalizes to disorder-order type, information theoretic qualia qualia about the state of self: hot-cold and pain-pleasure type sensations and also more abstract experiences associated with various sub-selves of self. These qualia are strongly emotional single-pixel holistic qualia measuring whether some kind of an entropy variable is increasing or decreasing. The total entropy for the statistical ensemble defined by self determines how sharp the the mental image is. Low entropy content means alertness and attentiveness. High entropy content means fuzzy mental image. Getting tired means inability to keep mental images in low entropy state.

2. Kinestetic qualia defined by generalized forces

p-V pair corresponds to the geometric existence and is replaced with generalized force-generalized coordinate pairs in quantum fluctuating degrees of freedom. The increments of maximum number of mutually commuting Poincare, color and electroweak quantum numbers define this kind of qualia. The increments of four-momentum code for the sensation of force whereas the increments of orbital angular momentum code for the sensation of torque. Spin flip could code for something else. Tactile senses such as pressure sense and their generalizations involve kinestetic qualia. The increment of energy or equivalently, increment of frequency, can be identified as correlate for hearing in generalized sense responsible for the dynamical nature of auditory experience (hearing is timelike version of force sense). It is not clear whether spin flip has interpretation as torque or possibly as figure background separation. In TGD based model of auditory experience hearing relates to Z^0 magnetic spin flip phase transitions for cognitive neutrino pairs.

The rate for the increase of the two diagonal color quantum numbers should code intensity type variables associated with color sensation. The rate for the increase of electric charge of sub-self should code for electric sense possessed by, say, fishes. Also $B - M$, $\phi\rho$ and $E - P$ pairs correspond to generalized forces since electromagnetic fields are reduced to space-time geometry in TGD framework.

3. Generalized chemical qualia vm

$\mu - N$ pair corresponds to 'objective existence' defined by quantum histories and N is generalized to a number of particle like excitations in the Fock state resulting in the state preparation. In this case there must be a flow of particle number in the direction of the subjective time, that is Bose-Einstein condensation type process for, say Cooper pairs. Quite generally, supercanonical and quaternion conformal super algebras should define these qualia and the number of these qualia is very large.

i) One can assign particle numbers to phases with various magnetic quantum numbers and these could define generalized chemical qualia which could perhaps be regarded as qualia and subqualia of chemical qualia defined by a particular ion and chemical qualia could actually reduce to magnetic qualia. Since the changes of magnetic field induce these quantum phase transition, it would seem that magnetic and Z^0 magnetic quantum phase transitions at superconducting magnetic flux tubes could correspond to this kind of qualia. In principle, endogenous NMR and its generalizations induced by the interaction of magnetic and Z^0 magnetic fields of MEs with magnetic and Z^0 magnetic flux tube structures are possible. Chemical qualia would very naturally correspond to the Bose-Einstein condensation of ions to the superconducting magnetic flux tubes: these ions could be even the ions of tastant or odorant. Also secondary representations at the level of cortex in terms of superconducting light ions are possible and would give rise to classification of tastes and odours. Magnetic qualia are characterized by definite transition frequencies and this makes possible place-/time coding by magnetic transition frequencies if magnetic or Z^0 magnetic field varies along magnetic flux tube/is a function of time. The activation of a point of living map would generate some quale at that point.

ii) For super canonical qualia the number of Bose-Einstein condensed 'configuration space photons' having nontrivial dependence on configuration space degrees of freedom replaces number of molecules. The condensation rates for the numbers of the configuration space photons with nonvanishing color quantum numbers could be interpreted as correlates of color qualia whereas the condensation rates for color singlet configuration space photons could relate to the intensity of color sensation. If the rates for the trasfer of color quantum numbers define intensity type variables associated with color experience then BE condensation to color singlet states does not give rise to experienced quale so that only non-diagonal color generators correspond to visual colors. Also the BE condensation of the ordinary coherent light should give rise to some kind of quale: perhaps vibratory sense which can be developed to effective vision, could correspond to non-colored vision. Configuration space Hamiltonians are also labelled by 2-dimensional orbital spin quantum number and longitudinal momentum. Polarization sense and sensation about motion of the object of visual field would naturally relate to spin and longitudinal momentum.

iii) Tactile senses involve topological phase transitions involving the creation of join along boundaries contacts between object and skin whose number would thus be the relevant variable. The purely sensory aspect of physical pain could correspond to a topological phase transition involving the splitting of join-along boundaries bonds between space-time sheets (MEs could even define these bonds) so that N would be now the number of join along boundaries bonds. The simplest picture requires that the MEs associated with sensory organs are connected to the MEs responsible for our experience. Of course, splitting and generation of join along boundaries contacts could occur also at the level of

sensory representations.

4. Boolean qualia

The transitions associated with the fermionic generators of supercanonical algebra can be identified as Boolean consciousness with intrinsic meaning ('This is true'). Boolean cognition without intrinsic meaning and/or conscious feeling of quantitity can be understood as associated with sequences of cognitive neutrino pairs. A general model for abstraction process not only explains the basic numbers of the genetic code but also suggests an entire hierarchy of codes [L1] in accordance with fractality of TGD Universe.

The next code in the hierarchy is very attractive candidate for a 'memetic code'. The hypothesis predicts correctly the .1 second time scale for the duration of 'our' self (immediate short term memory, duration of psychological moment). Code-words correspond to the sequences of 126 bits with a duration of 1/1260 seconds: this is slightly below the time scale of nerve pulse so that membrane oscillations are perhaps a more natural realization for the code. Temporal sequencies of Z^0 magnetized cognitive antineutrino systems with a varying direction of magnetization and having a duration of order millisecond would realize the memetic code. The frequency of about 10 Hz is in EEG frequency range and also corresponds to ELF topological field quanta with size of Earth representing our cognitive sub-self. Remarkably, the Z^0 cyclotron frequencies of all particles with non-vanishing neutron number are around 10 Hz.

2.4.3 Geometric qualia and zero modes

The zero modes of the configuration space are special in the sense that in each quantum jump localization occurs in this space. Zero modes characterize the size and shape of 3-surface and are excellent candidate to represent information about the state of organism (3-surface itself) geometrically. Zero modes can be parametrized as an infinite-dimensional flag-manifold associated with the algebra of the infinitesimal canonical transformations of $E^2 \times CP_2$, where S^2 is sphere at the lightcone boundary extended by Virasoro algebra acting in radial direction of lightcone boundary. Physically this space corresponds to all possible choices of the quantization axes for generators of Super Canonical Algebra and, in accordance with the basic assumptions of quantum measurement theory, each quantum jump involves this kind of choice. Infinite-dimensional flag manifold contains as sub-flag-manifold $S^2 \times F_3$ parameterizing choices of quantization axes of spin and color ($F_3 = SU(3)/U(1) \times U(1)$). Lorentz invariance suggests the extension of S^2 to 2+2 dimensional flag-manifold $F = SO(3,1)/SO(2) \times R$ parameterizing various choices of the quantization axes for Lorentz quantum numbers [K3].

There are continuous, geometric and kinestetic (both geometric in four-dimensional sense) qualia like position and velocity; orientation and angular velocity, and also geometric time and experienced rate of time flow. All these pairs correspond to mutually in-compatible observables quantum mechanically. The hypothesis motivated by the work of Barbara Shipman [Shipman$_{1,2,3}$] is that some coordinates of F_3 parametrize positions. The generalization of this hypothesis is that the infinite-dimensional flag-manifold associated with the zeromode part supercanonical algebra somehow gives rise to a conscious representation of continuous, classical qualia basically assignable to the choise of quantization axes. The hypothesis indeed makes sense: the entire isometry group of the configuration space, in particular the sub-group defined by zero modes, leaves induced Kähler form invariant but affects magnetic and Z^0 magnetic fields and hence magnetic transition frequencies. Also color rotations act in F_3 nontrivially and, although they leave Kähler form invariant, they affect magnetic and Z^0 magnetic fields and thus the corresponding magnetic transition frequencies. This means that a curve of the infinite-dimensional flag-manifold can be mapped to a varying cyclotron frequency.

2.5 Solutions to some paradoxes

The TGD inspired theory of consciousness provides a solution to the many paradoxes related to the basic quantum physics and the philosophy of conscious mind. The solution of these paradoxes is basically due to the replacement of the dualistic and monistic world views by the tripartistic world view of TGD.

2.5.1 Paradoxes related to quantum physics

The basic paradox is the conflict between the non-determinism of the state function reduction and the determinism of the Schrödinger equation. At a more general level this paradox is the conflict between the subjectively experienced actuality of the free will and the determinism of the objective world. The resolution of this paradox is simple in TGD context. One must give up the idea of single objective reality and replace it with a deterministic quantum history, which changes in each quantum jump, which is a genuine act of free will occurring outside the realm of the geometric space-time. Thus the objective reality, in the sense of a physical theory, is indeed deterministic, apart from the non-determinism related to the special properties of the Kähler action. In fact, a determinism of the Kähler action is achieved by replacing the ordinary concept of the 3-space with the concept of an association sequence and this naturally leads to a model for thinking systems. Volition seems to correspond to the selection between various degenerate absolute minima of the Kähler action and has thus a direct classical counterpart.

In the context of the deterministic physics, theoretician encounters two rather unpleasant paradoxes. The determinism implies that the unique objective reality corresponds to a single solution of the field equations. The first question is "What determines the initial conditions, say at the moment of the big bang?" and the attempt to answer this question leads necesssarily outside the physical theory: one possibility is to postulate antrophic principle. In TGD objective reality changes at each quantum jump and the localization in zero modes and NMP imply a genuine evolution: therefore the recent objective reality is an outcome of conscious selections. The second problem encountered by a theoretician is that in principle it is not possible to test a deterministic theory since only single solution of the field equations is realized and a genuine testing would require the comparison of the time developments for various initial data. In practice this problem can be circumvented by assuming the existence of identical sub-systems having very weak interactions with the external world but in principle the problem remains unsolved.

The famous Einstein-Bohr debate was related with the question whether God plays dice or not. Amusingly, in TGD context both were correct in their own ways! Quantum histories are indeed deterministic but God can replace the old quantum history with a new one: perhaps one should not however call this act dice playing but simply an act of free will. Einstein was also an advocate of local realism: this led to Einstein-Podolski-Rosen paradox created by the possibility of quantum entanglement between distant system. In TGD framework local realism holds true at the level of the infinite-dimensional configuration space but not at the level of space-time since point like particles are replaced with 3-surfaces.

The Schrödinger cat paradox has also an elegant solution in TGD context. The point is that conscious experience is associated with a quantum jump leading to a final state in which cat is either dead or alive. There is no conscious experience about the situation in which the cat is both dead and alive giving answer to the question "Dead or alive?". More generally, this feature of consciousness also could explain why the world of our conscious experience looks classical: it simply cannot look but classical since the very moment of consciousness makes it classical. In fact, the world *is* predicted to be genuinely classical to the extent that mutual quantum entanglement between different p-adic sub-Universes seems impossible for purely mathematical reasons. The localization into zero modes occurring in quantum jumps strengthens this conclusion considerably since it implies that the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces: the world of conscious experience is genuinely classical.

The phenomenon of dissipation is paradoxal from the point of view of standard physics. It is generally accepted that the fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of the fundamental physics and the irreversible and mathematically rather ugly "real" world, seem to exist simultaneously. The quantum jumps between quantum histories concept solves the paradox and one can understand the dissipative world as an effective description forming an 'almost'-envelope for the sequence of reversible worlds (time developments).

2.5.2 Paradoxes related to the theories of consciousness

Chalmers describes in his book 'Conscious Mind' [43] several paradoxes related to the materialistic and dualistic theories of mind. A common denominator for these problems is the assumption that

consciousness is a property of a physical state: hence these paradoxes disappear in TGD context. These paradoxes are encountered also in the quantum theories of consciousness identifying consciousness as a property of a macroscopic quantum state, say Bose Einstein condensate.

In the materialistic theories of mind, postulating a unique objective reality, consciousness is an epiphenomenon and free will is necessarily a peculiar illusion and one can always ask why the consciousness is needed at all: nothing changes in the physical reality if consciousness is dropped away. It is also very difficult to understand how the contents of consciousness are determined by the state of the material world.

In the dualistic theories postulating a unique objective reality (say the theory of Chalmers [43]), the problems are related to the coupling between matter and mind. The basic problem of the dualistic theories is what Chalmers calls hard problem: how the physical processes in the brain give rise to conscious experience? If the laws of the physics determine the behaviour of the system completely then one ends up immediately either with a complete separation of the mind and matter so that our conscious experience tells nothing about the material world or with materialism and epiphenomenalism. One can also consider a non-trivial coupling between matter and "mind like" fields but assuming a deterministic physics one ends up with a situation in in which the mind fields are effectively just additional physical fields and consciousness is again redundant.

An exotic example of this kind of a paradox is the following one described in [43]. In the dualistic theories in which the physical laws determine the objective reality, all psychological (third person) aspects of the mind are in principle purely physical. The book written by Chalmers about consciousness is obviously an example of a completely physical phenomenon. Therefore the contents of the book need not have anything to do with Chalmers's ideas about consciousness! More generally, the reports about the states of consciousness need not have anything to do with the states of consciousness in the dualistic theories of this kind. The only manner to save the day (and the uniqueness of the objective reality) is to accept materialism and epiphenomenalism.

In TGD framework, which could be called tripartistic, hard problem and other problems of the dualistic theories disappear since there is no need to assign consciousness to quantum history. Moment of consciousness as quantum jump between quantum histories hypothesis allows even to define measures for the information contents of the conscious experience despite the fact that one cannot write explicit formulas for the contents of conscious experience.

2.5.3 Logical paradoxes and concept of time

Many logical paradoxes could be resolved if one assumes that there are two times: geometric and subjective and that the space-time surface providing linguistic representations changes quantum jump by quantum jump. In particular, during the conscious argument leading to the logical paradox!

The objections of Uri Fidelman [28] against the Platonic vision about reality involve the paradoxes of the cyclic cosmology (one might think that Turing machine in cyclic cosmology might be able to 'know' whether it has halted immediately after starting and thus be much more powerful than ordinary Turing machine). Basic paradox is that in cyclic cosmology allowing time travel one can imagine a son who murders his mother.

It is interesting to consider this paradox as resulting from identification of the identification of subjective time with geometric time, which I see only as an approximation. In TGD the counterpart of time travel would be sequence of quantum jumps changing the entire classical history quantum jump by quantum jump and inducing the shift of the space-time region, where the contents of consciousness of time traveller are concentrated, to the geometric past. No paradoxes result since space-time is not a fixed arena of dynamics but changes in each quantum jump.

As a second example one can take the second objection of Uri Fidelman [28] against Penrose's program known as Berry's paradox. *Non-formalizable theory cannot provide a model of the physical world which includes the brain's cognitive function, since such a model must be lingual, written or spoken. However, such a model implies the following paradox of Berry: Let n be the smallest number which cannot be defined by an English sentence having less than, say, a hundred letters. This number exists, since the number of all possible combinations of a hundred letters is finite. Nevertheless, it has just now been defined by a sentence comprising less than a hundred letters.*

Berry's paradox could be understood when the piece of text is seen as inducing a sequence of quantum jumps in which the space-time region at which the argument is represented symbolically changes. For the initial space-time region representing my cognitive state there is indeed smallest

number n which cannot be defined by using less than one hundred words (using the English in that space-time!). After reading the statement quantum history is replaced by a new, more complex one in which this this number can be defined by using less than one hundred words since a new reflective level of cognitive consciousness has emerged and is represented at space-time level.

This example encourages to think the possibility of replacing the idea of a fixed axiomatic system with a living and dynamically evolving system becoming conscious of new axioms from which new theorems can grow. Mathematician would not be anymore an outsider but and active participator affecting the mathematical system he is studying. For instance, when paradoxal statement represented symbolically becomes conscious in quantum jump sequence, also the context in which it was originally stated changes. This dynamical view about mathematical system could allow to solve antinomies.

2.6 Hyper-finite factors of type II_1, dark matter hierarchy, and consciousness

This section is devoted to the progress that has occurred during the period 2004-2006, about one decade after the first draft of this chapter was written. The realization that the von Neumann algebra known as a hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition. One of the most important outcomes is a prediction of a hierarchy of quantum phases with arbitrarily large values of quantized Planck constant identified as dark matter and assumed to be the quintessence of living matter.

2.6.1 Hyper-finite factors of type II_1 and quantization of Planck constant

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the configuration space of 3-surfaces ("world of classical worlds"). As a matter fact, it seems that the infinite-dimensional character of this algebra implies the rest of TGD. 4-D space-time, imbedding space $M^4 \times CP_2$, and the entire quantum TGD could emerge from the extension of the hyper-finite factor of type II_1 to a local algebra. This extension is local with respect to an octonionic coordinate whose non-associativity guarantees that the algebra does not reduce back to a mere hyper-finite factor of type II_1. The dynamics of quantum TGD would follow from the associativity condition: in particular, space-time surface would be maximal associative or co-associate sub-manifolds of imbedding space.

The quantization of Planck constants assignable to M^4 and CP_2 degrees of freedom as integer multiples of the ordinary Planck constant is strongly suggestive in this framework and the phases with large Planck constant are interpreted as a dark matter quantum controlling ordinary matter in living matter. The average geometric durations of quantum jumps are naturally quantized as multiples of the integer characterizing M^4 Planck constant. This allows the reduction of the notion of self to that of quantum jump at higher level of hierarchy. A strong quantitative prediction for the preferred geometric durations of quantum jumps emerges.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a justification from the quantum measurement theory for hyper-finite factors of type II_1.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II_1 and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II_1 and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

2.6.2 Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [D6, J6, C7] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text.

Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [C7]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [C9].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [C7]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value $\hbar_0$ of Planck constant: $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$. This in terms of a mild generalization of standard Jones inclusions [C7]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.

3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of M^4 and $n(G_a)$-fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.

4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of $\hbar$ in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2, C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2, C) \times SU(2)$.

5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimick these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

2.6.3 Dark matter hierarchy and the notion of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n, p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m, n, p) =$

$mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. $m = 2^{11}$ seems to be favored in living matter [M3]. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

2.7 The most recent view about cognition and intentionality at level of basic physics

In this section, which is probably somewhat too technical for the reader without strong background in quantum TGD, I try to describe the most recent view (the date while I am writing this is 30 July 2006) about quantum TGD, and how it leads to a rather detailed view about cognition and intentionality as basic elements of physics even at elementary particle level.

Forgetting technicalities the first message is that in TGD Universe all quantum states have vanishing net conserved quantum numbers and decompose into positive and negative energy parts with positive energy part identified as ordinary matter in the usual ontology. This makes possible to identify p-adic-to-real transition as a transformation of intention to action.

The so called infinite primes [O2] were one of the first mathematical fruits of TGD inspired theory of consciousness. The hypothesis has been that they code for the space-time correlates of quantum states. The second message is that a detailed view about this coding is possible and reveals the difference between the space-time correlates of intentions and cognitions besides showing that quantum classical correspondence relates to each other the identification of the p-adic space-time sheets as space-time correlates of cognition and the identification of fermionic degrees of freedom as correlates of Boolean cognition.

2.7.1 Zero energy ontology, cognition, and intentionality

One could argue that conservation laws forbid p-adic-real phase transitions in practice so that cognitions (intentions) realized as real-to-padic (p-adic-to-real) transitions would not be possible. The situation changes if one accepts what might be called zero energy ontology [C1, C2].

Zero energy ontology classically

In TGD inspired cosmology [D5] the imbeddings of Robertson-Walker cosmologies are vacuum extremals. Same applies to the imbeddings of Reissner-Nordström solution [D3] and in practice to all solutions of Einstein's equations imbeddable as extremals of Kähler action. Since four-momentum currents define a collection of vector fields rather than a tensor in TGD, both positive and negative signs for energy corresponding to two possible assignments of the arrow of the geometric time to a given space-time surface are possible. This leads to the view that all physical states have vanishing net energy classically and that physically acceptable universes are creatable from vacuum.

The result is highly desirable since one can avoid unpleasant questions such as "What are the net values of conserved quantities like rest mass, baryon number, lepton number, and electric charge for the entire universe?", "What were the initial conditions in the big bang?", "If only single solution of field equations is selected, isn't the notion of physical theory meaningless since in principle it is not possible to compare solutions of the theory?". This picture fits also nicely with the view that entire universe understood as quantum counterpart 4-D space-time is recreated in each quantum jump and allows to understand evolution as a process of continual re-creation.

Zero energy ontology at quantum level

Also the construction of S-matrix [C2] leads to the conclusion that all physical states possess vanishing conserved quantum numbers. Furthermore, the entanglement coefficients between positive and negative energy components of the state define a unitary S-matrix. S-matrix thus becomes a property of

the zero energy state and physical states code by their structure what is usually identified as quantum dynamics.

Also the transitions between zero energy states are possible but general arguments lead to the conclusion that the corresponding S-matrix is almost trivial. This finding, which actually forced the new view about S-matrix, is highly desirable since it explains why positive energy ontology works so well if one forgets effects related to intentional action.

At space-time level this would mean that positive energy component and negative energy component are at a temporal distance characterized by an appropriate p-adic time scale and the integer characterizing the value of Planck constant for the state in question. The scale in question would also characterize the geometric duration of quantum jump and the size scale of space-time region contributing to the contents of conscious experience. The interpretation in terms of a mini bang followed by a mini crunch suggests itself also.

Hyper-finite factors of type II_1 and new view about S-matrix

The representation of S-matrix as unitary entanglement coefficients would not make sense in ordinary quantum theory but in TGD the von Neumann algebra in question is not a type I factor as for quantum mechanics or a type III factor as for quantum field theories, but what is called hyper-finite factor of type II_1 [C7]. This algebra is an infinite-dimensional algebra with the almost defining, and at the first look very strange, property that the infinite-dimensional unit matrix has unit trace. The infinite dimensional Clifford algebra spanned by the configuration space gamma matrices (configuration space understood as the space of 3-surfaces, the "world of classical worlds") is indeed very naturally algebra of this kind since infinite-dimensional Clifford algebras provide a canonical representations for hyper-finite factors of type II_1.

The new view about quantum measurement theory

This mathematical framework leads to a new kind of quantum measurement theory. The basic assumption is that only a finite number of degrees of freedom can be quantum measured in a given measurement and the rest remain untouched. What is known as Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of von Neumann algebras allow to realize mathematically this idea [C7]. $\mathcal{N}$ characterizes measurement resolution and quantum measurement reduces the entanglement in the non-commutative quantum space $\mathcal{M}/\mathcal{N}$. The outcome of the quantum measurement is still represented by a unitary S-matrix but in the space characterized by $\mathcal{N}$. It is not possible to end up with a pure state with a finite sequence of quantum measurements.

The obvious objection is that the replacement of a universal S-matrix coding entire physics with a state dependent unitary entanglement matrix is too heavy a price to be paid for the resolution of the above mentioned paradoxes. Situation could be saved if the S-matrices have fractal structure. The quantum criticality of TGD Universe indeed implies fractality. The possibility of an infinite sequence of Jones inclusions for hyperfinite type II_1 factors isomorphic as von Neumann algebras expresses this fractal character algebraically. Thus one can hope that the S-matrix appearing as entanglement coefficients is more or less universal in the same manner as Mandelbrot fractal looks more or less the same in all length scales and for all resolutions. Whether this kind of universality must be posed as an additional condition on entanglement coefficients or is an automatic consequence of unitarity in type II_1 sense is an open question.

The U-matrix for p-adic-real transitions makes sense

In zero energy ontology conservation laws do not forbid p-adic-real transitions and one can develop a relatively concrete vision about what happens in these kind of transitions. The starting point is the generalization of the number concept obtained by gluing p-adic number fields and real numbers along common rationals (expressing it very roughly). At the level of the imbedding space this means that p-adic and real space-time sheets intersect only along common rational points of the imbedding space and transcendental p-adic space-time points are infinite as real numbers so that they can be said to be infinite distant points so that intentionality and cognition become cosmic phenomena.

In this framework the long range correlations characterizing p-adic fractality can be interpreted as being due to a large number of common rational points of imbedding space for real space-time sheet and p-adic space-time sheet from which it resulted in the realization of intention in quantum

jump. Thus real physics would carry direct signatures about the presence of intentionality. Intentional behavior is indeed characterized by short range randomness and long range correlations.

One can even develop a general vision about how to construct the U-matrix elements characterizing the process [C2]. The basic guideline is the vision that real and various p-adic physics as well as their hybrids are continuable from the rational physics. This means that these U-matrix elements must be characterizable using data at rational points of imbedding space shared by p-adic and real space-time sheets so that more or less same formulas describe all these U-matrix elements. Note that also $p_1 \to p_2$ p-adic transitions are possible.

2.7.2 Infinite primes, cognition and intentionality

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether configuration space degrees of freedom and configuration space spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionionic primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling super-generators to the finite primes. One must also remember that the infinite primes considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

Precise space-time correlates of cognition and intention

The best manner to end up with the proposal about how p-adic cognitive representations relate bosonic representations of intentions and actions and to fermionic cognitive representations is through the following arguments.

1. In TGD inspired theory of consciousness Boolean cognition is assigned with fermionic states. Cognition is also assigned with p-adic space-time sheets. Hence quantum classical correspondence suggets that the decomposition of the space-time into p-adic and real space-time sheets should relate to the decomposition of the infinite prime to bosonic and fermionic parts in turn relating to the above mention decomposition of physical states to bosonic and fermionic parts.

   If infinite prime defines an association of real and p-adic space-time sheets this association could serve as a space-time correlate for the Fock state defined by configuration space spinor for given 3-surface. Also spinor field as a map from real partonic 3-surface would have as a space-time correlate a cognitive representation mapping real partonic 3-surfaces to p-adic 3-surfaces obtained by algebraic continuation.

2. Consider first the concrete interpretation of integers m_B and n_B. The most natural guess is that the primes dividing $m_B = \prod_i p^{m_i}$ characterize the effective p-adicities possible for the real 3-surface. m_i could define the numbers of disjoint partonic 3-surfaces with effective p_i-adic topology and associated with with the same real space-time sheet. These boundary conditions would force the corresponding real 4-surface to have all these effective p-adicities implying multi-p-adic fractality so that particle and wave pictures about multi-p-adic fractality would be mutually consistent. It seems natural to assume that also the integer n_i appearing in $m_B = \prod_i q_i^{n_i}$ code for the number of real partonic 3-surfaces with effective q_i-adic topology.

3. Fermionic statistics allows only single genuinely q_i-adic 3-surface possibly forming a pair with its real counterpart from which it is obtained by algebraic continuation. Pairing would conform with the fact that n_F appears both in the finite and infinite parts of the infinite prime (something absolutely essential concerning the consistency of interpretation!).

   The interpretation could be as follows.

   i) Cognitive representations must be stable against intentional action and fermionic statistics guarantees this. At space-time level this means that fermionic generators correspond to pairs of real effectively q_i-adic 3-surface and its algebraically continued q_i-adic counterpart. The quantum jump in which q_i-adic 3-surface is transformed to a real 3-surface is impossible since one would obtain two identical real 3-surfaces lying on top of each other, something very singular and not allowed by geometric exclusion principle for surfaces. The pairs of boson and fermion surfaces would thus form cognitive representations stable against intentional action.

   ii) Physical states are created by products of super algebra generators Bosonic generators can have both real or p-adic partonic 3-surfaces as space-time correlates depending on whether they correspond to intention or action. More precisely, m_B and n_B code for collections of real and p-adic partonic 3-surfaces. What remains to be interpreted is why m_B and n_B cannot have common prime factors (this is possible if one allows also infinite integers obtained as products of finite integer and infinite primes).

   iii) Fermionic generators to the pairs of a real partonic 3-surface and its p-adic counterpart obtained by algebraic continuation and the pictorial interpretation is as fermion hole pair.

   iv) This picture makes sense if the partonic 3-surfaces containing a state created by a product of super algebra generators are unstable against decay to this kind of 3-surfaces so that one could regard partonic 3-surfaces as a space-time representations for a configuration space spinor field.

4. Are alternative interpretations possible? For instance, could $q = m_B/m_B$ code for the effective q-adic topology assignable to the space-time sheet. That q-adic numbers form a ring but not a number field casts however doubts on this interpretation as does also the general physical picture.

Number theoretical universality of S-matrix

The discreteness of the intersection of the real space-time sheet and its p-adic variant obtained by algebraic continuation would be a completely universal phenomenon associated with all fermionic states. This suggests that also real-to-real S-matrix elements involve instead of an integral a sum with the arguments of an n-point function running over all possible combinations of the points in the intersection. S-matrix elements would have a universal form which does not depend on the number

field at all and the algebraic continuation of the real S-matrix to its p-adic counterpart would trivialize. Note that also fermionic statistics favors strongly discretization unless one allows Dirac delta functions.

Quantum classical correspondence requires that the flow of subjective time identified as a sequence of quantum jumps should have the flow of geometric time as a space-time correlate. The understanding of the detailed relationship between these two times has however remained a long standing problem, and only the emergence of zero energy ontology allows an ad hoc free model for how the flow and arrow of geometric time emerge, and answers why the relationship between geometric past and future is so asymmetric and why sensory experience is about so narrow interval of geometric time. Also the notion of self reduces in well-defined sense to the notion of quantum jump with fractal structure.

2.7.3 About the arrow of psychological time

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

Two times

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which represent basic types for them.

The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

2.7.4 Questions related to the notion of self

I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot

remember anything about this period? The work with the model of topological quantum computation has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time

surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configurations space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

Does entanglement mean loss of consciousness?

The ability to avoid entanglement with environment would be essential for the original notion of self and incase of sub-selves it would explain the finite life-time of mental images. One can of however ask whether the assumption about the loss of consciousness in entanglement - that is during sleep - is really necessary. One could however argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday. Furthermore, during topological quantum computation entanglement is absent and thus this state should correspond to conscious experience. Night time is however the best time for tqc since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at some level during sleep and perform quite a long tqc. Perhaps we are!

Could it be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with some system means only diving into the ocean of consciousness as someone has expressed it. We would be Gods as also quantum classical correspondence in the reverse direction requires (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions). This would be the most optimistic view that one can imagine.

What after biological death?

Could the new option allow to speculate about the course of events at the moment of death? Certainly this particular sensory "me" would effectively meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape sooner later brings into the volume of attention (which might also change) a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what she might call enlightment.

2.7.5 Memory and time

Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [H6].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [27].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [K6]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [H6]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [28] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$, $k = 0, 1, 2,$, and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

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Chapter 3

Negentropy Maximization Principle

3.1 Introduction

Quantum TGD involves 'holy trinity' of time developments. There is the geometric time development dictated by the absolute minimization of Kähler action crucial for the realization of General Coordinate Invariance. There is the unitary "time development" U: $\Psi_i \to U\Psi_i \to \Psi_f$, associated with each quantum jump, which is the counterpart of the Schrödinger time evolution $U(-t, t \to \infty)$. There is however no actual Schrödinger equation involved: situation is in practice same also in quantum field theories. Quantum jump sequence itself defines what might be called subjective time development.

Some dynamical principle governing subjective time evolution should exist and explain state function reduction with the characteristic one-one correlation between macroscopic measurement variables and quantum degrees of freedom and state preparation process. Negentropy Maximization Principle is the candidate for this principle, which I have been developing during last almost decade.

3.1.1 Evolution of ideas related to NMP

The evolution of ideas related to NMP has been slow and tortuous process and has basically evolution of ideas related to the anatomy of quantum jump and quantum TGD.

1. The first form of NMP was rather naive. There was no idea about the anatomy of quantum jump and NMP only stated that the allow quantum jumps are such that the information gain of conscious experienced measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Already at this stage it however became clear that the special features of p-adic entropy in p-adic context might have deep implications.

2. Later it became clear that quantum jump has complex anatomy: unitary process is followed by the TGD counterpart of state function reduction and state preparation. State function reduction would naturally correspond to localization in zero modes strongly suggested by a mere mathematical consistency. There is no well-defined integration measure in the infinite-dimensional space of zero modes which by definition do not contribute the line element of the configuration space. This does not lead to difficulties if one assumes that complete localization in zero modes occurs in each quantum jump.

3. One of the last outcomes of the slow process has been the realization that complete localization in zero modes in every quantum jump is un-necessarily strong condition. It is enough that discretization in zero modes occurs in each quantum jump meaning that a state consisting of superposition of completely localized states in zero modes with quantum fluctuating degrees of freedom could survive under some conditions. This in fact is even suggested by the requirement that quantum measurement lasts for a finite time and thus corresponds to a sequence of quantum jumps. This picture would suggest that NMP could be completely general principle applying to both state function reduction step and to state preparation and these two processes do not differ so much from each other as believed originally.

4. At some state the importance of the trivial fact that bound state entanglement must be stable against NMP, become obvious. The problem is however the characterization of bound state entanglement. At the level of space-time correlates the identification of join along boundaries bonds between space-time sheets as correlate for bound state entanglement suggests itself. The question is how to characterize bound state entanglement universally. NMP would suggest that bound state entanglement negentropy should be positive but this is impossible if entanglement negentropy is defined using Shannon's formula.

5. An important step in the process was the realization that the generation of macro-temporal quantum coherence means effective gluing of quantum jumps in quantum jump sequence to single quantum jump. This means that in appropriate degrees of freedom state function reduction and state preparation cease to occur during macro-temporal quantum coherence. This makes sense if macro-temporal quantum coherence means generation of bound state entanglement.

6. Many-sheeted space-time and p-adic length scale hierarchy force to generalize the notion of sub-system. The space-time correlate for the bound state entanglement is the formation of join along boundaries bonds connecting two space-time sheets. The basic realization is that two disjoint space-time sheets can containing smaller space-time sheets topologically condensed on them and connected by join along boundaries bonds. Thus systems un-entanglement at given level of p-adic hierarchy can contain entanglement subsystems at lower level. In TGD inspired theory of consciousness this makes possible sharing and fusion of mental images by entanglement. The resolution dependence for the notions of sub-system and bound state entanglement means that the entanglement between sub-systems is not "seen" in the length scale resolution of unentangled systems. This phenomenon does not however result as an idealization of theoretician but is a genuine physical phenomenon. Obviously this generalized view about sub-system poses further challenges to the detailed formulation of NMP.

7. p-Adic length scale hypothesis leads to the view that there is entire hierarchy of durations for effective quantum jumps and this forces to ask whether the quantum jumps sequence decomposes into a hierarchy of effective quantum jumps of increasingly long duration just like physical systems form a hierarchy starting from the level of elementary particles and continuing through hadronic, nuclear, atomic and molecular physics up to level where astrophysical objects take the role of particles. The usually un-noticed fact that hadrons can be regarded as quantum objects in long length and time scales whereas quark description treats hadrons as dissipative systems forces to make the following questions. Could state function reductions and preparations form a hierarchy and that the dissipative processes in short scales could occur in quantum parallel manner in longer scales. Using quantum computer language this would mean the possibility of quantum superposition of classical dissipative quantum computations.

8. The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures. In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive. In p-adic physics one can generalize this information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $log_p(||_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real number by the so called canonical identification $x = \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

   There is however interesting special case. When the entanglement probabilities are rational numbers or at most finitely extended rational numbers one can still define logarithms of probabilities as p-based logarithms $log_p(||_p)$ and interpret the entropy as real number. In this case the entropy can be however negative and positive definite information measure is possible. Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes. This suggests that the notion of bound state could be number theoretic: perhaps bound state entanglement can be defied as entanglement with finitely extended rational entanglement probabilities and cannot be reduced in quantum jump since this would be in conflict with NMP. Bound state entanglement can of course be generated in quantum jump.

9. The fusion of real and p-adic physics to single physics has been a long standing challenge for TGD. The previous findings might have served as strong motivation for how to achieve this fusion. In fact, the motivations came from TGD inspired theory of consciousness, in fact the attempt to model how intentions having p-adic space-time sheets as space-time correlates are transformed to action having real space-time sheets as correlates. The proposal is that state function reduction and preparation number theoretical necessities. Unitary process creates a superposition of states in various number fields and the first step in the reduction process is to select number field, real number field or extension of p-adic number. After the process continues so long that a state contains only finitely extended rational entanglement stable under NMP and can be regarded as a product of states with entanglement probabilities in discrete number fields defined by finite extensions of rationals. Thus the entire process leads from continuum to discrete and is consistent with basic aspects of cognition and analytic thought.

3.1.2 NMP, self measurements, cognition, state preparation, qualia

That the reduction of the standard quantum measurement theory to the effective classicality of zero modes results as a basic prediction of quantum TGD, was not at all obvious from the beginning. In fact, the original proposal was that subjective time development should be governed by the so called Negentropy Maximization Principle (NMP), which should replace the standard quantum measurement theory.

The realization that standard quantum measurement theory results from the localization in zero modes does not however mean that NMP should be thrown away. Rather, NMP could be seen as the variational principle governing the dynamics of *self measurements* giving rise to state preparation. It will be assumed that this self measurement process continues until the system decomposes into unentangled subsystems consisting of subsystems which for which entanglement is bound state entanglement.

NMP applies to any unentangled subsystem resulting in this cascade of self measurements and tells that self measurement is performed for the subsystem (or equivalently, its complement) which gives rise to maximum entanglement negentropy gain in the self measurement.

NMP applies to the anatomy of a single quantum so that there is actually no need to mention the notion of self at all in the context of NMP. Despite this it is useful to introduce the basic concepts related to self. Self is a subsystem able to remain unentangled in sequential quantum jumps and preserving its identity in some sense: presumably the p-adic prime characterizing self (and also the real space-time sheet associated with self) is what characterizes the self identity. One can define irreducible self as a self which does not decompose to further sub-selves in state preparation process, that is irreducible self is bound state of more elementary subsystems. A second reason for introducing the notion of self is that for a self in a state of macro-temporal quantum coherence the sequence of quantum jumps effectively fuses to single quantum jump representing single long lasting moment of consciousness.

Some comments about NMP are in order.

1. Standard quantum measurement theory does not allow a spontaneous reduction of entanglement between quantum fluctuating degrees of freedom of two subsystems associated with 3-surface. This kind of entanglement can be reduced only by introducing entanglement with zero mode degrees of freedom, that is 'observer'. Thus NMP is the principle governing the dynamics of spontaneous self measurements by selecting which subsystem-complement division of given unentangled subsystem is self measured.

2. Self measurement involves the division of unentangled subsystem (possibly self, mental image) into two unentangled subsystems. Analytical thought creates separations and comparisons so that this division could be identified as the basic mechanism of cognition. Also sensory experience generates separations and distinctions so that NMP should be identified as the variational principle governing the dynamics of cognition and perception. State preparation process makes the world of conscious experience to look completely classical since only bound state entanglement is stable against self measurement. One can thus say that state function reduction and the cascade of self measurements lead leads from a maximally entangled multiverse state $U\Psi_i$ to a maximally analyzed state: from quantum holism to classical reductionism. At the level of

standard quantum measurement theory this process is equivalent with state preparation process yielding totally unentangled product state as incoming state of particle physics experiment.

3. Self measurements are distinguishable from standard quantum measurements. Thus it is in principle possible to experimentally detect the presence of self measurements. Their presence distinguish selves from non-selves. The fact that self measurement reduces entanglement entropy allows the system to fight against thermalization and self measurement could be also seen as a self repair mechanism.

4. Irreducible self *effectively* obeys in quantum fluctuating degrees of freedom a unitary time development defined by n:th power of U for a sequence of n quantum jumps, at least in reasonable approximation. This means fractality of consciousness: one can approximate sequences of quantum jumps with single quantum jump such as one can approximate molecules consisting of elementary particles with a point like particle. This observation is of crucial importance for understanding how quantum computing is possible in TGD universe despite that single quantum jump to an increment of psychological time equal to CP_2 time. Also Penrose-Hameroff hypothesis generalizes to TGD framework and one can understand the purely phenomenological notion of quantum de-coherence at fundamental level and also how the quantum spin glass nature of TGD Universe allows to circumvent the objections against Penrose-Hameroff hypothesis.

5. The fact that state preparation is not a deterministic process, forces a statistical modelling of the state of self using the ensemble formed by the prepared states defined by the sequence of quantum jumps in turn defining the contribution to the contents of consciousness of self as a statistical average. The simplest description is in terms of thermodynamics. Thermodynamical density matrix gives the probabilities for various states of a subsystem in the sequence of quantum jumps occurred after the last 'wake-up'. What is of paramount importance is that the contents of consciousness of self can be modelled using statistical thermodynamics. Non-geometric sensory qualia indeed have a close relationship with conjugate pairs of thermodynamical variables such as temperature-entropy, pressure-volume, chemical potential-particle number,... The sequence of quantum jumps also defines a sequence of quantum jumps in zero modes. Statistical averaging is not so natural for the values of zero modes characterizing the outcomes of the quantum measurements, which suggests that they could be experienced as separate ones by self and would correspond to geometric qualia experienced as being sharp and dynamical.

3.1.3 Quantum jump as number theoretic necessity

The hypothesis that state function reduction and preparation are essentially number theoretic necessities is a new idea inspired by the formulation of quantum TGD using generalized notion of number based on fusion of real and p-adic number fields to a larger structure by gluing them along common rationals. Unitary process generates a superposition of states in different number fields. Even more, entanglement between two systems can be real, p-adic or finitely extended rational entanglement (and thus correspond to discrete number field) irrespective of what are the number fields associated with entangled systems provided the states in question are orthonormalized. The sole goal of the state function reduction and preparation process is to lead to a final state containing only finitely extended rational entanglement identified as bound state entanglement. The process leads thus from continuum to discrete as far as number field is considered. Why this kind of entanglement is so special is that the number theoretic entanglement entropy associated with it is negative and has interpretation as a measure for genuine conscious information accompanying the experience of understanding. Thus NMP can be assumed to govern both state function reduction and preparation and force generation of bound state entanglement. The cognitive interpretation of quantum jump and its fractally scaled up counterparts would be as an analysis leading to an experience of understanding.

This vision forces to revise the interpretation of second law of thermodynamics. Only the coherence associated with non-bound entanglement is destroyed in quantum jump whereas bound state entanglement is preserved and even generated. Thus information is actually generated and one can give up with a sigh of relief the gloomy visions about the heat death of the universe.

The implications for quantum computing are especially important. Macro-temporal quantum coherence made possible by quantum spin glass degeneracy increasing the life times of bound states allows to circumvent standard objections against quantum computing in biological length scales. A

generalization of quantum computation paradigm seems to be necessary since p-adic length scale hierarchy makes possible quantum parallel dissipation so that quantum parallel classical computations become possible.

Before continuing, I want to represent my apologies to the readers: the development of the TGD inspired theory of consciousness has been so fast that I simply have not had time to update the chapters accordingly: also this chapter documents some unavoidable side tracks and should be taken as a lab note book rather than a final documentation.

3.1.4 Hyper-finite factors of type II_1 and quantization of Planck constant

The realization that the von Neumann algebra known as hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the configuration space of 3-surfaces ("world of classical worlds"). As a matter fact, it seems that the infinite-dimensional character of this algebra implies the rest of TGD. 4-D space-time, imbedding space $M^4 \times CP_2$, and the entire quantum TGD could emerge from the extension of the hyper-finite factor of type II_1 to a local algebra. This extension is local with respect to an octonionic coordinate whose non-associativity guarantees that the algebra does not reduce back to a mere hyper-finite factor of type II_1. The dynamics of quantum TGD would follow from the associativity condition: in particular, space-time surface would be maximal associative or co-associate sub-manifolds of imbedding space.

The quantization of Planck constants assignable to M^4 and CP_2 degrees of freedom as integer multiples of the ordinary Planck constant is strongly suggestive in this framework and the phases with large Planck constant are interpreted as a dark matter quantum controlling ordinary matter in living matter. The average geometric durations of quantum jumps are naturally quantized as multiples of the integer characterizing M^4 Planck constant. This allows the reduction of the notion of self to that of quantum jump at higher level of hierarchy. A strong quantitative prediction for the preferred geometric durations of quantum jumps emerges.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a justification from the quantum measurement theory for hyper-finite factors of type II_1.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II_1 and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II_1 and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

3.2 General conceptual background

NMP was originally formulated to generalize quantum measurement theory and dictate which subsystems in a given quantum state suffer quantum jump interpretable as a measurement of the density matrix of subsystem.

What NMP states is that self measurement occurs for the quantum subsystem (or equivalently, its complement) for which the negentropy gain ΔN is largest. In the p-adic context the real counterpart of the total negentropy gain is maximum for the allowed quantum jump. NMP applies separately to each unentangled subsystem of the state resulting in state function reduction from the state $U\Psi_i$. Note that the values of zero modes do not change during state preparation process. NMP should specify more or less uniquely which quantum subsystem of unentangled system performs the self measurement. It could happen that there are several quantum subsystem-complement pairs giving the same maximum negentropy gain: the simplest possibility is that the selection among these alternatives takes place randomly.

It is convenient to introduce the concept of irreducible self as a self for which the entanglement between subsystems is always bound state entanglement which by definition is stable against self measurement. The notion of bound state is taken as granted in the real case. In p-adic case the identification of the bound state entanglement as entanglement with vanishing entanglement entropy is attractive (in this case NMP predicts nothing). Clearly, one can assign with a given subsystem a unique number telling to how many irreducible subsystems it decomposes. In the following the conceptual background of NMP will be discussed. before dwelling on the technical problems related with the precise formulation of NMP.

3.2.1 What happens in the quantum jump?

The detailed analysis of quantum jump between quantum histories leads to surprisingly strong general predictions as the following considerations intend to show.

The general structure of quantum jump

It has gradually become clear that TGD involves 'holy trinity' of dynamics.

1. The dynamics defined by absolute minimization of Kähler action corresponds to the dynamics of material existence, with matter defined as 'res extensa', three-surfaces.
2. The dynamics defined by the action of the unitary "time development" operator U can be regarded as informational "time development" occurring at the level of objective existence. The construction of U is completely analogous to the construction of the time evolution operator $U(-t,t)$, $t \to \infty$ associated with the scattering solutions of Schrödinger equation. It seems however un-necessary and very probably also impossible to assign Schrödinger equation with U.
3. The dynamics of quantum jumps governed by the hypothesis about localization in zero modes and by NMP corresponds to the dynamics of subjective existence.

In accordance with this, quantum jump decomposes into informational time development

$$\Psi_i \to U\Psi_i \ ,$$

followed by quantum jump

$$U\Psi_i \to \Psi_{f_0}$$

involving a localization into some sector D_P of the configuration space and a sequence of self measurements

$$\Psi_{f_0} \to \Psi_{f_1} ..... \to \Psi_f$$

governed by NMP.

A good metaphor for the quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization to the final sector D_p of the configuration space and self measurement cascade). One could formally regard each quantum jump as analogous to a quantum computation lasting infinitely long time interval $(-\infty, \infty)$.

A second useful metaphor is as generation of infinite number of quantum parallel potentialities in which entire universe is in a totally entangled holistic state of oneness followed by state function reduction and self measurement cascade analyzing the state into maximally unentangled subsystems. NMP states that the analysis produces maximum amount of conscious information. For irreducible selves analysis process do not continue and the sequences of quantum jumps effectively take the role of single quantum jump. Therefore this structure characterizes also conscious experience in macro-temporal time scales. Clearly, quantum measurement theory has fascinating parallels with Krishnamurti's philosophy of consciousness which underlines the competing holistic and reductionistic aspects of consciousness.

A third useful metaphor comes from particle physics. Moment of consciousness can be seen as elementary particle of consciousness and selves as the atoms, molecules, ...galaxies,... of consciousness. Fractality hypothesis allows to get general vision about structure of consciousness even in the time scale of human life.

Localization in zero modes is necessary

The detailed inspection of what happens in quantum jumps leads to the surprising result that quantum jump involves always a complete localization in the zero modes. The argument leading to this conclusion goes as follows.

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of configuration space spinors at given point Y^3 of the configuration space. This suggests that subsystem should be defined as a function of Y^3 and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.

2. Configuration space spinor field can be formally expressed as a superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence configuration space spinor field can be formally written as

$$\sum_{Y^3} C(Y^3)(n,N)|n\rangle|N\rangle$$

   for any subsystem-complement decomposition defined in Y^3. Clearly, configuration space coordinates appear in the role of additional indices with respect to which entanglement coefficients are diagonal. The requirement that final state is pure would suggest that the quantum jump reducing the entanglement must involve a complete localization of the configuration space spinor field to some Y^3 plus further quantum jump reducing the entanglement in Y^3. Complete localization in configuration space is however not physically acceptable option since the action of various gauge symmetries on quantum states does not commute with a complete localization operation. In particular, the requirement that physical states belong to the representations of Super Virasoro and Super Canonical algebras, is not consistent with this requirement.

3. Under rather reasonable assumptions one can however replace complete localization with the localization in zero modes. Configuration space has fiber space structure. Configuration space metric is non-vanishing in fiber degrees of freedom and since propagator for small fluctuations equals to the contravariant metric of configuration space, fiber degrees of freedom correspond to genuine quantum fluctuations. Configuration space metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self-organization. Quantum entanglement occurs in fiber degrees of freedom. The requirement that various local symmetries act as gauge symmetries. provide good reasons to expect that *entanglement coefficients are gauge invariants and hence depend on the zero modes only.* If this is really the case then the localization in zero modes leads to a state for which entanglement coefficients in the fiber degrees of freedom are constant so that localized quantum state reduces to a tensor product of nonlocalized states in fiber degrees of freedom.

4. Since the decomposition of the configuration space to sectors D_P is induced by the corresponding decomposition in zero modes, this hypothesis only strengthens the hypothesis about localization to D_P. The time development by quantum jumps in the zero modes is effectively classical: Universe is apparently hopping around in the space of zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface. Therefore each quantum jump gives very precise conscious geometric information about the space-time geometry and about configuration space in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for the localization to given point of zero mode space is given by the reduced probability density Q defined by the integral of the probability density R defined by the configuration space spinor field over fiber degrees of freedom. The local maxima of Q appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of maximum.

5. The degrees of freedom characterizing the non-determinism of the Kähler action can be regarded as fiber degrees of freedom and the experience with standard quantum field theory suggests that only 4-surfaces around single maximum of Kähler function is selected in quantum jump: this

might follow from the requirement of internal consistency and would correspond essentially to what happens in spontaneous symmetry breaking. Localization in the zero modes is completely analogous to Higgs mechanism in which scalar field attains vacuum expectation value. Thus the general structure of the configuration space spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD based version (note however that particle massivation relies on p-adic thermodynamics in TGD framework). Universe according to TGD is a superposition of parallel classical universes (3-surfaces). Therefore quantum entangled state can can be regarded as a superposition of parallel entangled states, one for each 3-surface. Formally entanglement coefficients can be regarded as coefficients having the configuration space coordinates of 3-surfaces as an additional index.

6. Localization in zero modes provides simple explation for why the universe of conscious experience looks classical: moment of consciousness makes it classical. It also explains why the physics treating space-time as a fixed arena of dynamics has been so successful.

7. Mathematical consistency requires complete localization in p-adic configuration space degrees of freedom which are thus zero modes. This means that the world of cognitive experience is completely classical.

U correlates completely zero modes with quantum fluctuating degrees of freedom

The localization in zero modes is consistent with the unitarity only if U itself in suitable basis can be regarded as inducing a flow in the zero modes. This means that for each values z of zero modes there exist preferred basis of the configuration space spinor fields in quantum fluctuating nonzero modes such that the action of U reads as

$$\begin{aligned} &|n,z\rangle \rightarrow U|m,z\rangle = |\hat{n}, z_1(z,n)\rangle \ , \\ &|\hat{n}\rangle = \textstyle\sum_m S^\dagger_{nm}|m\rangle \ . \end{aligned} \tag{3.2.1}$$

Clearly, U acts effectively as a flow in zero modes for any state $|n\rangle$. This assumption translates the basic assumption of classical quantum measurement theory about one-one correlation between classical macroscopic states and preferred basis of quantum states to TGD framework. The standard objection against the purely formal notion of S-matrix is that one can always go a state basis, in which S-matrix is diagonal and reduces to a multiplication by a phase factor. In TGD framework this objection does not apply since S-matrix is defined only in a preferred state basis for which the outgoing states are localized in zero modes.

The state basis $|\hat{n}\rangle$ is the natural basis for the outgoing states and S-matrix can be identified as the matrix relating the initial state basis $|n\rangle = S_{nm}|\hat{m}\rangle$ localized in z and the outgoing state basis $|\hat{n}\rangle$. Note that one must assume that the correlation between zero modes and quantum states is controllable: it is clearly absent in the initial state. This corresponds to the possibility to control whether the measurement interaction is on or off. In TGD framework measurement interaction has description as a coupling of the measured subsystems with larger space-time sheets representing measurement apparatus and observer.

The consistency with unitarity thus implies that also the action of U-matrix in zero modes is effectively classical in preferred states basis: the reason is that no dispersion which is characteristic of Schrödinger time evolution occurs. A further implication is that density matrix for the subsystems defined by quantum fluctuating degrees of freedom on one hand and zero modes on the other hand is diagonal. Therefore the localization in zero modes can be interpreted as a quantum measurement of this density matrix and since density matrix is a Hermitian operator, there is a complete consistency with standard quantum measurement theory.

The localization in zero modes has an interesting relationship with the proposals that the breaking of unitarity and the concept of symmetry breaking are necessary for understanding of bio-systems [19]. The localization in zero modes implies the breaking of quantum ergodicity since quantum jumps to states which are superpositions of states in zero modes are not possible final states of quantum jump. As will be found, this also implies evolution as the increase of the infinite prime characterizing Universe. This is in accordance with the fact that also thermal spin glasses break ergodicity. The

breaking of unitarity can also be interpreted as the counterpart of symmetry breaking which also involves localization in zero mode type variables (say the direction of magnetization).

The localization in zero modes implies evolution

According to the number theoretic vision about quantum TGD [E3], there are reasons to consider the possibility that the configuration space of 3-surfaces decomposes into union of sectors D_P labelled by infinite primes and each infinite prime P. The notion of infinite-p p-adic topology indeed makes sense.

Infinite primes can be constructed by a process analogous to a repeated second quantization of an arithmetic quantum field theory for which states are labelled by primes. For given infinite prime P the number of infinite primes larger than P is infinitely larger than the number of infinite primes smaller than P. Zero modes characterize the value of the infinite prime and all points in the fiber of the configuration space correspond to same P for given values of zero modes. This means that the localization in zero modes implies a localization into some sector D_P and P must obviously increase in the long run.

Infinite prime P measures is in a well defined sense a composite of finite primes and defines a decomposition of space-time surface into regions labelled by finite primes. Thus the increase of P is achieved either by increase of the finite primes or by the emergence of new space-time sheets labelled by finite primes. Finite-p p-adic topologies in turn correspond to a hierarchy of increasingly refined topologies. Also the maximum increment of the p-adic entanglement negentropy in quantum jump increases with p. These features suggest that p serves as a kind of intelligence quotient for cognitive system. In the same manner also infinite primes serve as effective intelligence quotient. This obviously means that localization in zero modes implies evolution as increase of infinite prime P characterizing the universe.

Quantum jumps involve conscious choice of zero modes and thus the choice of some sector D_P. Since the increase/decrease of P corresponds to evolution/decline, the obvious interpretation is that this kind of choices are moral choices. The fact that the number of alternatives is infinite suggests however that our moral choices might basically involve comparison of the initial and final sectors D_P rather than comparison of alternative selections. The fact that we are moral agents forces to consider the possibility that our conscience corresponds to infinite prime contribution to our conscious experience coming from entire initial and final quantum histories. This in turn suggests that the mathematics of infinite might provide the proper tool for saying what one can say about such abstract concepts as moral, society and spirituality. One must however notice that an increase of infinite prime is induced by the increase of finite primes decomposing it and the appearance of new finite primes into decomposition. Thus local evolution implies global evolution. Therefore also our choices are basically between finite p-adic primes and infinite primes need not contribute to our conscious experience.

3.2.2 The concept of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed.

Original definition of self

According to the original definition prior to the introduction of the dark matter hierarchy self is identified as a subsystem able to remain unentangled during the informational 'time evolutions' U associated with the sequential quantum jumps. Or putting it differently: self is a subsystem behaving like its own sub-Universe (with respect to NMP). Space-time surface decomposes into regions corresponding to real or various p-adic topologies. In p-adic case only quaternion conformal spin degrees of freedom can entangle. If one allows rational entanglement between different number fields and if entanglement entropy is regarded as a rational number in this case, NMP dictates uniquely the dynamics of also this process which necessarily precedes self measurements inside various number fields. The interpretation as cognitive self measurements is natural.

Since connected space-time sheets correspond to irreducible selves, the entanglement reduced in these self measurements is between disjoint space-time sheets belonging to the same number field. Thus it is possible to have in the real context a situation in which some real entanglement entropies are infinite.

Self identity can be defined by the prime characterizing p-adic and also real space-time sheet. If this space-time sheet disappears, self loses consciousness. The formation of a join along boundaries bond with another space-time sheet corresponds to the generation of bound state entanglement, and also now self loses consciousness. Here one must however consider also a weaker condition: real self loses consciousness if it bound-state-entangles with a real self characterized by a larger p-adic prime. One could interpret the process as a phase transition in which the p-adic prime characterizing the smaller space-time sheet increases and corresponding self disappears.

The hypothesis that the experiences of self associated with the quantum jumps occurred after the last 'wake-up' sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore self becomes an extended object with respect to subjective time and has a well defined 'personal history'. If temporal binding of experiences involves kind of averaging, quantum statistical determinism makes the total experience defined by the heap of the experiences associated with individual quantum jumps reliable. Subjective memory has natural identification as a short term memory.

A given self S behaves essentially as a separate sub-Universe with respect to NMP. If one postulates that the conscious experiences of sub-selves S_i of an self S integrate with the self experience of S to single experience, one obtains a filtered hierarchy of conscious experiences with increasingly richer contents and at the top of the hierarchy is entire universe, God, enjoying eternal self-consciousness since it cannot get entangled with any larger system.

An attractive hypothesis is that the experience of self is abstraction in the sense that the experiences of sub-selves S_{ij} of S_i are abstracted to average experience $\langle S_{ij}\rangle$. This implies that the experiences of sub-sub-...selves of S are effectively unconcious to S. This hierarchy obviously has extremely far-reaching consequences. Temporal binding implies that experiences of individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles.

The binding of *experiencers* is also possible. The binding of selves by quantum entanglement however destroys the component selves (note however the comment about situation in which the p-adic primes are different for real entangling selves). This process could correspond to the formation as wholes from their parts, say the formation of the mental image representing word from the mental images representing letters, which are all represented as sub-selves. Associative learning might correspond to the generation of entanglement between selves representing objects of the sensory experience and conscious association would correspond to the reduction of this entanglement generating associated sub-selves. The entanglement of sub-selves of two selves is possible if one accepts the length scale dependent notion of subsystem and means sharing and fusion of mental images, binding of experiences. Entanglement might make possible communication between selves belonging to different levels of the self hierarchy and to different number fields: this entanglement would be reduced always in state function reduction step.

Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [D6, J6, C7] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [C7]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of

Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

2. Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [C9].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [C7]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value $\hbar_0$ of Planck constant: $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$. This in terms of a mild generalization of standard Jones inclusions [C7]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.

3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of M^4 and $n(G_a)$-fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.

4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of $\hbar$ in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2,C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2,C) \times SU(2)$.

5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimick these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n,p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m,n,p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. $m = 2^{11}$ seems to be favored in living matter [M3]. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

3.2.3 Length scale dependent definition of subsystem

The challenge of defining the notion of sub-system is highly non-trivial in TGD framework. The notions of many-sheeted space-time and p-adic length scale hierarchy inspire a generalization of the sub-system concept. This generalization is already inherent in the renormalization group philosophy of quantum field theories relying on the notion of resolution.

Elementary particle black hole analogy

A highly nontrivial point is related to the fact that the space-time sheet glued to a larger space-time sheet is separated from the latter by wormhole contacts which have Euclidian signature of metric unlike the space-time sheets which have Minkowskian signature. This means the presence of 'elementary particle horizons' surrounding the wormhole throats such that the induced metric is degenerate at these horizons. This implies metric 2-dimensionality and conformal invariance identifiable as so called

quaternion conformal invariance playing the same role in TGD as conformal invariance in string models.

What is of utmost importance is that the smaller space-time sheet is much like a black hole and elementary particle horizon plays the role of the black hole horizon. Also now only mass, angular momentum, charge and some other quantum numbers of subsystem are visible at the larger space-time sheet (hadronic physics is an excellent example of this) and Hawking-Bekenstein law generalizes and "explains" p-adic length scale hypothesis.

p-Adic length scale hypothesis and more abstract definition of sub-system-system relationship

Previous arguments suggests strongly that the ordinary description of the subsystem as a tensor factor of the larger system is not enough, and that one must adopt the length scale dependent description applied also in quantum field theories. p-Adic length scale hypothesis indeed gives a precise quantitative content for the notion of length scale cutoff and predicts a hierarchy of p-adic cutoff length scales.

Instead of one huge state space for which various space-time sheets correspond to tensor factors, one has a hierarchy of state spaces such that subsystem-system relation is described more abstractly. This has an important implication: two unentangled systems can have subsystems which are entangled (the entanglement is not visible at the level of systems). Therefore two selves can have sub-selves entangled to single common sub-self, which means fusion and sharing of mental images making possible quantum communications and telepathy.

One can wonder what might be the deeper mathematical formulation for this idea. The ordinary quantum measurement theory is formulated for von Neumann algebras of type I and does not work for hyper-finite factors of type II_1 since it the probability for a projection to single ray vanishes. Rather, the projection is always into an infinite-dimensional subspace. Therefore the quantum measurement is never ideal and gives information about finite number of degrees of freedom only with infinite number of them remain remaining untouched. Length scale cutoffs in quantum field theory represent a typical example of a finite experimental resolution of this kind.

The proposed generalization of quantum measurement theory discussed in [C2] is based on Jones inclusions $\mathcal{N} \subset \mathcal{M}$, where $\mathcal{N}$ represents the degrees of freedom about which quantum measurement does not provide any information. The quantum space $\mathcal{M}/\mathcal{N}$ defines the space of observables. In this situation quantum measurement reduces entanglement only in $\mathcal{M}/\mathcal{N}$ degrees of freedom. There is a strong temptation to assign the entanglement between subselves and sharing of mental images with $\mathcal{N}$.

The notion of causal determinant

How one could define precisely the notion of subsystem at space-time level so that one could apply this definition also at configuration space level? The identification of the subsystem as a 3-surface acting as a causal determinant of Kähler action is suggestive here. Causal determinant can be defined as a minimal set of 3-surfaces determining absolute minimum of Kähler action containing these 3-surfaces as sub-manifolds. In principle, these surfaces are defined apart from the action of 4-dimensional general coordinate transformations but one can select natural preferred representatives for them.

1. The space like 3-surfaces at the boundary of the future light cone (moment of big bang) would be natural representatives for the causal determinants of the Kähler action if Kähler action were deterministic. One could say that the boundary of imbedding space acts as quantum gravitational hologram coding all information about the geometric time development.

2. Kähler action is however non-deterministic and allows several absolute minima going through a given space like 3-surface at the light cone boundary. This leads to the necessity of allowing causal determinants consisting of sequences of space like 3-surfaces. But even this is probably not enough.

3. The sign of energy depends on time orientation of the space-time sheet. This means that space-time counterpart of pair creation is possible in the sense that pairs of space-time sheets with opposite energies can be generated from vacuum. The very special properties of light like 7-surfaces $X_l^3 \times CP_2$ of $H = M_+^4 \times CP_2$, where X_l^3 is light like 3-surface of M_+^4, suggests that

pair creation of space-time sheets having opposite energies occurs at these surfaces analogous to the boundary of the imbedding space (TGD counterpart for the moment of big bang). In fact, the most elegant and predictive variant of TGD inspired cosmology is based on the assumption that the net flows of energy and other quantum numbers vanish also at $\delta H = \delta M^4_+ \times CP_2$. The net quantum numbers of the Universe would vanish, and one would avoid the philosophically painful questions like "What are the values of conserved fermion numbers of the Universe?". Big Bang would reduce to a "silent whisper amplifying to big bang" as TGD inspired cosmology assumes. All matter would be generated from vacuum, perhaps as an intentional process in which p-adic space-time sheets are transformed to real space-time sheets of opposite energies. Negative and positive energy regions would separate later from each other and the generation of matter antimatter asymmetry might relate to this process.

4. Even this is probably not enough. Also elementary particle horizons which are light like 3-surfaces $X^3_l \subset H$, seem to act as causal determinants in the sense that one must specify also a set of elementary particle horizons to fix a given sector of the configuration space completely. These causal determinants are actually all that is needed to understand the elementary particle physics in TGD Universe -whereas the 7-dimensional causal determinants $X^3_l \times CP_2$ would represent new physics relevant for the intentional action.

Few years after the discovery of the importance of 3-D light like causal determinants X^3_l it became clear that its possible to formulate quantum TGD as almost-topological quantum field theory at these causal determinants having interpretation as orbits of partons [B4, C2]. The action determining X^3_l is Chern-Simons action for the induced Kähler gauge potential, and any surface having at most 2-dimensional CP_2 projection is solution of field equations. Also the modified Dirac equation can be solved explicitly.

The light-likeness condition involves induced metric and breaks almost-topological QFT property. The generalized Dirac determinant determined as the product of eigenvalues of the modified Dirac operator therefore depends on the entire induced metric and one can hope that it gives the exponent of Kähler action for the preferred extremals of Kähler action identifiable as Bohr orbits [B4]. What is nice that the resulting theory has all the expected super-conformal symmetries at parton level and one can also understand the proposed dualities easily. This formulation allows also to understand how to achieve the p-adicization of the theory both at the level of space-time level and of S-matrix [E1]. Also very profound insights about the concrete realization of cognition and intentionality present at the elementary particle level emerge [H8].

3.2.4 Basic definitions related to density matrix and entanglement entropy

In this sequel the detailed definitions of density matrix and entropy are discussed. It has become clear that one must distinguish between three kinds of systems systems.

1. Genuinely real systems for which entanglement probabilities are not rational numbers or finitely extended rational numbers. In this case one can regard the probabilities as limiting values of frequencies for outcomes of measurement defined by a time series. This is also the case when the entanglement coefficients are rational or algebraic numbers but the number of entangled state pairs is infinite so that the entanglement probabilities need not be algebraic numbers anymore.

2. A genuinely p-adic system is a p-adic system in which entanglement probabilities are not positive rational numbers so that one cannot interpret the entanglement probabilities as a limit for frequencies defined by any ensemble.

3. Finitely extended rational entanglement probabilities allow an interpretation as ordinary probabilities. In this case one can regard the probabilities as belonging to an extension of rationals or to any p-adic number field. What is essential is that the number field is now discrete whereas it is continuous in above mentioned cases.

   One must use different definition for the real counterpart of the entanglement entropy in these two cases. In the first case standard Shannon's entropy works. In the second case p-adic counterpart of the Shannon entropy mapped to a real number by the canonical identification is the only possibility. In the third case the number theoretic entropies S_p based on p-adic norm

can be regarded as extended rational numbers as such. In this case S_p can be negative, and one can fix the value of p used to define the entropy by requiring that entropy is maximally negative and thus identifiable as a genuine information measure.

Density matrix

The density matrix of subsystem, call it A, can be defined using the standard formulas of QM: essentially trace over the degrees of freedom associated with the complement of A, call it B, is performed. B could effectively reduce to a sub-system of the complement. Density matrix is Hermitian matrix and can be diagonalized in the real context. Eigenvalues are real and give the weights for various eigen states in the superposition. There is important *duality* present: in the basis of A in which the density matrix for A is diagonal also the density matrix of B is diagonal.

Density matrix actually determines one-one-correspondence between certain states of the system A and system B. The state in eigen state basis can be written as

$$|A,B\rangle \quad = \quad \sum_m c_m |m\rangle \times |M(m)\rangle \quad , \tag{3.2.2}$$

where the map $m \to M(m)$ defines identification of certain states of A with certain states of B.

Quantum measurement of density matrix means that subsystem goes to an eigen state of density matrix. In the p-adic context the diagonalization of the density matrix requires special assumptions about the form of the state since the p-adic number fields are not closed with respect to algebraic operations. There is an algebraic extension obtained by requiring that each 'real' p-adic number has square root [E4]. The extension is 4-dimensional for $p \geq 3$ and 8-dimensional for $p = 2$. It can quite well happen that density matrix can be diagonalized only partially in this extension since the eigenvalues of the density matrix are in general algebraic numbers determined as a solution of polynomial eigenvalue equation.

One can however allow the extension of the p-adic number field to allow eigenvalues in an algebraic extension. Unless this is allowed the concepts of density matrix and entropy are not well defined for a generic subsystem. Physically this would mean that quantum state can have irreducible number theoretic entanglement besides the entanglement related to the quantum statistics. The vision about TGD as a generalized number theory encourages the allowance of the algebraic extension. This means that quantum subsystems can be classified using as criterion the dimension of the p-adic algebraic extension needed to define the eigen states and eigenvalues of the density matrix. In well defined sense physical systems generate increasingly complicated number fields as algebraic extensions of the p-adic numbers.

An interesting possibility is that Hermiticity in the p-adic context must be defined so that the eigenvalues of the density matrix are *ordinary p-adic numbers*: if this is the case then the algebraic extension is needed only for the diagonalization of the density matrix but the diagonalized density matrix itself is 'p-adically real'. This option seems however un-necessarily restrictive and will not be considered in the sequel.

If entanglement coefficients are algebraic numbers then also entanglement probabilities are algebraic numbers in the case that the number of entanglement state pairs is finite. Even finite-dimensional extensions of p-adic number numbers involving transcendentals such as $e, e^2, ..., e^{p-1}$) can be allowed. If the number of entangled state pairs is infinite, entanglement probabilities need not belong to a finite extension of rationals and it seems that entanglement cannot be regarded as bound state entanglement in this case.

p-Adic entanglement negentropy

In the real context negentropy is defined using the standard formula for Shannon entropy:

$$N \quad = \quad \sum_k p_k \cdot ln(p_k) \quad . \tag{3.2.3}$$

In the real context one could equally well replace the e-based logarithm $ln(x)$ by a-based logarithm (a could be any positive real) since this introduces only multiplicative factor ($log_a(x) = \frac{ln(x)}{ln(a)}$).

p-Adic thermodynamics has turned out to be surprisingly successful for the calculation of elementary particle masses. p-Adic thermodynamics is however naturally based on p-based logarithm log_p rather than the ordinary e-based logarithm since Boltzmann weights are powers of p rather than exponents. This would suggest the following definition

$$N = \sum_k p_k \cdot log_p(p_k) \ . \tag{3.2.4}$$

There are however two problems:

1. p-based logarithm exists only for $p_k = p^r$, that is power of p. One should somehow modify the definition of the logarithm so that it is defined for all p-adic numbers.

2. Since the probabilities p_k correspond to eigenvalues of density matrix, they in general belong to some algebraic extension of p-adic numbers. Thus the modified logarithm should also exist for any algebraic extension of p-adic numbers.

The definition of the modified p-based logarithm $Log_p(x)$ should satisfy following constraints.

1. If argument is power of p then modified logarithm must be equal to p-based logarithm:

$$Log_p(p^n) = log_p(p^n) \ .$$

2. Modified logarithm must be additive in order to make negentropy additive for systems having no interactions:

$$Log_p(xy) = Log_p(x) + Log_p(y) \ .$$

These requirements fix the definition of logarithm uniquely. The modified logarithm can depend on the p-adic norm of the argument only. Or in terms of canonical identification

$$I : \sum x_n p^n \to \sum x_n p^{-n} \ ,$$

mapping p-adics to reals and p-adic norm $N_p(x)$ one must have

$$\begin{aligned} Log_p(x) &= log_p([x]) \ , \\ [x] &= I^{-1}(N_p(x)) \ , \\ &= \left[\sum_{n \geq n_0} x_n p^n \right] = p^{n_0} \ . \end{aligned} \tag{3.2.5}$$

This definition works also for the algebraic extensions, for which p-adic norm is defined as the p-adic norm for the determinant of the linear map induced by a multiplication with z in algebraic extension: it is easy to see that the determinant of this map is indeed a power of p always (note that this norm is multiplicative, which implies the additivity of modified logarithm and entropy).

For the algebraic extensions of p-adic numbers one must define how the units e_k of algebraic extension $z = x + \sum_k y^k e_k$ are mapped to the reals in the canonical identification map. e_k are typically roots of integers in the range $-1, ..., p$. The rule is following: if e_k is not a root of p then it is mapped to e_k interpreted as a real number: for instance, $2^{1/3}$ is mapped to $2^{1/3}$ for $p \neq 2$ in case that $2^{1/3}$ does not exist as p-adic number. If e_k is root of p it is mapped to its inverse: for instance, $\sqrt{p}$ is mapped to $\frac{1}{\sqrt{p}}$.

Note that p-adic entanglement entropy can be also expressed as a sum over the derivatives of the p-adic entanglement probabilities with respect to p:

$$S = \sum_i \frac{d}{dp} p_i \ . \tag{3.2.6}$$

The real counterpart of the p-adic entanglement entropy is obtained by canonical identification $x = \sum x_n p^n \to \sum x_n p^{-n} = x_R$

$$S_r = S_R \times log(p) \ . \tag{3.2.7}$$

$log(p)$ factor must be included in order to make possible the comparison of entropies associated with different values of p.

The value of the p-adic entanglement entropy is always non-negative. It vanishes if the p-adic entanglement entropies have unit p-adic norm. Thus $S = 0$ p-adic entanglement is possible. This entanglement need not be stable since a direct sum of eigen spaces of density matrix with finitely extended rational entanglement probabilities has negative entanglement entropy.

Unless some p-adic probabilities do not have p-adic norm larger than one, p-adic entanglement entropy is of order $O(p)$ for genuinely p-adic systems so that negentropy gain is below $log(p)$ irrespective of the size of the system. This situation is realized in p-adic thermodynamics. There is a nice connection with p-adic mass calculations: p-adic thermal mass squared expectation value is essentially the p-adic entropy. This connection was noticed already earlier [E5] and it was suggested that p-adic primes associated with elementary particles could correspond to entropy maxima as function of p. This connection suggests that the proper definition of p-adic entropy is based on the canonical identification.

Remark: Statistics does not give rise to entanglement entropy as one might erratically conclude by considering the symbolic representation of tensor product suggesting the identification of 'left' and 'right' members of the tensor product as subsystems A and B: the concrete representation of the states using oscillator operators associated with Y^3 and its complement shows that there is no statistical entanglement entropy between the subsystem and its complement: if this were the case the entire universe should behave like a single conscious being and this would be a catastrophe as far as NMP is considered.

Systems with finitely extended rational entanglement

In the case of an finitely extended rational entanglement one can map the p-adic entropy to its real counterpart using the identification by common rationals instead of the canonical identification. This gives the formula

$$\begin{aligned} S_R &= S_p log(p) \ , \\ S_p &= \sum_n p_k Log_p(p_k) log(p) \ , \\ Log_p(x) &= log_p(|x|_p) \ . \end{aligned} \tag{3.2.8}$$

where the p-adic entropy which can be regarded as a rational number is re-interpreted as a real number. Note that the probabilities p_k are positive numbers. What is remarkable is that in this case entanglement entropy can be a negative rational number or a number in a finite extension of rational numbers. These states are obviously stable against self measurements and ideal for cognitive quantum computing. If these states are interpreted as bound states there is no need to postulate that bound state entanglement is stable against self measurements.

The consistency with the standard quantum measurement theory requires that the process corresponds to a measurement of the density matrix so that a projection must occur to an eigen space or sub-space of eigen space of the density matrix if this maximizes negentropy gain. The density matrix of the system would become

$$\rho \to \frac{1}{D_i} P_i \ . \tag{3.2.9}$$

Here D_i and P_i denote the dimension of the eigen space associated with p_i and corresponding projection operator. Assuming that D_i has the decomposition

$$D_i = \prod_{i \in I} q_i^{n_i}$$

to a product of powers of primes, the negentropy of the final state can be written as

$$N_R \quad = \quad Max\{n_i log(q_i) | i \in I\} \ . \tag{3.2.10}$$

The maximization of the increment of entanglement entropy gives a criterion selecting the final eigen space or its sub-space. Quantum classical correspondence suggests that one can assign similar inherent negentropy to the space-time sheet consisting of D strictly deterministic regions.

Quantum computers typically operate with systems for which entanglement probabilities are identical and the process would thus produce quantum computer type state. The eigen spaces of the density matrix with dimensions $D = p^N$ are of special interest. The entanglement negentropy for $D = p^N n_0$, n_0 integer not divisible by p, is $N_R = Nlog(p)$. The reduction to a sub-space of the eigen space can yield higher negentropy gain than the reduction to the entire eigen space and powers of prime are favored as dimensions of these sub-spaces.

The entanglement negentropy per single dimension of eigen space is $N_R/D = Nlog(p)p^{-N}/n_0$. For $D = p^N$ the entanglement negentropy per dimension of eigen space is $N_R/D = Nlog(p)/p^N = log(D)/D$ and maximum as a function of n_0. N_R/D as a function of D has a maximum $N_R/D = .3662$ for $D = 3$ rather than $D = 2$ as one might expect. For $D = 2$ and $D = 4$ one has $N_R/D = .3466$ (note that there are 4 DNA nucleotides). For other values of D N_R/D is smaller.

For extended rational entanglement the measurement of the density matrix can occur only in special cases. For instance, when the probabilities p_k belong to a finite extension of rational numbers and are different, the measurement of the density matrix would reduce the negentropy to zero and NMP does not therefore allow the measurement of density matrix to occur. Degenerate eigen spaces do not correspond to the maximum entanglement negentropy per dimension. $p_k = n_k/p^N$, n_k not divisible by p, gives $N_R = Nlog(p)$ irrespective of dimension D, and $N_R/D = Nlog(p)/2$ for $D = 2$ ($p_1 = m/p^N$ and $p_2 = (p^N - m)/p^N$, m not divisible by p) is the best one can achieve. Since there is no upper bound for N nor p even in the case of a 2-state system, the negentropy gain can be arbitrarily high. One could criticize this result as counter intuitive.

The number field characterizes entanglement rather than entangled systems

On basis of the preceding considerations it is clear that it is possible to assign number field to the entanglement irrespective of the properties of the systems. If orthonormalized state basis are used for entangled systems, it does not matter at all which number field one assigns with them. Therefore states orthonormalized but decomposing into entangled states in different number fields R_{p_1} and R_{p_2} can entangle in R_{p_3}. Entanglement seems to be a notion conforming with the spirit of category theory and thus allows a considerable generalization in the sense that the structure of states which are entangled does not matter at a given level of entanglement hierarchy.

For extended rational entanglement this number field can be regarded as a finite extension of p-adic numbers for any R_p. The requirement that entanglement entropy is maximally negative fixes the choice of p in this case and the interpretation as bound state entanglement is natural.

These observations are in line with the number theoretical ideas about quantum jump and number theoretic origin of the state function reduction and preparation to be discussed in the next section.

3.3 Physics as fusion of real and p-adic physics and NMP

In this section the vision about state function reduction and preparation processes as number theoretic necessities is developed: also the chapter "Fusion of p-Adic and Real Variants of Quantum TGD to a More General Theory" contains related topics. The proposal raises NMP to fundamental principle applying also to the state function reduction step.

3.3.1 Generalization of the notion of information

TGD inspired theory of consciousness, in particular the formulation of Negentropy Maximization Principle (NMP) in p-adic context, has forced to rethink the notion of the information concept. In TGD state preparation process is realized as a sequence of self measurements. Each self measurement means a decomposition of the sub-system involved to two unentangled parts. The decomposition is fixed highly uniquely from the requirement that the reduction of the entanglement entropy is maximal.

The additional assumption is that bound state entanglement is stable against self measurement. This assumption is somewhat ad hoc and it would be nice to get rid of it. The only manner to achieve this seems to be a generalized definition of entanglement entropy allowing to assign a negative value of entanglement entropy to the bound state entanglement, so that bound state entanglement would actually carry information, in fact conscious information (experience of understanding). This would be very natural since macro-temporal quantum coherence corresponds to a generation of bound state entanglement, and is indeed crucial for ability to have long lasting non-entropic mental images.

The generalization of the notion of number concept leads immediately to the basic problem. How to generalize the notion of entanglement entropy that it makes sense for a genuinely p-adic entanglement? What about the number-theoretically universal entanglement with entanglement probabilities, which correspond to finite extension of rational numbers? One can also ask whether the generalized notion of information could make sense at the level of the space-time as suggested by quantum-classical correspondence.

In the real context Shannon entropy is defined for an ensemble with probabilities p_n as

$$S = -\sum_n p_n log(p_n) \ . \tag{3.3.1}$$

As far as theory of consciousness is considered, the basic problem is that Shannon entropy is always non-negative so that as such it does not define a genuine information measure. One could define information as a change of Shannon entropy and this definition is indeed attractive in the sense that quantum jump is the basic element of conscious experience and involves a change. One can however argue that the mere ability to transfer entropy to environment (say by aggressive behavior) is not all that is involved with conscious information, and even less so with the experience of understanding or moment of heureka. One should somehow generalize the Shannon entropy without losing the fundamental additivity property.

p-Adic entropies

The key observation is that in the p-adic context the logarithm function $log(x)$ appearing in the Shannon entropy is not defined if the argument of logarithm has p-adic norm different from 1. Situation changes if one uses an extension of p-adic numbers containing $log(p)/log(2)$ so that the number of bits is expressible as a number defining a finite-dimensional extension. The character of this is extension is already discussed. One might however argue that Shannon entropy should be well defined even without the extension.

p-Adic thermodynamics inspires a manner to achieve this. One can replace $log(x)$ with the logarithm $log_p(|x|_p)$ of the p-adic norm of x, where log_p denotes p-based logarithm. This logarithm is integer valued ($log_p(p^n) = n$), and is interpreted as a p-adic integer. The resulting p-adic entropy

$$\begin{aligned} S_p &= \sum_n p_n k(p_n) \ , \\ k(p_n) &= -log_p(|p_n|) \ . \end{aligned} \tag{3.3.2}$$

is additive: that is the entropy for two non-interacting systems is the sum of the entropies of composites. Note that this definition differs from Shannon's entropy by the factor $log(p)$. This entropy vanishes identically in the case that the p-adic norms of the probabilities are equal to one. This means that it is possible to have non-entropic entanglement for this entropy.

One can consider a modification of S_p using p-adic logarithm if the extension of the p-adic numbers contains $log(p)$. In this case the entropy is formally identical with the Shannon entropy:

$$S_p = -\sum_n p_n log(p_n) = -\sum_n p_n \left[-k(p_n)log(p) + p^{k_n} log(p_n/p^{k_n}\right] \ . \quad (3.3.3)$$

It seems that this entropy cannot vanish.

One must map the p-adic value entropy to a real number and here canonical identification can be used:

$$\begin{aligned} S_{p,R} &= (S_p)_R \times log(p)) \ , \\ (\sum_n x_n p^n)_R &= \sum_n x_n p^{-n} \ . \end{aligned} \quad (3.3.4)$$

The real counterpart of the p-adic entropy is non-negative.

Number theoretic entropies and bound states

In the case that the probabilities are rational or belong to a finite-dimensional extension of rationals, it is possible to regard them as real numbers or p-adic numbers in some extension of p-adic numbers for any p. The visions that rationals and their finite extensions correspond to islands of order in the seas of chaos of real and p-adic transcendentals suggests that states having entanglement coefficients in finite-dimensional extensions of rational numbers are somehow very special. This is indeed the case. The p-adic entropy entropy $S_p = -\sum_n p_n log_p(|p_n|)log(p)$ can be interpreted in this case as an ordinary rational number in an extension containing $log(p)$.

What makes this entropy so interesting is that it can have also negative values in which case the interpretation as an information measure is natural. In the real context one can fix the value of the value of the prime p by requiring that S_p is maximally negative, so that the information content of the ensemble could be defined as

$$I \equiv Max\{-S_p, \ p \ \text{prime}\} \ . \quad (3.3.5)$$

This information measure is positive when the entanglement probabilities belong to a finite-dimensional extension of rational numbers. Thus kind of entanglement is stable against NMP, and has a natural interpretation as bound state entanglement. The prediction would be that the bound states of real systems form a number theoretical hierarchy according to the prime p and and dimension of algebraic extension characterizing the entanglement.

Number theoretically state function reduction and state preparation could be seen as information generating processes projecting the physical states from either real or p-adic sectors of the state space to their intersection. Later an argument that these processes have a purely number theoretical interpretation will be developed based on the generalized notion of unitarity allowing the U-matrix to have matrix elements between the sectors of the state space corresponding to different number fields.

Number theoretic information measures at the space-time level

Quantum classical correspondence suggests that the notion of entropy should have also space-time counterpart. Entropy requires ensemble and both the p-adic non-determinism and the non-determinism of Kähler action allow to define the required ensemble as the ensemble of strictly deterministic regions of the space-time sheet. One can measure various observables at these space-time regions, and the frequencies for the outcomes are rational numbers of form $p_k = n(k)/N$, where N is the number of strictly deterministic regions of the space-time sheet. The number theoretic entropies are well defined and negative if p divides the integer N. Maximum is expected to result for the largest prime power factor of N. This would mean the possibility to assign a unique prime to a given real space-time sheet.

The classical non-determinism resembles p-adic non-determinism in the sense that the space-time sheet obeys effective p-adic topology in some length and time scale range is consistent with this idea since p-adic fractality suggests that N is power of p.

3.3.2 Generalized Quantum Mechanics

One can consider two generalizations of quantum mechanics to a fusion of p-adic and real quantum mechanics.

1. For the first generalization the guiding principle for the generalization of quantum mechanics is that quantum mechanics in a given number field is obtained as an algebraic continuation of the quantum mechanics in the field of rational numbers common to all number fields or in finite-dimensional extensions of rational numbers. This means that U-matrices U_F for transitions from H_Q to H_F, where F refers to various completions of rationals, are obtained as algebraic continuations of the unitary U-matrix U_Q for H_Q. The generalization means enormously strong algebraic constraints on the form of the U-matrix.

2. A more radical option is that transitions from rational Hilbert space H_Q to the Hilbert spaces H_F associated with different number fields occur. This requires that U-process is followed by a process analogous to a state function reduction and preparation takes care that the resulting states become states in H_Q: this is what makes this generalization of a special interest. In this case one can speak about total scattering probability from H_Q to H_F. The U-matrices U_F are not anymore mere analytic continuations of U_Q. A possible interpretation of the unitary process $H_Q \to H_F$ is as generation of intention whereas the reduction and preparation means the transformation of the intention to action.

The assumption that H_Q allows an algebraic continuation to the spaces H_F is probably too strong an idealization in p-adic and even in the real case. For instance, one cannot allow all rational valued momenta in p-adic case for the simple reason that the continuation to the p-adic case involves always some momentum cutoff if the extension of p-adics remains finite. Even in the real case the summation over all rational momenta in the unitarity conditions of U-matrix fails to make sense and cutoff is needed. A hierarchy of cutoffs suggests itself and has a natural interpretation as number theoretical hierarchy of extensions of p-adics.

In order to avoid un-necessary complications the following formal discussion however uses H_Q as a universal Hilbert space contained by the various state spaces H_F.

Quantum mechanics in H_F as a algebraic continuation of quantum mechanics in H_Q

The rational Hilbert space H_Q is representable as the set of sequences of real or complex rationals of which only finite number are non-vanishing. Real and p-adic Hilbert spaces are obtained as the numbers in the sequences to become real or p-adic numbers and no limitations are posed to the number of non-vanishing elements. All these Hilbert spaces have rational Hilbert space H_Q as a common sub-space. Also momenta and other continuous quantum numbers are replaced by a discrete value set. Superposition principle holds true only in a restricted sense, and state function reduction and preparation leads always to a final state which corresponds to a state in H_Q. This picture differs from the earlier one in which p-adic and real Hilbert spaces were assumed to form a direct sum.

The notion of unitarity generalizes. Contrary to the earlier beliefs, U-matrix does not possess matrix elements between different number fields but between rational Hilbert space and Hilbert spaces associated with various completions of rationals. This makes sense since the final state of the quantum jump (and thus the initial state of the unitary process, is always in H_Q.

The U-matrix is a collection of matrices U_F having matrix elements in the number field F. U_F maps H_Q to H_F. Each of these U-matrices is unitary. Also U_Q is unitary and U_F is obtained by algebraic continuation in the quantum numbers labelling the states of U_Q to U_F.

Hermitian conjugation makes sense since the defining condition

$$\langle \alpha_F | U n_Q \rangle \quad = \quad \langle U^\dagger \alpha_F | n_Q \rangle \ . \tag{3.3.6}$$

allows to interpret $|n_Q\rangle$ also as an element of H_F. If U would map different completed number fields to each other, hermiticity conditions would not make sense.

The hermitian conjugate of U-matrix maps H_F to H_Q so that $UU^\dagger$ *resp.* $U^\dagger U$ maps H_F *resp.* H_Q to itself. This means that there are two independent unitarity conditions

$$\begin{aligned} U_F U_F^\dagger &= Id_F \ , \\ U_F^\dagger U_F &= Id_Q \ . \end{aligned} \tag{3.3.7}$$

One can write $U = P_Q + T_F$ and $U^\dagger = P_Q + T_F^\dagger$, where P_Q refers to the projection operator to H_Q. This gives

$$\begin{aligned} T_F + T_F^\dagger &= -T_F T_F^\dagger \ , \\ P_Q T_F + T_F^\dagger P_Q &= -T_F^\dagger T_F \ . \end{aligned} \tag{3.3.8}$$

It is convenient to introduce the notations $T_Q = P_Q T_F$ and $T_Q^\dagger = T_F^\dagger P_Q$ with analogous notations for U and $U^\dagger$. The first condition, when multiplied from both sides by P_Q, gives together with the second equation unitarity conditions for T_Q

$$\begin{aligned} T_Q + T_Q^\dagger &= -T_Q T_Q^\dagger \ , \\ T_Q + T_Q^\dagger &= -T_F^\dagger T_F \ . \end{aligned} \tag{3.3.9}$$

This means that the restriction of the U-matrix to H_Q is unitary.

The difference between the right hand sides of the equation should vanish. The understanding of how this happens requires more delicate considerations. For instance, in the case of $F = C$ continuous sum over indices appears at the right hand side coming from four-momenta labelling the states. The restrictions of quantum numbers to Q and its subsets could be a process analogous to the momentum cutoff of quantum field theories. The continuation from discrete integer valued labels of, say discrete momenta, to continuous values is performed routinely in various physical models routinely, and it would seem that this process has cognitive and physical counterparts. This picture conforms with the vision that the rational (or extended rational) U-matrix U_Q gives the U-matrices U_F by an algebraic continuation in the quantum numbers labelling the states (say 4-momenta).

Could U_F describe dispersion from H_Q to the spaces H_F?

One can also consider a more general situation in which the states in H_Q can be said to disperse to the sectors H_F. In this case one can write

$$T = "\sum_F" T_F \ . \tag{3.3.10}$$

Here the sum has only a symbolic meaning since different number fields are in question and an actual summation is not possible. The T-matrix T_Q is the sum of the restrictions of T_F to H_Q and is the sum of rational valued T-matrices: $T_Q = \sum_F P_Q T_F$.

The T-matrices T_F are not anymore obtainable by algebraic continuation from same T-matrix T_Q. The unitarity conditions

$$\sum_F (P_Q T_F + T_F^\dagger P_Q) = -\sum_F T_F^\dagger T_F \tag{3.3.11}$$

make sense only if they are satisfied separately for each T_F, exactly as in the previous case. T

The diagonal elements

$$T_F^{mm} + \overline{T}_F^{mm} = \sum_\alpha T_F^{m\alpha} \overline{T}_F^{m\alpha} = \sum_r T_F^{mr} \overline{T}_F^{mr}$$

give essentially total scattering probabilities from the state $|m\rangle$ of H_Q to the sector H_F, and must be rational (or extended rational) numbers. One can therefore say that each U-process leads with a definite probability to a particular sector of the state space.

The fact that states which are superpositions of states in different spaces H_F does not make sense mathematically, forces the occurrence of a process, which might be regarded as a number theoretical counterpart of state function reduction and preparation. First a sector H_F is selected with probability p_F. Then F-valued (in particular complex valued) entanglement in H_F is reduced by state reduction and preparation type processes to a rational or extended rational entanglement having interpretation as bound state entanglement. It would be natural to assume that Negentropy Maximization Principle governs this process. Obviously the possibility to reduce state function reduction to number theory forces to consider quite seriously the proposed option.

Do state function reduction and state-preparation have number theoretical origin?

The foregoing considerations support the view that state function reduction and state preparation are number theoretical necessities so that there would be a deep connection between number theory and free will. One could even say that free will is a number theoretic necessity. The resulting more unified view provides the reason why for state function reduction, and preparation and allows to generalize previous views developed gradually by physics and consciousness inspired educated guess work.

1. Negentropy Maximization Principle as variational principle of cognition

It is useful to discuss the original view about Negentropy Maximization Principle (NMP) before considering the possible generalization of NMP inspired by the number theoretic vision.

NMP was originally motivated by the need to construct a TGD based quantum measurement theory. Gradually it however became clear that standard quantum measurement theory more or less follows from the assumption that the world of conscious experience is classical: this meant that NMP became a principle governing only state preparation.

State function reduction is achieved if a localization in zero modes occurs in each quantum jump, and if U matrix in zero modes corresponds to a flow in some orthogonal basis for the configuration space spinor fields in the quantum fluctuating fiber degrees of freedom of the configuration space. The requirement that U-matrix induces effectively a flow in zero modes is consistent with the effective classicality of the zero modes requiring that quantum evolution causes no dispersion. The one-one correlation between preferred quantum state basis in quantum fluctuating degrees of freedom and zero modes implies nothing but a one-one correspondence between quantum states and classical variables crucial for the interpretation of quantum theory. It seems that number theoretical vision forces to generalize this view, and to raise NMP to a completely general principle applying also to the state function reduction as the original proposal indeed was.

In its original form NMP governs the dynamics of self measurements and thus applies to the quantum jumps reducing the entanglement between quantum fluctuating degrees of freedom for given values of zero modes. Self measurements reduce the entanglement only between subsystems in quantum fluctuating degrees of freedom since they occur after the localization in the zero modes. Self measurement is repeated again and again for the unentangled subsystems resulting in each self measurement. This cascade of self measurements leads to a state possessing only extended rational entanglement identifiable as bound state entanglement and having negative number theoretic entanglement entropy. This process should be equivalent with the state preparation process assumed to be performed by a conscious observer in standard quantum measurement theory.

NMP states that the self measurement can be regarded as a quantum measurement of the subsystem's density matrix reducing the counterpart of the entanglement entropy of some subsystem to a smaller value, and that this occurs for the subsystem for which the reduction of the entanglement entropy is largest among all subsystems of the p-adic self. Inside each self NMP fixes some subsystem which is quantum measured in the quantum jump. One could perhaps say that self measurements make possible quantum level self repair since they allow the system in self state to fight against thermalization which results from the generation of unbound entanglement between subsystem-complement pairs.

2. NMP and number theory

The requirement the universe of conscious experience is classical is one manner to justify quantum jump. This hypothesis could be replaced by a postulate that state function reduction and preparation project quantum states to a definite number field and that only extended rational entanglement identifiable as bound state entanglement is stable. This is consistent with NMP since it is possible

to assign to an extended rational entanglement a non-negative number theoretic negentropy as the maximum over entropies defined by various p-adic entropies $S_p = -\sum p_k log(|p_k|_p)$.

The unitary process U would thus start from a product of bound states for which entanglement coefficient are extended rationals, and would lead to a formal superposition of states belonging to different number fields. Both state function reduction and state preparation would begin with a localization to a definite number field. This localization would be followed by a self measurement cascade reducing the entanglement to extended rational entanglement.

This vision forces to challenge the earlier views about state function reduction.

1. There is no good reason for why NMP could not be applied to both state function reduction and preparation.

2. If the entanglement between zero modes and quantum fluctuating degrees of freedom involves only discrete values of zero modes, the problems caused by the fact that no well-defined functional integral measure over zero modes exists, find an automatic resolution. Since extended rational entanglement possesses negative entanglement entropy, it is stable also against reduction if NMP applies completely generally. A discrete entanglement involving transcendentals not contained to any *finite* extension of any p-adic number field is unstable and reduced.

3. The quantum measurement lasts for a time determined by the life-time of the bound state entanglement between zero modes and quantum fluctuating degrees of freedom. Physical considerations of course support the view that it takes more than single quantum jump (10^{-39} seconds of psychological time) for the state function reduction to take place. The notion of zero mode-zero mode bound state entanglement seems however to be self-contradictory. If join along boundaries bonds are space-time correlates for the bound state entanglement, their formation should transform roughly half of the zero modes associated with the two space-time sheets to quantum fluctuating degrees of freedom.

4. If p-adic length scale hierarchy has as its counterpart a hierarchy of state function reduction and preparation cascades, one must accept the quantum parallel occurrence of state function reduction and preparation processes in the parallel quantum universes corresponding to different p-adic length scales. This picture provides a justification for the modelling of hadron as a quantum system in long length and time scales and as a dissipative system consisting of quarks and gluons in shorter length and time scales. The bound state entanglement between subsystems of entangled systems having as a space-time correlate join along boundaries bonds connecting subsystem space-time sheets, is a second important implication of the new sub-system concept, and plays a central role in TGD inspired theory of consciousness.

3.4 Some consequences of NMP

In the sequel the most obvious consequences of self measurement and NMP are discussed from the point of view of physics, biology, cognition, and quantum computing.

3.4.1 NMP and physics

Since NMP relates to self measurement, which is something new from the point of view of standard physics, NMP has nontrivial implications also in real context.

NMP and the second law of thermodynamics

The relationship of NMP to the second law has been a longstanding open issue. One is also forced to ask whether TGD really predicts second law in its standard form or should one introduce a fractal version of the second law taking into account the p-adic length scale hypothesis.

1. NMP, de-coherence, and macro-temporal quantum coherence

NMP means maximization of the information content of conscious experience if interpreted as negentropy gain. In case of un-bound entanglement elimination of entanglement means information gain and this means also de-coherence which in turn corresponds to dissipation and is interpreted as

implying second law. NMP can however also generate bound state entanglement and makes possible macroscopic quantum coherence since the sequence of quantum jumps corresponding to the lifetime of the bound state effectively integrates to single quantum jump. A possible conscious experience accompanying negentropic bound state entanglement would be as experience of understanding.

If finitely extended rational entanglement is identified as bound state entanglement, one can understand dissipation as a process eliminating unbound entanglement and leaving bound state entanglement or even strengthening it and thus leading to a genuine generation of order. De-coherence is loss of non-bound coherence. One could also say that state function reduction and preparation are analogous to Darwinian selection destroying what is unstable. Thus it seem that the interpretation of the second law is not quite correct. Only if one forgets bound state entanglement second law leads to the illusionary conclusion that universe is becoming gradually more and more disordered. The belief on the eventual heat death of Universe is perhaps the dramatic misunderstandings following from the neglect of bound state entanglement.

The cascade of state function function reductions and self measurements occurring in different scales and perhaps even in quantum parallel manner is very much analogous to a conscious analysis. This process is not however a mere decay process since the outcome of the process is stable finitely extended rational entanglement giving rise to an experience of understanding as a result of this analysis. By macro-temporal quantum coherence this process occurs in various time scales. The basic aspect of conscious thought and of theoretical description is that it can model the reality using only discrete mathematical structures and the outcome of the quantum jumps indeed is quantum entanglement in discrete number fields.

2. Thermodynamics for qualia and thermodynamics for matter

Second law seems to hold also at the level of conscious experience of self: the non-determinism of the state function reduction and preparation processes implies that conscious experience involves statistical aspects in the sense that the experienced qualia correspond to the averages of quantum number and zero mode increments over the sequence of quantum jumps. When the number of quantum jumps in the ensemble defining self increases, qualia get more entropic and qualia fuzzy unless macro-temporal quantum coherence changes the situation. Thus the maximization of information at the level of single quantum jump implies loss of information at the level of self and vice versa. NMP destroys non-bound quantum coherence but tends to generate bound quantum coherence.

Important difference between the statistical physics for qualia and material world is that qualia correspond to averages for the increments of quantum numbers and zero modes in the ensemble of quantum jumps defining sub-self (mental image) whereas in ordinary statistical physics measured quantities would correspond to zero modes and quantum numbers basically. Of course, sequence of quantum jumps defines also this kind of ensemble but the averages over this ensemble are not experienced directly as suggested by various arguments relying on symmetries (it is not possible to experience symmetry related quantum numbers and zero mode values as different). Thus also the statistical ensembles of thermodynamics could be identified at the fundamental level as ensembles defined by quantum jump sequences. The basic function of sensory organs is to relate thermodynamical ensembles to corresponding qualia ensembles by mapping quantum numbers to quantum number increments so that our sensory perception is in reasonable approximation about world rather than changes of the world.

3. Quantum classical correspondence

Quantum-classical correspondence requires that second law must have a classical space-time description. The classical non-determinism of Kähler action indeed makes it possible to represent quantum jump sequences symbolically at space-time level and therefore the increase of entropy at the level of conscious experience should have counterpart at the level of the symbolic representations of conscious experience. This makes sense also for the p-adic cognitive representations of conscious experience.

Intuitively it seems clear that the classical non-determinism of Kähler action is what allows to understand second law since without it everything would effectively reduce to the light cone boundary and entropy would be the same for all cosmic time constant sections as a general coordinate invariant.

To make this intuition more transparent, notice that entanglement entropy is associated with causal determinants which correspond to light like 3-surfaces $X^3_l \subset H$ (elementary particle horizons) or to light like 7-surfaces $X^3_l \times CP_2 \subset H$ (analogs of $\delta H = \delta M^4_+ \times CP_2$, initial moment of "big bang"),

both playing the role of the role of quantum hologram. If Kähler action were deterministic, general coordinate invariance would imply that the whole physics could be reduced to δH and time would be lost. Kähler action is however not deterministic, and entropy in general increases since the presence of the topologically condensed space-time sheets inside space-time sheets implies additional additive contributions to the entropy. Topological light rays (MEs) represents perhaps the most important contributions of this kind. Thus an observer represented by a mind like space-time sheet drifting to the direction of future would find that entropy tends to increase. There are of course also other sources to what might be called classical space-time entropy.

The formal definition of entropy for a given space-time sheet has been already considered. Space-time sheet decomposing to N strictly deterministic regions defines in a natural manner ensemble and one can calculate thermodynamical averages for various observables in this ensemble. The probabilities are always proportional to $1/N$ and thus number theoretic entropies S_p are negative for primes p appearing as factors of N. This raises the question whether the entropy due to the non-determinism could be actually regarded information. This view is supported by the fact, that classical non-determinism makes possible for the system to represent symbolically other systems in its state. Perhaps it depends to some degree on observer whether the non-determinism corresponds to information or entropy.

4. Entropy of conscious experience, thermodynamical entropy, classical space-time entropy: how do they relate?

There are three kinds of entropies and the basic question is how these entropies relate.

1. Does the entropy characterizing the experience of self relate to the thermodynamical entropy of some system? The fact that non-geometric sensory qualia have a statistical interpretation, suggests that the entropy associated with the qualia of the mental image corresponds to the thermodynamical entropy for a system giving rise to the qualia via the sensory mapping. The thermodynamics of quantities in the external world would thus be mapped to the thermodynamics of qualia, increments of quantities, in the inner world. Selves could also represent the fundamental thermodynamical ensembles since they define also statistical averages of quantum numbers and zero modes although these are not directly experienced.

2. Could one interpret the entropies of the space-time sheets as entropies associated with the symbolic representations of conscious experiences of selves? Could one see the entire classical reality as a symbolic representation? Does the entropy of conscious experience correspond to the thermodynamical entropy of the perceived system, which in turn would correspond to the classical space-time entropy of the system representing the perceived system symbolically? Does this conclusion generalize to the case of p-adic entropy? Quantum-classical correspondence would encourage to cautiously think that the common answer to these questions might be yes.

4. Questions about second law

One can question also the second law.

1. Could it be that second law is an illusion created by the fact that we do not realize that besides us there is infinite hierarchy of selves which also have conscious information about world? What looks like a loss of information for us, could be gain of information for lower levels of consciousness.

2. Is the notion of p-adic evolution consistent with the second law? Is second law perhaps true only in time scales longer than the p-adic time scale $T_p = L_p/c$ at the space-time sheet characterized by the p-adic prime p? This would mean a fractal hierarchy of breakings of the second law.

3. Spin glasses are non-ergodic systems: does the quantum spin glass property of the TGD universe imply the breaking of the second law? Gravitation has been seen as one possible candidate for the breaking second law because of its long range nature. It is indeed classical gravitational energy which distinguishes between almost degenerate spin glass states.

4. How the possibility of irreducible selves in a state of oneness and able to quantum compute relates to second law? In this situation most of the zero modes are transformed to quantum fluctuating degrees of freedom and very many quantum jumps bind to a single effective quantum

jump. State function reduction and self measurement cascade, which ought to take care of quantum de-coherence guaranteing that second law is obeyed, do not occur. Doesn't this mean the breaking of second law in the time scale defined by the duration of the bound state?

Note that by the previous argument it is precisely the quantum spin glass degeneracy caused by classical gravitational energy differences which makes the lifetimes of bound states much longer than they should be otherwise.

5. What do experiments say?

That the status of the second law is far from settled is demonstrated by an experiment performed by a research group in Australian National University [35]. The group studied a system consisting of 100 small beads in water. One bead was shot by a laser beam so that it became charged and was trapped. The container holding the beads was then moved from side to side 1000 times per second so that the trapped bead dragged first one way and then another. The system was monitored and for monitoring times not longer than .1 seconds second law did not hold always: entropy could also decrease.

What is remarkable that .1 seconds defines the duration τ of the memetic code word and corresponds to the secondary p-adic time scale $T_p(2) = \sqrt{p}L_p/c$ associated with Mersenne prime $p = M_{127}$ characterizing electron. This correspondence follows solely from the model of genetic code predicting hierarchy of codes associated with $p = 3, 7, 127$ (genetic code), $p = M_{127}$,... τ should be the fundamental time scale of consciousness. For instance, average alpha frequency 10 Hz corresponds to this time scale and 'features' inside cortex representing sensory percepts have average duration of .1 seconds.

This raises some intriguing questions:

1. Could super-computing non-decohering irreducible selves/mental images in a state of oneness lasting for .1 seconds be involved? Could selves representing memetic codewords be generated also in the water outside our brain? Does this mean that formation of the clusters of water molecules is the fundamental mechanism giving rise to these super-conducting selves?

2. The experiment involves also the millisecond time scale, roughly the duration of single bit of the memetic codeword and the duration of the nerve pulse. Could this have some significance?

NMP and self-organization

The notion of self allows a nice solution to the problem by providing the fundamental mechanism of dissipation. Self is s dissipative structure and perceiving self maps the dissipation at the level of quantities in the external world to dissipation at the level of qualia in the internal world. Dissipation in turn reduces basically to the non-determinism of the Kähler action. In particular, the emergence of sub-selves inside self looks like dissipation from outside but corresponds to self-organization from the point of view of self.

Dissipation leads to self-organization patterns and in the absence of external energy feed to thermal equilibrium. Thus thermodynamics emerges as a description for an ensemble of selves or for the time average behavior or single self when external energy feed to system is absent. One can also understand how the dissipative universe characterized by the presence of parameters like diffusion constants, conductivities, viscosities, etc.. in the otherwise reversible equations of motion, emerges. Dissipative dynamics is in a well defined sense the envelope for the sequence of reversible dynamical evolutions modelling the sequence of final state quantum histories defined by quantum jumps.

Quantum self-organization leads to fixed point self-organization patterns analogous to the patterns emerging in Benard flow. Since selves approach 'asymptotic selves', dissipation can be regarded as a Darwinian selector of both genes and memes. Thus not only surviving physical systems but also stable conscious experiences of selves, habits, skills, behaviors, etc... are a result of Darwinian selection.

The new element in the picture is that even quantum jump itself can be seen as a self-organization process analogous to Darwinian selection, which eliminates all unbound entanglement and yields a state containing only bound state state entanglement and representing analog of the self-organization patterns. By macro-temporal quantum coherence effectively gluing quantum jumps sequences to single quantum jump this pattern replicates itself fractally in various time scales. Thus self-organization patterns can be identified as bound states and the development of the self-organization pattern as a fractally scaled up version of single quantum jump. Second new element is that dissipation is not

mere destruction of order but producer of jewels. A further new element is that dissipation can occur in quantum parallel manner in various scales.

The arrow of psychological time is closely related to second law of thermodynamics. Psychological time can be identified as kind center of mass time for cognitive space-time sheet of finite time duration representing self and is zero mode with precisely defined value in each final state of the quantum jump. The arrow of psychological time derives from the drift of the mind like space-time sheet in future light cone: for a given point of future light cone there is much more room in the future light cone than in its past. A more precise view about the emergence of psychological time is based on p-adic-to-real phase transitions identified as transformation of intentions to actions.

NMP and p-adic length scale hypothesis

The original form of the p-adic length scale hypothesis stated that physically most interesting p-adic primes satisfy $p \simeq 2^k$, k prime or power of prime. It has however turned out that all positive integers k are possible. Surprisingly few new length scales are predicted by this generalization in physically interesting length scales. p-Adic length scale hypothesis leads to excellent predictions for elementary particle masses (note that the mass prediction is exponentially sensitive to the value of k) and explains also some interesting length scales of biology: for instance, the thicknesses of the cell membrane and of single lipid layer of cell membrane correspond to $k = 151$ and $k = 149$ respectively.

The big problem of p-adic TGD is to derive this hypothesis from the basic structure of the theory. The most convincing argument is based on black hole-elementary particle analogy [E5] leading to the generalization of the Hawking-Bekenstein formula: the requirement leading to the p-adic length scale hypothesis is that the radius of the so called elementary particle horizon is itself a p-adic length scale. This argument involves p-adic entropy essentially and it seems that information processing is somehow involved.

An exciting possibility, suggested already earlier half seriously, is that there is *evolution already at elementary particle level*. The identification of p-adic physics as physics of cognition indeed forces this interpretation. In particular, one can understand p-adic length scale hypothesis as reflecting the survival of the cognitively fittest p-adic topologies. It will be found that a model for learning as a transformation of the reflective level of consciousness to proto level supports the view that evolution and learning occur already at elementary particle level as indeed suggested by NMP: the p-adic primes near power of prime powers of two are the fittest ones. The core of the argument is the characterization of learning as a map from 2^N many-fermion states to M association sequences. The number of association sequences should be as near as possible equal to 2^N. If M is power of prime: $M = p^K$, association sequences can be given formally the structure of a finite field $G(p, K)$ and p-adic length scale hypothesis follows as a consequence of $K = 1$. NMP provides the reason for why $M = p^K$ is favored: in this case one can construct realization of quantum computer with entanglement probabilities $p_k = 1/M = 1/p^K$ and the negentropy gain in quantum jump is $Klog(p)$ while for M not divisible by p the negentropy gain is zero.

A possible physical reason for the primes near prime powers of 2 is that survival necessitates the ability to co-operate, to act in resonance: this requirement might force com-measurability of the length scales for p-adic space-time sheet (p_1) glued to larger space-time sheet ($p_2 > p_1$). The hierarchy would state from 2-adic level having characteristic fractal length scales coming as powers of $\sqrt{2}$. When $p > 2$ space-time sheet is generated during cosmological evolution $L(p)$ for it must correspond to power of $\sqrt{2}$ so that one must have $p \simeq 2^n$. This argument does not however explain why *power of prime* powers of 2 are favored.

NMP and dark matter hierarchy

The hierarchy of Planck constants seems to reduce the notion of self to that of quantum jump at the higher level of self hierarchy so that lower level quantum jumps correspond to sub-selves giving rise to mental images and experienced flow of time. The finite geometric duration of quantum jump corresponds to the time that subsystem remains un-entangled. NMP holds still true as a variational principle for the dynamics of quantum jumps at each level of the hierarchy and the quantum jump would be actually replaced by a process proceeding from long time and length scales to short length scales.

3.4.2 NMP and biology

The notion of self is crucial for the understanding of bio-systems and consciousness. By leaving cognition (p-adic physics) outside biology, one can restrict the considerations to the real form of NMP.

Life as islands of finitely extended rational numbers in the seas of real and p-adic continua?

If quantum jump is indeed number theoretic necessity, the generation of macro-temporal quantum coherence means generation of states with extended rational entanglement. Macro-temporal quantum coherence is basic aspect of life and consciousness and one could therefore say that life corresponds to an island of extended rationality in the seas of real and p-adic continua. One could also see evolution of cognition as gradual emergence of extensions of p-adic number fields (in particular, p-adic space-time sheets) of increasing value of p and increasing algebraic dimension.

The view about the crucial role of rational and finitely extended numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that also algebraic numbers rather besides rationals are essential for life.

Also finite-dimensional extensions of p-adic numbers involving transcendentals are possible and in fact necessary (say the extension containing $e, e^2, .., e^{p-1}$ as units (e^p is ordinary p-adic number). Thus one could see the discovery of transcendentals as an emergence of transcendentals like e and π to the finite-dimensional algebraic extension associated with p-adic space-time sheets serving as correlates for mathematical cognition.

It however turns out that $log(p)$ and π cannot belong to a finite-dimensional extension of p-adic numbers (see the chapter "Fusion of p-Adic and Real Variants of Quantum TGD to a More General Theory"). One might however hope that $log(p)/log(2)$ belongs to an extension of rationals defining finite-dimensional extension of p-adics so that p-adic entropy would be always extended rational multiple of bit. This is achieved if one has

$$log(p) \quad = \quad e^{q_1(p)} q_2(p) \times t \quad , \quad q_2(p_1) \neq q_2(p_2) \ \text{ for } \ p_1 \neq p_2 \tag{3.4.1}$$

such that t is a transcendental number other than root of e so that one does not get contradiction by exponentiating both sides of the above equation. This ansatz does not lead to any obvious contradictions. For instance, power of π is a reasonable candidate and for physical reasons $t = 1/\pi$ is a favored value of t.

How second law and evolution can be mutually compatible?

Second law is associated with psychological time characterizing the mind like space-time sheet of observer and reflects (or is reflected by) the classical non-determinism of Kähler action. With respect to subjective time evolution takes place since the localization in zero modes implies that the infinite p-adic prime of the universe increases in the long run since the number of primes larger than given infinite prime P is infinitely larger than the number of primes than P. The infinite prime P characterizing the entire universe decomposes in a well defined manner to finite primes and p-adic evolution at the level of entire universe is implied by local p-adic evolution at the level of selves. Therefore maximum entanglement entropy gain for p-adic self increases at least as $log(p)$ with p in the long run. This kind of relationship might hold true for real selves of p-adic physics is physics of cognitive representations of real physics as suggested by the success of p-adic mass calculations. Thus it should be possible to assign definite prime to each real space-time sheet.

The arguments leading to p-adic evolution and the arrow of psychological are very similar and are in accordance with TGD inspired generalization of 'Ontogeny Recapitulates Phylogeny' principle which says that the evolution at the level of space-time reflects the evolution at the level of the configuration space. The occurrence of phase transitions leading to the emergence of larger and larger space-time sheets characterized by increasingly larger p-adic primes indeed leads to the increase of the entropy.

p-Adic evolution is consistent with NMP. NMP forces the generation of bound state entanglement with maximal entanglement negentropy in given quantum jump. Therefore it would not be surprising if the entanglement negentropy per space-time volume would gradually increase in the evolution by quantum jumps.

A further new perspective to the second law is implied by the dark matter hierarchy predicting existence of an infinite hierarchy of quantum jumps with increasing geometric time durations. The dark matter hierarchy is not taken into account in standard physics based view about information. In this framework it is quite possible that second law is actually an illusion reflecting only the character of conscious experience rather than that of the underlying reality.

More precisely, the highest dark matter level associated with self corresponds to its geometric duration which can be arbitrarily long: the typical duration of the memory span gives an idea about the level of dark matter hierarchy involved. For instance, as the model for a hierarchy of generalized EEGs predicts, in the case of humans the highest level would be $k = 7$ corresponding to the time scale defined by the human lifetime [M3]. Mental images of self correspond always to the lower levels of dark matter hierarchy and to ensembles formed by the corresponding quantum jump sequences and the longer the sequence, the more entropic it is bound to be.

Second law is true as long as it characterizes what happens to the mental images. Second law however neglects completely the existence of all levels except the lowest level of the dark matter hierarchy and must therefore be illusory as a physical law. Second law can be seen as an unavoidable implication of the materialistic ontology allowing only the lowest level of the dark matter hierarchy and justifying itself by limiting all scientific tests to those which are consistent with it. It is possible to get temporarily rid of this illusion during experiences often characterized as enlightment experiences accompanied by the experiences of oneness and complete emptiness. During this kind of experiences the entropic contribution of the mental images to the conscious experience is absent.

Binding and quantum metabolism as different sides of the same coin

Only bound state entanglement is stable against the state preparation whose dynamics NMP dictates. Hence the fusion of the mental images implicates the formation of a bound state. This process is expected to involve a liberation of the binding energy as a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and binding are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enhanced oxidative metabolism [29]. A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

3.4.3 NMP, consciousness, and cognition

As already found NMP dictates the subjective time development of self and is therefore the basic law of consciousness. If p-adic physics is the physics of cognition, the most exotic implications of NMP relate to cognition rather than standard physics.

Quantum jump and cognition

The interpretation of quantum jump as a creation of a totally entangled holistic state $U\Psi_i$ which is then analyzed to stable bound state entangled pieces allows to interpret self measurement cascade as a conscious analysis: this interpretation generalizes by temporal fractality of consciousness. The resulting stable negentropic pieces give rise to experience of understanding.

One can see the situation also differently. The conscious experience of self is average over moments of consciousness and the eventual thermalization induced by the quantum jump sequence destroys all conscious information. To achieve macro-temporal quantum coherence self must be irreducible self for which self measurements and analysis do not occur. The self must also have large number of zero modes transformed to quantum fluctuating degrees of freedom and this achieved if self corresponds to a join along boundaries condensate able to carry out quantum computer like information processing which is the diametrical opposite of analysis. In this state self does not analyze. Thus the reductionistic and holistic modes of consciousness can be seen as different modes of consciously knowing and understanding.

There is obviously a conflict of interests. Selves want to achieve the state of oneness: this means bound state entanglement for sub-selves. On the other hand, my sub-selves want to stay conscious and are fighting against becoming bound state entangled.

There are rather interesting connections with altered states of consciousness and states of macro-temporal quantum coherence.

1. Making mind empty of mental images could perhaps be interpreted as a mechanism of achieving irreducible self state. In this state the sub-selves representing mental images fuse to single mental image which represents highly stable bound state. Effectively single long-lasting quantum jump results. The formation of bound state leads to the liberation of the binding energy utilizable as a useful energy. This might relate to the reports of meditators about lowered metabolic needs.

2. When mind is empty of mental images, self measurements do not occur. This means that quantum computations are also possible in good approximation in quantum fluctuating degrees of freedom. Thus state of oneness empty of mental images often paradoxically claimed to be source of infinite wisdom is a state in which quantum computation and direct experience of macroscopic multiverse become possible.

3. The ordinary wake-up consciousness is identifiable as the analytical mode in which each quantum jump is followed by a complete state preparation yielding a short-lived bound state so that effective moments of consciousness remain short. The basic reason for this would be sensory input. Krishnamurti has talked a lot about states of consciousness in which no separations and discriminations occur and timelessness prevails. These states could correspond to long-lived bound states giving rise to very long effective moments of consciousness. In this kind of situation NMP does not force cognitive self measurements to occur (cognitively enlightened state cannot become more cognitively enlightened) and analysis and separations can thus be avoided.

4. Sharing and fusion of mental images by entanglement of sub-selves of separate selves makes possible quantum realization of telepathy and could be a universal element of altered states of consciousness.

The concepts of resolution and monitoring

When the fundamental observable (density matrix or entropy operator) has degenerate eigenvalues, one can only speak about probability for quantum jump to a particular eigen space of the the observable since there is no preferred basis in this eigen space. This leads to the concept of resolution: one cannot distinguish between states belonging to a given eigen space of density matrix and one can make predictions for the probabilities for quantum jumps to given eigen space only.

p-Adic probability concept implies additional exotic effect. The total real probability for quantum jump to degenerate subspace is the real counterpart for sum of p-adic probabilities rather than sum of the real counterparts of the p-adic probabilities. This can lead to rather dramatic effects: for instance, the sum of p-adic probabilities can be very small even when the sum of the real probabilities is large.

The notion of resolution is closely related to the notion of monitoring: resolution can be defined as a decomposition of the p-adic state space to a direct sum of subspaces such that the p-adic density matrix is degenerate inside each subspace. If p-adic probabilities are defined modulo $O(p)$ pinary cutoff this kind of degeneracy is bound to occur if the dimension of the state space is larger than p.

An interesting possibility is that the notions of resolution and monitoring could be important in the physics of cognition. Perhaps the well-known fact that the behavior of cognitive systems is sensitive to monitoring, might have something to do with the density matrix characterizing the entanglement

between the monitoring and monitored systems. The behavior of monitored system would depend on the resolution of the monitoring, that is on how interested monitorer is about behavior of monitored system. In the limit that monitorer is not interested at all on the behavior, entanglement probabilities would in general be identical and unless the number of states is power of p, $S = 0$ state would result.

The total probability for a set of independent events to occur depends on the resolution of monitoring: not only the behavior of individual quantum system in ensemble but also the *statistical* behavior of the ensemble of systems characterized by same p-adic prime depends on the resolution of the monitoring.

Standard probability theory, which also lies at the root of the standard quantum theory, predicts that the probability for a certain outcome of experiment does not depend on how the system is monitored. For instance, if system has N outcomes $o_1, o_2, ...o_N$ with probabilities $p_1, ..., p_N$ then the probability that o_1 or o_2 occurs does not depend on whether common signature is used for o_1 and o_2 or whether observer also detects which of these outcomes occurs. The crucial signature of p-adic probability theory is that monitoring affects the behavior of the system. NMP provides precise definition for the concept of monitoring. There are two forms of monitoring depending on whether the fundamental observable, denote it by O, is density matrix or entropy operator.

Consider first the situation in which all entanglement probabilities have p-adic norm different from unity. Physically monitoring is represented by quantum entanglement and differentiates between two eigen states of O (density matrix or entropy operator) only provided the eigenvalues of O are different. If there are several degenerate eigenvalues, quantum jump occurs to any state in the eigen space and one can predict only the total probability for the quantum jump into this eigen space. Hence the p-adic probability for a quantum jump to a given eigen space of density matrix is p-adic sum of probabilities over the eigen states belonging to this eigen space:

$$P_i = \frac{(n(i)P(i))_R}{\sum_j (n(j)P(j))_R} \quad .$$

Here n_i are dimensions of various eigen spaces.

If the degeneracy of the eigenvalues is removed by an arbitrary small perturbation, the total probability for the transition to the same subspace of states becomes the sum for the real counterparts of probabilities and one has in good approximation:

$$P^R = \frac{n(i)P(i)_R}{[\sum_{j\neq i}\sum_j (n(j)P(j))_R + n(i)P(i)_R]} \quad .$$

Rather dramatic effects could occur. Suppose that that the entanglement probability $P(i)$ is of form $P(i) = np$, $n \in \{0, p-1\}$ and that n is large so that $(np)_R = n/p$ is a considerable fraction of unity. Suppose that this state becomes degenerate with a degeneracy m and $mn > p$ as integer. In this kind of situation modular arithmetics comes into play and $(mnp)_R$ appearing in the real probability $P(1\ or\ 2)$ can become very small. The simplest example is $n = (p+1)/2$: if two states i and j have *very nearly equal but not identical* entanglement probabilities $P(i) = (p+1)p/2 + \epsilon$, $P(j) = (p+1)p/2 - \epsilon$, monitoring distinguishes between them for arbitrary small values of ϵ and the total probability for the quantum jump to this subspace is in a good approximation given by

$$\begin{aligned} P(1\ or\ 2) &\simeq \frac{x}{\left[\sum_{k\neq i,j}(P_k)_R + x\right]} \quad , \\ x &= 2\left[(p+1)p/2\right]_R \quad . \end{aligned} \tag{3.4.2}$$

and is rather large. For instance, for Mersenne primes $x \simeq 1/2$ holds true. If the two states become degenerate then one has for the total probability

$$\begin{aligned} P(1\ or\ 2) &\simeq \frac{x}{\left[\sum_{k\neq i,j}(P_k)_R + x\right]} \quad , \\ x &= \frac{1}{p} \quad . \end{aligned} \tag{3.4.3}$$

The order of magnitude for $P(1\ or\ 2)$ is reduced by a factor of order $1/p$!

A test for the notion of p-adic quantum cognition would be provided by the study of the dependence of the transition rates of quantum systems on the resolution of monitoring defined by the dimensions of the degenerate eigen spaces of the subsystem density matrix (or entropy operator). One could even consider the possibility of measuring the value of the p-adic prime in this manner. The behavior of living systems is known to be sensitive to monitoring and an exciting possibility is that this sensitivity, if it really can be shown to have statistical nature, could be regarded as a direct evidence for TGD inspired theory of consciousness. Note that the mapping of the physical quantities to entanglement probabilities could provide an ideal manner to compare physical quantities with huge accuracy! Perhaps bio-systems have invented this possibility before physicists and this could explain the miraculous accuracy of biochemistry in realizing genetic code.

If some entanglement probabilities have unit norm so that their contributions to the p-adic entanglement entropy vanish, quantum jump to an entangled final state can occur: this is genuinely p-adic effect and serves as a second test for p-adic cognition. If density matrix is the fundamental observable, quantum jump can occur to an entangled final state, which corresponds to any $S = 0$ subspace of $S = 0$ eigen space of the entropy operator with is eigen space of the density matrix. If entropy operator is the fundamental observable, quantum jump can occur to any $S = 0$ subspace of entropy operator. Again the total probability for the transition is determined by the p-adic sum of the probabilities and dramatic 'interference' effects at the level of probabilities are possible.

The notion of resolution emerges naturally for the hyper-finite factors of type II_1. The trace of the unit operator is unit for the infinite-dimensional space in question so that any projector with a finite trace must project to an infinite dimensional space so that there would always an infinite-dimensional degeneracy involved with the eigenvalues of the measured observables.

Resolution and monitoring and hyperfinite factors of type II_1

One could however consider the formulation of the theory in terms of p-adic probabilities and for this formulation resolution and monitoring emerge naturally. One could go even further. For instance, if one can specify the infinite number of degrees of freedom as a p-adic integer, say $N = -1 = (p-1)\sum_{k=0}^{\infty} p^k$, which in a well-defined sense represents the largest p-adic integer, one can say that the p-adic probability for a given state is $1/N$ and finite as a p-adic number. It is finite also as a real number and equal to $1/p$ if canonical identification is used to map N to a real number. For a given finite-dimensional density matrix with finite number of distinct eigenvalues it would be possible to have projections to one-dimensional subspace but there would always infinitely degenerate eigenvalue present in accordance with the notion of finite resolution.

A natural question concerns the implications of the assumption that the map of p-adic probabilities to real ones conserves probabilities without additional normalization.

3.4.4 NMP and quantum computer type systems

TGD Universe can be regarded as an infinite quantum computer. Unitarity informational "time development" U is analogous to a quantum computation lasting infinitely long time. The last step in the quantum jump $U\Psi_i \to ....\Psi_f$ corresponds to the halting of the computation. The average duration of the quantum computation with respect to the psychological time of self is of order CP_2 time about 10^4 Planck times, if the simplest estimate is correct. Thus 10^{39} infinitely long quantum computations per second by infinite quantum computer occur! Selves, being subsystems able to remain unentangled, are effectively quantum sub-Universes and quantum computers in this very general sense.

The problem is however that conscious experience about the result of the computation is an average over the results of very many quantum computations and thus fuzzy. The statistical description of the conscious experience implies that mathematically the situation is very much analogous with that encountered in the standard quantum computation. Macro-temporal quantum coherence which basically corresponds to the formation of bound states made possible by the spin glass degeneracy of TGD Universe however resolves this problem. Long sequence of quantum jumps fuse effectively to single quantum jump in bound state entangled degrees of freedom and unitary time evolution is at least good approximation for the time evolution.

Number theory and quantum computation in TGD Universe

The notion of number theoretical entanglement entropy has deep implications for understanding what quantum computation really means.

1. For finitely extended rational entanglement entropy can be identified as the number theoretical entanglement entropy which is always negative. Otherwise ordinary Shannon entropy or its p-adic variant must be used. One must distinguish between two kinds of quantum computational modes corresponding to living and dead quantum computers. For dead quantum computers quantum coherence is extremely fragile and lasts for single quantum jump only. For living quantum computers entanglement is bound state entanglement and NMP takes care that quantum coherence lasts for the duration of the bound state. Thus bio-systems would be especially attractive candidates for performers of quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes might involve new physics not taken into account in the standard physics based biochemistry.

2. Macro-temporal quantum coherence is what makes quantum computation like processes possible since a sequence of quantum jumps effectively binds to a single quantum jump with a duration, which corresponds to the lifetime of the bound state. Quantum computation like process starts, when the quantum bound state is generated and halts when it decays. Spin glass degeneracy increases the duration of the quantum computation to time scales which are sensible for human consciousness. In case of cognitive quantum computation like processes the quantum coherence is stabilized by NMP. Spin glass degeneracy also provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along boundaries bonds and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis emerges.

3. The mechanism of macro-temporal quantum coherence is roughly following. In the formation of bound state entanglement join along boundaries bonds are generated between 3-space sheets involved and only the over all cm zero modes characterizing the shape and size of the resulting 3-surface remain zero modes. In these new quantum fluctuating degrees state function reduction does not occur anymore and the quantum de-coherence otherwise occurring in each quantum jump is absent. The number of these degrees of freedom is huge so that they are excellent candidates for quantum computation purposes (consider as an example tubulin molecules of micro-tubule or clusters of water molecules) and one ends up with TGD based variant of biological supercomputers. In p-adic context all configuration space variables are zero modes so that in this case this mechanism does not work. However, quaternion conformal spin degrees of freedom do not have any zero modes as correlates and they allow p-adic counterpart of quantum computation which halts when $S \leq 0$ system ends up to $S > 0$ state.

4. One must generalize the standard quantum computer paradigm since ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic entanglement two-state systems are naturally replaced with p-state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which means gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127} - 1$ M_{127}-qupits making about 254 bits. The idea about neuron as a classical bit might be little bit wrong!

5. Bio-systems are especially attractive candidates for performers of conscious quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes would involve new physics not taken into account in the standard physics based biochemistry.

6. The number theoretic formulation of state function reduction and preparation encourages to think that there is an entire hierarchy of these processes labelled by p-adic length and time scales and that these processes occur in quantum parallel manner in different p-adic length and time scales. This would allow to understand why it is possible to describe hadrons as genuine

quantum systems in long scales whereas perturbative QCD describes hadrons as dissipative systems using kinetic equations in short scales. This forces to ask whether quantum parallel dissipative computations each of them very similar to ordinary classical computation could be possible. If so then the strengths of classical and quantum computation might be combined.

7. It might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macro-temporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

Quantum computation and stereo consciousness

The fusion of two or more mental images to single one (binding) and the decomposition of this mental image back to the component mental images would be the counterpart of quantum computation like processes at the level of brain and could allow to think several thoughts or experience several sensory images simultaneously. Stereovision could be seen as basic example about the fusion of mental images to single mental image containing something essentially new.

Neuronal synchrony might be basic example of quantum computation like process. During neuronal synchrony oxidative metabolism is indeed lowered which has interpretation as a generation of bound state entanglement liberating binding energy as a usable energy so that oxidative metabolism is not needed. Bio-systems are especially attractive candidates for performers of quantum computation like processes. The binding of molecules by lock and key mechanism is basic processes in living matter and the binding of information molecules to receptors is a special case of this process. All these processes might involve new physics not taken into account in the standard physics based biochemistry.

Quantum computation, MEs, and time mirror mechanism

One can also consider more concrete ideas about quantum computation. Time mirror mechanism as basic mechanism of consciousness and bio-control is especially attractive in this respect.

1. Unitary process U from conformal invariance

For a quantum jump sequence lasting n steps under previously stated conditions the time development operator is in a good approximation n:th power of the operator U. Quantum-classical correspondence suggests that U has space-time representation. The natural guess inspired by string models is that U decomposes into stringy propagators and vertices. For the metric conformal degrees of freedom single particle time development operators at the light like boundaries of MEs along light like direction would give rise to stringy propagators whereas vertices would be identifiable as 3-surfaces connected by MEs. The reason why these propagators are non-trivial is that single particle conformal invariance ceases to be an exact symmetry just as single particle zero modes cease to be zero modes.

For quaternion conformal fermionic degrees of freedom, which do not have any obvious zero mode counterparts, single particle time evolution operator along the null direction of the elementary particle horizons would give rise to stringy propagator. The fusion of elementary particle horizons would in turn define the basic vertex possibly giving rise to annihilation and creation of wormhole contacts. Quaternion conformal time development operator would be realized also in p-adic fermionic degrees of freedom.

2. Long length scales are not a problem

A heavy objection against light like computation is that the length scales are so large for reasonable computation times. One can however consider the possibility that MEs are reflected again like in mirror and again in a finite volume and that each reflection preserves quantum information and is represented by a unitary transformation. In TGD framework also pairs of MEs with opposite time orientations are possible so that the result of computation in future and at distance of light years could be communicated backwards in time along the second space-time sheet. Also the reverse process might be possible. For instance, long term memory and anticipation could rely on this mechanism. In the chapter "Quantum antenna hypothesis" the idea about DNA as a sequence of MEs realizing laser mirror idea of [33] is discussed.

The reflection of ME could occur from curved almost vacuum space-time surface and have interpretation as topological realization of self energy diagram. The mirror mechanism of long term memories would also have interpretation in terms of the topological Feynman diagrams associated with the expression of the operator U. Thus the mechanism of long term memory would reduce to the fundamental quantum level.

In the p-adic context, p-adic non-determinism allows the reflection of ME to occur in both spatial and temporal directions since conserved quantities are only pseudo constants. Thus cognitive processes could use light like quantum computation routinely if one can assign quaternion conformal degrees of freedom to the light like boundaries of MEs (this is not obvious). The temporal and spatial reflection give also rise to p-adic teleportation and replication of p-adic MEs and could be crucial element of cognition (see the chapter "Quantum model for cognition"). Temporal reflection is in fact the counterpart for the formation of phase conjugate of a hologram, and in TGD framework it corresponds to time reversed cognition.

3. Cognitive codes and quantum computation

p-Adic length scale hypothesis leads to the idea that each $p \simeq 2^k$, k integer, defines a hierarchy of cognitive codes with code word having duration given by the n-ary p-adic time scale $T(n,k)$ and number of bits given by any factor of k. Especially interesting codes are those for which the number of bits is prime factor or power of prime factor of k. This is a strong quantitative prediction since the duration of both the code word and bit correspond to definite frequencies serving as signatures for the occurrence of commutations utilizing these codes.

If k is prime, the amount of information carried by the codon is maximal but there is no obvious manner to detect errors. If k is not prime there are several codes with various numbers of bits: information content is not maximal but it is possible to detect errors. For instance, $k = 252$ gives rise to code words for which the number of bits is $k_1 = 252, 126, 63,\ 84, 42, 21_2, 9,\ 7, 6_2, 4, 3_2, 2$: the subscript $_2$ tells that there are two non-equivalent manners to get this number of bits. For instance, $126 = 42 \times 3$-bit codon can have 42 -bit parity codon: the bits of this codon would be products of three subsequent bits of 126-bit codon. This allows error detection by comparing the error codon for communicated codon and communicated error codon.

Dark matter hierarchy and quantum computation

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Each p-adic length scale corresponds to this kind of hierarchy and number theoretical arguments suggest a general formula for the allowed values of Planck constant λ depending logarithmically on p-adic prime [C7]. Also the value of $\hbar_0$ has spectrum characterized by Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$, varying by a factor in the range $n > 3$ [C7]. The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

From the point of view of quantum computations these levels would be of crucial importance since the durations of macroscopic quantum coherence increase like $\hbar$. For instance, EEG time scales corresponds to $k = 4$ and a time scale of .1 seconds [J6] and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Bio-systems might perform various kinds of quantum computations. Quantum parallel nerve pulse patterns could make possible quantum computation like activities, for instance during sleep [M2]. The braids formed by magnetic flux tubes are ideal for the realization of topological quantum computations. I have discussed some manners how DNA could act as a topological quantum computer in [E9].

Abstraction hierarchy and genetic code

Mersenne primes $M_n = 2^n - 1$, which seem to play fundamental role in elementary particle physics and it has been already found that their emergence is natural consequence of NMP. This would put primes 3, 7, 31, 127, etc. in a special position. Primes appear frequently in various bio-structures

and this might reflect the underlying p-adicity for the association sequences providing 'plan' for the development of bio-system. For instance, we have actually 7 (!) fingers: two of them have degenerated during evolution but can be seen in the developing embryo. There are 31 subunits in our spinal chord, etc...

In the model of genetic code based on a simple model of abstraction process [L1] the so called Combinatorial Hierarchy $2, 3, 7, 127, 2^{127} - 1, ...$ of Mersenne primes emerges naturally. The construction for a model of abstraction process proceeds as follows.

1. At lowest level there are two digits. The statements Yes and No.
2. At the next level one considers all Boolean statements about these two statements which can be regarded as maps from 2-element set to 2-element set. There are 4 of them. Throw one away and you get 3 statements.
3. At the next level one considers all Boolean statements about these 3 statements and the total number of them is 2^3. Throw one away and you get 7 statements. And so on.

The mystery is why one statement must be thrown away at each level of the construction. The answer might relate to a concrete model of quantum computation.

1. A possible neurolevel realization of a quantum computation is following. Entangle in the proposed manner two memetic codewords represented as temporal sequences of 127 cognitive Z^0 magnetized antineutrino ensembles with bit represented as the magnetization direction. The phase transitions changing the direction of magnetization are assumed to involve classical non-determinism.
2. Nerve pulse (or pulse like membrane oscillation) results from each flip of the direction of the Z^0 magnetization. The temporal sequence for which all Z^0 magnetization are in the the direction of the external Z^0 magnetic field is excluded because this state does not give rise to a nerve pulse pattern (or membrane oscillation pattern). In this manner a quantum computer with $N = 1$ and $p = 2^{127} - 1$ results. Incoming nerve pulse patterns could be taken to be identical memetic codewords and out would go a a pair of memetic codewords representing the initial memetic codeword and the result of the quantum computation. The duration of the computation is .1 seconds and involves $2^{127} - 1$ quantum jumps effectively glued to single quantum jump by macro-temporal quantum coherence.

3.5 Generalization of NMP to the case of hyper-finite type II_1 factors

The intuitive notions about entanglement do not generalize trivially to the context of relativistic quantum field theories as the rigorous algebraic approach of [25] based on von Neumann algebras demonstrates. von Neumann algebras can be written as direct integrals of basic building blocks referred to as factors [16]. Factors can be classified to three basic types labelled as type I, II, and III. Factors of type I appear in non-relativistic quantum theory whereas factors of type III_1 in relativistic QFT [25]. Factors of type II_1 [17], believed by von Neumann to be fundamental, appear naturally in TGD framework [C7].

3.5.1 Factors of type I

The von Neuman factors of type I correspond to the algebras of bounded operators in finite or infinite-dimensional separable Hilbert spaces. In the finite-dimensional case the algebra reduces to the ordinary matrix algebra in the finite-dimensional case and to the algebra of bounded operators of a separable Hilbert space in the infinite-dimensional case. Trace is the ordinary matrix trace. The algebra of projection operators has one-dimensional projectors as basic building blocks (atoms), the notion of pure state is well-defined, and the decomposition of entangled state to a superposition of products of pure states is unique. This case corresponds to the ordinary non-relativistic quantum theory. Ordinary quantum measurement theory and also the theory of quantum computation has been formulated in terms of type I factors. Also the discussion of NMP has been formulated solely in terms of factors of type I.

3.5.2 Factors of type II_1

The so called hyper-finite type II_1 factors, which are especially natural in TGD framework, can be identified in terms of the Clifford algebra of an infinite-dimensional separable Hilbert space such that the unit operator has unit trace. Essentially the fermionic oscillator operator algebra associated with a separable state basis is in question. The theory of hyper-finite type II_1 factors is rich and has direct connections with conformal field theories [18], quantum groups [18], knot and 3-manifold invariants [20, 22, 26], and topological quantum computation [26, E9].

The origin of hyper-finite factors of type II_1 in TGD

Infinite-dimensional Clifford algebra corresponds in TGD framework to the super-algebra generated by complexified configuration space gamma matrices creating configuration space spinors from vacuum spinor which is the counterpart of Fock vacuum [C7]. By super-conformal symmetry also configuration space degrees of freedom correspond to a similar factor. For type hyper-finite II_1 factors the trace is by definition finite and normalized such that the unit operator has unit trace. As a consequence, the traces of projection operators have interpretation as probabilities.

Finite-dimensional projectors have vanishing traces so that the notion of pure state must be generalized. The natural generalization is obvious. Generalized pure states correspond to states for which density matrix reduces to a projector with a finite norm. The physical interpretation is that physical measurements are never able to resolve completely the infinite state degeneracy identifiable in TGD framework as spin glass degeneracy basically caused by the vacuum degeneracy implying non-determinism of Kähler action. An equivalent interpretation is in terms of state space resolution, which can never be complete.

In TGD framework the relevant algebra can also involve finite-dimensional type I factors as tensor factors. For instance, the entanglement between different space-time sheets could be of this kind and thus completely reducible whereas the entanglement in configuration space spin and "vibrational" degrees of freedom (essentially fermionic Fock space) would be of type II_1. The finite state-space resolution seems to effectively replace hyper-finite type II_1 factors with finite-dimensional factors of type I.

The new view about quantum measurement theory

This mathematical framework leads to a new kind of quantum measurement theory. The basic assumption is that only a finite number of degrees of freedom can be quantum measured in a given measurement and the rest remain untouched. What is known as Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of von Neumann algebras allow to realize mathematically this idea [C7]. $\mathcal{N}$ characterizes measurement resolution and quantum measurement reduces the entanglement in the non-commutative quantum space $\mathcal{M}/\mathcal{N}$. The outcome of the quantum measurement would still represented by a unitary S-matrix but in the space characterized by $\mathcal{N}$. It is not possible to end up with a pure state with a finite sequence of quantum measurements.

The measurement of components of quantum spinors does not make sense since it due to the non-commutativity it is not possible to talk about quantum spinor with single non-vanishing component. Therefore the measurements must be thought of as occurring in the state space associated with quantum spinors. The possible consequences of non-commutativity are considered from the point of view of cognition in [C7] by starting from the observation that the moduli squared of quantum spinor components are commuting Hermitian operators possessing a universal rational valued spectrum which suggests interpretation in terms of quantum version of fuzzy belief.

The obvious objection is that the replacement of a universal S-matrix coding entire physics with a state dependent unitary entanglement matrix is too heavy a price to be paid for the resolution of the above mentioned paradoxes. Situation could be saved if the S-matrices have fractal structure. The quantum criticality of TGD Universe indeed implies fractality. The possibility of an infinite sequence of Jones inclusions for hyperfinite type II_1 factors isomorphic as von Neumann algebras expresses this fractal character algebraically. Thus one can hope that the S-matrix appearing as entanglement coefficients is more or less universal in the same manner as Mandelbrot fractal looks more or less the same in all length scales and for all resolutions. Whether this kind of universality must be posed as an additional condition on entanglement coefficients or is an automatic consequence of unitarity in type II_1 sense is an open question.

What happens in repeated measurements?

The assumption of the standard quantum measurement theory is that the outcome of state function reduction does not change in further measurements if the combined system consisting of measured system and performer of measurement is isolated. This hypothesis generalizes to the case of hyper-finite type II_1 factors. Suppose that the outcome of a quantum jump represented by a projection operator P. If the combined system is not isolated, P can replaced by an arbitrary projection operator in the next unitary process. If the combined system is isolated, the next unitary process leads to a state in which P is replaced by a state expressible in terms of projection operators P_i projecting to the sub-space defined by P, and one of them is selected in the next state function reduction or state preparation. A never-ending series of quantum jumps forcing the state to a smaller and smaller but always infinite-dimensional corner of the state-space would result in absence of the unitary process regenerating the entanglement. This process could be seen as a counterpart for the process in which state function reduction and state preparation processes propagate from long to short length scales.

The notion of rational entanglement has a natural type II_1 counterpart and corresponds to rational valued traces for the projection operators involved and rational valued coefficients for these projection operators in the expression of the density matrix. The idea about rational entanglement (or algebraic entanglement in algebraic extension of p-adics in question) as bound state entanglement carrying negative entanglement entropy generalizes.

Rational density matrices are in a special role since they can be thought of as being common to the real and p-adic variants of the state space. The information measures based on p-adic norm and allowing negative entanglement entropy make sense also now. The question whether there might be some deeper justification for the stability of the generalized rational (algebraic) entanglement against state function reduction/preparation reducing entanglement negentropy in the context of hyper-finite type II_1 factors, remains to be answered.

Consider a rationally entangled state characterized by projection operators P_i such that the probabilities p_i are rational and remain stable in the unitary process. For factor of type I, a situation in which P_i are replaced by 1-dimensional projectors $Q_i < P_i$ is achieved sooner or later. In the infinite-dimensional case this situation can be approached but never reached.

p-Adic thermodynamics with conformal cutoff and hyper-finite factors of type II_1

For hyper-finite factors of type II_1 the unit matrix has unit trace. Hence real probabilities assignable to finite-dimensional projectors vanish so that the eigenvalues of the density matrix are always infinitely degenerate in the real context. p-Adic probabilities however make sense as finite p-adic numbers even if they vanish as real numbers. This raises the idea that p-adic probabilities are more natural for hyper-finite factors of type II_1 than real ones. Indeed, in p-adic context one could have finite probabilities for even one-dimensional sub-spaces, which would definitely mean an enhanced expressive power of the formalism. Thus hyper-finite factors of II_1 would give the reason why for p-adic thermodynamics [6].

The interpretation of p-adic probabilities is of overall importance from the point of view of physics. When probabilities are rational, the number field does not matter. If not, it seems necessary to map the p-adic probabilities to real ones. One can ask whether this mapping should respect probability conservation without normalization by hand. The variants of canonical identification with some additional conditions on probabilities satisfied for instance in p-adic thermodynamics provide a possible manner to perform this map (see [6]). In [E4, E1] it is found that so called canonical identification seems to provide a tool to achieve this.

Canonical identification in its basic form is defined as $I : \sum_{k=0}^{\infty} \alpha_k p^k \mapsto \sum_{k=0}^{\infty} \alpha_k p^{-k}$.

Canonical identification for rational numbers is defined using the unique representation $q = r/s$ as

$$I(\frac{r}{s}) = \frac{I(r)}{I(s)} \quad . \tag{3.5.1}$$

Canonical identification allows a further generalization to the case of p-adic thermodynamics where Boltzmann weights b_n are fundamental and their sum defines partition function as $Z = \sum_{n=0}^{\infty} g_n b_n$,

where g_n is the degeneracy of the state with a given "energy" (or any conserved quantity whose thermal average is fixed). In real thermodynamics Boltzmann weights are given by

$$b(E_n) = g(E_n)exp(-E_n/T) \ , \tag{3.5.2}$$

where E_n is "energy" and $g(E_n)$ the integer valued degeneracy of states with energy E_n. In p-Adic thermodynamics the partition function would not converges for this form of Boltzmann weights, which are therefore replaced by $b(E_n) = g(E_n)p^{E_n/T}$ and E_n/T is integer valued to guarantee the p-adic existence of the conformal weight. The quantization of E_n/T to integer values implies quantization of both T and "energy" spectrum and forces so called super conformal invariance in applications of topological geometrodynamics (see [E2, 6]), which is indeed a basic symmetry of the theory [C1]. Thus the mere number theoretical existence fixes the physics to a high degree and indeed leads to the understanding of elementary particle mass scales. For applications to the calculations of elementary particle masses see [6].

In p-adic thermodynamics the probabilities would be given by $p_n = b_n/Z$ and N_{max} would be replaced by Z. When b_n are integers it is natural to define the canonical identification as

$$I(p_n) = I(\frac{b_n}{Z}) \equiv \frac{I(b_n)}{I(Z)} \ . \tag{3.5.3}$$

A physically very powerful additional constraint is that the additivity of probabilities for independent events holds true also for the *real* counterparts of the p-adic probabilities obtained by canonical identification so that one would obtain also a real probability theory without ad hoc normalization of the real images of p-adic probabilities. This condition is satisfied only if the Boltzman weights b_{n_1} and b_{n_2} for any pair (n_1, n_2) are p-adic integers having no common pinary digits so that no "interference" in the sum of the p-adic probabilities occurs.

The selection of a basis for independent events would correspond to a decomposition of the set of integers labelling pinary digits to disjoint sets and brings in mind the selection of orthonormalized basis of quantum states in quantum theory such that quantum measurement can give only one of these states as an outcome. One can say that the probabilities define distributions of pinary digits analogous to non-negative probability amplitudes in the space of integers labelling pinary digits, and the probabilities of independent events must be orthogonal with respect to the inner product $\sum_n \alpha_n\beta_n p^n$ of integers $x = \alpha_n p^n$ and $y = \beta_n p^n$ defining analogs of wave functions in the space of pinary digits. Or putting it somewhat differently: Boltzman weights b_n for orthogonal quantum states represent them as orthogonal states in the space of binary digits with orthogonality realized as vanishing of the overlap for non-negative "wave functions". This map puts strong constraints on the probabilities of elementary independent events and is therefore highly interesting from the point of view of physics.

p-Adic thermodynamics satisfies the constraint that p-adic probabilities have no common pinary digits provided the degeneracies satisfy the condition $g(E_n) < p$ (later a somewhat more general conditions is deduced). For p-adic mass calculations (see [F3]) the degeneracies $g(n)$ of states with conformal weight $L_0 = n$ (taking the role of "energy") however increase exponentially so that the condition is not satisfied for very large values of n. Since $g(n)$ increases exponentially (say as 2^{nx}, where x is some parameter), probability conservation requires a cutoff of order $n_{max} \sim log_2(p)$ to the number of terms in the sum defining the partition function. In practice this cutoff has no implications since already the two lowest terms give excellent approximation to the elementary particle masses.

For instance, the value of p is $M_{127} = 2^{127} - 1 \sim 10^{38}$ in the case of electron so that higher terms in partition function Z are extremely small. The physical interpretation for the cutoff n_{max} would be in terms of p-adic length scale hypothesis (see [E4, E1] stating that the length scales $L_p \propto \sqrt{p}$ with primes $p \simeq 2^k$, k prime, are physically favored and the exponentially smaller p-adic length scale $L_k \propto \sqrt{k}$ defines the size scale of the elementary particle [F3].

For the ordinary thermodynamics of strings the exponential increase gives rise to Hagedorn temperature T_H as the maximal temperature possible for strings (see [27]). The interpretation is that the heat capacity of system grows without bound since the number of excited degrees of freedom increases without bound as T_H is approached. Clearly Hagedorn temperature is somewhat analogous to the pinary cutoff in p-adic thermodynamics.

The interpretation of the conformal cutoff in terms of factors of type II_1 factor would be that all conformal weights $n > n_{cr}$ correspond to the same p-adic probability so that it is not possible to distinguish experimentally between these states. This interpretation fits nicely with the notions of resolution and monitoring.

3.5.3 Factors of type III

For algebras of type III associated with non-separable Hilbert spaces all projectors have infinite trace so that the very notion of trace becomes obsolete. The factors of type III_1 are associated with quantum field theories in Minkowski space.

The highly counter-intuitive features of entanglement for type III factors are discussed in [25].

1. The von Neumann algebra defined by the observables restricted to an arbitrary small region of Minkowski space in principle generates the whole algebra. Expressed in a more technical jargon, any field state with a bound energy is cyclic for each local algebra of observables so that the field could be obtained in entire space-time from measurements in an arbitrary small region of space-time. This kind of quantum holography looks too strong an idealization.

   In TGD framework the replacement of Minkowski space-time with space-time sheet seems to restrict the quantum holography to the boundaries of the space-time sheet. Furthermore, in TGD framework the situation is nearer to the non-relativistic one since Poincare transformations are not symmetries of space-time and because 3-surface is the fundamental unit of dynamics. Also in TGD framework M^4 cm degrees of 3-surfaces are present but it would seem that they appear as labels of type II_1 factors in direct integral decomposition rather than as arguments of field operators.

2. The notion of pure state does not make sense in this case since the algebra lacks atoms and projector traces do not define probabilities. The generalization of the notion of pure state as in II_1 case does not make sense since projectors have infinite trace.

3. Entanglement makes sense but has very counter-intuitive properties. First of all, there is no decomposition of density matrix in terms of projectors to pure states nor any obvious generalization of pure states. There exists no measure for the degree of entanglement, which is easy to understand since one cannot assign probabilities to the projectors as their traces.

4. For any pair of space-like separated systems, a dense set of states violates Bell inequalities so that correlations cannot be regarded as classical. This is in a sharp contrast with elementary quantum mechanics, where "de-coherence effects" are believed to drive the states into a classically correlated states.

5. No local measurement can remove the entanglement between a local system and its environment. In TGD framework local operations would correspond to operations associated with a given space-time sheet. Irreducible type II_1 entanglement between different space-time sheets, if indeed present, might have an interpretation in terms of a finite resolution at state space level due to spin glass degeneracy.

On basis of these findings, one might well claim that the axiomatics of relativistic quantum field theories is not consistent with the basic physical intuitions.

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Chapter 4

Self and Binding

4.1 Introduction

For a long time the basic hypothesis of TGD inspired theory of consciousness was that *single* quantum jump between quantum histories determines the contents of conscious experience associated with a particular moment of consciousness. It however became gradually clear that this hypothesis is subject to several objections, the most serious one being that genuine memories about previous conscious experiences (quantum jumps) are not possible if single quantum jump determines everything. These counter arguments served as a pressure forcing the discovery of the quantum notion of self. An essential prerequisite for the notion of self were parallel developments related to the p-adic aspects of quantum TGD.

The understanding of the notion of self did not emerge as an instantaneous flash but has been plagued by some mis-interpretations as the evolution of the new concepts usually is. The progress in the understanding of quantum TGD, initiated by 'TGD as a generalized number theory' vision, has been of importance also in attempts to achieve a more precise definition of the notion of self. The most central clarifications in the conceptual framework have been following ones. p-Adic physics is physics of imagination, cognition and intention and space-time has a genuine decomposition into regions with a local topology which is real or p-adic (what these p-adic regions really mean turned out to be highly non-trivial question!); quantum jump decomposes into a TGD counterparts of the unitary process followed by the state function reduction process followed by a TGD version of the state preparation process governed by Negentropy Maximization Principle; quantum measurement theory follows as a basic prediction of quantum TGD; the sequences of quantum jumps defining selves define what might be identified as fundamental statistical ensembles growing in size quantum jump by quantum jump; statistical physics becomes part of the theory of consciousness, in particular the theory of qualia.

Further steps in the progress were the observation that only bound state entanglement is stable in quantum jump so that the binding of mental images involves liberation of usable energy (quantum metabolism); the realization that sub-selves of two separate selves can entangle and that this corresponds to the fusion and sharing of mental images providing a fundamental mechanism of quantum communication; the realization that the sharing of mental images is only possible by adopting a length scale dependent definition of sub-system motivated the fact that topologically condensed space-time sheets resemble black holes in many respects; and the idea about how the formation of many particle bound states might allow sequences of quantum jumps to combine to single effective quantum jump making possible macro-temporal quantum coherence and quantum computation type processes for irreducible selves in a state of 'oneness'.

Ironically, the latest step in the progress means an almost return to where all began. The notion of self might be reduced to quantum jump after all by adding to it the attribute "fractal". The idea was motivated by two new concepts: zero energy ontology and the generalization of the notion of imbedding space predicting a hierarchy of Planck constants labeling a hierarchy of phases of matter identified as dark matter. It took some years to decide whether the reduction of self to a fractal hierarchy of quantum jumps within quantum jumps can be consistent with the earlier view about self. This seems to be the case. Also it took time to give a real meaning to the phrase "quantum jumps within quantum jumps". The new picture allows surprisingly quantitative answers to a long list of

questions about the relationship of geometric and subjective time: this will be summarized later in the introduction and discussed in detail later.

There has been also a lot of pseudo progress. The understanding of the relationship between geometric and subjective time in TGD framework has been especially difficult challenge. By quantum classical correspondence the arrow of subjective time should be mapped to the arrow of geometric time at the level of conscious experience. In similar manner the asymmetry between subjective future and past should be correspond to an asymmetry between geometric future and past. What this means at the level of details has been far from clear and I have proposed many partial answers to the question about the arrow of geometric time. For instance: the geometric future inside light-cone contains much more room than geometric past so that the space-time region about which the contents of conscious experience are about tends to diffuse to the direction of the geometric future defined by light-cone proper time; perhaps the flow of geometric time corresponds to a wave front of intentional action identifiable as a phase transition changing intentions identified as p-adic space-time sheets transformed to real space-time sheets; maybe the space-time sheet assignable to self topologically condensed to a larger space-time sheet shifts in quantum jumps to the direction of geometric future some average temporal distance perhaps defined by CP_2 length scale. All these proposals have provided only partial answers, have led to paradoxes, and failed to give a firm quantitative grasp about the situation.

Also the original wrong view about the correspondence of real and p-adic numbers has generated a lot of confusion. The natural belief of topologist would be that p-adic space-time sheets are mapped to their real counterparts by a continuous map (some variant of what I called canonical identification making sense in p-adic thermodynamics). This map did not however respect symmetries and was inconsistent with field equations. Finally I was able to accept the natural belief of algebraist: reals and various p-adic number fields must be glued to together along rationals and common algebraic numbers to achieve generalization of the number concept and also that of imbedding space. What was difficult to accept was the highly non-intuitive implication that most points of p-adic space-time sheets are at spatial and temporal infinity in real (but not in p-adic) sense so that cognition and intentionality would be literally cosmic phenomena and only cognitive representations would be realized in a finite space-time volume in real sense (causal diamond) in terms of intersections of real and p-adic space-time sheets consisting of rational and some algebraic points.

I have tried to tidy up the chapters so that they would not contain too many mammoth bones. Since I can use only a finite amount of time to documentation purposes, I have not been completely successful and this chapter as also others resembles a lab notebook rather than a Handbook of Consciousness and might contain statements which represent earlier archeological strata. I hope that reader could forgive this. Benevolent reader might even take these chapters as documents about how ideas have developed.

4.1.1 Self as a sub-system able to remain unentangled

The manner to circumvent the objections against quantum jump as a moment of consciousness identification is surprisingly simple and general and relies on the idea that selves are effectively their own sub-Universes,that is sub-systems able to remain unentangled in subsequent quantum jumps consisting of the unitary process U followed by TGD counterparts of state function reduction and state preparation. The hypothesis is that the self experience of a sub-system lasts for so many quantum jumps as sub-system avoids entangling with some other self. The highly nontrivial question is what defines the identity of the self as a physical system: it seems that the p-adic prime characterizing the space-time sheet serving as the geometric correlate of self characterizes self identity.

The unitary process U generates a maximally entangled state, a multiverse superposition of quantum potentialities. State function reduction step corresponds in the TGD framework to a localization in so called zero modes which thus behave as effectively classical variables. State preparation consists of a cascade of self measurements proceeding from long to short length scales and giving rise to maximally unentangled state. Essentially a conscious analysis is in question.

Space-time surface decomposes into real and p-adic regions and rational entanglement between regions corresponding to different number fields is in principle possible. Rational entanglement is allowed because rational numbers are in a well-defined sense common to both reals and p-adic number fields. This entanglement is reduced during the first step of the state preparation phase. The interpretation would be as a cognitive measurement. Selves can be identified as unions various real and p-adic space-time sheets of surface whereas irreducible self corresponds to single space-time sheet. Self can

disappear only by a topological phase transition changing the number field associated with the self, if the space-time sheet disappears, or if a join along boundaries bond connects two space-time sheets and gives rise to a fusion of selves and formation of quantum bound state representing the fused self.

In the formation of a quantum bound state by join along boundaries bonds only overall zero modes remain zero modes whereas the remaining zero modes become quantum fluctuating degrees of freedom. The irreducible self (no sub-selves) generated in this manner has the property that state function reduction does not occur in the former zero modes and state preparation does not occur neither. This means that the entire sequence of quantum jumps during which bound state property is preserved, corresponds effectively to a single quantum jump. This means macro-temporal quantum coherence in the time scale of the duration of the bound state. Otherwise macro-temporal quantum coherence lasts only for the average increment of the geometric time associated with single quantum jump, which is about CP_2 time equal to 10^{-39} seconds. Macrotemporal quantum coherence makes possible for the self to act as a quantum computer type system. Also the experience of self, which is subjecto-temporal average over quantum jumps, contains in this case useful information since complete thermalization is avoided.

4.1.2 Is genuine subjective memory necessary?

For a long time the basic hypothesis of TGD inspired theory of consciousness was that the contents of conscious experience are determined totally by the initial and final states of *single* quantum jump. A heavy objection against this assumption is that the hypothesis makes it impossible to have genuine memories about previous conscious experiences. The concept of self however allows the possibility that the connected series of sequential quantum jumps performed by self after its last "wake-up" integrates to single conscious experience. This hypothesis realizes self as an extended object in subjective time allowing it to have memories about previous conscious experiences rather than only memories with respect to geometric time. An attractive additional assumption is that the conscious experiences of self are kind of subjecto-temporal statistical averages. This would make experiences reliable. In particular, sensory experiences can give objective reliable knowledge despite the fact that the outcomes of individual quantum jumps are not predictable. The undesired implication is that for long sequences of quantum jumps averaging leads to a total loss of information.

Geometric memory is made possible by the finite temporal duration of the mindlike space-time sheets. p-Adic space-time sheets are correlates of intentions, plans, desires,... whereas real space-time sheets correspond to ordinary memories. The phase transition front at which p-adic intentions transform to real actions defines psychological time. p-Adic (real) geometric memories are about geometric future (past) and serve as prophecies telling what would happen (would have happened) if quantum jumps were not constantly replacing macroscopic space-time with a new one. Subjective memory makes it possible to compare what actually happened with what was expected to happen. It might be that this comparison is one of the fundamental irreducible mental acts.

A natural identification of the subjective memory is as immediate short term conscious memory, or actually a hierarchy of short term memories corresponding to the hierarchy of selves. This identification requires that the subjective durations of our sensory selves are typically of a fraction of second, .1 second is suggested by various arguments relating to the ability to experience subsequence stimuli as separate ones and corresponds to the duration of psychological moment. The narrative character of the long term memories suggests their identification as geometric memories: long term memories could correspond to multitime experiences with contributions coming also from the geometric past (say childhood). It turns out that this identification explains basic facts about long term memories.

4.1.3 Binding of experiencers and quantum entanglement

How different components of conscious experiences, such as various sensory qualia and the active components of conscious experience involving thoughts, conscious selections and volition, integrate to single experience, is known as binding problem. In TGD framework one can distinguish between binding of *conscious experiences* and binding of *conscious experiencers*. Quantum entanglement provides a possible mechanism of binding of conscious *experiencers* to larger selves. At the level of mental images (sub-selves) this corresponds to the integration of parts to wholes. If the p-adic primes associated with the two p-adic sub-systems are different, the p-adic prime p of either system must change in topological phase transitions so that the local topologies (real or p-adic) are same.

The successes of p-adic physics suggest that it should be possible to label also real selves/space-time sheets by p-adic primes. Hence also real selves would form a hierarchy. If the entanglement with a higher level self is preceded by a phase transition changing local topology to that of the surrounding space-time region, it should lead to a loss of consciousness so that it is not possible to remember anything about the period of entanglement (sleep and trance would present basic examples of this).

Since only a bound state entanglement is stable against the state preparation process occurring in each quantum jump, the fusion of selves to a larger self means a formation of a bound state and the liberation of the binding energy as a usable energy. Thus quantum metabolism is predicted to accompany the binding of the mental images. Second aspect is a transformation of zero modes to quantum fluctuating degrees of freedom implying macro-temporal quantum coherence with a sequence of quantum jumps behaving effectively as a single quantum jump.

4.1.4 Binding of experiences and summation hypothesis

Unentangled sub-system X possessing self behaves essentially as a separate sub-Universe with respect to NMP. This means that unentangled sub-systems X_i of X, in particular sub-selves, participate in each quantum jump. If one postulates that the conscious experiences of sub-systems X_i of unentangled sub-system X integrate with the self experience of X to form single experience, one obtains a filtered hierarchy of conscious experiences with increasingly richer contents. The integrated experience cannot a simple sum of individual experiences of sub-selves (we do not experience the conscious experiences of neurons separately). Rather, the experience of X is most naturally sum of abstractions about experiences of X_i. A natural hypothesis is that X forms kind of abstraction or average $\langle X_{ij} \rangle$ about the experiences of sub-selves X_{ij} of X_i representing what it is to be average X_{ij}, that is average over the mental images of X_i.

4.1.5 Some consequences

Summation hypothesis, when combined with the mechanism for the formation of abstractions and mechanism of subjective memory, has rather nontrivial consequences.

Infinite hierarchy of selves with God at the top

A rather dramatic prediction is a Russian doll like hierarchy of conscious experiencers having the entire Universe, God, at the top. The necessary localization in zero modes making the Universe of conscious experience classical together with the proposed concept of self allows to understand both active and passive aspects of consciousness and a general classification of various types of conscious experiences becomes possible. Summation hypothesis, sharing of mental images and 'enlightment' by entanglement (perhaps preceded by a phase transition increasing the value of p-adic prime of sub-self) hypothesis provide a general framework for interpreting various transpersonal experiences and altered states of consciousness as resulting from entanglement with larger units of consciousness.

Reducible and irreducible selves

Sub-selves correspond to mental images of self. Irreducible selves do not posses sub-selves and have thus no mental images. The interpretation of this kind of experience would be as pure awareness without content. Whether this kind of states are really possible is not obvious since any spacetime sheet contains smaller space-time sheets. When all sub-selves of self fuse together to yield kind of stereo-consciousness (fusion of left and right visual fields gives rise to 3-D stereo vision), something exceptional results also. One might interpreted this kind of state as whole-body consciousness, a state of oneness in very literal sense. Synchronous neuronal firing could give be a signature of this kind of states. Reducible selves have several sub-selves experienced as mental images. One can model conscious processing as cascades leading to creation of sub-selves of sub-selves of ... : selves are interpretable as symbolic representations of objects of sensory experience and a close parallelism with computationalism and connectivism emerges.

Self-organization, ageing, death

Living systems are autonomous systems and selves, being effectively their own sub-Universes, are indeed autonomous. Selves define statistical ensembles in a natural manner and dissipation is naturally related to the ageing of self since the statistical ensemble in question grows quantum jump by quantum jump. The cascade of self measurements serves as a kind of self repair mechanism and is necessary for self for self to retain its identity.

On the other hand, state function reduction and state preparation imply quantum decoherence and averaging over quantum jumps which means that the contents of consciousness of self thermalize with mental images becoming more and more fuzzy. Haken's classical theory of self-organization applies almost as such since time development by quantum jumps means hopping around the space of zero modes characterizing the size and shape and Kähler fields associated with the space-time surface $X^4(X^3)$.

Subjective ageing results from dissipation and is the price paid for having self. Very concretely, the mental image represented by self gets more and more entropic during ageing. One can also formulate questions about what happens in death in terms of physical concepts. Does only the bodily sub-self (mental image about body) cease to exist in the physical death so that only the field body consisting of magnetic flux tube structures and massless extremals (MEs, topological counterparts of light rays) remains? Can one identify the field body as the counterpart of what is called soul? Could the field body get interested of some new physical body and use it as sensory and motor organ (re-incarnation)? Is entanglement with some larger self generated after death (and during sleep)? Or does only the crucial p-adic-to-real phase transition for MEs (say) representing the transformation of intentions to actions cease during sleep and in death so that neither sensory mental images nor memories are formed but consciousness might still continue?

Self-organization implies Darwinian selection performed by dissipation inside each self. Dissipation selects also surviving sub-selves having interpretation as mental images. Hence the selection of memes is also in question.

How psychological time and its arrow emerge?

There are many difficult questions related to the relationship between subjective and geometric time. How the arrow of subjective time is mapped to the arrow of geometric time? How to understand the sharp distinction between geometric future and past at the level of conscious experience? What is the average interval of geometric time assignable to quantum jump and how it depends on the p-adic prime p characterizing system and on the value of Planck constant? Can one assign to quantum jumps space-time region about which the contents of conscious experience are, and how the temporal and spatial scales of this region depend on p and the value of Planck constant?

The picture of self having mind-like space-time sheet with a finite time span motivated the first attempts to understand how psychological time emerges.

1. Psychological time might identified as the center of mass time coordinate for the mindlike space-time sheet and is zero mode so that each quantum jump localizes quantum state to a sharp value of psychological time (actually several values of psychological times). The local arrow of psychological time in turn can be understood as resulting from the diffusion and drift of the mindlike space-time sheets in the future lightcone induced by quantum jumps. Diffusion and drift result from the facts that there is much more room in the future of the lightcone than in its past and the total probability for the transitions increasing the value of the light-cone proper time is slightly more higher than for those reducing it. For large values of the light-cone proper time the drift dominates and implies constant average increment of the light-cone proper time in quantum jump.

2. This picture is however not quite complete. The mirror model of long term memories implies that the contents of conscious experience are determined by the entire life cycle and that even the geometric future could contribute. This raises the question about what gives for the psychological now its special status. The identification of the psychological now as the time coordinate characterizing the position for the front of a p-adic-to-real phase transition (occurring for, say, massless extremals) proceeding in the direction of the geometric future could resolve the problem

and also other paradoxes. p-Adic-to-real phase transition has an interpretation as a transformation of an intention to an action and psychological time corresponds to the center of mass time coordinate for the space-time region where the volition is concentrated. Simple arguments lead to the conclusion that psychological time is very probably common to the entire biosphere (p-adic hierarchy of psychological times is involved). Although the transformation of intentions to action is localized around sharp moment of geometric time, the proposed explanation involves the ad hoc assumption about propagation of conscious experience to the direction of geometric future.

Neither of these approaches led to quantitative success whereas the emergence of zero energy ontology and hierarchy of Planck constants allowed a picture allowing much more detailed answers to the questions posed in the beginning.

1. The common quantitative denominator is the fact that one can assign to a given zero energy state is identifiable in positive energy ontology as a physical event, say elementary particle scattering such that positive and negative energy parts of the state correspond to the initial and final states of the event. The geometric correlate is a causal diamond formed by a pair of future and past directed light-cones of M^4 and corresponds to a region of the imbedding space rather than that of space-time.

2. The temporal distance T between the tips of the causal diamond brings to physics a new time scale and simple argument predicts p-adic length scale hypothesis (favored primes p satisfy $p \simeq 2^k$, k prime), and that T corresponds to secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$. For nonstandard values of $\hbar$ T scales like $\hbar\hbar_0$. In the case of zero energy state describing electron this time scale is .1 seconds and corresponds to the 10 Hz frequency defining the fundamental biorhythm, and the duration of moment of sensory experience.

3. The simplest explanation for the arrow of geometric time assumes that the attention of self is directed to a fixed volume of imbedding space defined by the causal diamond. In other words, self has this causal diamond as a geometric correlate and conscious experience of self is about this causal diamond. The long lasting misconception causing all the fuss was that the regions of 4-D space-time surface rather than those of imbedding space serve as correlates for selves.

4. If the quantum superposition of space-time surfaces in the first approximation shifts in a given quantum jump to the direction of geometric past a distance given by T, the arrow of geometric time can be understood and T defines the lapse of geometric time in quantum jump. The hierarchy of quantum jumps inside quantum jumps corresponds to both p-adic and $\hbar$ hierarchies and the experience of flow of time can be understood in terms of sequences of sub-quantum jumps defining mental images. A more precise formulation allows also to understand why sensory experience is about narrow time interval. Absolutely essential elements of this explanation is the representability of the space-time as a 4-D surface of a higher-dimensional imbedding space, multi-verse picture and quantum coherence in macroscopic scales, as well as the assignment of unique space-time surface to given 3-surface required by General Coordinate Invariance. The original defining assumptions relate to the notion of self can be assumed to hold true for sub-selves identified as sub-quantum jumps.

A couple of comments about the relationship to the earlier visions are in order.

1. These visions need not be completely wrong. For instance, first vision might apply when one wants to answer the question whether the attention of self (position of causal diamond) can shift in quantum jump and whether this causal diamond tends to in the direction of geometric future. They however contain as an un-necessary ad hoc assumption the postulate of standard physics that consciousness corresponds to something moving towards geometric future in space-time.

2. The original belief was that mind-like space-time sheet with finite geometro-temporal size serves as correlate of self but that also space-time sheets with infinite temporal size are possible. This concept turned out to be an idea much before its time. In zero energy ontology all quantum states have this kind of space-time sheets as space-time correlates. The identification of mind-like sheet as a correlate of self was however wrong: only the realization that causal diamond - region of imbedding space - serves the space-time correlate of self allowed to achieve answers to the basic questions.

Quantum model for intelligent system

The concept of self provides justification for the assumptions behind the quantum model for intelligent systems [H7]. One can understand at very general level the mechanism for how universe forms abstractions about itself. Even the basic hierarchical structures of language could be identified in terms of Russian doll like structure formed by selves with phonemes possibly representing the lowest level selves in case of language.

The close connection with the computationalistic approach to psychology and consciousness is obvious. The hierarchy of selves is analogous to a hierarchy of higher level computer languages. Note also the analogy with the the hierarchy of the modules of a computer program. Selves could be interpreted as symbolic representations for the objects of external (and internal) world and cascades of selves generating selves inside selves provide a model for sensory experience and cognition. This model provides also a possible representation for logical implication sequences as temporally ordered sequences generating sub-selves. Quantum entanglement between selves is a good candidate for representing how wholes are formed from parts consciously as also for the formation of associations. Since bound state entanglement is necessarily involved, the formation of wholes involves the liberation of binding energy as a usable energy. Abstraction process emerges naturally as a formation of quantum average selves about the sub-sub-selves of self.

Quantum statistical determinism makes possible reliable thinking and sensory experiencing at the level of self and one could in principle model brain and sensory organs as ensembles of sub-sub-systems for which quantum measurement of certain observables occurs in quantum jump leading to the thought or sensory experience[H7]. What is especially nice is that temporal statistical averages become possible since mindlike space-time sheets can have also timelike distance: thus individual can learn form experience if temporal ensemble of cognitive space-time sheets is available.

Binding of sensory experiences

Different sensory qualia naturally correspond to separate sub-selves, whose individual experiences are separate but combine to form various qualia in our experience. In TGD framework they could correspond to sensory pathways or parts of them and perhaps containing also primary sensory organs. Quite generally, it seems that the reliability of the sensory experiences and the absence of experienced volition is guaranteed by the hypothesis about subjective memory. Experienced volition is most naturally related to the selection between different absolute minima of Kähler action rather than quantum jumps reducing the entanglement.

For instance, synchronous neuronal firing could be understood as a consequence of almost simultaneous wake-up of neuronal sub-selves near criticality for phase transition changing the local topology of the space-time sheets associated with sub-self. If neurons have sub-selves, also subneuronal quantum jumps are possible and this could eventually make synchronous assembly and de-assemly of microtubules and even synchronously occurring biochemical reactions possible. Primary sensory experiences could occur in part of the sensory pathway containing also primary sensory organ and nerve pulse activity could be regarded as resulting from the creation or wake-up of sensory sub-self by quantum jump leading to state able to remain unentangled. It came as a surprise that in TGD universe *our* sensory representations (an entire hierarchy is involved) are most probably realized at the magnetic sensory canvas associated with the electromagnetic body accompanying the physical body and having size much larger than the physical body.

4.2 Quantum self

Everyday experience suggest that consciousness is a property of the physical state and that self corresponds to a continuous stream of consciousness rather than quantum jumps occurring only now and then. On the other hand, it is not possible to be conscious of being not conscious: hence one cannot exclude the possibility that our consciousness might correspond to quantum jumps occurring occasionally in the sequence of quantum jumps. However, the idea that sub-systems participating in sequential quantum jumps possess self, very natural and the successes of this hypothesis is the best support for it.

4.2.1 Why the contents of conscious experience cannot be determined by the initial and final states of single quantum jump?

The quantum notion of self as a sub-system able to remain unentangled during subsequent quantum jumps emerged from four strong objections against the theory of consciousness relying solely on the identification of the quantum jump as a moment of consciousness.

1. The contents of conscious experience is determined by both the initial and final states so that it seems not possible to get any objective information about quantum states as such: we are doomed to live in the world of Maya, contrary to what mystics argue. One can consider a weaker form of objectivity for which state remains invariant in quantum statistical sense: this would suggest that sensory experiences involve ensembles of 'sub-observers' and that 'our' sensory experience is kind of mean experience, whose objectivity is guaranteed by statistical determinism.

2. If moments of consciousness correspond to quantum jumps between quantum histories, any conscious experience should involve a conscious selection between various outcomes of the quantum jump or at least experience of free will. Sensory experience does not certainly always involve this kind of selection.

3. The idea of self as a continuous stream of consciousness is very attractive and it seems difficult to imagine that our consciousness could be actually a sequence of moments of consciousness with gaps between. This argument is not so strong as it might sound: one cannot experience the gaps between moments of consciousness since it is not possible to be conscious of not being conscious. One could however argue that system possessing 'self' must be as near as possible to a continuous stream of consciousness: perhaps systems able to participate to sequential quantum jumps have self.

4. If the contents of conscious experience are defined by the initial and final states of only single quantum jump, it is impossible to have subjective memory, that is memories about previous conscious experiences.

For a long time these problems remained a challenge for TGD inspired theory of consciousness. The progress in the understanding of quantum TGD led however to a notion of self providing a beautiful resolution of these problems. The most important pieces of the puzzle identified during the last year are the following ones.

1. p-Adic physics can be identified as physics of cognition and space-time surfaces decompose into real and p-adic regions. If bound state entanglement between spaceetime regions belonging to different number field is not possible, selves are stable objects and can disappear only in a quantum jump inducing a topological phase transition changing the topology of space-time sheet associated with self to that of the surrounding space-time region.

2. Geometric matter-mind duality realized in terms of mindlike and matter like space-time sheets is crucial for understanding how cognitive and sensory mental images emerge. Infinite primes [O2] are very closely related concept: infinite primes could code in itself the decomposition of the space-time surface to matter and mindlike (cognitive) space-time sheets labelled by p-adic primes at lower level of infinity.

3. Dissipation can be regarded as a direct signature for the occurrence of quantum jumps between quantum histories (and, in fact, for the existence of real selves). More generally, entropy gradients, which are well defined also for p-adic selves, serve as a signature of consciousness.

4. Each quantum jump involves a localization in zero modes (associated with infinite-dimensional configuration space of 3-surfaces and characterizing the macroscopic shape and size of 3-surface), which implies the classicality of the universe of the subjective experience. The localization in zero modes together with the assumption that the unitary 'time evolution' operator U corresponds to effective flow in zero modes correlating measured quantum numbers with zero modes serving as macroscopic variables, means that state function reduction becomes part of the quantum jump. If the localization in zero modes is followed by a cascade of self measurements leading to a completely unentangled state, state preparation becomes a part of quantum jump. The dynamics of self measurements is governed by Negentropy Maximization Principle.

5. A precise definition for the sub-system concept constrained by the requirement that the definition reduces to the quantum field theoretical definition in the QFT limit. This is achieved if sub-system concept is local at the level of configuration space and relies one the geometric definition of the sub-system at space-time level relying on the identification of self as a connected region of space-time corresponding to a particular number field. A highly nontrivial point is that standard identification of sub-system as a tensor factor does not seem to work. The reason is that a space-time sheet representing a sub-system is glued by wormhole contacts to the larger space-time sheet and these contacts are surrounded by so called elementary particle horizons at which induced metric becomes degenerate. Sub-system space-time sheet is information-theoretically more like a blackhole like object and ahierarchy of statespaces results with sub-system-system inclusion described in a more abstract manner taking into account that 'blackhole has no hair'.

6. Quantum-classical correspondence is a correspondence principle stating that subjective time development by quantum jumps and geometric time development at the space-time level must correspond to each other.

The notion of self allows rather detailed answers to some other deep questions related to TGD inspired theory of consciousness. Some examples of these questions are following.

1. How the components of conscious experience bind together to form experience and how to achieve general classification of conscious experiences to various types (volition, sensory experiences, thinking,...)?

2. How psychological time and its arrow emerge? How we are able to genuinely remember something about the previous moments of consciousness?

3. What is the precise relationship between various macroscopic quantum phases and consciousness?

4. What is the relationship of TGD inspired theory of consciousness to the computational approach to mind applied in neuro sciences and cognitive science?

4.2.2 Self as a sub-system able to not generate bound state entanglement

A natural identification of self is as sub-Universe behaving autonomously. Thus sub-systems able to remain un-entangled are natural candidates for selves. As already described the identification of geometric correlates of selves as regions of space-time appearing in the decomposition of space-time into regions belonging to various number fields solves this problem: bound state entanglement does not simply occur between different number fields. If rational entanglement is allowed between different number fields, it must be reduced during the state preparation process. Entanglement probabilities and entanglement entropy are algebraic numbers in this case. If the entanglement entropy is interpreted as a real number, it is uniquely defined, and the real version of NMP forces self measurement to occur.

The sub-system representing self must have some characteristic property remaining invariant from quantum jump to quantum jump and the p-adic prime characterizing the space-time sheet representing self is an excellent candidate for this invariant.

The basic prediction is the existence of infinite hierarchy of selves and this has rather dramatic consequences. One can say that at the top of the infinite hierarchy is God, the entire Universe. This structure is not entangled with any larger structure of same kind so that this self can be said to live eternal life. God abstracts all experiences in the infinite hierarchy of sub-selves to single experience. If infinite primes are allowed, as required by simple physical arguments, God corresponds to infinite p-adic prime characterizing entire universe and since this prime grows, also God evolves.

4.2.3 Two kinds of sub-selves?

There is an interesting delicacy related the definition of sub-self due to the fact that there are two kinds of sub-systems: ordinary sub-systems identifiable as tensor factors and smaller space-time sheets glued to larger ones by wormhole contacts and analogous to black holes. Thus depending on the definition of self, self could have two kinds of sub-selves.

1. A self consisting of a set of quantum entangled disjoint space-time sheets is reducible and decomposes in self measurement to 'tensor factor type' sub-selves represented by these sheets and identifiable as mental images of self.

2. Space-time sheet can however contain smaller space-time sheets representing sub-selves of 'blackhole type'.

Can one say that space-time sheet containing space-time sheets represents an irreducible self? If so then irreducible self could have mental images. If not then it is difficult to imagine how irreducible selves are possible at all since any space-time sheets presumably contains smaller space-time sheets (say elementary particles). If there are several sub-selves these sub-selves become de-entangled in quantum jump and this means analysis and experience of separations at level of mental images.

These arguments suggest that self is in a state of oneness if the 'blackhole like' sub-selves represented by smaller space-time sheets are fused by join along boundaries bonds to single one: there is only one mental image. This definition is consistent with the identification of the neuronal synchrony as a correlate for the bound state formation at neuronal level, with the idea about macrotemporal quantum coherence as a prequisite for the state of oneness, and with the idea that the fusion of sub-selves leads to a kind of stereo consciousness (as in case of the fusion of right and left visual fields).

One could quite well give up the assumption that self can consist of several disjoint space-time sheets entangled with each other. With this identification selves correspond to join along boundaries condensates of space-time sheets and irreducible self has only single sub-self (mental image) represented by similar join along boundaries condensate. The analysis process generating separations and distinctions would be equivalent with the existence of several sub-selves.

The sub-selves of different selves can entangle and this corresponds to the formation of join along boundaries bonds between corresponding space-time sheets. This is not possible if sub-self is identified as a tensor factor. This process gives rise to a fusion and sharing of mental images and is of crucial importance in understanding how conscious communications are possible.

An interesting question is what kind of experience self having to several sub-selves, each in state of whole-body consciousness, has: there is no averaging involved so that the mental images of self could be identical with the experiences of sub-selves. The absence of 'tensor factor type' sub-selves suggests that dissipation is anomalously small during 'whole-body consciousness' and could serve as a physical signature of this state.

4.2.4 Active and passive aspects of consciousness

When self has no sub-selves, the experience of self reduces to pure awareness without any mental images. This raises the question whether the basic structure of the quantum jump could allow the general identification of the passive and active aspects of the conscious experience. In the following two possible identifications of these aspects are considered. The first approach was developed when I still believed in standard positive energy ontology. Second approach emerges naturally in zero energy ontology. Many elements of the first approach are consistent with the latter one.

Passive and active aspects of conscious experience in positive energy ontology

The experienced volition must be kind of an average over the subjective history of self and thus quantum jumps reducing entanglement do not probably contribute to the experience of volition.

1. Active aspects of consciousness could be related to the localization in zero modes occurring in quantum jump, which implies that the world of conscious experience looks classical. In particular, the localization in discrete zero modes labeling various degenerate absolute minima of Kähler action is a good candidate for experienced volition. That classical non-determinism corresponds to volition would conform with the quantum-classical correspondence. On the other hand, degenerate absolute minima lead to the notion of association sequence making possible to understand the emergence of symbolic representations and language.

2. It seems that the contribution of the quantum measurement part of the quantum jump reducing entanglement for a system with given values of zero modes need not involve conscious experi-

ence of volition or selection and could therefore be regarded as the passive aspect of conscious experience, such as sensory qualia.

3. Volition involves also intention. The first two identifications do not explain intentionality: only a selection between given alternatives is in question. Furthermore, selections of this kind are between a finite number of alternatives, which is however not the case for the first two options. A quantum jump in which p-adic space-time sheet is replaced with a real one is the natural candidate for volition transforming intention to action. The number of p-adic space-time sheets counts the number of intentions and the number of alternative choices is finite as it should be. Clearly, this option is the most realistic one.

Note that the passive and active aspects of conscious experience correspond directly to the Yin-Yang duality of the Eastern philosophies and might also corresponds to the basic sensory perception-reaction feedback loop appearing in the bio-systems.

These two types of quantum jumps provide a very general classification of conscious experiences and one can even understand at general level the differences between right and left brain. In particular, the allowance of self-generating quantum jumps is crucial for the model of cognition as cascades creating selves, sub-selves of selves,.... such that sub-selves can be interpreted as representations of symbols for the objects of external world.

Passive and active aspects of conscious experience in zero energy ontology

In zero energy ontology all physical states have vanishing total conserved quantum numbers. Zero energy states decompose into pairs of positive and negative energy states localizable at the boundaries of future and past directed light-cones defining causal diamond. In positive energy ontology zero energy states correspond to physical events -say particle scattering. Everything can created from vacuum so that one can avoid frustrating questions such as *What are the total conserved quantum numbers of the Universe?*.

The formulation of quantum TGD in terms of zero energy ontology forces to identify the counterpart of S-matrix of particle physics as M-matrix defining time-like entanglement coefficients between positive and negative energy parts of zero energy state. M-matrix need not be unitary and thermodynamics becomes part of quantum theory if one assumes that M-matrix is a square root of density matrix expressible as a product of positive real square root of density matrix and unitary S-matrix. The notion of finite measurement resolution realized in terms of inclusions of hyper-finite factors of type II_1 leads to the conclusion that the S-matrix is highly unique and expressible in terms of Connes tensor product. This framework leads also to the understanding of p-adic length scale hypothesis and predicts that the time scale associated with the causal diamond corresponds to secondary p-adic time scale $T_p = \sqrt{p}L_p/c$. In particular, electron corresponds to the time scale of .1 seconds: the connection with the fundamental 10 Hz biorhythm is obvious.

What is important that M-matrix is a *property* of zero energy state. M-matrix does not make sense between different number fields so that it cannot be assigned with intentional action. Therefore M-matrix, which is indeed associated with quantum measurement in the most general sense of the world, naturally corresponds to the passive aspects of conscious experience.

In zero energy ontology U-matrix characterizing the unitary process part of quantum jump describes scattering between zero energy states: this is something totally new from the viewpoint of standard physics. Because of the zero energy property, U-matrix can have matrix elements between different number fields if it is expressible in terms of rational numbers or algebraic extension of rationals. Hence U-matrix can can be assigned to intentional action and can correspond to the active aspects of conscious experience.

4.2.5 Self as a statistical ensemble

The sequence of quantum jumps defining self defines also a sequence of completely unentangled quantum states resulting in the state preparation process governed by NMP. This set of states, which grows in size quantum jump by quantum jump, defines in a natural manner a statistical ensemble identifiable as the fundamental realization of the otherwise fictive notion of statistical ensemble fundamental in the formulation of statistical physics. There are actually two statistical ensembles: the first one being associated with the final states of quantum jump and the second one being associated with the

values of zero modes resulting in quantum jump. As far as conscious experience is involved, it however seems that it is the increments of quantum numbers and zero modes which are the relevant statistical variables.

This observation anchors the theory of conscious experience to statistical physics [K3]. For instance, the increments of zero modes resp. quantum numbers are responsible for geometric resp. non-geometric qualia. More precisely, the gradients with respect to subjective time for the zero modes and for the net quantum numbers associated with selves correspond to qualia. One can classify non-geometric qualia to entropy type qualia (emotions in accordance with the fact that peptides are both informational molecules and molecules of emotion); kinestetic qualia (sense of pressure and force and, more generally, gradient of any conserved (with respect to geometric time) quantity associated with self with respect to subjective time); and generalized chemical qualia (rates for the changes of numbers of particles with various quantum numbers). Various entropies associated with self and sub-selves in turn characterize the sharpness of the mental images, and one can relate concepts like attentiveness, alertness and the level of arousal to these variables.

CP_2 time provides a simple estimate for the average increment of psychological time per quantum jump. The occurrence of 10^{39} quantum jumps per second probably means that statistical averaging thermalizes sub-selves completely so that mental images contain no information. Decoherence is the physical counterpart of this process. The manner to achieve macrotemporal quantum coherence is the formation of bound states of several systems giving rise to a larger irreducible self. In this process the zero modes of the binding systems are tranformed to quantum fluctuating degrees of freedom and state function reduction and state preparation do not occur in these degrees of freedom. The sequence of quantum jumps defined by the duration of the bound state behaves effectively as a single quantum jump and no averaging occurs in these degrees of freedom so that the mental image represented by this kind of sub-self stays sharp.

The feed of the metabolic energy takes care that these bound states are destroyed sooner or later. If metabolic energy is not fed to the system, bound state could last for a very long time. Interestingly, there is a reported disease in which patient can live for decades in single frozen moment of consciousness. Perhaps the lack of metabolic feed of energy allowing mental images to last forever is what causes this sickness.

4.2.6 How to define measures for the information contents of conscious experience?

Despite the fact that one cannot write formula for the contents of conscious experience, one can define information measures for conscious experience as differences of the information measures for the initial and final quantum histories. Infinite number of different types of information characterized by information measures for single quantum jump can be found. For instance, the sum of the net entanglement negentropy gains over the steps of the self measurement cascade could define a quantity characterizing net information gain for a single moment of consciousness.

Contrary to the original beliefs, the information measures associated with single quantum jump are not probably very useful for characterizing the information content of self. Since self defines a statistical ensemble, one expects that the information gain of conscious experience should approach zero at the limit when self approaches thermal equilibrium. Thus it seems that the deviation of the average information gain over the quantum jumps defining self from the value of this quantity at the limit when self approaches thermal equilibrium, could be a relevant measure for the information gain of conscious experience. Furthermore, the sequence of quantum jumps defines distributions over zero mode – and quantum number increments, and the deviations of the entropies associated with these distributions from the corresponding entropies in thermal equilibrium state could be used to characterize the information contents of conscious experience. The formation of bound states implies that the system does not thermalize and entanglement entropy in the real context stays small.

The definition above is somewhat problematic. The subtraction of the entropy of the maximally entropic state is somewhat adhoc procedure and need not be even well-defined. It might be that one must just accept that in the real sector the best one can achieve is empty mind free of illusions. The interpretation would be that sensory experience as such can only carry disinformation.

p-adic physics is the physics of cognition and one can wonder whether one might assign a positive entanglement negentropy to some cognitive systems. For p-adic systems for which entanglement probabilities are rational numbers for any sub-system-complement pair, p-adic entanglement entropy

can be regarded as a rational number and can be identified as such as a real number when $log(p)$ is used as a unit of negentropy. With this definition entanglement negentropy can be positive and this kind of states can be seen as p-adic counterparts of bound states containing genuine cognitive information. In p-adic context also $S = 0$ states with vanishing entanglement entropy are possible. The systems with positive entanglement negentropy are ideal for the realization of cognitive quantum computer like systems [H2]. Perhaps frontal lobes have specialized to the generation of this kind of sub-selves besides generating p-adic intentions and transforming them to real actions.

p-Adic-real cognitive entanglement makes sense only if entanglement coefficients are algebraic numbers. In this case one can use a number theoretic definition of entropy and also states with negative entanglement entropy are possible. These states are stable against NMP, have positive definite information content, and give tise to experiences of understanding.

Entropy gradients with respect to subjective time could be used to characterize how the information gain of conscious experience of self changes. These gradients approach zero when self approaches thermal equilibrium. In TGD framework entropy gradients correlate with emotions, which means a somewhat counter intuitive connection between emotions and information gain or loss (consistent however with the fact that peptides are both informational molecules and molecules of emotion [35]). Note that the binding of information molecules to receptors means the formation larger bound states accompanied by the experience of oneness at molecular level (are sex and spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

4.2.7 How selves wake-up and fall asleep?

If the impossibility of entanglement between different number fields is what makes selves possible, the wake-up of the mental image most probably means generation of space-time region with topology different from that of surrounding space-time region. For instance, p-adic space-time regions surrounding real regions with different p could serve as shields allowing real space-time sheets to stay in self state and vice versa. Topologically the death of the mental image would mean a phase transition in which the topology of the mental image becomes that of the surrounding space-time region or a fusion with a larger region when it forms an extrusion through the shielding region. If our sensory mental images are real this could be one of the mechanisms involved. For instance, falling asleep could involve either phase transition or fusion mechanism.

It seems that this characterization is un-necessarily restrictive. Also real space-time sheets are labelled by primes characterizing the p-adic length scale associated with the space-time sheet. The assumption that there is no bound state entanglement between real space-time sheets characterized by different primes is natural since the space-time sheets communicate only via wormhole contacts surrounded by elementary particle horizons (wormhole contacts have induced metric with Euclidian signature). With this characterization self corresponds to a set of disjoint space-time sheets characterized by the same prime and irreducible self corresponds to a set of space-time sheets characterized by same p-adic prime and fused together by join along boundaries bonds. In particular, real selves can topologically condense on real selves. With this definition the wake-up of an irreducible self can be due to the emergence of a new space-time sheet, the change of the number field characterizing the space-time sheet, or the splitting of the join along boundaries bonds connecting two space-time sheets leading to a decay of a bound state. Falling asleep corresponds to the reversals of these processes.

The function of sleep would be obvious: when mental image ages, its entropy grows and it becomes fuzzy. One manner to avoid this is a temporary death and re-incarnation as a brisk and young mental image. Of course, also we are mental images and the reason for why we die physically might be precisely this. This would encourage to believe that our bodily sub-self (also mental image!) has a duration determined by our lifetime. Second manner to achieve this is to somehow reduce the entropy growth rate or change its sign. The formation of bound states is the fundamental mechanism of this kind. Very probably biosystems are full of mechanisms tending to achieve this kind of state. For instance, de-differentiation of cells to stem cell stage would be an example of this mechanism. The basic function of metabolism would be to help this fight against second law. Note however that this war against second law could occur both at the level of mental images and the matter at atomic space-time sheets and it might be that a neglilible fraction of metabolic energy is needed to to keep our mental images sharp. An interesting possibility is that second law holds true at a given space-time sheet only in time scales longer than the corresponding p-adic time scale. This would mean that the

typical duration of the bound state is of order of p-adic time scale (also secondary, tertiary, etc... p-adic time scales are possible).

4.2.8 Self has genuine subjective memory

That the contents of consciousness are determined totally by the initial and final states of the quantum jump was the basic assumption of TGD inspired theory of consciousness for a long time. A heavy objection against this assumption is that, since the contents of consciousness are determined by the initial and final state of the quantum jump, it is not possible to have any genuine memories about previous quantum jumps. One could even argue that in this kind of universe it is not possible to discover the idea of quantum jump as a moment of consciousness. One can imagine a possible way out of this problem. The ensemble of mindlike space-time sheets performing quantum jumps with time dependent average outcome makes in principle possible to have memories about earlier experiences by re-experiencing the thoughts generated by them. Of course, only simulations are in question and one could argue that this is not enough.

The proposed identification of self however forces to reconsider this assumption. Nothing precludes the possibility that a connected series of the sequential quantum jumps performed by self after its "wake-up" integrate to single conscious experience, the subjective history of self. A natural additional hypothesis is that the integrated experience is kind of an average over the quantum jumps, possibly a weighted average such that weighting favours the latest quantum jumps. This hypothesis guarantees the objectivity and reliability of sensory experiences and thoughts despite the fact that the outcomes of the individual quantum jumps are not predictable. This hypothesis would provide strong realization for the idea about continuous streams of consciousness and realize self as an extended object in subjective time. The assumption is supported by the resolution time of the visual experience: if the interval between sequential pictures is shorter than .1 seconds, pictures are not experienced as separate ones. This is indeed expected to happen if given visual sub-self (mental image) contains experience about several pictures leading to temporal averaging.

A possible identification of the subjective memory is as immediate short term memory. Duration of immediate short term memories is typically fraction of seconds and this would suggest that the duration of self might be typically of the same order. This is of course in conflict with the intuitive view that our wake-up consciousness is continuous. Actually an entire hierarchy of subjective memories is predicted. Note that a conscious memory about our good and not so good deeds and great moments of life could live even after our physical death as an abstracted average self at the next level of the hierarchy as long as this higher self stays alive!

The sub-selves of self can form subjecto-temporal sequences. Since no averaging over these sub-selves is performed, it is possible to remember the digits of phone number. Therefore the temporal resolution of sensory experience of about .1 seconds does not pose any bound for the duration of our self (as I have erraneously claimed in some contexts). A periodic sequence of sub-selves defines a conscious clock and it seems that living systems are full of this kind of clocks. Examples of mechanisms probably inducing conscious (not necessarily conscious-to-us) clocks are retinal microtremor at frequency of 80 Hz, muscle tremor and presumably also EEG oscillations. Musical rhytms obviously create this kind of conscious clocks. Also a cat which is preparing to catch a mouse develops a rhytmic movement: the conscious clock presumably helps it to coordinate its own motions appropriately.

Mindlike space-time sheets which can also have timelike separations and ensembles of sub-selves in the geometric time axis are possible. A self containing these kind of sub-selves presumably experiences the sub-selves of the geometric past as memories. This mechanism provides very attractive realization of long term memory.

The temporal integration of the conscious experiences to single experience conforms with the quantum-classical correspondence principle in the sense that the integration corresponds to the necessary generalization of 3-surface to association sequence consisting of minimal number of spacelike 3-surfaces with timelike mutual separations. These 'association sequences' provide symbolic representations for the quantum jump sequences defining contents of consciousness of self and make possible organized view about space and time. They would also make possible self reference in the sense that it is possible to be conscious about.... p-Adic nondeterminism in turn allows cognitive representations about the contents of consciousness and also helps to build self model based on p-adic space-time sheets.

4.2.9 Self as an observer

In standard physics context observer is something external to the physical system. In principle physical theory should however also provide a natural description of the observer. System with self can be regarded as an observer. The hypothesis about subjective memory provides the observer with memory. Natural, but not absolutely necessary, hypothesis is that this memory performs kind of quantum average about the experiences of individual quantum jumps and hence stabilizes the experiences of observer. TGD based concept of psychological time implies that the entire space-time surface is populated by mindlike space-time sheets giving rise to observers.

This might mean that geometric future contains physicists who have long ago (with respect to subjective time) developed unified theories we are only dreaming about! Note also that these grand unified physicists could have subjective memory extending possibly to the moment of big bang! Whether this is really the case depends on wheter the p-adic-to-real phase transition front defining the value of the psychological time is universal or only local and restricted to our biosphere. Fractality of consciousness would suggests that there is a fractal hierarchy of these phase transition fronts inside phase transition fronts.

4.2.10 Self and the emergence of psychological time and its arrow

The explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

4.2.11 Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD

inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configurations space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

4.2.12 Space-time as a 4-dimensional living being

The new concept of the psychological time means a dramatic generalization of the standard view about subjective existence. mindlike space-time sheets are distributed everywhere around material space-time sheets of infinite time duration and all of them can participate in a given quantum jump. Therefore one can say that the entire space-time is a conscious, living being. Civilizations of the geometric past and future exist simultaneously with us. We are members of a four-dimensional society in the sense that our actions affect the life of selves of both geometric past and future since each quantum jump performed by us changes the macroscopic space-time in both past and future.

Everyday experience suggest that the geometric past is relatively rigid. Although changes in a given time scale can occur below some length scale, changes in larger scales are probably rare. Sensory representations could however change and this could explain the instability of long term memories. Turning point decisions are probably not possible for the me of my geometric past: otherwise dramatic quantum jump changing completely my personal identity would occur.

The notion of the four-dimensional body (both material and field bodies) becomes natural and only the concentration of consciousness to the psychological now during the physical life creates the

illusion that the reality corresponds to the time=constant snapshot of the time evolution. Near death experiences indeed support the view that life is experienced as a temporal whole when the dominating contribution from the p-adic-to-real phase transitions and sensory input is absent. 4-dimensional body is not static but changes quantum jump by quantum jump which suggests that life is like a four-dimensional sculpture which is gradually refined. We in our youth now experience in slightly more deeper manner and live in a society having slightly higher level of moral. Note that the newest view about arrow of time means that the the creation of this 4-D sculpture can be also seen as classical time evolution in the first approximation.

4.2.13 Self, evolution and self-organization

The generalization of the notion of unitarity forced by the introduction of the p-adic numbers [H1] implies that time evolution by quantum jumps corresponds to a sequence of p-adic primes increasing in a statistical sense. This means that the concept of nearness defining the effective topology becomes gradually more refined, the complexity of the universe increases, and the maximal information contents of the conscious experience increase in the long run (like $p \times log(p)$ or at least as $log(p)$ as a function of p-adic prime characterizing the system). This is nothing but evolution. NMP, which states that entanglement negentropy gain maximal for allowed quantum jumps, enhances this tendency.

Quantum jumps between quantum histories make also possible genuine quantum self-organization. The concept of self-organization gets quite new additional meaning in TGD framework. Self-organization means also evolution of self-hierarchies. Self-organization by quantum jumps can be regarded as a hopping in the zero modes characterizing the macroscopic aspects of the space-time surface. Each self is a dissipative system which ends up to some asymptotic self-organization pattern in the presence of the external energy feed (and even without it). Dissipation is the ultimate Darwinian selector picking up the winning selves as favored self organization patterns. Since sub-selves correspond to mental images, the immediate implication is that also memes are subject to similar selection. For instance, the formation of long term memories and habits could be understood as a formation of surviving sub-selves.

The TGD based realization of the quantum criticality, besides making macroscopic quantum systems possible, in a well-defined sense maximizes the intelligence and complexity of the universe [H7]. In biosystems a concrete realization of quantum criticality is in terms of magnetic flux tube structures and electret type space-time sheets representing solutions of field equations dual to each other and having opposite signs of Kähler action density.

TGD universe is quantum spin glass and this adds additional aspect to the self-organization process. For instance, the energy landscape of the spin glass is fractal like structure containing valleys inside valleys and provides an ideal dynamical memory mechanism. Spin glass degeneracy also provides a mechanism increasing the lifetimes of the bound states formed by join along boundaries condensates and thus could allow macrotemporally quantum coherent states able to perform quantum computation like activities. The impossibility of macrotemporal quantum coherence is indeed the main objection against quantum theories of consciousness.

This looks nice but one can ask whether the framework of standard quantum theory is all that is needed to formulate quantum TGD and the notion of quantum criticality. The original motivations for introducing the hierarchy of Planck constants and the generalization of the imbedding space to a book like structure having as pages the almost copies of the imbedding space were purely physical. Now it seems that this generalization is required by a need to have a proper formulation of quantum criticality of TGD Universe. The hierarchy of Planck constants leads to a whole bundle of ideas about quantum biology and evolution of consciousness and also to a detailed model for how living matter can perform topological quantum computation like activities [E10, L6, L7, J7].

4.2.14 Self as a moral agent

One could argue that the randomness of the quantum jump means that moral choices are impossible. Volition can however be associated with the selection of an intention realized in p-adic-to-real phase transition.

Evolution, both p-adic evolution and evolution as increase of the Planck constant, defines the fundamental value of the quantum ethics. The selections which tend to increase the value of the

p-adic prime represent good deeds since they mean evolution. The values of this ethics are not in the physical world but in the quantum jumps defining the subjective reality.

Selves can make plans since they have 4-dimensional geometric memory (conscious experience contains information about a *four-dimensional* space-time region, rather than only time=constant snapshot, and p-adic space-time sheets give rise to a "prophecies", predictions for the future and past, which would be reliable if the world were completely classical). Selves can make decisions and select between various classical macroscopic time developments. Selves are able to remember their choices since they have subjective memories about the previous quantum jumps and also geometric memories providing representations of the past. Thus selves are genuine moral agents if they can experience directly that increase of p is 'good' and decrease of p is 'bad'.

4.3 Binding of experiencers and binding of experiences

One can consider two forms of binding: binding of *experiencers* and binding of *experiences*. The original hypothesis was that binding of experiencers by entanglement is all that is needed but it seems that the notion self leads to the self experiences its sub-selves as mental images and to the summation hypothesis stating that the experiences of sub-systems of sub-self sum up to single abstracted experience at the level of self. It must be emphasized that there is also a third meaning of binding in which various attributes are assigned with the object of the perceptive field: this binding however reduces to the entanglement of sub-selves (sub-experiencers). A concrete model for binding understood in this sense is discussed in [H4].

4.3.1 Binding of experiencers by entanglement

Quantum entanglement provides a mechanism for binding experiencers to a larger experiencer, and thus also a fusion of mental images to single mental image. Quantum entanglement was originally proposed as a solution of the binding of experiences but it seems that entanglement must form wholes from parts such that parts disappear in the process. Certainly this kind of binding is also an essential part of consciousness and direction of attention presumably corresponds to the division of entangled whole into 'figure and background'. In any case, entanglement 'kills' entangling sub-selves and change of the higher level experience to a holistic experience with no divisions and separations. A possible example of the binding of sub-selves is the binding of right and left visual fields to single visual field. The visual fields can sometimes fail to bind: this should result from the failure of the corresponding sub-selves to generate mutual entanglement with sufficient rate.

Bio-feedback is a well-established phenomenon in which person receives feedback from the behaviour of, say, single neuron and learns to control voluntarily its behaviour. A possible mechanism of bio-feedback is based on quantum entanglement generated between the (sub)self of the person and the self of neuron. Socio-feedback at the level of entire society could be important mechanism making possible to establish moral and behavioural rules of the society: this socio-feegback is perhaps the basic function of sleep.

4.3.2 Entanglement and altered states of consciousness

The succesful applications of p-adic physics give good reasons to believe that also real space-time regions can be a labelled by p-adic primes. This prime perhaps labels the local p-adic topology to which the real region can be transformed easily (, that is is near criticality against this kind of transition). If this is the case then also real space-time regions form a hierarchy labelled by p-adic primes.

The p-adic prime characterizing a real or a p-adic space-time region can change and this change might be interpreted as a phase transition. It however seems that in p-adic case this phase transition destroys the old self and creates a new self. In the real context the situation might be different and this transition might be experienced as a kind of enlightment experience.

The entanglement of sub-self with a sub-self of some higher level self means sharing and fusion of mental images and might provide a Golden Road to the understanding large number of altered states of consciousness. If self corresponds to a real space-time region, it can have a p-adic space-time region characterized by arbitrarily high p-adic prime p. If this cognitive sub-self entangles with a cognitive

sub-self of some higher level self, it is possible to have mental images with an arbitrarily high positive entanglement negentropy. Certain kind of personal moral and intellectual evolution is believed to be a prequisite for enlightment experiences. The increase of the p-adic prime of sub-self meaning cognitive evolution indeed has interpretation as this kind of evolution.

Also the entanglement of a real sub-self with a real sub-self characterized by a larger p-adic prime can give rise to an enlightment experience. An alternative mechanism of self-extension in real case is simply the increase of the geometric size of self without entanglement with higher level self. This is quite possible and could also lead to an increased span of the geometric memory.

Examples of alterned states of consciousness are transpersonal experiences and enlightment experiences in which one identifies with some larger consciousness. For instance, prenatal experiences could result from the entanglement of sub-self with subsef having a temporal extension of order lifetime and having kind of abstracted experience about the period of life before birth. Experiencing the sorrow of all mothers of dead soldiers could involve the entanglement of sub-self with a collective mental image resulting in the entanglement of mental images of very many mothers. If the notion of field body having size at least of order Earth size makes sense, this idea does not look so implausible anymore.

What happens for our self during sleep? There are several options.

1. We really lose consciousness during sleep.

2. Long term memory representations are not constructed during sleep so that we do not remember anything about sleep time consciousness except when we wake up from REM sleep: note that in this case the memories fade rapidly in accordance with the idea that long term memories are not constructed. Synchronous hippocampal theta is indeed absent during sleep.

3. We are able to remember what happened during sleep only if we are asleep. Perhaps synchronous theta and delta oscillations are involved with the construction of memory representations experienced only during sleep. The mirror mechanism of long term memories might allow this kind of possibility.

The first option is the 'obvious' one. Perhaps the function of sleep is to make possible formation of larger collective selves. During sleep our selves could entangle to form kind of a stereo consciousness representing human condition. This process could involve either phase transition changing local topology or a formation of join along boundaries contacts with much larger space-time sheets characterized by same local topology. This mechanism could make possible subconscious communication between the members of society and also establish conscience and moral. The topological field quanta associated with photons generated by EEG during sleep have frequency smaller than 7 Hz [L1]. This suggests that the higher level selves in question correspond to these topological field quanta and thus have a wake-up time of order .5 seconds during delta wave sleep. Therefore thoughs would not disappear but would become more abstract during sleep.

Physical death could mean the loss of sub-self representing body image and involve extension of the physical self: this would explain out of body experiences and near death experiences (person near death looking his body from outside). In fact, an attractive hypothesis, motivated by the quantum model of brain, is that the topological field quanta associated with photons generated by EEG currents having size of order Earth by Uncertainty Principle, could correspond to highest selves in our personal self hierarchy. Also magnetic flux tube structures associated with body and brain could have similar sizes and serve as a magnetic body [H4]. In physical death these ELF selves could continue to oscillate as Schumann resonances in the wave cavity between Earth's surface and ionosphere interacting with magnetic flux tube structures!

4.3.3 Summation hypothesis and binding of conscious experiences

The hypothesis about self leads immediately to ask how the experiences of self are determined. The geometric picture suggests strongly that self has sub-selves having their own experiences and these sub-selves correspond to space-time sheets or islands of different number field inside self. An attractive working hypothesis is that the experiences of sub-selves somehow sum up to a total experience of the entire self: various sub-selves would naturally represent separate mental images, such as various objects of the sensory experience and words and other substructures of linguistic though. The self Y

containing self X would in turn form some kind of abstraction or average $\langle Z_i \rangle$ about sub-selves Z_i of X.

This kind of mechanism would explain why we do not experience experience of individual neurons, microtubules, DNA:s, etc... as huge multitude of separate experiences. Combining summation hypothesis with the hypothesis about subjective memory (described in previous section), one can understand self as an object having genuine extension in subjective time. In particular, it is possible to identify short term memory as a subjective memory. Also temporal average in geometric sense is possible since mindlike space-time sheets can have also timelike separation.

A possible problem for the hypothesis of self and summation hypothesis is provided by split brain patients. It seems that in most serious cases either right or left half dominates the behavior of the split brain patient and communication between brain hemispheres is lacking. It is known that brain hemispheres learn to communicate indirectly. Thus one can wonder whether the hypothesis about summation of the right and left selves to higher self consistent with the behaviour of split brain patients. there are several possibilities.

1. The dominance of either hemisphere is completely analogous to the dominance of a person over another one. This could partially explain why either left of right hemisphere dominates. The sudden changes of personality can be understood as result of different cognitive specializations of the two hemispheres. The lacking information transfer between hemispheres explains why right and left brain behave so differently (to the extend that they can have different future plans!). It is well known that in early childhood hemispheres behave as separate personalities and certain period in the learning of language seems to involve communication between brain hemispheres: left hemisphere comments what right hemisphere is doing. This kind of direct communication usually ceases, when the direct physical connection between brain hemispheres has developed. One can of course ask what 'dominance' means. A possible definition is based on the notion of self hierarchy. Dominant hemisphere has larger p-adic prime and dominated hemisphere entangles with some sub-self of the dominant hemisphere. The question is whether the join along boundaries bonds needed to achieve this entanglement are there in case of split brain patients.

2. The two hemispheres are not simultaneously awake in the sense of having self: this would mean also the absence of the higher self. The length of time-interval during which hemispheres are awake could be rather short. This might apply occasionally also to healthy persons. In fact, it is known that in case of dolphins the situation is just this. This kind of mechanism together with impaired communication between hemispheres could explain sudden changes of the personality.

3. For split brain patients the absence of physical connection between hemispheres makes impossible quantum entanglement binding the hemispheres together to form single coherent whole and the body of the patient is inhabited by two persons.

4.3.4 Binding geometrically

Quantum-classical correspondence principle suggests that the concept of binding should have counterpart at the level of space-time geometry. The gluing of the space-time sheets by topological sum to larger space-time sheets creates nested hierarchical structures. This suggests that the binding of the *experiences* that is mental images to mental images experienced by same self corresponds geometrically to the gluing of the material space-time sheets of sub-selves to the material space-time sheet of self by topological sum operation involving formation of 'wormhole contacts'. One could also require that sub-selves have p-adic prime smaller than that of self but this assumption is not absolutely necessary: certainly the local topologies must be different.

The binding of *experiencers* in turn would naturally correspond to the glueing of 3-surfaces together along their boundaries by join along boundaries bonds (actually topological sum for boundaries). In fact, join along boundaries mechanism has been identified as the mechanism leading to the formation of macroscopic quantum systems at the level of material space-time sheets. Join along boundaries bonding would make possible to get entangled with selves at the same level of the p-adic hierarchy of selves but not at different levels unless rational bound state entanglement between different number fields is possible. If experiencers are sub-selves, the formation of join along boundaries bonds means the fusion of mental images: basic example is the fusion of right and left visual fields to single visual

fields and giving rise to stereo vision. Also the mental images of separate selves can fuse and this means sharing of the fused mental image.

The identification of the geometric counterpart of self with mindlike space-time sheet makes it possible to identify uniquely the subjective history of the self as induced by its space-time history. For instance, larger mindlike space-time sheets at the higher level of the hierarchy could contain or generate wholes making possible for smaller mindlike space-time sheets to form join along boundaries bonds. This mechanism would provide a concrete geometric realization for the communication between different levels of the hierarchy of selves. For instance, long term memories could become conscious through this kind of mechanism. Also the question what happens for self after physical death could reduce to the question what happens to the mindlike space-time sheet of self. For instance, a fusion to some mindlike space-time sheet, whose p-adic prime characterizes the fate of the self in future (in the sense of subjective time) life, could take place.

There are several arguments supporting the importance of join along boundaries bonds between matter- and mindlike space-time sheets and also demonstrating that the two views need not be mutually conflicting. It is however clear that one should not take the idea about the importance of join along boundaries bonds to extreme.

1. The dynamical realization of the self hierarchy as a master-slave hierarchy of various kinds of super conductors [I4, I5] relies on the identification of the join along boundaries bonds between the space-time sheets belonging to various levels of hierarchy as Josephson junctions. The "biofeedback" made possible by the join along boundaries bond makes it possible for the selves at higher levels of the hierarchy to experience what it is to be lower level self. In particular, our immediate sub-selves are represented by topological field quanta of ELF em fields associated with EEG frequencies and thus have size of order Earth's circumference by Uncertainty Principle, whereas sensory experiences involve in essential manner entanglement with sub..sub-selves with size scale of neuronal circuits.

2. One could argue that mindlike space-time sheets become actually material space-time sheets in the gluing along boundaries process since energy and matter from the material space-time sheets flow to the mindlike space-time sheets freely through join along boundaries bonds. This objection can be circumvented. 'Free' mindlike space-time sheets could correspond actually to pairs of space-time sheets with opposite time orientations such that various classical fields are generated by rotating gauge charged wormhole contacts on the boundaries of these space-time sheets. These two space-time sheets have opposite classical energies so that the net energy for the system vanishes. If this kind of a pair is glued to a material space-time sheet by join along boundaries bonds connecting the mindlike space-time sheet with a positive time orientation to the material space-time sheet, continuity requires that classical fields on the two mindlike space-time sheets of the pair have similar strength. Thus a cognitive representation of the material space-time sheets by a direct mimicry results [J5]! In this view mindlike space-time sheet pairs would realize phycisist's version of the computer scientist's universe as consisting of Turing machines emulating other Turing machines.

3. If one regards the mindlike space-time sheet with a positive time orientation as a part of the material space-time sheet, one can also regard negative energy mindlike space-time sheet as a mindlike space-time sheet glued near to the boundary of the material space-time sheet by topological sum contacts! Mindlike space-time sheets would obtain classical information only about the *boundary regions* of the material space-time sheets. As a matter fact, our conscious experience actually does just this: whether this is mere coincidence, must be left open here. One could argue that this kind of restriction is not consistent with the idea that the universe is maximally intelligent. Of course, mindlike space-time sheets appear in all length scales so that this restriction is perhaps not a problem. An open question indeed is whether cell membranes could be regarded as two-sheeted structures glued by join along boundaries bonds to the space-time sheets representing cell interior and exterior. If this is the case then cell membrane space-time sheet would represent space-time sheet with negative time orientation and negative classical energy.

4. The localization of cognition to boundaries, if taken to extreme, might force to modify the basic ideas about the identification of the quantum correlates of the sensory qualia and thought. For

instance, the idea that cognitive neutrino pairs would correspond neutrino and antineutrino space-time sheets glued to the boundaries of a material space-time sheet does not seem to make sense. Rather, the members of the cognitive neutrino pair are both glued to material space-time sheets of a positive time orientation and cognitive antineutrinos are delocalized in the entire cell membrane space-time sheet. Note that this argument does not bite if one assumes that the members of cognitive neutrino pair do not entangle with material space-time sheet at which they topologically condense.

4.3.5 General structure of conscious experience

Combining summation hypothesis and the hypothesis about subjective memory one can understand quite a lot about the phenomenology of consciousness.

Experiences of self as abstractions and averages

Summation hypothesis means that self forms abstractions about experiences of its sub-selves: this means that the separate experiences of sub-sub-selves are replaced with some kind of average experiences. NMP states that the experiences of sub-systems and sub-selves are maximally interesting in the sense that each step in the cascade of self measurements representing state preparation yields maximal entanglement negentropy gain. Self is an ideal 'boss' since it forms abstractions about the most interesting potential experiences. Note that abstraction hierarchy is analogous with the hierarchy of higher level computer languages and with the hierarchy of modules of a computer program.

If subjective memory is possible in the sense that self integrates to single experience all the conscious experiences after the the moment when it 'wake-up', one could expect that self performs automatically also time-averaging: in biologically interesting time scales of about one second the averaging would mean use of 'temporal' ensembles with something like 10^{38} experiences! Thus the reliability and stability of experiences is reached already at the level of single irreducible self. Subjecto-temporal sequences of sub-selves experienced as separate mental images in turn make it possible to have structured experiences so that one can remember digits of a phonenumber.

Statistical aspect could be involved with sensory experiences also in the sense of ensemble averaging. For intance, various cones of retina are sensitive to different wavelength regions (red, green, blue) and their experiences must correspond to different colors. Therefore our color experience, which corresponds to average color, should be abstraction about experiences of a small group of retinal cells. Ensemble averaging could be present in case of sense such as temperature and pressure sense. Also temporal averaging with respect to *geometric* time would be made possible by mindlike space-time sheets and could be present.

Parts, wholes and entanglement

The basic feature of higher level cognition is formation of wholes from parts. Quantum entanglement between selves representing parts provides an attractive model for this process. Selves represent symbolically the components of conscious experience, say letters of the word: in absence of entanglement between these 'letter' selves the sum experience is set of letters whereas higher level experiences is about average letter. If sub-selves get entangled, there are no sub-self-experiences and sum-experience is about the word as is also the higher level experience. The application of this hypothesis to the modelling of music experience will be considered later. The hypothesis will be also applied to explain paradoxal result of certain experiment testing righ-left brain differences.

What is the most general structure of the self hierarchy?

Self hierarchy need not be a simple nested hierarchy represented by a tree or a union of disjoint trees. On the other hand, arbitrary connections between the levels of the hierarchy imply paradoxal situations. Simple questions help to get a grasp on the problem. What happens if the branches of a given tree or separate trees are connected? What kind of connections are allowed without ending up with a paradoxical situation in which one cannot tell which one of the two selves is the sub-self of another self. The appearance of loops in the self hierarchy certainly leads to this kind of paradoxal situations since self can become its own sub-self.

This kind of paradoxal situations are avoided if only those selves which belong to the same level of the self hierarchy can fuse so that one has a collection of trees which can have horizontal connections (both intra- and inter-tree) between the nodes belonging to the same hierarchy level. The presence of a horizontal connection means that two separate selves share the mental image resulting in the fusion. Of course, the same mental images could be shared by an arbitrary number of selves, and this could be one of the mechanisms making possible both social behaviour and the propagation of memes. Also a genuine communication might necessitate sharing of the mental images rather than being only active sending and passive receival. Sharing of mental images might occur also in hypnosis and various remote mental interactions and identification phenomena ('experiencing the sorrow of all mothers lost their son in war'). Long term memory could also involve the sharing of the same mental image by the selves of the geometric past and geometric now.

The paradox-free situation is achieved if the selves are arranged according to the local space-time topology so that all p-adic selves with given prime are at the same level in the hierarchy and real selves ($p = \infty$ formally) are at the top of the hierarchy. Sub-selves must always have smaller p than self and real selves are at the top. Quantum entanglement allows only fusion of selves at the same level of the hierarchy and thus having the same local topology labelled by the p-adic prime p. Algebraic extensions of p-adic numbers presumably bring in more refined sub-hierarchies for a given value of p and they could correspond to various levels of mathematical cognition. This hierarchy is represented by a collection of trees which can have horizontal connections joining nodes at the same level. The sharing of mental images by the fusion of sub-selves is thus possible. The level of the self in the hierarchy can change and is induced by a quantum jump in which the local number field (p-adic or real) associated with the space-time sheet representing self changes from R_{p_1} to R_{p_2}.

Anyone can do a simple but thought provoking experiment suggesting the presence of the macroscopic quantum entanglement at the level of brain and a change of the level of sub-self in the self hierarchy. Look at a mirror, direct your attention at your left eye, and redirect the gaze to the right eye. What you find that it is impossible to perceive the change in the direction of the eye gaze.

This might have a trivial explanation: the change in the direction of the gaze could be too small to be perceived. But also quantum entanglement might be involved. What must be crucial is that the change of the orientation of the eyeball is caused by brain itself rather than some external agent as in the case of a moving object belonging to the external world. The changing orientation of an external object of the perceptive field is consciously perceived by comparing it with the orientations of other objects of the perceptive field. That is, self compares its sub-selves (mental images) with each other. When the direction of the gaze is changed, quantum entanglement between self and the visual-cognitive mental image representing eyes is generated to achieve the needed motor response. The visual-cognitive sub-self representing eyes is temporarily lifted to a higher level in the self hierarchy and becomes part of higher level self (the change of the local number field is involved). The other sub-selves at the same p-adic level cannot anymore serve as a reference against which the changing orientation would be perceived. Since self cannot compare itself with itself, it cannot perceive visually the changing direction of the gaze.

Objectivity of conscious experiences

Understanding the objectivity of conscious experience has been longstanding problem of TGD inspired theory of consciousness. The contents of conscious experience can depend on both initial and final states of the quantum jump. Quantum theory does not necessarily tell how the contents of conscious experience are determined.

1. Are the contents of sensory experience defined by the final state of the quantum jump?

The most optimistic assumption is that the contents of the conscious experience depends on the final state only or contains precise information about both initial and final state simultaneously. The standard quantum measurement theory would suggest that the measured quantum numbers of the final state could determine the contents of conscious experiences but this is obviously purely formal guess. Quantum jump involves localization in zero modes and thus quantum measurement of zero modes. If the localization is complete (in discrete zero modes this need not be the case), the information about the position of the Universe in configuration space zero modes is maximal. Hence the information gain in zero modes defined as the difference $I(\Psi_f) - I(U\Psi_i)$ [H7] is certainly nonvanishing even for states remaining invariant in quantum jump ($\Psi_f = \Psi_i$).

Hence one could say that quantum jump can give objective information in zero modes and that the information contained by geometric aspects of the sensory experiences might be information about the zero modes of the final state. This conclusion would be in accordance with the fact that zero modes correspond to order parameters characterizing the classical features of the space-time surface. The contents of the geometric aspects of the experience might be determined by the location in zero modes for ordinary vision, sense of touch and sense of smell: of course, the location would occur simultaneously for a large number of neurons and our experience would be averaged over these experiences.

Consider now the objections against this hypothesis. Zero modes form an infinite-dimensional space analogous to symmetric space and its should be possible to experience only their increments since configuration space geometry by no means distinguishes between various values of zero modes. Also the very notion of subjective experiencing as associated with quantum jumps favours the idea that it is only increments which are experienced. This principle could be seen as some kind of principle of relativity at the level of conscious experience.

2. Are the contents of conscious experience determined by both initial and final states of the quantum jump?

A more pessimistic, and presumably realistic, assumption is that only some kind of comparison of initial states Ψ_i and final states Ψ_f, or more probably, comparison of the zero mode localization $Loc(U\Psi_i)$ of the state $U\Psi_i$ and the state Ψ_f is in question. This would suggest that information about initial and final states is only relative information, information about differences, and that absolute information about state is impossible to achieve. This would mean that the increments of quantum numbers in quantum phase transitions and increments of zero modes determine consciousness experience. Certainly this is in accordance with the view that subjective existence corresponds to quantum jumps and objective existence corresponds to quantum states.

Considerable support for this line of thinking comes from the model for the quantum correlates of the sensory qualia [K3] in which various geometric and nongeometric sensory modalities are characterized by the increments of various quantum numbers and of zero modes in quantum jumps. In particular, magnetic transition frequencies correspond to the differences of the initial and final state energies and indeed depend on both the initial and final states of the quantum jump.

Consider now various definitions of objectivity.

1. The strongest form of objectivity requires that sub-system state remains essentially unchanged both in the informational "time evolution" U and in quantum jump. This kind of ideal situation might be realized in 'that-which-is' experiences. The fact that various information gains for conscious experiences are differences for information gains associated with the initial and final quantum histories and vanish at the limit when state remains unchanged, supports the conclusion that the knowledge provided by 'that-which-is' experiences cannot be regarded as information but means only direct experiencing of what it is to be that particular state. This would suggest that we are doomed to live in Maya basically. In accordance with this pessimistic view one could interpret information gains as measures for how much illusions are reduced in the experience.

2. The requirement that state remains invariant in statistical sense provides a weaker form of objectivity. If one assumes that all the experiences of self after wake-up integrate to single subjective time-continuum, quantum statistical determinism is automatically achieved in biologically interesting time scales of order second and statistical objectivity is achieved since the number of quantum jumps can be as high as 10^{38} per second. If one does not assume subjective memory, one must assume that self consists of subensembles of identical sub-selves. One can represent an objection also against this view: at the limit when the statistical ensemble representing self is thermalized the experience does not fluctuate but the price paid for this is that mental image is completely thermalized and has no information content. Thus it would seem that there is a competition between information content and reliability of conscious experience associated with self. Too short time series is not reliable, too long time series does not give information at all. Formation of bound states allows to effectively bind large number of quantum jumps to single quantum jump with duration of the bound state so that information is not lost totally.

4.4 Some applications at brain level

4.4.1 A simple model for cognition

The hierarchy of selves and summation hypothesis allows to construct a very general model for cognitive processes including as a special case thinking, analysis of visual experience, and language. In nutshell: cognitive process could be regarded as cascade like process leading to a generation of selves followed by generation of sub-selves for these and so on. Quantum jump becomes the building block of cognition and thought but is not sufficient alone. p-Adic space-time sheets as fundamental cognitive representations providing geometric correlates for thoughts, intentions, plans, etc.. are a fundamental element of cognition. In the following considerations, which date back to the time when I had not yet realized the proper meaning of the p-adic physics, this aspect is not taken into account. It is of course a matter of definition what one regards as cognition.

Two modes of consciousness

Self can be in two modes of consciousness. Irreducible self having just single mental image in a state of oneness must experience 'whole-body consciousness', state of one-ness. These states of consciousness might correspond to the mystic experiences described by mystics like Krishnamurti. The life long training of yogis and meditators could help to achieve skill to induce phase transitions eliminating the sub-selves representing mental images representing sensory input and thoughts. There are no dissipating sub-selves during these experiences and hence one might argue that neurons, etc... do not get older nor suffer irreversible changes. Reduced dissipation during meditation provides a test for this prediction. The binding energy liberated in the formation of bound state of sub-selves in turn could be used as metabolic energy: metabolic energy would be however needed to destroy the bound state. Whole body consciousness, if it could be generated artificially, could have obvious medical applications and even save lives. For instance, entangling the brain of a victim of brain infarct with his body could hinder irreversible neuronal changes otherwise caused by bleeding in brain!

It seems that these two modes of consciousness could explain wide range of dichotomies of consciousness like rational/mystic, left brain/right brain, masculine/feminine, Western/Eastern, etc... A self consisting of sub-selves, which are dominantly in these opposite modes could form representations about external world as a summary from two highly different world views and perhaps cope better in the survival for fittest. If this is the case, evolution would favour selves which find their opposites attractive: this could be the origin of the sex. Binary systems are abundant in biology. Examples are pairs of microtubules, DNA double helix, lipid layers of cell membrane and cell layers of epithelial sheets in skin and various organs. A possible explanation is that these structures correspond to selves consisting of sub-selves in analytic and holistic modes of consciousness.

Quantum criticality of TGD and existence of selves

The model of cognition provides a new view to the role of quantum criticality of TGD. One consequence of the quantum criticality could be the existence of a lot of sub-systems which are near the critical line at which phase transition changing the local topology (real or p-adic) occurs. TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our cognitive acts would be only part of the cognitive acts of the entire Universe proceeding from top to bottom as infinite trees with branches representing new selves and nodes representing moments of wake-ups for the selves. Or expressing it in the terminology of AI: we would be like subprograms of infinite program represented by entire universe. The presence of higher level selves means that cognitive acts can proceed from the level of even entire biosystem to the level of DNA. This encourages to interesting speculations: for instance, the ideas of Sheldrake about learning at the level of species and even biosphere might find justification [I1].

Thoughts, perceptions, cognitions as sequences of awakenings

Before the discovery of the notion of self, the idea was that thought corresponds to single quantum jump. The idea was that the experienced temporal duration of thought results from the time nonlocality of the contents of thought made possible by temporal duration of the mindlike space-time sheets. One could however claim that temporal extension of mindlike space-time sheets need not explain the

experienced time duration associated with thoughts. The time duration of thought is subjective time duration whereas mindlike space-time sheets have geometric time duration.

Furthermore, it is subjective rather than geometric time which has natural arrow and the arrow of psychological time reflects the arrow of subjective time. Taking also into account that the average increment of psychological time in single quantum jump is extremely small, perhaps only 10^4 Planck times on the average, one must give up the idea that single quantum jump could correspond to single thought. This leaves only one conclusion: single thought cannot correspond to single quantum jump but to a sequence of very many quantum jumps.

Basic cognitive act, identified as a generation and subsequent development of self, corresponds to a cascade like process in which new selves are generated as sub-selves of already generated selves. Thus cognitive act can be characterized by a dynamically generated tree in which each node corresponds to generation of sub-selves of self represented by the branch leading to the node. This leads naturally to a modular structure of cognitive acts analogous to the modular structure of a computer program: starting of subprogram means wake-up of sub-self. Sub-selves cannot wake-up before the self containing them has woken-up and this gives natural time ordering for the execution of these 'program modules'. The decomposition of the sensory experience to modular pieces corresponds directly to the decomposition to sub-selves. Subjective memory makes it possible for main program to experience the entire subjective histories of subprograms as abstracted experiences.

1. The dynamically generated nested inclusion of selves inside selves is crucial for cognitive acts. The most natural interpretation of this process is as analysis, in which initial experience gradually sharpens and gets more and more structured during the decomposition into sub-selves. Sub-selves could be thought as symbols of language or as logical statements or objects in picture: interpretation depends on what kind of cognitive process is in question.

2. In this picture basic elements of conscious experience are sequences of awakenings. In each step several sub-selves of given self can be created. What would happen could be something like follows:

   i) Self A wakes up and begins to perform quantum jumps (perhaps something like 10^{38} per second!).

   ii) Sub-self B of A is generated by a topology changing phase transition.

   iii) Cognitive process proceeds in a cascade like manner starting from the root of tree and going downwards along the tree choosing at each node some branches. For instance, understanding of a sentence would correspond to waking up of large self A representing sentence in its entirety, words its sub-selves B_i, phonemes to sub-selves C_{ij} of B_i, etc... waking-up in this order. Similarly, the act of decomposing the figure to objects and of objects to sub-objects would correspond to a temporal sequence generating selves within selves. Background would be the largest conscious self and objects would correspond to a sequence of selves. Selves C_{ij} and further sub-selves can be generated before generation of next C_{i+1}: this should occur in case linguistic mental image: generation of word self would be followed by the generation of syllables and phonemes and only after this would next word be generated. Time nonlocality of self experience with respect to geometric and subjective time would be essential.

3. Statistical determinism implies reliability if there is ensemble of 'big' selves. If sub-selves make with high probability the same matter-mind type quantum jump repeatedly and if the process of self generation is more or less deterministic, thoughts are reliable. This is certainly possible. Learning as habituation could be possibly understood as a gradual development of highly predictable cascades of selves.

4. The sequential quantum jumps performed by self need not be identical. Quantum statistical determinism in temporal domain could be at work and it is enough that some state is favoured as final state of quantum jump for long enough periods of time. Note also that self experience must be kind of statistical average if subjective memory is possible.

At formal level one could consider the self cascade as a realization of logical implication sequence $A \to B$ as inclusion of sets: $B \subset A$. This would be standard set theoretic realization of Boolean algebra: A implies B when the self representing B is sub-self of self representing A. $A, B, ...$ are

experienced simultaneously as sub-selves of entire self sub-selves of A and B are created later than their predecessors. Logical causation would also correspond to temporal causation. The objection against this idea is that self experiences only its sub-selves directly. A more plausible interpretation of the self cascade is as a representation for an abstraction process representing thoughts about thoughts about... Our poor ability to form statements about statements about ... would correspond to the fact that self experiences only its sub-selves directly. A more plausible realization for logical thinking is as learned associations in which sub-self representing premises of logical statement wakes-up sub-self representing the conclusions of the statement and belonging to the *same* level of self-hierarchy. Neural circuits would represent typically linear sequences of selves waking up in linear order: TGD based model for brain cognition indeed favors this option [H7, L1].

4.4.2 Differences between left and right brain hemisphere

The differences between left and right brain hemisphere are a challenge for any theory of consciousness. In TGD framework one can imagine several mechanisms contributing to the differences between right and left brain hemisphere (these mechanisms need by no means be mutually exclusive). The differences could be related to the number, size and wake-up time of the sub-selves, to the nature of self cascades and even to the manner the sub-selves wake-up. Also the time span and temporal and spatial resolutions of the geometric memory could be different for left and right brain. Linguistic cognition represented by cognitive antineutrinos is in a well-defined sense critical phenomenon and could be more dominant in the left brain hemisphere: one could even say that left brain talks while right brain sings. p-Adic cognitive representations might be more dominating on the left hemisphere: of course, it could also be that the character of p-adic representations depends on hemisphere.

It seems however that the most fundamental characteristic explaining all the listed differences derives from the fact that for MEs in time scales of long term memory right brain hemisphere possesses a reversed arrow of geometric time whereas left brain has a normal arrow of geometric time. For the right brain hemisphere long term memories are episodal memories, re-experiences involving a time-like entanglement with the geometric past and a direct sharing of mental images. Negative energy Z^0 MEs are excellent candidate for the space-time correlates of this entanglement. Left brain generates positive energy MEs and the very low value of the effective phase velocity allows it to communicate non-episodal memories classically.

Linear/parallel dichotomy

The model of cognition [L1] suggests that left brain decomposes to many sub-selves which reside on linear brain circuits and wake up each other sequentially, whereas right brain contains only few sub-selves which correspond to larger brain regions. This would explain linear/parallel and analytic/holistic dichotomies. At the level of subjective experience this means long subjecto-temporal sequences of sub-selves (say words of a sentence) in case of the left hemisphere, and large number of longlived subjectively parallel sub-selves in case of the right hemisphere (say separate items of a picture).

Linear/parallel dichotomy could physically correspond to the dominance of propagating (resp. nonpropagating) EEG waves in left (resp. right) brain hemisphere [M4]. Nonpropagating EEG waves are possible for large brain regions whereas propagating EEG waves are possible only for linear circuits. During nonpropagating EEG phase nerve pulse activity associated with Boolean mind would be be supressed which is consistent with the observation that right brain is less verbal. Also the Combinatorial Hierarchy model for the memetic code suggests that 'Boolean' cognition involving sub-selves which correspond to linear circuits, is more prevalent in the left brain hemisphere.

Left brain seems to be skilled in forming mental images about structures consisting of well defined components whereas right brain can grasp the general shape and size of the structure. This could be understood if left brain represents structures linguistically as associative linear structures consisting of parts represented as sub-selves. Thus structure could be realized as a reverberating neural circuit in which sub-selves representing parts of the structure keep each other awake.

Why right brain hemisphere is less analytic?

The requirement that the number of right brain sub-selves does not require that the depth for the cognitive cascades is small. Thus the notion that right brain is analytic than left brain requires the

additional assumption that right brain self cascades are short. The sub-selves of right brain avoid decomposition into smaller sub-selves if they remain for sufficiently long time in a state of 'whole-body' consciousness. This requires that the entanglement between sub-systems is genereted rapidly enough, perhaps event resonantly, during sequential time developments U.

'One-ness' requirement implies that linear information processing is not possible for right brain below the length scale at which enlightened state endures. Of course, linear processing of information with generation of hierarchy of sub-selves could become possible after the state of one-ness ceases unless sub-selves in question fall asleep. This would mean that sub-self begins to analyze its 'enlightment' experience, when the stimulus giving rise to the experience of one-ness ceases. Note that this picture implies that the metaphor describing states of one-ness as a resonance like phenomenon is more than metaphor. The interpretation for two kinds of cognitive modes is as ordinary analytic intelligence relying on linear information processing and as emotional, holistic intelligence relying on parallel information processing (the states of one-ness in each level of hierarchy are indeed purely emotional since analytic thought is completely absent).

Why left brain talks and right brain sings?

That left brain talks whereas right brain (almost) sings is more than a loose metaphor: it is known that people who have left brain injury and cannot talk can sometimes express themselves by singing. Linear-parallel dichotomy would suggest that left brain is specialized to subjecto-temporal sequences of parallel small-sized mental images of short duration (say words of speech) whereas right brain is specialized to large selves formed by the fusion of parallel sub-selves formed by, say, separate notes of music which can last long time and have no linguistic content. Although the notes of song are heard one in time, they would continue to live in right brain as parallel mental images and make possible to experience the melody as sad or joyful.

This could be due to a neuronal specification: according to the model of cognition [L1], in the left brain the cognitive inputs from the auditory pathway to the association regions could consist of memetic codewords with fixed Z^0 magnetic transition frequency corresponding to the frequency defined by the duration of the nerve pulse. In the right brain hemisphere the inputs from the auditory pathway to the associative region could correspond to varying Z^0 magnetic transition frequencies. These frequencies could be above or below the audible frequency range.

At the deeper level the difference between right and left brain hemispheres could reflect their different roles in the mechanism of the long term memory. Talking-singing dichotomy could correspond to the classical-quantum dichotomy for communications.

1. Negative energy Z^0 MEs sent by right brain hemisphere would generate a timelike entanglement and a sharing of the mental images with the geometric past. This alone could give rise to an episodal memory. The mechanism would not however be very flexible, and it is questionable whether it might allow active memory recall at all. In this case individual Z^0 MEs need not carry any information since their sole role is to entangle. Hence monochromatic Z^0 MEs would be enough. The frequency pattern of various Z^0 MEs however could however carry emotional information as in music so that there would not be any absolute need for the individual Z^0 ME to entangle with a complex mental images. Right brain would sign in multisono.

2. In the case of non-episodal memories active memory recall could be realized in the same manner but now the quantum answer would be only a statement that the question has been received. The left hemisphere would provide the real answer by classical communications by sending positive energy Z^0 MEs with extremely slow effective phase velocity $v = L/T$, where L is an appropriate distance inside brain and T is the time span of the long term memory. Ca^{++} have extremely wide velocity spectrum and would most naturally be associated with these Z^0 MEs. For the classical communications a modulation at single carrier frequency to realize memetic codewords is enough. Presumably this frequency is 1260 Hz corresponding to the bit of the memetic codeword. Left brain would talk.

Why right brain has a poor time resolution and is more emotional?

If right brain sub-selves have time like entanglement to form temporal wholes, the time resolution is poor. Time resolution requires a sequence of separate sub-selves and in left brain the duration of the

sub-selves is short. For instance, the cognitive antineutrinos of the right hemisphere could entangle both in spatial and temporal directions to form spatio-temporal wholes whereas in left brain they would behave as separate sub-selves. This would indeed mean poor spatial and temporal resolution as a price paid for temporal holism. Also the mechanism of episodal memories based on time-like entanglement is consistent with this view.

One could consider also the possibility that the spin flips of cognitive antineutrinos which correspond in one-one manner to nerve pulses are more frequent in left brain: this would obviously increase the information content of the memetic codewords. The average temporal distance between spin flips would define the time resolution of the sensory experience so that the typical number of nerve pulses per time in given axon could be larger in left brain hemisphere.

Is also spatial holism characteristic of right brain information processing? Right brain has better skills in recognizing and expressing emotions and in grasping spatial shapes and has worser ability to recognize temporal order. If emotions are qualia having entropy gradients as their correlates and give information about what happens for the entire system, one could perhaps understand this. Large sub-selves formed by fusion of sub-selves would give rise to large entropic gradients and coherent emotions whereas a large number of unentangled sub-selves in left brain would not give rise to any coherent emotion just as left brain vision does not give rise to any coherent picture (say face) but only a collection of features.

Holism and reductionism: why we have two brain hemispheres?

One of the basic features of conscious experience is the formation of wholes and parts. As already described, quantum entanglement provides a quantum description of this process. Sub-selves represent the components of experience and in the absence of entanglement between selves the net experience is sum of the parts without an idea what the whole is. If sub-selves get entangled, the sum experience represents the irreducible whole without any idea about parts. This gives rise to reductionism-holism dichotomy which seems to characterize all cognitive activity.

This tension between holism and reductionism suggests a general explanation for why we have two brain hemispheres. There are two basic cognitive representations: reductionistic and holistic corresponding to the knowledge about parts without knowledge of the whole and vice versa. Single self (and presumably also brain hemisphere) cannot provide these representations simultaneously. Two brain hemispheres can however achieve this and this might be one the most important reasons why we have two hemispheres! If this hypothesis is correct, then information processing in brain involves co-operation of and communication between the brain hemispheres so that the special skills of the hemispheres are used in the optimal manner. The hemisphere more skilled in dicriminating geometric, linguistic, etc.. details provides a representation or parts in terms of unentangled sub-selves whereas the less skilled brain hemisphere provides simultaneous representation as an entangled whole and entire brain has reductionistic and holistic representations as its simultaneous sub-selves.

This hypothesis can be tested by applying it to explain a rather paradoxal experimental result which is in conflict with the idea about the differences between right and left brain. In [30] there is report about two experimental situations testing right-left differences.

1. Subject persons saw figure S consisting of smaller figure F:s. It was found that left brain seemed to recognize smaller F:s whereas right brain seemed to recognize the entire figure S: just as expected.

2. For control purposes figure S consisting of small F:s was replaced with a figure of anchor consisting of small cups. What happened was that left brain recognized the anchor and right brain recognized the cups! It was conjectured that the smallness of cups might have something to do with the unexpected result.

The result provides a challenge for left-right brain dichotomists and also for the proposed conceptual framework. The idea about division of labour to build reductionistic and holistic representations suggests an explanation of the paradox.

1. A plausible assumption is scale invariance in the sense that the recognition of a particular linguistic symbol or geometric shape cannot depend on its size above some resolution scale. This resolution scale depends on the brain hemisphere. Zooming could be involved and correspond

to a formation of cognitive representation about part of figure and involving same neuron group as the representation of the entire figure.

2. Since right (resp. left) brain hemisphere is more skilled in the recognition of shapes (resp. linguistic symbols), one would expect that it is able to recognize smaller shapes (resp. linguistic symbols) than left (resp. right) brain hemisphere by directing attention to a small part of the figure. This dictates the optimal division of labour. Since the first (resp. second) figure consists of linguistic symbols (geometric shapes), left (resp. right) brain hemisphere takes care of details and right (resp. left) brain hemisphere takes care of the whole.

An alternative explanation is based on the observation that the figure in the first case is letter consisting of letters whereas in the second case the figure is geometrical shape consisting of geometrical shapes. This would suggest that it is left/right hemisphere which recognizes the figure in the first/second case. Just the opposite seems however to occur! Could it be that the neural activity observed is not associated with recognition but with the receipt of a message about the recognition actually carried out by the opposite hemisphere? This would suggest that recognition itself is quantum level process not involving neural activity at all! 75 per cent of cortical projections in human brain are inhibitory: for monkey the corresponding number is 45 per cent. This is consistent with the idea that large part of conscious activity might not manifest itself as neural activity.

Dr. P. and twins who saw primeness

Oliver Sack's book 'The man who mistook his wife for a hat' [52] contains fascinating stories about those aspects of brain and consciousness which are more or less mysterious from the view point of neuroscience. There are two stories which relate very closely to reductionism-holism tension of conscious experiencing.

The first story is about Dr. P. who suffered visual agnosia and could not recognize concrete objects, say faces unless some nonvisual association was involved. He could however recognize abstract symbols or objects containing some symbolic details making possible the recognition (he recognized Einstein's face, which has indeed become a symbol of wisdom!). Sacks tells about how his patient tried to recognize glove. 'A curved shaped containing five small bags' was his abstract analysis: he could not identify the glove as a glove unless he got it in his hand! He could however define glove as an abstract geometric shape allowing simple linguistic description. Dr. P. could identify abstract shapes and symbols like letters and geometric objects but could not recognize real world objects. Amazingly, Dr. P. used musical associations as a manner to cope with the complexities of everyday life. He singed through all his everyday activities and lost control totally if this was for some reason not possible. He could also continue teaching of this music class. For instance, he could recognize his music students only when they moved by recognizing their 'body music'.

As discussed, reductionism-holism duality provides the deep reason for why we have two brain lobes. This allows to understand what might be possibly involved with Dr. P:s case. Dr. P:s right visual areas had been damaged and he could not recognize faces and concrete objects of the visual field. Left visual areas were in good condition and he could identify abstract objects. Other than visual areas were still in good condition in both hemispheres and he could perform recognition using musical associations, associations created by smells, etc... Sacks notices also a deep analogy with Dr. P.:s case and neuroscience. Expressing rather freely what Luria said, entire neuroscience up to seventies provided analytic description of left brain about left brain. It had indeed turned out very difficult to assign any easily identifiable cognitive dysfunctions with localized right brain injuries and Luria's opinion was that this necessitated completely different approach which he called 'romantic' (stories of right brain about both right and left brain!).

In fact, one can formulate new kind of Uncertainty Principle, perhaps it might be called Uncertainty Principle of cognition. Same mental image cannnot be both holistic and reductionistic simultaneously. The combination of reductionistic and holistic descriptions (and all possible intermediate descriptions combining parts to subwholes in various manners) to single description is impossible even in principle! Science and Art as descriptions of the world are very much like mutually incompatible observables of Uncertainty Principle!

Sacks tells also about twins, John and Michael, who had mysterious ability to 'see' large numbers. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately '111!'. Then John mumbled '37', Michael repeated it and John said

'37' third time. Obviously this was their cognitive representation for the decomposition 111=3x37 of number 111 to a product of primes!

How John and Michael did these numerical feats? The first thing to notice is that twins had intelligence quotient of about 60 and could not perform even simplest arithmetical operations. They did not even understand what the concepts of prime and decomposition into prime factors mean conceptually. They however experienced primes as especially interesting numbers and even played a game in which they invented new primes. One can safely assume that they did not consciously calculate the decomposition of number 111 to a product of primes. When asked how they were able to tell the number of matches, they told that they 'saw' it. In fact, their eyes moved in strange manner always when they were performing numerical tasks and stopped when the solution was found. Also the decomposition of 111 to a product of 3 primes '37' seemed to occur completely spontaneously 'in front of their eyes'.

The mysterious ability of twins is not a mere curiosity but could provide a crucial clue to the problem of understanding of how numbers are realized as mental images. Indeed, also ordinary human beings are able to experience directly 'N-ness', when the size of N is small. The natural working hypothesis is that the difference between ordinary human being and numerical genius is only quantitative. Thus the problem transforms to a more general question 'How integers are experienced?'.

In TGD framework the answer to the question is obvious. Experiencing of 'N-ness' means experiencing 'N' separate objects as a single whole and corresponds quantum physically to the generation of entanglement between the cognitive representatives of individual objects. If the resulting mental image associates automatically with a linguistic expression for 'N-ness', say '$N = 5 \leftrightarrow five$', reportable recognition of 'N-ness' occurs. 7 ± 2 law suggests that this entanglement and association usually occurs only for maximal number of objects not larger than $N = 7 \pm 2$. In case of a numerical genius this number seems to be drastically higher. The generation of this entanglement should be spontanous self-organization process in either brain hemisphere and entangled objects could correspond to separate neuron groups or neurons.

The decomposition of integer $N = N_1 \times N_2$ to a product of integers must in this picture correspond to the spontaneous formation of identical 'sub-wholes'. This process must be a quantum self-organization process. It could favour the decomposition of $N = N_1 \times N_2$ objects to N_1 'sub-wholes' consisting of N_2 entangled basic objects or decomposition of N_2 sub-wholes consisting of N_1 basic objects or something else depending on factors of N. This kind of final states of self-organization are natural since they are very symmetrical consisting of a repetition of an identical basic unit. This kind of self-organization patterns are analogous to the lattice-like self-organization patterns of Benard flow.

The model also explains the ability of twins to see whether a given number is prime or not. Primes are stable against decomposition into sub-wholes and are therefore 'elementary particles of cognition'. Hence primeness is a 'visible' property: primes are numerical mental images stable against decay to a set of identical numerical mental images. Note that this dynamical process breaks the symmetry between the factors of integer. This clearly occurred in 111= 3x37 example. Twins did not 'see' '3': they saw only some 37's and did not explicitely tell that there were precisely three 37:s!

In [K4] a more concrete model for how real space-time sheets could represent integers and their prime factorization by their effectively p-adic topology, is discussed.

4.4.3 Music and summation hypothesis

Music experience provides an interesting testing ground for several ideas:

1. Summation hypothesis stating that self is sum of abstracted experiences of sub-selves and thus representing kind of averages about the experiences of sub-sub-selves.

2. The idea of subjective memory.

3. The idea about entanglement creating wholes from parts.

4. The idea about cognitive act as a cascade like generation of selves having sub-selves having... providing symbolical hierarchical representations and cognitive analysis of the experience into objects.

5. The idea that there are two modes of conscious existence. The first mode creates a burst of parallel small-sized sub-selves forming linear subjecto-temporal sequences creating reductionistic experiences. The second mode creates fusions of large number of parallel sub-selves having short temporal duration creating holistic experiences. Information processing in left and right brain might correspond to these two modes respectively in some important length scales below cell membrane length scale.

6. The idea that there are two basic types of cognition depending on whether self is in a state of whole body consciousness (emotional, holistic intellect) or decomposes into hierarchy of sub-selves (analytic intellect). This applies in all length scales.

7. The idea that canonical identification map with pinary cutoff maps 'reality' to the personal 'p-adicity' of the experiencer.

Simple model for music experience

The following simple model tries ot abstract the idea that the dominantly parallel nature of right brain information processing is crucial for music experience.

1. Assume that there is ensemble of potential 'frequency selves' sensitive to wake-up by frequencies in a frequency range around some mean frequency characteristic for a particular frequency-self. The quantum model for hearing indeed allows to identify 'frequency selves' as associated with axons specialized to hear sound with a particular frequency [K3]. In accordance with the idea about parallel information processing in right brain, assume that these selves are located in right brain. Hence each frequency wakes up its own frequency-self provided the intensity of Fourier component associated with that frequency is above some threshold value. In some cases, the overall frequency scale of the frequency-selves could be temporally stable, perhaps due to the temporal stability of the Z^0 magnetic fields involved with hearing [M6]. This could explain the phenomenon of the absolute music ear.

2. An interesting possibility is that frequency self is in a state of whole-body consciousness and having experience of one-ness. This guarantees that information processing is not possible during experience.

3. There are several options as to what happens when the stimulus ceases. Frequency self could either fall asleep or it could just continue its existence by analyzing its enlightment experience by generating a hierarchy of p-adic sub-selves. It could also transform to p-adic self so that sensory experience would transform to thought about it.

4. One of the mysteries of the music experience is the ability of the listener to remember the basic key and the desire for the piece to end to the basic key even when several intermediate keys appear. If frequency selves stay awake as p-adic susselves during entire music experience, one could understand this phenomenon in terms of memories with respect to subjective time. Note however that the presence of mindlike space-time sheets whose duration is longer than the duration of music piece could explain this ability as the duration of memories with respect to the geometric time.

5. Discretization of frequencies, or rather the division of frequency range to subranges occurs. In p-adic context the ranges might well be disjoint since p-adic distance function defines naturally decomposition of p-adic axis to disjoint intervals ($N_p(x-y) \leq p^n$ defines this kind of decomposition). The inverse of the frequency gives lower bound for the duration of mindlike space-time sheets resonating with given frequency. Note that on left brain the selves would not resonate for incoming frequencies but would wake-up by a generation of large quantum entanglement followed by quantum jump and not depending much on the frequency of the incoming sound wave. The selves relevant for information processing should not be 'enlightened' selves since they must have ability to rapidly generate further sub-selves.

Harmony and self-organization

The phenomenon of harmony should be somehow related to quantum self-organization: perhaps the often used metaphor of harmonious co-existence could be turned around. Various notes correspond to sub-selves in the population of sub-selves and it might be that self-organization favours simultaneous conscious existence of sub-selves corresponding to subsets of frequencies defining basic chords. One could even consider some kind of co-operation between the frequency selves belonging to same basic chord.

The simplest model for the phenomenon of harmony relies on the identification of the chords as 'chord selves' formed by entangled 'note selves'. The listener is self having as sub-selves (mental images) note selves and chord selves which correspond to the same level of the self hierarchy. The entanglement between note selves could occur even at the level of ear between the mindlike space-time sheets sensitive to various frequencies. Topologically it would correspond to the formation of join along boundaries bonds between the note selves. The ability of the 'note selves' of the chord to have stable join along boundaries bonds between themselves should depend crucially on the fact that the frequencies of the notes of the basic chords have simple rational ratios so that the oscillations involved are commensurate and match together. Hence a resonance phenomenon ins spirit of classical physics involving rational ratios of frequencies would be in question. During listening the chord self continually decomposes into sub-selves when listener consciously concentrates attention to some notes in the chord.

The ability of the music to occasionally create thrills in spine could correspond to whole-body consciousness in unusually large length scale. It presumbly involves a resonant fusion of also other than note sub-selves to larger sub-selves by the formation of stable join along boundaries bonds. The ability of certain sounds ('Om') to promote the emergence of whole-body consciousness could be due to the ability to very effectively generate entanglement and stable join along boundaries bonds. Perhaps the frequency spectrum of 'Om' contains resonant frequencies of several sub-selves and induces large sub-selves. Also the healing effect of music and sounds could rely on this mechanism.

Focusing attention to some instrument producing melody creates kind of figure-background relationship. This requires that entire instrument playing the melody is represented by 'instrument self'. An interesting possibility is that various instruments give rise to their own ensembles of frequency-selves. Note that the model makes it easy to understand why experienced performance is not simply the sum of invidividual performances. Music experience is a complicated self-organization process in which parts compose to wholes by quantum entanglement and vice versa according to how the listener directs his/her attention.

Why octaves are experienced similarly?

The model should explain the basic features of music experience. There are many interesting questions related to this. One of the most important is why frequencies which are 2^k- multiples of the fundamental frequency, notes differing by octaves, are experienced as identical notes.

1. p-Adic length scale hypothesis and octaves

Real selves are labeled by p-adic primes labelling the p-adic topology to which the real topologies of the corresponding mindlike space-time sheets can transform. Thus the phenomen of octaves could relate to the p-adic length scale hypothesis, which implies that physically preferred p-adic primes corresponds to primes near prime power powers of two. For instance, this implies that the massless extremals (MEs) associated with physically important p-adic primes have fundamental frequencies which are octaves of each other. Therefore a classical resonance via the formation of join along boundaries bonds becomes possible and real space-time sheets corresponding to preferred p-adic primes can form larger resonant structures. This universal resonance could explain why octaves are experienced similarly.

2. Is sensory experience 2-adic in some sense?

A stronger hypothesis for the phenomenon of octaves is that cognitive music selves are 2-adic or that real music selves can transform easily to 2-adic selves. One might even consider the possibility that the phenomenon is much more general. Music metaphor has indeed turned out to be of crucial importance for the theory of qualia. Thus music metaphor could reflect the underlying 2-adicity of the

sensory experience (at some level of self hierarchy). Perhaps at least some aspects of our experience result from a mimicry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When overlearning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [34] such that the plateus, where response remains constant are octaves of each other.

This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has a multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jumpwise replacement of the n:th harmonic by n+1:th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of overlearning or neurons involved act unisono and the underlying 2-adicity is not masked anymore.

At the level of ELF selves this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier. This certainly would mean that cognition is an important part of music experience. The strongest assumption is that the real note selves are able to transform to 2-adic selves by a phase transition changing local topology from real to 2-adic. Note however that p-adic length scale hypothesis might be enough.

3, Octaves appear at the level of fundamental formulation of quantum TGD

Octaves might have much deeper significance than I thought originally and seem to emerge at the level of fundamental formulation of quantum TGD rather than characterizing only a very special kind of sensory experience. In the recent formulation of quantum TGD using zero energy ontology [C1, C2] one uses zero energy states which have their positive and negative energy parts at the light-like boundaries of causal diamonds consisting of future and past directed light-cones.

Physics as a generalized number theory vision, in particular the assumption that real physics and various p-adic physics result as algebraic completions of rational physics, motivates the hypothesis that the temporal distance T between the tips of the causal diamond is quantized and corresponds to powers of 2 using time scale defined by CP_2 size as a basic unit. This assumption allows to deduce p-adic length scale hypothesis ($p \simeq 2^k$, k integer), and to identify T as a secondary p-adic time scale. For electron this time scale is .1 seconds and corresponds to the fundamental 10 Hz biorhythm. For non-standard values of Planck constant T is scaled by a factor $\hbar/\hbar_0$. Thus octaves become a key element of fundamental physics. One can say that causal diamonds as space-time correlates of self appear naturally as octaves. Also rational multiples of fundamental frequency emerge via the hierarchy of Planck constants: in principle all rational scalings of the basic hierarchy are allowed.

Basic scales and 2-adicity

A further fascinating question is why 5-tone scale (pentatonic), 7-tone scales (say Cmajor) and 12-tone (chromatic scale used in atonal music) scales seem to be so fundamental. A part of answer is certainly the fact that the ratios of the frequencies of the musical scale are relatively small rational numbers so that the note selves can form join along boundaries bonds and generate resonating chord selves. Dissonance would mean that chord self is rarely formed. For two nearly identical frequencies the ratio of the corresponding periods $T_i = n_i T_0$ is a ratio n_1/n_2 of large integers n_1 and n_2 having no common factors. Hence the period of the superposed signal is $T = n_1 n_2 T_0$ and can be even longer than the duration of either note. Thus resonance making possible fusion of note sub-selves to chord sub-self is expected to be weak and even impossible.

One can consider this problem also from p-adic viewpoint. In p-adic case genuine rationals correspond to p-adic integers which are infinite as real integers but for which pinary cutoff is finite real integer. Thus rational harmony in the real context would correspond to superposition of harmonic multiples in p-adic context.

1. Canonical identification and 2-adic harmony

Interestingly, the mapping of the real frequencies to p-adic frequencies by canonical identification maps the preferred frequencies to *integer valued p-adic frequencies*: in particular rational frequencies are mapped to integers (infinite as real integers for genuine rationals), which converge rapidly as p-adic power series $f = \sum_n x_n p^n$. Thus all real frequencies correspond to p-adic harmonics trivially and harmony in the precise sense of the world would be achieved p-adically. Obviously one must make some natural restrictions to integers in question. The natural requirement is smallness of the normalized p-adic frequencies as ordinary integers. Part of the explanation is 7 ± 2 rule of psychology, which suggests that the number of cognitive sub-selves (now 'note selves') which can be simultaneously awake, is limited by this number.

It is well known [50] that basic scales corresponds to multiples of the basic frequency divided by a suitable power of two such that result is between 1 and 2, that is in single octave normalized to range $[1, 2]$. Even integer multiples give redundant results so that one can restrict the consideration to odd integers. This could be understood 2-adically. The crucial observation is that real frequencies can be obtained as canonical images of odd integers regarded as 2-adic numbers and mapped to real numbers by canonical identification

$$\sum_i x_k 2^k \to \sum_k x_k 2^{-k} \quad .$$

If p-adic number represents odd integer the image has unit p-adic norm and is always in the range $[1, 2]$ and hence in the basic octave.

In light of 2-adic fractality, scaling invariance under scalings by power of 2 commuting with canonical identification, it would not be surprising if the 2-adic images of frequencies differing by power of 2 were equivalent from the point of view of subjective experience. Of course, p-adic length scale hypothesis alone might be sufficient to explain this as already found. This would explain why notes differing by octaves are experienced as similar. 2-adic fractality might be a property of experiencer also: the temporal durations of sub-selves could come as powers of two and perhaps realize the idea about hologram memory. This observation, together with the observation that our engineering feats resemble remarkably 2-adic fractals, suggests that at least some of our sub-selves represent the lowest level of intelligence in the hierarchy of intelligences! An interesting question is whether $p > 2$-adic music is possible and is it only for higher level intelligences! One could do experimentation with this kind of music and listen the result with 2-adic ears.

A counter argument against two-adicity is that the overall frequency scale (basic tone) and hence basic p-adic time scale can be chosen freely whereas p-adic length scales are completely fixed. The objection can be circumvented if the p-adic time scale is related to genuine p-adic length scale by equation $T_n = p^{n/2} L_p / v$, such that v is some characteristic velocity, which adapts to different value depending on key. n defines which level of p-adic fractal is in question. For $p = 2$ $n/2$ must be about $M_{127} = 2^{127} - 1 \simeq 10^{38}$ to yield correctly the frequency 64 Hz of basic C for $v = c = 1$. It could also be that p-adic length scale itself is dynamical in some sense, at least at the level of cognitive experience.

2. Concrete model for the canonical identification map

The mapping of reals to 2-adics by canonical identification maps all frequencies above the basic frequency setting the scale to odd 2-adic integers and it is of interest to find how naturally the basic scales emerge.

i) The range $n = 1, 3, 5$ gives the notes of the basic major chord, say (C, E, G). The appearece of three smallest odd integers supports the idea about basic chords as self-organized ensembles of p-adic frequencies.

ii) The integers $C = 1, G = 3, E = 5, D = 9, A = 11$ corresponds to the pentatonic scale used in Chinese music.

iii) The integers $C = 1, G = 3, E = 5, (Bb = 7), D = 9, A = 11, F = 13, H = 15$ give good fit to 7-tone scale. Integer $n = 7$ is absent from both scales. For even scale a better fit for the note A is $A = 27$ instead of $A = 11$. The note $(Bb = 7)$ added to the 7-tone scale corresponds to the 'blue' note. $Eb = 25$ which is second blue note. $F\# = 19$ and $G\# = 29$ adds to the scale the additional notes appearing in A minor scale.

iv) The integers $C = 1, G = 3, E = 5,\ Bb = 7, D = 9, A = 11,\ F = 13, H = 15, Db = 17, G\# = 19,\ Eb = 25, F\# = 29$ give 12-tone or chromatic scale. Note that the integers $n = 21, 23, 27$ are not present in the set. A slightly better fit is given by the integers $1, 3, 5, 7, 9,\ 13, 15, 17, 19$ and $25, 27, 29$: now the integers $11, 21, 23$ are lacking from the set. All keys are obtained as subscales using chromatic

scale although the ratios of the frequencies are not exactly the same since canonical identification does not commute with scalings: in practice instruments use this scale and this cause pains for the people having absolute ear.

One could of course criticize this representation: by using sufficiently rough resolution one can arrange that p-adic integers corresponding to notes of the basic scale are reasonably small. One could also claim that good explanation for the lacking integers is needed. This picture is however consistent with the general ideas about p-adic self-organization. Integer valued harmonic oscillator energies (when suitable units are used) appear always when one approximates system as a collection of harmonic oscillators. Integer valued spectrum of Hamiltonian is also a necessary ingredient for the existence of p-adic thermodynamics since Boltzman weights $exp(-E/T)$ are replaced by $p^{E/T}$, which exists only provided E/T is integer so that E itself must be integer valued in suitable units. Note that p-adic thermodynamics leading to the predictions for elementary particle masses involves in a crucial manner the fact that the spectrum of Virasoro generator L_0 taking the role of energy is integer valued.

A further criticism concerns the use of the canonical identification map. Canonical identification makes sense for probabilities (p-adic thermodynamics) but one cannot map p-adic space-time surfaces to their real counterparts or vice versa by canonical identification. Hence the mapping of frequencies by canonical identification need not make sense.

4.5 Whole-body consciousness: physical evidence and tests

Whole-body consciousness is one of the most dramatic predictions of the proposed theory and anomalously low dissipation can be regarded as the most dramatic physical signature of whole-body consciousness. This prediction provides a manner to test the theory.

4.5.1 Dissipation and consciousness

In TGD framework dissipation can be regarded as a signature for the presence of consciousness and selves, which are identified as sub-systems able to remain unentangled in sequential quantum jumps. Anomalously low dissipation in turn can be regarded as a signature for the states of 'one-ness' in which self does not decompose into sub-selves. In the following I describe the basic ideas, and suggest some experimental evidence and tests for the picture.

Dissipation as a signature of consciousness

In TGD framework dissipation caused by quantum jumps is signature of consciousness and can be interpreted as a direct evidence of quantum jumps between quantum histories concept: dissipative irreversible quantum history can be interpreted as kind of envelope for the sequence of reversible quantum histories. This makes also sense at the level of the classical space-time since quantum jumps involve localization in zero modes characterizing space-time surface classically.

Self decomposes in general into sub-selves which in turn decompose to subsub-selves which..., and a model of cognitive phenomena based on cascade like process in which selves of sub-selves wake-up in a cascade like manner, suggests itself. Selves can provide conscious representations for objects of picture, for basic structures of language, etc.. and are analogous to modules of a computer program with a hierarchical structure. Probably the range of modes of consciousness between calmness and anxiety could be characterized partially by the degree of the decomposition into sub-selves (also the entropy of sub-selves is important factor since it measures the fuzziness of the mental images).

The generation of selves by quantum jumps would presumably lead to a cascade of small sub-selves of short duration whereas second mechanism could lead to a generation of only few large sub-selves having long duration. One can wonder whether these two mechanisms have something to do with the linearity of left brain information processing and parallel nature of the right brain processing in some length scales, presumably longer than cell membrane thickness. TGD inspired model for EEG and nerve pulse predicts, not only propagating EEG waves associated with neural circuits, but also non-propagating EEG waves associated with entire regions of brain (say gap junction connected cell groups). These two kinds of EEG waves could correspond to linear (resp. parallel) information processing modes dominating in left (resp. right) brain [M4].

It must be emphasized that it is not all obvious which corresponds to which.

1. The synchrony-holism association would suggest that holism corresponds to non-propagating EEG waves, synchronous neuronal firing and formation of wholes via entanglement of sub-selves. The model of synesthesia in which left brain works much like right brain and synchronous firing is observed, supports this view.

2. Computationalism would seem to suggest a different picture. Standing EEG wave makes the group of neurons to behave in unisono and to form single sub-self. Information processing would be sequential rather than parallel with the entire neuron group behaving a choir singing in unisono. In this picture the decomposition into axonal sub-selves defined by the propagating EEG MEs would mean a large number of separate sub-selves and parallel information processing. Furthemore, the coding of the nerve pulse patterns to lightlike vacuum currents of stationary MEs would occur naturally in this state and the interpretation as representation of thought seems reasonable.

What is the correct option? It would seem that 1). The basic counter argument against the option 2) is following. The fusion of sub-selves into single sub-self gives rise to holism and the fusing sub-selves give each their own parallel contribution like notes in a chord: information is not lost although firing takes place in unisono: different features are only bound together in accordance with the model for the sensory representations [H4]. Fusion of the right and left visual fields to single visual field with is excellent example of what happens in this process. Something qualitatively like 3-dimensional shape emerges in this process.

Reduced dissipation and absence of decoherence as a signature of whole-body consciousness

As noticed, both irreducible and reducible selves are possible. The dissipation rates in these two states of consciousness can be quite different since the entanglement involved is of quite different type. It would not be too surprising if the net dissipation rate for irreducible selves would be smaller than for reducible selves having several dissipating sub-selves. In p-adic context the notion of dissipation must be defined more generally: intuitively dissipation means that self gets more and more entropic and the distributions of zero mode and quantum number increments thermalize and mental images get fuzzier and fuzzier.

The absence of decoherence is also a correlate for the formation of state of oneness. This means that quantum jump sequence effectively binds to single quantum jump. This state lasts as long as bound state endures. In the time scale defined by the duration of the bound state the second law of thermodynamics is broken and serves as a signature for the effect. In this state the zero modes of the binding systems transform to quantum fluctuating degrees of freedom and the state is kind of multiverse state.

Enlightment by entanglement mechanism provides a mechanism binding selves to larger selves and disappearance of component selves. This mechanism does not inhibit the formation of smaller sub-selves of entangled selves unless the higher self is in state of whole-body consciousness. The small net dissipation rate in states of whole-body consciousness would be a rather dramatic effect supporting TGD based view. For instance, it could lead to lowering of body temperature or cell temperature since thermal energy would be gradually lost from the system!

Note that the state of whole body consciousness need not be whole-timely even in meditative state. It is enough that sub-selves are short-lived. The artificial generation of quantum entanglement between some part of body with larger sub-system in a state of whole-body consciousness could have medical applications some day. Perhaps entangling brain with body (be it physical or electromagnetic!) could even hinder irreversible effects caused by the lack of oxygen or by the bleed caused by brain injury.

Evidence and tests for reduced metabolism as concomitant of whole-body consciousness

Consider now possible evidence and tests for the reduced metabolism as a signature of whole-body consciousness.

1. In synesthesia different sensory modalities are associated with a regular manner just as thoughts are associated with speech. A dramatic signature of synesthesia is the lowering of the metabolism by as much as about 18 per cent from average in left brain (synesthete should become blind or

paralyzed if standard wisdom would hold true!). This is what is expected if entire left brain gets entangled with, say parts of limbic brain and with sensory organs associated with coupled sensory modalities, or possibly with electromagnetic body of much larger size. The extended self in state of oneness does not dissipate significantly since there are no sub-selves performing quantum jumps.

2. The metabolism of trained yogis provides a test for the hypothesis: measure some signatures for neuronal or cellular dissipation occurred during the meditative state and find whether the dissipation is reduced during meditation. The lowered dissipation rate could even lead to the lowering of the body temperature or the temperature of nearby region.

3. There are even anecdotal claims about the ability of the dead bodies of gurus to resist natural decay. I am not certainly trying to convince any sceptic and, still having very living personal body, I have no personal opinions about the reality of the claimed phenomena. It would be however good to be open-minded.

4. There is (I believe well documented) phenomenon in which persons in trance are able to dance on burning charcoals without any disastrous consequences. Certainly there are standard science explanations for this. A possible nonstandard sicence explanation is that state of a whole-body consciousness is involved and no dissipation in cellular scale occurs. Since dissipation is not possible, the irreversible effects caused by the heatflow from burning charcoals are not possible and only reversible and curable effects can occur.

5. The reduction of the dissipation rate in some length scales should occur also during sleep, which is one example of this kind of state (obviously reduction of metabolism occurs).

6. Also hypnosis might involve quantum entanglement between some part of the brain of subject person and hypnotizer: the fusion of some sub-self with sub-self of hypnotized could explain the effect of hypnosis. This could reflect itself as correlations between EEGs of hypnotized and hypnotized.

4.5.2 Synesthesia

Synesthesia [20] is a phenomenon, which seems to give direct experimental evidence for a reduced rate of metabolism in 'holistic' states of mind. Synesthesia provides an excellent counter argument against the idea that sensory organs are primary experiencers unless one is ready to believe that cross-modal associations involve macroscopic quantum systems formed by the primary sensory organs involved and parts of brain.

TGD based quantum model for EEG and nerve pulse suggest that synesthesia is a natural by-product of the holistic states of mind involving enchanced EEG in large regions of brain. Coherent large amplitude EEG induces synchronous neural firing in memory circuit containing hippocampus and thalamus. This leads to a 'leakage' or nerve pulse activity in lateral thalamic nuclei from inducing sensory pathway to the indced sensory pathway An interesting possibility is that the non-propagating EEG waves predicted by TGD [M4] and possibly explaining the ability of right brain hemisphere to process information in a parallel manner are involved in synesthesia: the left brain hemisphere of synesthetes would be like right brain hemisphere during synesthesia.

Does synesthesia involve left cortex whole-body consciousness?

The following aspects of synesthesia suggest that left cortex whole-body consciousness might be involved with it.

1. Synesthesia depends on left brain hemisphere only. A dramatic signature of synesthesia is the lowering of the metabolism in the left cortex by about even 18 per cent compared to the baseline (synesthete should become blind or paralyzed if standard wisdom holds true!). This leads to relatively enhanced limbic expression. Hippocampus, which is believed to be crucial for long term memories, is critical for synesthetic experience.

2. Synesthesia is emotional: the experiences are accompanied by a sense of certainty ('this is it') feeling. This is in accordance with the observation that limbic brain expression is enhanced.

3. Holism is an important aspect of synesthesia. Synesthetes can precisely remember entire passages of text, re-experience entire episodes of previous life, remember precise locations of various objects in a room. Synesthetic experiences are emotional. Synesthetes also tend to have 'unusual experiences' like deja vu, clairvoyance and pre-cognitive dreams. This kind of personality constellation characterizes temporal-limbic epileptics.

4. Synesthetes have un-even cognitive skills. Dyslexia, dyscalculia in some degree, inability to transform words to digits, right-left confusion, etc.. Synesthetes are also non-right-handed.

A possible TGD based interpretation is that part of the left cortex is in whole-body consciousness so that there are very few, sub-selves (mental images) in the left cortex and these sub-selves have long duration so that temporal resolution is poor. In this state left cortex does not dissipate as much as usually since in state of 'one-ness' there are no sub-selves performing quantum jumps and dissipating. Since left cortex would contain very few sub-selves (mental images), limbic brain would dominate as far as mental images are considered: this would be consistent with the emotionality of synesthesia.

Whole-body consciousness (and also consciousness with very few mental images resulting from the fusion of smaller mental images) is accompanied by the generation of bound state entanglement and thus also by a liberation of the binding energy as a usable energy. This superfluous energy might partially explain why the metabolism can be reduced during synesthesia below the level causing death under normal circumstances. Thermal noise destroys this bound state sooner or later and one can say that buy now-pay later mechanism is at work: the system actually loans thermal energy. This mechanism resembles somewhat the Brownian ratchet mechanism [18] discussed in [K6].

The exceptional episodal sensory memories could perhaps be understood if the formation of large irreducible self in a state of one-ness has also large temporal extension so that long sequences of events of geometric past are re-experienced. In [H4] a model for long term episodal memories as questions sent to the geometric past inducing entanglement with the self of the geometric past making possible episodal memory as a shared sensory experience is discussed. The question sent to the geometric past is coded to the lightlike vacuum current associated with a stationary ME, usually in right brain but in left brain in case of synesthesia. The time like entanglement of the mindlike space-time sheets located in geometric now and past (or future in case of clairvoyance) makes possible the episodal memory. States of one-ness are emotional since holism implies emotionality. The explanation for cognitive disabilities is that holistic left brain does not generate temporal sequences of sub-selves of short duration so that there is averaging over very many quantum jumps implying pure temporal resolution: a good temporal resolution is however essential for the mentioned cognitive skills.

The extraordinary memory achievements could also involve the temporal absence of the highest abstraction level of consciousness leading to abstraction and averaging implying highly symbolic verbal representations. This kind of mechanism is extremely useful for filtering of the conscious sensory information in order to cope with the practicalities of the everyday life. The mechanism might also explain both the extraordinary memory feats of some autistic persons and their difficulties with the challenges of the everyday life. Dramatic example is a person able to draw from memory an area of London with size of several square kilometers as seen from air. The same person draws from memory a building having hundreds of windows and the number of windows comes out correctly although this same person is not able to count corretly the number of three objects. Also in case of synesthetes cognitive impairments could be necessary prequisites of the extraordinary gifts. These impairments could be also due the fusion of a large number of mental images in left brain replacing the analytic view with a holistic one. Although the person cannot count how many windows the mental image of the building has, he can draw them correctly just by drawing along the image he sees in full concreteness.

Basic observations

The following observations provide a valuable information making possible to construct a more detailed model of synesthesia.

1. Synesthesia is in-voluntary and usually uni-directional: for instance, auditory experience creates visual association but not vice versa. Cross-modal associations, just like ordinary associations, do not change in the course of time. It has not been possible to find any rule telling which kind of associations are possible. It seems that cross-associated experiences are however generic and

simple so that one can speak of form invariants which are kind of primitive building blocks of perception: for instance, visual associations tend to be blobs, lines, spirals and lattice shapes.

2. Synesthesia is projected: synesthetes experience their secondary sensory experiences in the space in the immediate surroundings of the body, never at large distances as is in principle possible in case of vision and hearing. For instance, visual associations are seen on screen near to eyes.

3. The reduction of the metabolism is concentrated in the cortical regions whereas relatively enhanced metabolism occurs in the limbic brain, in particular hippocampus. Seizure discharges in hippocampus induce synesthesia in non-synesthetes: associations are simple experiences and become more complicated if seizures spread to the temporal lobes. The fact that exceptional activity of hippocampus is involved, correlates the exceptional ability to have precise episodal memories.

4. According to [20] it is very rare that taste or smell is a synesthetic response or trigger of it. In fact that author of the articles knows no case in which smell alone would be the inducing sensory modality. This could relate to the fact that olfactorion is exceptional sensory modality in the sense that there are two olfactory pathways: the first one projects directly to amygdala whereas second projects to cortex via thalamus as do also the sensory pathways associated with order sensory modalities [21]. Furthermore, the olfactory pathway to the thalamus projects to the medial dorsal nuclei whereas other sensory pathways project to the lateral dorsal nuclei.

5. Synesthesia can also generate sensory-motor associations. For instance, visual input can generate well defined motor outputs and synesthete can express sensory experiences by dancing!

Memory coordination circuit and Papez circuits as brain circuits possibly involved with synesthesia

Hippocampus is believed to be crucial for the formation and experiencing of long term memories. This suggests that an enhanced activity in some neural circuits involving hippocampus in a form of increased EEG amplitudes (at theta frequencies) is essential for generating the sensory leakage between neural circuits and sensory pathways leading to synesthesia. For this kind of mechanism synesthetic mode need not be the only mode of experiencing: ordinary and synesthetic modes could also alternate. If synesthetic and non-synesthetic periods alternate, synesthesia cannot interfere radically with the real experience. This is clearly the safest option and perhaps favoured by natural selection. The ability to control theta wave amplitudes in hippocampus could make possible an artificial generation of synesthesia.

There are two important circuits going through hippocampus [55]. The first circuit is memory coordination circuit having the following structure:
1. Lateral dorsal nucleus and anterior nuclear group of the thalamus
2. Cingulate cortex
3. Subiculum and the rest of the hippocampal formation with input via entorhinal cortex and output via the subiculum and fornix
4. Back to 1.

Fornix is known to be the circuit responsible for slow theta rhytm of about 3-7 Hz, which does not correspond to a conscious experience: thus memory coordination circuit is believed to be unconscious to us under normal circumstances [55]. Temporal cortex contains a region which projects to hippocampus and receives input from all sensory modalities. Memory circuit is believed to somehow to provide a handle to the memory constellations believed to reside in the temporal lobes. That the EEG amplitude associated with the fornix would be exceptionally large during synesthesia is in accordance with the fact that that synesthetes tend to have personal constellation of limbic-temporal epileptics. Also the abnormal episodal memories (Nabokov is one of the best known synesthetes with miraculous memory) supports resonance in this circuit. Only memory circuit projects to the thalamic nuclei receiving both sensory and motor input. Hence also the occurrence of the motor synesthesia supports the view that the sensory leakage occurs in the thalamic nuclei contained by the memory circuit.

Papez circuit is second circuit containing hippocampus. Papez circuit has following structure:
1. Anterior nuclear group of the thalamus
2. Cingulate cortex

3. Hippocampal formation
4. Hypothalamus
5. Back to 1.

The enhanged activity of the Papez circuit induced by the hippocampus could correlate with the emotionality of the synesthetic experience.

The general picture about the sensory leakage

These observations and facts suggests the following general model for synesthesia.

1. Contrary to the original expectations, the hypothesis that the primary sensory qualia are associated with the sensory organs can be be defended against various objections if one assumes that brain and sensory organs quantum entangle so that a fusion of sensory mental images with cognitive mental images occurs. The hypothesis explains elegantly the differences between imagination, dreaming, hallucinations, and ordinary sensory experience. Dreams and hallucinations would involve a back projection from brain to sensory organs giving rise to a "qualiafication" of the cognitive mental images represented by the nerve pulse patterns. In the case of synesthesia the back projection would assign to a sensory input from the inducing sensory modality an artificial sensory input in the induced sensory modality.

2. If the cross-modal communication between sensory organs occurs through thalamic nuclei common to the cross-associated sensory modalities, one can understand why smells alone are never the inducing sensory modalities. Lateral dorsal thalamic nuclei would be the sites of the sensory leakage. Furthermore, in the case of hearing, vision, and tactile senses it is easy to produce artificial sensory experience than in case of chemical senses (molecules attaching to the sensory receptors would be required).

3. The possibility of the sensory-motor synesthesia suggests that the back-projection involves artificial sensory input to the motor organs inducing a motor activity, which in TGD framework corresponds to a geometric time reversal of the sensory perception starting from the level of motor organs and proceeding in a time reversed direction. Only memory coordination circuit involves thalamic nuclei receiving both sensory and motor inputs. Memory coordination circuit involves lateral dorsal nuclei (all modalities except olfaction) but not medial dorsal nuclei (olfaction). This leads to the hypothesis that the exceptionally high activity of the memory coordination circuit induces a sensory leakage in the lateral dorsal nuclei of the thalamus belonging to the memory coordination circuit.

4. The mechanism giving rise to the episodal memories would be following. If the net metabolic feed to the left brain stays constant, a reduced metabolism in some areas results. As an emergency reaction to the reduced metabolism, the neurons in these areas send negative energy Z^0 MEs to gain metabolic energy by buy now-let others pay mechanism. Negative energy Z^0 MEs generate time-like entanglement with the geometric past by the mirror mechanism of long term memory, and episodal memories result as shared mental images. Also the life review experience during NDEs would be based on the same mechanism since the reduction of the metabolic energy feed would occur also now. Rather paradoxically, long term episodal memories would require a neuronal starvation and the over-activity of the memory coordination circuit would force this activity. This mechanism could also explain why the damage of some left brain regions can induce the ability to have sensory memories.

Synesthesia as a sensory leakage between thalamic nuclei common to the memory coordination circuit and primary sensory pathways

Synesthesia could be a byproduct of an abnormally large EEG amplitude in the memory coordination circuit and possibly also Papez circuit inducing a 'leakage' of nerve pulses between sensory pathways in thalamus in turn giving rise to synesthetic crossmodal associations. That synesthetic associations are projected, is consistent with the sensory leakage hypothesis.

The resonant EEG amplitude associated with the thalamic nuclei of the resonating memory coordination circuit spreads out to the primary sensory or motor pathways in the physical vicinity of the resonating pathway and generates a sensory leakage and a back projection to the sensory organs of

the induced modality thus inducing synesthesia. The structure of the synesthetic association is determined by the pattern of neurons activated and thus creating the virtual sensory input backprojected to the sensory organ of the induced sensory modality. One can imagine each neuron as a pixel of a sensory picture and the pattern of activated pixels determines the synesthetic association.

The model makes testable predictions.

1. The assumption that the sensory leakage occurs in the thalamus could be tested. One could study whether the crossmodal associations change, when the sensory input from right or left side of body is lacking. For instance, one could find what happens if audio-to-visual synesthete blocks left/right ear during audio-to-visual synesthesia.

2. The generation of artificial sensory experience by back-projection to the sensory organ of the induced sensory modality means that a permanent or an artificially induced temporal loss of the induced sensory modality (by a local anaesthesia of the axons of the sensory pathway) should lead to the loss of the synesthesia.

How to understand the memory feats of synesthetes and the reduced metabolism in the left hemisphere?

Negative energy Z^0 MEs can be interpreted as classical signals sent to the geometric past, and they should be crucial for an active memory recall involving a question sent to the geometric past. There are reasons to believe that right-left dichotomy corresponds to the negative energy-positive energy dichotomy for MEs in ULF range. This suggests that the question to the geometric past is sent by the right brain hemisphere as a negative energy Z^0 ME. Episodal and verbal memories would correspond naturally to quantum and classical communications.

1. Episodal memories and mirror mechanism

Mirror mechanism is the simplest quantum mechanism of episodal memories and involves only a sharing of mental images by entanglement. The brain hemisphere sends a negative energy Z^0 ME to the geometric past reflected at a large distance and returning back to the hemisphere. The question and answer fuse to a single mental image shared by the hemispheres of the geometric past and now. Usually only the right brain hemisphere would have episodal memories but in the case of synesthetes also left brain hemisphere would be forced to have this ability.

The generation of negative energy Z^0 MEs would involve a phase transition to a state in which the positive Z^0 MEs propagating along axons with a subluminal effective phase velocity transform to negative energy Z^0 MEs leaving the brain and reflected back. Synchronous membrane oscillations could accompany negative energy Z^0 MEs [M2]. If negative energy MEs are sent by the region of the left brain hemisphere, it gains some energy by pay now-let others pay mechanism.

This would not explain the reduction of the metabolism by 18 per cent during synesthesia. Rather, the generation of the negative energy Z^0 MEs would be forced by the starvation of the neurons induced by the over-activity of the neurons of the memory coordination circuit. The miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction. The starving cortical neurons of the left hemisphere send negative energy Z^0 MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. The same mechanism might work also in the normal situation but involve a less dramatic artificial starvation.

2. Non-episodal memories

Also in the case of non-episodal memories the question to the geometric past could be communicated by the mirror mechanism using negative energy Z^0 MEs and the sharing of mental images but the immediate answer would be more like a statement that the question has been received. The real answer would be communicated classically by the left brain hemisphere using positive energy Z^0 MEs with an extremely low effective phase velocity and accompanied by some neuronal excitation. The classical signal sent by the left hemisphere of the geometric past to the left hemisphere of the future would propagate a finite distance L within brain in a time interval T defining the temporal span of the memory (say years) so that the Z^0 ME would propagate with an effective phase velocity $v = L/T$.

The velocities of Ca^{++} waves span an extremely wide spectrum and provide a natural candidate for the physiological excitations associated with ultraslow MEs involved with the long term verbal memory. One can wonder whether the right hemisphere communicate the question classically to the geometric past using negative energy Z^0 MEs with superluminal effective phase velocity. If Ca_{++} waves are correlates for these Z^0 MEs they should "propagate" with superluminal velocity and would look like collective excitations with a slowly varying spatial phase.

4.6 Higher levels of biological self hierarchy

Am important question concerns about actual biological realization of the self hierarchy predicted to begin already at elementary particle level and continuing indefinitely. TGD indeed leads to rather concrete ideas about how this hierarchy is possibly realized.

4.6.1 General ideas about biological self hierarchy

Neurons are only one level of selves in the hierarchy starting from the level of body and sensory organs (or possibly from much higher level) and ending up to the level of 64 basic DNA triplets via neurons and microtubules and all between (or probably continuing even further downwards as suggested by the estimate for the duration of self as p-adic time scale associated with the system).

Buddhists classify fundamental experiences to 64 basic types in I Chin. Thus one can wonder whether they have achieved in meditation the level of DNA selves and recognized its presence clearly? I have proposed very simple model of abstraction process reproducing the basic numbers of genetic code [L1] and in this framework DNA:s might provide a physical realization for selves representing basic mutually consistent statements of simple formal system.

The model for abstraction process also predicts higher levels of hierarchy and the identification of the next level as 'memetic code' leads to correct prediction for the duration of psychological moment as well as to a correct prediction for the time scale of nerve pulse duration. It turns out that these levels could involve also electromagnetic selves with size of entire Earth: the conclusion follows using only Uncertainty Principle and topological field quantization.

4.6.2 Higher level selves in biological self hierarchy

The basic inputs for the speculations about the higher levels of the biological self hierarchy are topological field quantization, the idea of memetic code and the observations about the effects of EFL em fields to brain suggesting that the higher levels correspond to em selves with sizes of order wavelength of photons generated by EEG currents having size of order of Earth and realized as topological field quanta. The general view about symbiosis of hierarchies of massless extremals (MEs) and superconducting magnetic flux tube structures with the ordinary matter at atomic space-time sheets provides strong constraints on the speculations. The general vision about sensory representations realized in terms of magnetic flux tube structures outside brain [H4] and having sizes of ELF wavelengths leads to rather concrete ideas about the self hierarchy and about our position in it.

Topological field quantization

Topological field quantization [D9] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized by the absolute minimization of the Kähler action making classical space-time surfaces the counterparts of the Bohr orbits. Feynmann diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" [J4] representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [G1]. Also bioystems might have invented negative energy space-time sheets: in fact, so called "massless extremals" provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [I3]. An interesting possibility is that quantum entanglement has the formation of the join along boundaries bonds as its geometric correlate.

The hypothesis of topological self-referentiality stating that the topological field quanta of classical fields form a symbolic representation for the system's properties, provides a strong interpretative tool. For instance, bound state entanglement is represented by negative energy MEs and the generation of macroscopic bound states essential for the binding of the mental images is accompanied by the liberation of the binding energy as a usable energy. Hence the ability of the system to behave as a single coherent whole and nonlocal quantum metabolism are different sides of the same coin. The concept of field body (or electromagnetic body) consisting of the topological field quanta is also of central importance. Field body could be seen as a 'manual' for the system providing a classical, topological representation for the quantum aspects of the material part of the system. The size of this field body is much larger than the material body of the system.

Topological field quanta (field bodies) could serve as templates for the formation of the biostructures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible biomatter and the visible part of biosystem might represent only a dip of an ice berg.

Topologically quantized classical fields as templates for self hierarchy?

The web like structure formed by topological field quanta representing classical fields, in particular em fields, is remiscent of structures formed by microtubules and collagens forming the connecting tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various biostructures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4 \times 10^{-6}$ meters for $B = .5 \times 10^{-4}$ Tesla. If magnetic flux tubes of Earth have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along microtubules, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level self! One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the so narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm) to the size of human brain lobe (10 cm) as well as the the ratio of the thickness of cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Thus it seems that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy.

The web formed by topological field quanta of the classical em and Z^0 fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [D6]. Perhaps

also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Identification of mindlike space-time sheets as massless extremals

So called 'massless extremals' (MEs) are basic solutions of field equations associated with Kähler action [J4]. MEs describe propagation of one-dimensional nondispersive wave with light velocity and are accompanied by lightlike vacuum current generating coherent photons. Since the vacuum current behaves in nondeterministic manner at given point of ME, it is ideal for the coding of information. MEs can appear also as pairs of space-time sheets such that the two space-time sheets have opposite time orientations and hence also energies so that the net energy of ME pair vanishes. MEs define a fractal hierarchy starting from elementary particle length scales and extending up to cosmic length scales.

The natural identification of MEs as building blocks of cognitive structures leads to rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other and biomatter. The model allows to understand EEG as a direct physical correlate of mindlike space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also so called RF (radiofrequency) and MW (microwave) MEs representing our mental images are crucial for the model. MEs are also crucial in the model of qualia. MEs are present also below cellular length scales and even at molecular level.

MEs can also serve as Josephson junctions and this could explain the observed intensity windows in the interaction of ELF em fields with biomatter [48]. The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our electromagnetic body. It took long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; with ULF ME having size of order order light years from the fact that we have long term memories in time scale of lifetime; or with self having literally infinite size. The last two options seem to be more plausible than the first three: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body.

MEs are accompanied by so called exotic representations of p-adic Super Virasoro and Super Canonical algebras generated by subalgebra of generators for which conformal weights vanish modulo some integer power p^n of p ($n > 0$) (the prime p characterizes the p-adic number field in question). The properties of these extremely light states, in particular, their gigantic degeneracy, make them ideal candidates for lifeforms and one ends up with nothing less than a general classification of lifeforms! This idea seemed too good and too big to be taken seriously but it indeed seems that one could understand life as symbiosis of these exotic Super Virasoro representations ('spirit') interacting with each other and 'matter' via classical gauge fields associated with MEs. For instance, primary sensory organs could be accompanied by lifeforms of this kind and the quantum transitions of the exotic Super Virasoro representations are crucial in the model of non-geometric qualia described in [K3].

Estimate for the "wake-up time" of sensory sub-selves from p-adic length scale hypothesis and from a model of memetic code

p-Adic length scale hypothesis suggests that the typical duration of a self characterized by p-adic prime p is given by the p-adic time scale $T_p = L_p/c$, where $L_p \simeq 10^4\sqrt{p}$ Planck lengths is the p-adic length scale. The duration of our immediate memory of about .1 second would correspond to a p-adic length scale of the order of the circumference of the Earth! Either the estimate is based on wrong assumptions or our picture about brain as a seat of consciousness is quite not correct! TGD predicts entire self-hierarchy so that it is not all obvious which option is correct.

Amazingly, .1 second time scale comes as a prediction from the model of abstraction process leading to the prediction of Combinatorial Hierarchy characterized by a sequence of Mersenne numbers $M(n+1) = M_{M(n)}$, $M_2 = 3$. This gives rise to the hierarchy $3, 7, 127, 2^{127} - 1$,... the first members of which are known to be primes. Genetic code corresponds to the level $M_7 = 127$. The natural question is whether a counterpart of the genetic code could make sense for memes. Combinatorial

Hierarchy model for abstraction process that memetic code should correspond to the level M_{127} of the hierarchy. This leads to a precise realization of the memetic code in terms of binary sequences. Codewords correspond to 126 digit sequences.

Combined with p-adic length scale hypothesis this leads to the prediction for the duration of memes identifiable as our cognitive sub-selves as the secondary p-adic time scale $T_p^{(2)} = \sqrt{p}L_p$ associated with M_{127}. The prediction for the duration is .1 seconds! Bit sequences should correspond temporal sequences of mindlike space-time sheets and the neutrino realization of Boolean mind leads to idea that each binary digit corresponds either to spin degree of freedom for cognitive neutrino or to neutrino-antineutrino cognitive pair or absence of it. If this time scale corresponds to a sequence consisting 126 bits, the duration of single bit is about one millisecond, which happens to correspond to a definite p-adic time scale and is of same order of magnitude as the duration of nerve pulse! It must be emphasized that this estimate does not allow to conclude anything about the duration of our self which could be much longer.

Cyclotron resonances as key to quantum consciousness

The estimate for the thickness of the magnetic flux tubes of Earth's magnetic field based on the quantization of the magnetic flux is about cell size. There is direct evidence for the hypothesis that ions in the magnetic field of .2 Gauss (Earth' magnetic field has nominal strength of $B_E = .5$ Gauss) form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size: in fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic field corresponds to the length scale $L(169) \simeq 5$ μm rather precisely. This length scale is indeed the p-adic length scale which seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries condensates. The work of Blackman and other pioneers of bioelectromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [59] provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system.

The discovery of Blackman means that frequencies having special effect on biomatter correspond to cyclotron resonances for ions like Ca_{++}, Na_+, K_+ and Cl_- in magnetic field $B = 2B_E/5 = .2$ Gauss. The cyclotron frequency for Ca_{++} is 15 Hz whereas the remaining frequencies are in the range $7 - 13$ Hz (theta waves) at which also the most important Schumann resonances lie. The cyclotron frequency 5.5 Hz of iron is also a bio-active frequency and is the lower edge of theta region of EEG. Also lower frequencies resonant frequencies such as 2.4 (Iodium ion) are present. Even more remarkably, the pattern of data forces to conclude that the interaction occurs at quantum level. This conclusion is is dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time but consistent with the many-sheeted space-time concept of TGD.

A confession is in order: for years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency 15 Hz as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value .3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [M3]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [M3]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest a general formula for the allowed values of λ [C9] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [C7]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \to h = nh_0$ in the transition

increasing Planck constant: this is achieved by scalings $L(k) \to nL(k)$ and $B \to B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 25$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [E9].

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field in the direction of axon carrying $B = 2B_E/5 = .2$ Gauss , is supported by the following observations.

1. The frequencies $15, 30, 45, 60, 75$ Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca_{++} ion. That these frequencies come in multiples is a direct signature of quantum: in classical world only basic frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency.

2. Even multiples of 15 Hz have a weak but non-vanishing effect. This can be understood as resulting from parity conservation for the simplest transitions induced by that part of the interaction Hamiltonian which does not depend on the longitudinal coordinate of the axon. The reason is that odd and even values of n for harmonic oscillator states have opposite parities and the interaction hamiltonian describing the transition has odd parity. The simplest possibility is that these transitions occur in second via intermediate virtual intermediate state and correspond to second order in perturbation theory. This observation provides additional strong support for the hypothesis that quantum transitions are involved.

These observations are consistent with the following interpretation. Ions with charge Z, spin S and mass m in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as multiples of

$$\begin{aligned} E &= (n + \frac{1}{2})\omega_c + \frac{S_z}{S}\omega_L \ , \\ \omega_c &= \frac{ZeB}{m} \ , \quad (\hbar = 1, c = 1) \ , \\ \omega_L &= \frac{gS\omega_c}{4} \ . \end{aligned} \tag{4.6.1}$$

Here S and S_z denote total spin and its projection to the direction of the magnetic field. The contribution to energy coming from longitudinal motion has not been written explicitly. Here g is so called Lande factor which for free elementary fermions equals to $g = 2$. The experimental findings suggests strongly that external em field induces resonant transitions from between magnetic states. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal size of the magnetic flux tube for the magnetic field of Earth is of order cell size. An attractive hypothesis is that the magnetic field in question is associated with axon and is parallel to it.

It must be emphasized that this vision is forced by hard experimental facts and is in dramatic contradiction with the standard physics view about brain. The wave functions of ions in magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{n/eB} \ ,$$

which is of the order of cell size for B=.2 Gauss: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the length scale $L(169) \simeq 4$ μm rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2e$. $L(169)$ seems to correspond to our sensory consciousness and various macroscopic quantum phases seem to reside at $k = 169$ space-time sheets probably forming join along boundaries condensates.

The binding energies of ions in Earth's magnetic field are extremely small: of order 10^{-14} eV, which is ridiculously small energy when compared with the natural energy scale of one eV and corresponds to a temperature of order 10^{-10} Kelvin. According to standard quantum physics, Earth's magnetic field should have absolutely no detectable effects in hot, wetty and noisy environment provided by brain. Many-sheeted space-time concept provides the solution to the riddle. Ions are not on the molecular space-time sheets but have dropped to the cellular space-time sheet and it is indeed very cold, dry and silent here: an ideal place for the formation of macroscopic quantum phases. The energy scale implies the upper bound $T < 10^{-10}$ Kelvin for the temperature at cellular space-time sheets.

A further empirical input of crucial importance were the observations challenging the cherished notions of ionic pumps and channels [21]. These findings lead to a concrete view about biosystems as three-levelled structures involving massless extremals (MEs), super conducting magnetic flux tube structures, and atomic space-time sheets containing the ordinary matter. MEs control the dynamics of the superconducting ions inside magnetic flux tube structures. Magnetic flux tubes in turn are in a many-sheeted ionic flow equilibrium with the atomic space-time sheets and thus control the ionic concentrations at these space-time sheets.

This general framework leads to a rather detailed model for the generation of nerve pulse and EEG; to a model of sensory representations based on the notion of sensory canvas realized in terms of magnetic flux tube structures outside body with MEs serving as projectors of the cortical sensory representations to this sensory canvas; to a model of cognition including the realization of the memetic code in terms of cognitive antineutrinos and a physical mechanism translating nerve pulse sequencies to the 126 bit long codewords of the memetic code; and finally, to a model for the quantum correlates of the sensory qualia and to what deserves to be called spectroscopy of consciousness.

Electromagnetic selves

Rather remarkably, the time scale of .1 seconds predicted by the model of the memetic code and also the time scales of the photons associated with the magnetic transition frequencies, in particular cyclotron frequencies, of ions correspond to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth: the lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21 ,... Hz [38] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere.

The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular,, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such microseizures and epilepsies [22]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

These observations suggests the identification of the relevant selves in our self-hierarchy are electromagnetic selves having the size of Earth and correspond to EEG frequencies! What happens is that Josephson currents generate classical ELF em fields represented by topological field quanta of this size (by uncertainty principle alone) which in turn couple resonantly to ions. These observations raise the question whether our "physical" body is only a dip of an iceberg and formed by the topological condensation of the biomatter around electromagnetic topological field quanta serving as templates for the biostructures [I3]. There is also neuropsycological evidence for the importance of ELF fields. In particular, the work of Michael Persinger is especially important [44, 20, 21, 22] [L1].

One possible scenario inspired by these observations is following.

1. The magnetic transition frequencies for the superconducting ions at the flux quanta of magnetic field B=.2 Gauss correspond to personal sensory consciousness. The magnetic flux tubes emanating more or less vertically from brain and accompanied by massless extremals could act as projectors defining personal sensory representations at the magnetic sensory canvas formed by the flux tubes (or possibly shell like topological quanta) of Earth's magnetic field.

2. Schumann frequencies associated with the oscillations of the flux tubes of Earth's magnetic field would in turn correspond to transpersonal aspect of consciousness. Schumann resonances could indeed induce a synchrony of the vertical magnetic flux tube structures associated with separate brains and even entangle them during sleep. This view is supported by some observations. In hypnagogic states (states between wake and sleep) EEG is peaked near the lowest Schumann frequency 7.8 Hz. During these states it is possible to experience hallucinations and identification experiences (I have now and then fleeting but completely 'real' experiences of being someone else). The so called sleeping spindles correspond to EEG patterns at 14 Hz which is the second Schumann frequency. A possible interpretation is that during sleep collective consciousness begins to dominate and brains form a highly synchronous whole. It would be interesting to test whether there are correlations between EEGs of different persons during sleep.

4.6.3 Quantum entanglement with higher level selves

Quantum entanglement with higher level selves has been one of the 'Eastern' ideas in development of TGD inspired theory of consciousness. The evolution in the very notion of 'self' however has been accompanied by the evolution of the notion of 'higher level self', and the views about the role of quantum entanglement have been fluctuating (and a tedious updating of the material related to this concept).

What 'higher level self' means?

When talking about quantum entanglement with higher level selves the first question is what 'higher level self' means. There are several manners to define this notion.

1. Self can correspond to space-time region of a given local topology contained inside larger region of different local topology. The larger region is in this case the 'higher level self'.

2. p-Adic hierarchy of the local space-time sheet topologies defines a hierarchy of selves and real selves are at the top of this hierarchy.

3. Real selves are expected to be near criticality against topological transitions to some p-adic selves and it should be possible to assign to each real self a p-adic prime characterizing its position in the hierarchy of real selves. Also p-adic selves could be near criticality against transition to some other p-adic topologies and again a hierarchy of selves with fixed p becomes possible.

The quantum entanglement with a self containing self as a region of different local topology (option a)) should always lead to the loss of consciousness since the phase transition changes the local topology of sub-self to that of self. Lower level self not only becomes unconscious but also loses its topological identity. This kind of phase transition could, but not need, occur for our self during sleep. The entanglement of sub-self understood in this sense need not be a completely passive state but higher level self could use lower level self as its instrument: trance could be an excellent example of this kind of situation.

An interesting question is what happens when sub-self entangles with a self of external world having same local topology (real or p-adic, option c)): this involves the formation of join along boundaries bonds fusing the two selves in question. Does sub-self remember anything about this period when it is sub-self of some other self? Could sub-self experience this period as an extended state of consciousness when the real self outside is characterized by a larger p-adic prime (option c))? In the sequel these questions and mechanism leading to entanglement with higher level self and signatures of this entanglement are discussed.

Possible geometric correlates of entanglement?

The geometric correlate for the entanglement between sub-systems is the generation of join along boundaries bonds combining the corresponding 3-surfaces to single 3-surface: this is nothing but the direct touching of the 3-surfaces. Actually, all that is needed is the fusion of the space-time sheets of same local topology (real or p-adic) to single sheet. The entanglement generated in this manner can be preserved even when direct geometrical contact between 3-surfaces is not present anymore. In TGD based model for brain these bonds are formed between parts of brain and sensory organs.

One can consider several models for join along boundaries bonds. Topological field quantization providing general description of classical gauge and gravitational fields in TGD framework implies that magnetic and electric flux tubes and "massless extremals" (MEs) are the basic building blocks of classical em fields. All these structures can serve as join along boundaries bonds.

MEs are especially interesting candidates for join along boundaries bonds. MEs are very general solutions of field equations of TGD and have properties making them ideal for realizing basic functions of biosystems.

1. MEs represent propagation of classical gauge fields with light velocity and can carry non-vanishing vacuum em currents and hence give rise to coherent photons. A tentative identification is as biophotons of Popp [23]. The hypothesis is that MEs make possible generation of quantum entanglement between brain and sensory organs. In this manner they provide a realization for neuronal window idea generalizing the idea about hologramic brain [H7]. MEs could make possible both classical (quantum) communication by the propagation of classical fields (coherent photons) along them and neuron could literally have a window to external world via sensory organ.

2. In TGD framework space-time sheets with negative time orientation are possible and carry negative classical energies (in General Relativity this is not possible). The generation of negative energy MEs provides "buy now, pay later" type mechanism for energy production. Generation of negative energy ME is classical counterpart for the generation of virtual particle and it is to be expected that the subjective lifetime of negative energy MEs is finite number of quantum jumps. Thus organism must eventually "pay", that is to compensate for the dissipation of the energy gained by the generation of the ME by metabolism. Therefore metabolism is still needed. Even more, organism must be able to give guarantees that it can pay! The ability to provide these guarantees is perhaps one of the great achievements of the biological evolution.

3. MEs carry large momentum since all Fourier components of the gauge fields have parallel lightlike momenta. Since classical 4-momentum is lightlike, the amount 3-momentum per energy is maximal. Thus, if the system is able to generate ME by quantum jump, it gains automatically large recoil momentum. Hence MEs could provide the fundamental mechanism making possible the coherent macroscopic motion of living systems. Negative energy ME of this kind might be identifiable as a mindlike space-time sheet representing the geometric correlate for the conscious decision to move.

4. MEs represent dispersionless propagation of a pulse preserving its shape and are thus ideal for classical communication. If negative energy MEs are possible, one can imagine a mechanism of "real subjective time" communication between selves of either geometric past or future having arbitrarly large timelike distance. This idea is not conflict with standard classical causality at given space-time sheet. Needless to say, this kind of possibility would realize concretely the idea about four-dimensional society and revolutionize our view about universe: living beings separated by billions of light years could in principle have "real subjective time" chat.

Direct eye contact as an example of quantum entanglement between experiencers?

Direct eye contact is fundamental in the communication between living creatures. The naive intuitive picture of cartoon drawings about direct eye contact is is as rays connecting the eyes of persons involved. TGD suggests that this naive picture actually represents fundamental mechanism for the temporal fusion of selves to form larger selves. What could happen is that join along boundaries bonds are formed between eyes, and, if the neural window hypothesis holds true, also between brains and eventually between sensory canvases.

MEs are optimal for this purpose. The coherent photons associated with them would be the required macroscopic quantum phase associated with the entire higher level self. Thus it is perhaps not accident that extended states of consciousness are so often described as experiences about radiance of light. A weaker hypothesis is that eye contact involves only the formation of join along boundaries bonds along which classical communication based on propagation of classical signals occurs. Also for this option MEs are optimal candidates for join along boundaries bonds.

The reader has possibly noticed that these arguments open up the possibility that our visual field in some sense corresponds to the actual visual field rather than only its cognitive representation provide

by the visual pathways. The photons arriving along MEs connecting our brain with the objects of the perceptive field could provide the join along boundaries bonds extending our sensory self to contain part of the external world. Our visual field would still be determined by the light entering to our eyes so that no contradictions with well established empirical facts about vision are encountered. This kind of extension of visual self could however provide completely new manners for brain to compute the distances to the objects of the perceptive field since the basic information would not be mere two-dimensional picture in retina. The most plausible option seems to be however the one in which ultimate sensory representations are realized outside brain at the sensory canvas provided by the magnetic flux tube structures which can be even of the order of Earth size. This option is discussed in [H4].

Semitrance mechanism

The notion of semitrance allows to understand how higher level selves can communicate to and control and coordinate the behaviour of lower levels selves. If individual contains at least part of time at least single sub-self, this sub-self can entangle with higher level self and in this trance state can communicate with the self and possible sub-selves and transmit commands, advices or messages. Communication is here quite generally understood as a generation of mental images, waking-up of sub-selves, these sub-selves could be p-adic sub-selves of real selves in accordance with the idea that communication is part of cognition. The wake-up process initiates self-organization leading to a final state pattern representing the message. Final state pattern depends only weakly on the stimulus serving as message: this is as it should be.

The entanglement of the right or left brain hemisphere (or some part of it, perhaps the linguistic regions with respect to which human brain has highest asymmetry) with a collective self could be the basic mechanism making it possible to communicate the commands of the collective self to left and/or right hemisphere as 'hallucinations'. This leads to a TGD variant of the vision of Jaynes about bicamerals and schizophrenics as persons who differ from the average modern man in that they are able to receive commands and advice from collective levels of consciousness as hallucinations [16]. The notion of semitrance leads to very general views about how various societies (cells as societies of proteins, organisms as societies of cells, societies of various animals) develop and allows also to understand various altered states of consciousness [N5, N6].

The semitrance mechanism involves the generation of a bound state entanglement accompanied by the liberation of the binding energy as a usable energy. This non-metabolic energy might have something to do with the miraculous architectural feats of the ancient bicameral cultures (consider only pyramides) and the unusual physical strength of schizophrenics discussed in [16].

4.6.4 Dark matter hierarchy and higher levels of self hierarchy

The identification of dark matter as phases having large value of Planck constant [D6, J6, C7] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [C7]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [C9].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [C7]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value $\hbar_0$ of Planck constant: $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$. This in terms of a mild generalization of standard Jones inclusions [C7]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.

3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of M^4 and $n(G_a)$-fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.

4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of $\hbar$ in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2,C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2,C) \times SU(2)$.

5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimic these gauge theories. For $\beta = 4$ all ADE Kac

Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

Dark matter hierarchy and the notion of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n,p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m,n,p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. $m = 2^{11}$ seems to be favored in living matter [M3]. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

Higher levels of self hierarchy as levels of dark matter hierarchy

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. The integer $n = 2^{k11}$, $k = 0, 1, 2, ...$ seem to define favored values of Planck constant in living matter. This means a hierarchy in which time and length scales are zoomed up by a factor of 2048 in the transition to the next level of hierarchy. This integer represents also fundamental constant in TGD Universe [D6].

For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal

threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in questions. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

4.7 Ageing and death

One can interpret the world ageing in two senses. The ageing with respect to geometric time and the ageing with respect to the subjective time.

Geometric ageing might correlate closely with entropy growth due to the non-determinism of Kähler action. Basically this classical non-determinism would gradually spoil the functioning of the physical body. In particular, the non-determinism of Kähler action implies that there is fractal hierarchy of MEs (massless extremals) inside MEs. The lightlike boundaries of MEs can be identified as an important instance of 3-surfaces identifiable as geometric correlates of selves. Geometric ageing could thus be closely related to the entropy growth associated with the emergence of MEs inside MEs.

What interests us mostly is obviously the subjective ageing: What ageing person experiences? Is there a continuity of subjective experience and what follows after physical death?[1] How our deeds affects to the experiences after the physical death? The situation is complicated by the fact that we possess entire hierarchy of selves. The selves associated with the physical body do not certainly survive with respect to the geometric time in the physical death whereas electromagnetic selves and field body could quite well do so. The second complication is that selves contain sub-selves located in various values of the geometric time, even childhood. The question is about what sub-selves dominate during ageing: are these selves electromagnetic selves or bodily selves and do sub-selves of geometric past, now or future dominate. Subjective ageing could proceed in many manners depending on these factors.

The basic problem involved is the identification of the after life self. Universe is full of selves and one cannot say anything definite about the fate of self after death unless one can decide which self can be regarded as the continuation of self before death. Since selves and mindlike space-time sheets are firmly associated with each other, the question about the reality of physical death reduces to the question about the fate of the 'personal' mindlike space-time sheet(s) during ageing and after death and the identification of the personal mindlike space-time sheet.

The notion of electromagnetic body, when combined with the view about psychological time as the value of the geometric time defining the front of the p-adic-to-real phase transition at which intentions are transformed to deeds, allows a general answer to these questions. Magnetic body certainly survives the physical death, and since it serves as the sensory canvas, there are all reasons to expect that consciousness continues after the physical death. The contents of consciousness would be determined by the 4-dimensional physical and electromagnetic bodies and the dominating contribution creating the illusion about reality as a time=constant snapshot would be absent. Kind of timeless consciousness would be in question in accordance with the life review experiences associated with NDEs.

[1] 'Physical' means here 'bodily' or 'material'.

4.7.1 Ageing as a price for having self

Self can be regarded as a statistical ensemble defined by the unentangled final states of the quantum jumps. Since the size of this ensemble increases quantum jump by quantum jump, the approach of this ensemble to thermal equilibrium is unavoidable although living matter has probably invented manners to fight against the second law of thermodynamics. In real context the ageing of self means dissipation. In p-adic context the notion of energy dissipation need not be especially useful. Rather the gradients of various entropy type variables associated with self with respect to subjective time variables are the proper variables to characterize what happens in dissipation understood as gradual thermalization of distributions of quantum number increments and zero mode increments.

Each p-adic length scale defines its own characteristic dissipation. In case of a self decomposing into sub-selves the rate of dissipation is sum over the real dissipation rates associated with the nested system formed by the self, its sub-selves, their sub-selves, etc.... The dissipation associated with states of whole-body consciousness can be anomalously small since only the highest level contributes to the dissipation rate. If the system is a join along boundaries condensate formed from a large number of sub-systems whose sizes are characterized by a p-adic length scale, especially low dissipation rate results. A possible test for this is the study of total rate of metabolism during meditation.

Dissipation implies thermodynamical arrow of time and this is directly related to the arrow of the psychological time, which can be understood as resulting from drift of the mindlike space-time sheets in the future lightcone occurring also when the sheets do not define separate selves. The interpretation of the psychological time as a zero mode and localization in zero modes in each quantum jump is absolutely crucial for this argument. The continual drifting of mindlike space-time sheet is supported also by the fact that psychological time grows steadily also during sleep.

Dissipation can be interpreted as the ageing of self: getting old is the price for having self. More concretely, the entropies associated with various distributions of quantum number and zero mode increments increase during ageing so that mental images are gradually blurred. Note that also our self which defines a mental image of a higher level self is blurred. Also physical death, or at least death experience, seems to be unavoidable fate of self. An open question is what happens for the mindlike space-time sheet carrying self after death. Could the mindlike space-time sheet be called soul? Does this soul continue drift in lightcone and get attached to some new material system so that reincarnation would occur? "Ontogeny recapitulates phylogeny" principle suggests that the evolution of an individual is image for the evolution of the entire universe. This would mean that "physical" death would be only a metamorphosis to some new form of existence, perhaps as topologically quantized classical fields associated with the physical body. Massless extremals (MEs) and magnetic flux tube structures having sizes measured in scale of light lifetime are especially promising candidates for the components of electromagnetic body surviving in the death of what is usually identified as the physical body. Some experimental facts lead to rather precise ideas about the geometric representation of our selves and also suggest that our existence continues in electromagnetic form after death [I3].

4.7.2 Death as disappearance of the mental image representing the physical body?

If one takes seriously the following two assumptions behind the TGD based model of quantum control and coordinate based on the symbiosis of MEs, magnetic flux tube structures, and matter at the atomic space-time sheets, one ends up with rather concrete view about what happens after the bodily death.

1. Our mental images actually correspond to ELF and even ULF MEs of size of order $L \sim \lambda = c/f$, where f is the frequency in question (not above EEG range), so that the sizes of these mental images are measured using Earth size as a unit. Sizes of MEs of order lightlife are possible.

2. The ultimate sensory representations are realized on the sensory canvas provided by magnetic flux tube structures of similar size, so that we have magnetic body providing sensory representation of the physical body and external world [H4]. Our magnetic self very probably survives in the physical death by the conservation of the magnetic flux.

Under these assumption our afterlife body would consists of the magnetic body plus MEs possibly surviving the death of the so called physical body. The only difference as compared to the life before

death would be that the sensory and cognitive mental images representing the physical body (sub-selves) would disappear and the attention of our self would be directed to something else. Near death experiences indeed support this view [I3]. In this picture re-incarnation is possible and even plausible and means only that the magnetic flux tube structure representing our bodily self turns its attention to some other physical body and uses it as a sensory and motor organ. This new physical body could be plant, animal, human, or perhaps something else. In this picture the metaphor about physical body as a cloth becomes very concrete.

Since self has an extension with respect to geometric time, it has memories about its earlier history and one could perhaps identify the continuation of self after the death as that self which has the memories of self with respect to geometric time before death. In this extended state of consciousness self could experience the subjective past of self's mindlike space-time sheet and associate it with self's recent mindlike space-time sheet. Note that this kind of mechanism could also explain why it is possible that I regard it obvious that I existed yesterday although my bodily self slept over night. This picture is consistent with the reported ability of some children to remember their past lives.

4.7.3 Ageing and death from the point of view entanglement generation

Ageing could be seen also as a process analogous to the process of getting drowsy and falling asleep but in much longer time scales. The process would involve generation of temporal entanglement of bodily sub-self with larger selves involving phase transition changing the topology of the space-time sheet representing self to that of the surrounding world. Bodily sub-self would not remember anything about these periods of different local topology. Our sub-self would not have no mental image about body during these periods. Also sleep could represent a similar conscious state without bodily mental image and the impossibility to remember anything about this period of consciousness might be simply due to the fact that one can remember something about sleep state only in sleep state.

An alternative option is that space-time sheet representing the bodily self preserves its local topology but fuses to a space-time sheet of similar local topology outside the physical body. Generation of join along boundaries bonds could be the geometric correlate of this process. During ageing bodily sub-self would spend more and more time near the critical line at which this transition occurs. If bodily sub-self ceases to be our self in this process we do not remember anything about these periods.

Perhaps the process of ageing could be a process of personal growth (in rather concrete sense!). The temporal entanglements generated with larger selves would give rise to larger temporal selves and the metaphor 'awakening' would thus be much more than a metaphor. Person would spend more and more time in extended state of consciousnesss and in death finally leave the confines of the physical body. Note that person need not, and probably doesn't, remember anything about the periods of entanglement in which the local topology of self changes. This would make possible the evolution of selves continuing after death to higher levels of conscious existence. This picture is rather optimistic: one must also consider the possibility that the evolution of self is not continuous growth! The fact that the individual development of most people seems to be a process of continual abstraction indeed that physical death is only one step in the process of abstractions and that our self consciously experiences the final transition to higher level of existence in death.

In death the space-time sheet representing bodily sub-self would get so far from the critical line for the phase transition of the local topology back to original one that wake-up becomes impossible for the sub-selves associated with the physical body. For instance, the effect of electric shocks on patients who have suffered heart attack and lost consciousness could be understood as a large enough perturbation able to bring the bodily sub-self back to the critical line.

4.7.4 Why childhood memories are recalled so intensely?

The first manner to see ageing is as a subjective experience: as ageing with respect to subjective time. Our self contains sub-selves representing our memories, sensory input from the geometric now and future plans. At the old age it often happens that childhood memories begin to dominate whereas the recall of more recent memories is gradually lost. Of course, the contribution of future plans becomes also gradually negligible. This suggests that the contents of consciousness for our self can suffer a gradual transformation such that the childhood begins to dominate: of course, this need not happen always. That the childhood dominates is not easy to understand if the memories of the past are stored in the geometric now as assumed in the standard brain science. In TGD framework the very fact that

the childhood consciousness is very intense and un-conceptual, explains the dominance of the episodal memories of childhood.

Who is the subjective experiencer in this kind of situation? Is it the old person with vivid memories or a child with some very diffuse ideas about future? The view about psychological time would suggest that the general experience gradually becomes some kind of a 4-dimensional life review such that the very intense childhood memories dominate but that the person in the psychological now is still the only one who can transform intentions to actions effectively whereas the 4-D body of the past is more or less frozen.

4.7.5 What after physical death?

In TGD framework physical body is accompanied by magnetic body and radiation body which provide representation for the physical (or better to say, material) body. The latter consists of radiation selves (massless extremals representing topologically rays of light) representing classically the ELF radiation fields generated by EEG currents, one is led to ask what happens for these em selves in physical death. Some of them correspond to resonant frequencies of the em fields in the 80 km thick wave cavity between Earth surface and ionosphere known as Schumann frequencies and one can consider the possibility that that something which might be called soul remains after the physical death and is represented as Schumann resonances.

The most plausible hypothesis is that both ULF MEs and magnetic flux tube structures remaining after physical death together with the 4-dimensional body of geometric past define our self after the physical death. This leads to the following speculative vision about consciousness after the physical death.

1. The transformation of intentions to actions as p-adic-to-real transitions ceases in the physical death so that the dominating contribution of the psychological now to the experience disappears and conscious experience becomes kind of four-dimensional life review in which also the contributions from other bodies (say deceased relatives) appear as unmasked.

2. The geometric past, or rather experiences about it, can be gradually refined but no big changes are possible, so that a totally new life based on different decisions does not seem to be possible. The assumption about totally new life would also lead to paradoxes. On the other hand, the unstability of the long term memories suggests that the memories about the past life could be edited. The conscious experience contains also the contribution of the magnetic body continuing to exist.

3. The surviving magnetic body could attach to some new organism which it begins to use as a sensory and motor organ. The re-incarnation would have the memories of the past life as an unconscious background masked strongly by the sensory input and coming clearly conscious only in some altered states of consciousness. The reports about children remembering they previous life could be understood in this conceptual framework. This of course makes one wonder whether young children could remember their past lives. Perhaps someone should ask!

There is a lot of subjective evidence consistent with life after death. Near-death experiences are not the only manner to get convinced for life after death. So called eye-movement desensitization and reprocessing (EMDR) discovered by Francine Shapiro [60, 21] induces what could be interpreted as after-death communications. The experiences of subject persons can be induced by this therapy in highly reliable manner: according to [21] 98 per cent of patients willing to participate the therapy had after death communication experience It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades in past. The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular rhytmic fashion while at the same time attending to a particular aspect of the traumatic memory. How EMRD works is poorly understood as yet: possibly the fact that the shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams. A possible explanation is that EMDR experiences could involve communication with

the recent selves of the deceased ones located possibly in the geometric recent or past and represented by magnetic flux tube structure and MEs interacting with them.

Indirect support for the survival of mindlike space-time sheets after death comes from rather unexpected direction. The phenomenon of phantom DNA suggesting that mindlike space-time sheets associated with DNA remain in the chamber which contained DNA: in the experiments of Poponin [36] the signature of phantom DNA is its interaction with laser light at visible frequencies. Phantom DNA would be represented by mindlike space-time sheets with size of at least the wavelength of visible light (10^{-7} meters). The em selves remaining after our death would have consirably larger size! One can however consider the possibility that some detectable interaction between EFL frequency em fields and 'phantom brain' ('em soul') could be possible and make it possible to prove experimentally the presence of em soul!

The claimed successes of homeopathy (For phantom DNA and homeopathy see [J5] and [K5]). could also have explanation in terms of the mindlike space-time sheets. Homepathic drugs are fabricated by a repeated dilution of the active drug so that the concentration of the drug in solution becomes extremely low. The method of fabrication could however imply that final product contains quite many mindlike space-time sheets of the drug molecules. These mindlike space-time sheets might be able to affect the sickness since the mindlike space-time sheets provide a cognitive representation for drug and this mimicry could 'cheat' the patient to cure. The law of similarities could have something to do with the mechanism involved.

More concretely, a given quantum transition frequency characterizing the medicine would be represented as ME with length equal to the wavelength associated with the transition frequency. The electromagnetic body of the molecule could be mimicked by liquid crystal water blobs producing similar transition frequencies and thus containing similar MEs in their electromagnetic bodies. The effect of the medicine would be mediated by the electromagnetic body so that the 'fake' medicine could indeed cure.

4.7.6 Near death experiences

Near death experiences provide a testing ground for the general ideas about what might happen in the physical death. Experiences resembling near death experiences can be produced now in controlled manner in laboratory circumstances for people well and alive and irrespective of their belief structure subject persons tell about light tunnels and meeting of deceased relatives [21]. These experiences have been found to be therapeutic and are indeed used as therapy to cure severe psychic traumas. Therefore the materialistic explanation as a hallucination associated with dying brain seems to be excluded. Near death experiences involve experiences like being in light tunnel, seeing beautiful and rich landscapes and meeting dead relatives. Also out-of-body experiences are involved. The model of NDEs are discussed in detail in [H9] and here only some brief comments are represented.

The proposed picture about physical death allows a lot of room to interpret these experiences. For instance, OBEs allow two explanations.

1. The first explanation is based on the fact that in TGD based model of sensory representations the magnetic sensory canvas far outside body basically sees the brain in ELF light. This light usually comes from brain and provides a sensory represention for the external world. TGD predicts also a mechanism producing background ELF radiation from the entire body at magnetic transition frequencies and this background would make possible to see the body 3-dimensionally from outside when the sensory input is absent and does not mask this weak contribution. NDE OBEs might correspond to this kind of vision reported also by yogis.

2. The experience looking one's body from outside could mean that some higher level self corresponding to slow EEG waves and higher em selves formed physically by the personnel of hospital in the hospital room begins to dominate. This self could perhaps see patient's body with the combined eyes of the hospital personnel. Indeed, since the sensory input from the physical body ceases, the illusory identification of 'me' with the physical body ceases and attention can be directed to this higher level sensory input.

Geometrically the em bodies of our dead relatives would exist in the geometric past and now, perhaps already in a re-incarnated form. This allows several explanation for the experience of meeting dead or living relatives. A very concrete model would be based on electromagnetic bridges formed by

magnetic mirrors and connecting us with our relatives and friends. This would make possible for us to see them in ELF light just like we would see ourselves.

The experience about meeting deceased relatives could be also understood as a special kind of geometric memory. Generation of the long term memory means classically looking to a magnetic mirror at classical level and seing the me of the past in the mirror. It is however possible to see someone else in the mirror since the magnetic fluxtube from the mirror could continue to the body of the deceased relative of friend instead of my body. In the usual states of consciousness the sensory input from the psychological now dominates and this contribution is masked. In near death experiences sensory input from the geometric now is diminished and the transpersonal background contribution becomes unmasked.

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Chapter 5

Quantum Model for Sensory Representations

5.1 Introduction

TGD inspired theory of consciousness allows to construct a general model of conscious experiences based on some very general principles.

1. The notion of quantum jump defines microscopic theory of consciousness whereas the notions of self and self hierarchy allow to understand macroscopic aspects of consciousness absolutely essential for brain consciousness. The assumptions about how the contents of consciousness of self is determined allow to understand the basic structure of conscious experience at general level. One can understand intentionality and volition as closely related to the p-adic nondeterminism; symbolic representations at space-time level are made by the classical nondeterminism of Kähler action; theory leads to a very general model of sensory experience and so called whole-body consciousness explaining basic characteristics of the mystic experiences is one of the basic predictions of the theory.

2. The understanding of the relationship between subjective and geometric time leads to the notion of psychological time involving in an an essential manner the new view about space-time, in particular the idea about mindlike space-time sheet as a geometric correlate of self. The notion of psychological time forces to view the entire many-sheeted space-time surface as a living system so that the standard notion of linear time is illusory and reflects the restricted information content of our conscious experience rather than fundamental 4-dimensional reality. The paradigm of 4-dimensional brain provides completely new understanding of the long term memory: no memory storage mechanisms are needed and one avoids the basic difficulties of neural net models. The fact that temporal duration of the lightlike self associated with ME can be arbitrarily long, is very probably of very high significance. There are two kinds of memories and emotions can be understood as resulting from the comparison of geometric memories (the expectation) with the subjective memories (what really happened).

3. Subjective time development by quantum jumps implies quantum self-organization which can be regarded as a sequence of quantum jumps between quantum histories. This evolution corresponds to a sequence of macroscopic space-time surfaces associated with the final state quantum histories. Quantum jumps imply dissipation at fundamental level. Dissipation serves as a Darwinian selector of self-organization patterns, which can represent both genes and memes. In particular, one can understand how habits, skills and behavioral patterns are gradually learned. The possibility of the reversal of the arrow of the geometric time below p-adic time scale characterizing the system brings in time reversed dissipation identifiable as a healing. Bio-rhytms could quite generally correspond to dissipation-healing cycles. Motor action could be understood as geometric time reversal for the build-up of sensory representation in an appropriate time scale.

4. An essential element is macrotemporal quantum coherence accompanying the formation of bound states. The transformation of zero modes of the binding subsystems to quantum fluctuating

degrees of freedom implies that a sequence of quantum jumps lasting for the lifetime of the bound state behaves effectively as single quantum jump and there is practically no quantum decoherence. Quantum spin glass degeneracy lengthens the lifetimes of the resulting bound states. The formation of the bound states, which is the TGD analog of Orch OR, is a key process in TGD based model of living matter and quantum brain.

This process gives deep insight to a repertoire of widely different phenomena.

i) The formation of bound states implies subjectotemporal fractality of consciousness meaning that the basic anatomy of quantum jump is replicated in various time scales, even that of human life cycle.

ii) Bound state entanglement means fusion of mental images and gives rise to experiences of 'oneness' at all levels of the self hierarchy. Telepathic sharing of mental images and remote mental interactions become possible. Sexual and spiritual experiences can be seen manifestations of the same basic process of fusion of selves and sex is present even at the molecular level. For instance, information molecules and receptors can be seen as having opposite molecular sexes with the binding of information molecule to receptor giving rise to the experience of 'oneness' and favoring co-operation instead of competition.

iii) Bound states give rise to mental images of low entanglement entropy in the real context and cognitive mental images of positive entanglement negentropy in p-adic context. Cognitive mental image with a positive entanglement negentropy gives rise to an experience of understanding.

iv) Both real and p-adic quantum computer like operations are possible for the bound states. Real-padic entanglement coefficients are necessarily algebraic numbers and a number-theoretic definition of entropy is possible: this entropy can be also negative so that it is possible assign genuine information to cognitive entanglement. This might make sense also for real bound states with an algebraic entanglement.

v) Jumping from the bottom of a valley of the quantum spin glass energy landscape to the bottom of another valley by a temporary delocalization in zero modes explains phase transition like processes ranging from a change of protein conformation to the replacement of a habit routine by a new one.

vi) The binding energy liberated in the binding process is usable energy: this means quantum metabolism based on buy now-pay later mechanism.

The general vision about different types of conscious experiences and about qualia was discussed in [H1]. In this chapter a general model of personal sensory representations is considered: in [K3] a more detailed model for these representations is discussed. The so called magnetospheric sensory and memory representations possibly responsible for the third person aspect of consciousness are dicussed in [N1].

5.1.1 The quantum hardware

The model involves the following basic notions and ideas about the quantal hardware of consciousness.

1. TGD universe is quantum spin glass and the plasticity of the brain is in accordance with a model of brain as point moving in an infinite-dimensional spin glass energy landscape. Inhibitory and excitatory nerve pulses induce motion in the energy landscape and justify the notion of frustration characterizing spin glass. The picture differs from ordinary neural net in that spin glass energy landscape has also time as one dimension in a well defined sense (this is due to the failure of the classical determinism in standard sense for the Kähler action defining the dynamics of the system). This allows a new view about what happens in learning.

2. The general model of sensory experience relies on the music metaphor. Axons are like strings of a music instrument. What this metaphor means is however not obvious. Frequency coding relates only the intensity of the sensory quale. Nerve pulses induce dropping of various ions to magnetic flux tubes in magnetic fields of $\simeq .2$ Gauss (Earth's magnetic field has nominal value .5 Gauss) and this generates EEG MEs at EEG frequencies serving as entanglers to the sensory magnetic canvas, and the variation of these frequencies could code for the distance to the object of the perceptive field.

A stronger interpretation of the metaphor is that sensory pathways are like strings of a musical instrument such that the sound produced by the string corresponds to a particular sensory modality and corresponding higher level cognitive representations associated with it. Primary sensory qualia can be associated with sensory receptors or primary sensory organ if brain and sensory organs are quantum entangled with each other. Nerve pulse patterns build up what could be regarded as notes representing the music whereas the music (primary sensory qualia) is produced by the primary sensory organs. This leads to a generalization of the idea about brain as an associative, cognitive net.

3. The notion of self hierarchy is central for the model and allows to understand quantum correlates of the sensory qualia.

   i) Self hierarchy is very much analogous to the hierarchy of subprograms of a computer program and defines a hierarchy of increasingly abstract experiences. Self hierarchy allows to understand computational aspects of brain although connectionistic picture realized as quantum association network seems to work at various levels of the hierarchy.

   ii) The empirical results [59, 48] about the effects of oscillating em fields on brain suggest that cyclotron frequencies, and more generally magnetic transition frequencies, of biologically important ions in magnetic field $B \simeq .2$ Gauss, which is by a factor 2/5 weaker then the magnetic field of Earth, correspond to important oscillation frequencies of Josephson currents or some other perturbations acting on the system. Also the magnetic transition frequencies of electronic Cooper pairs seem to be important as also Z^0 magnetic transition frequencies of neutrino and various ions and atoms and even molecules. Classically cyclotron frequency for Josephson current corresponds to resonance.

   iii) The role of massless extremals (MEs) have become more and more central in TGD inspired theory of consciousness as I have gradually understood their properties. Very briefly, MEs are ideal for both classical and quantum communications, they give rise to quantum holograms both in quantum gravitational and 'technological' sense. MEs make also possible the realization of long term memories as communications between future and past. The notion of conscious hologram makes these ideas very concrete.

   iv) The strange findings challenging the notions of ionic channels and pumps lead to the view about biosystem as a symbiosis of MEs, superconducting magnetic flux tube structures, and atomic space-time sheets. The latter two are in many-sheeted ionic flow equilibrium controlled by MEs and very elegant control mechanisms based on the classical em interaction between MEs and flux tubes inducing supra currents emerges.

   v) Self hierarchy has as its geometric correlate the hierarchy of space-time sheets. The fact that Josephson currents associated with ELF frequencies generate photons with wavelengths of size of Earth which by uncertainty principle correspond to topological field quanta with size of Earth. The only possible conclusion seems to be that our subselves correspond to (at least) these topological field quanta so that we are much more than our neurons.

   vi) It took years to arrive to the conclusion that also magnetic flux tube structures associated with various parts of brain could have same size as EEG MEs and serve as sensory canvas in the sense that the positions of objects of perceptive field are represented as subselves at the magnetic flux tubes of varying thickness woken-up by MEs generating magnetic transition frequencies. Obviously MEs and magnetic flux tubes associated with the sensory projectors must be very closely related (perhaps they are parallel to achieve Alfwen wave resonance). Various attributes associated with the object of the perceptive field are associated with these magnetic subselves and brain, or rather entire central nervous system, can be seen as a collection of pre-existing features of perceptive field which can be activated. Also long term memory recall can be understood in this framework as a communication between geometric now and geometric past made possible by MEs (which correspond to lightlike selves) and magnetic flux tube structures associated with brain, both having astrophysical sizes.

5.1.2 Me as a computer sitting at its own terminal?

It became as a surprise that the vision resulting from a long lasting thought experimentation is actually very much what the original, fifteen year old, altered state of consciousness experience about myself

as a computer sitting at its own terminal, when taken very literally in some aspects, actually suggests. This vision adds to the standard view about brain an additional layer responsible for the sensory representations and brings in the quantum level of control (possibly from magnetic body) so that nerve pulse patterns are only part of the control loop.

1. Magnetic flux tube structures serve as a sensory canvas analogous to the computer screen. The control commands realized by activating Z^0 MEs to em MEs, in which state they create coherent states of photons and possibly of "configuration space photons", generate magnetic quantum phase transitions, and induce supra currents, Josephson currents and Ohmic currents, provide a realization for the keyboard of this computer. Brain serves as central processing unit: the computations carried out are parallel computations and program modules are replaced by various self-organization patterns.

2. Motor actions and sensory representations differ in that they are time reversals of each other in a relevant p-adic time scale. For imagined motor actions and sensory experiences the first (rather than last as one might think!) step in the sequence of commands is simply not realized. For sensory experiences the first step means sensory input assuming that primary sensory qualia are at the level of sensory receptors. A real motor action proceeds like a geometric time reversal of the sensory input and starts from motor organs if it is real, and from some higher level if it is imagined. p-Adic-to-real phase transition is the basic step initiating neural activity leading to imagery.

3. Cortex can be seen as a collection of pre-existing cognitive features which are activated when they appear in the perceptive field or form a part of motor action. The basic task of cortex is to identify these features from the sensory input, entangle them with sensory input, and project to the magnetic body.

4. The decomposition of the perceptive field into objects is one of the basic aspects of sensory experiencing and TGD provides a mechanism generating these objects as mindlike space-time sheets: the boundaries of these objects correspond to regions of strong Kähler electric field whose strength is assumed to correlate with the intensity of the neural input. It might be that even the objects of perceptive field or thoughts could be regarded as features.

5. The computational activities associated with the construction of the sensory representations (say estimating distances and directions of the objects of perceptive field) and virtual sensory representations representing the goals of motor action are presumably realized as iterated processes in which virtual sensory inputs characterizing the expected experiences are compared with the real world sensory input. In a similar manner the goal of the motor action is compared with the sensory representation resulting from effect of a virtual motor action on the representation of the recent state of world and body. This comparison does not necessarily require sensory representation at any level of the self hierarchy and could be based on comparison circuits defined by parallel supra currents in which the inputs which are sufficiently near to each other generate constructive interference giving rise to a large Josephson current.

6. The neural realization of long term memories has remained to a high extent a mystery and TGD suggests that the fundamental realization is not in fact neural. TGD allows the geometric memory storage in the geometric past, where the things happened and still happen. MEs suggest several candidates for the memory recall mechanisms and the quantum communication between geometric future and past is one of the most promising ones. Active memory recall might involve a question sent to the geometric past as a classical signal, perhaps passive Z^0 MEs are involved at this stage. The answer presumably involves the generation of quantum entanglement: the recalled experience is shared by the experiencer now and in the geometric past. The recalled mental image is shared: there is no need to communicate the information defining the mental image classically since timelike entanglement is possible by the non-determinism of Kähler action.

   The mechanism involves several purely TGD based features: the lightlike character of the boundaries of MEs making possible lightlike selves; space-time sheets with a negative time orientation allowing classical signals to propagate backwards in time; the magnetic flux tube structures associated with brain having sizes of order light years making possible MEs to represent light reflected from the mirror formed by a magnetic flux tube at which MEs terminates.

7. The model of intentionality is mirror image of the model of long term memories obtained by real→ p-adic and geometric past→ geometric future replacements.

5.2 Quantum tools for biocontrol and -coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled super conductors would make possible quantum control.

This view allows to consider a more detailed mechanisms. What is certainly needed in the coordination of the grown up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [32]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in case of the verterbrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

5.2.1 Homeostasis as many-sheeted ionic flow equilibrium?

The experimental work of Ling, Sachs and Qin [42, 41] and other pioneers [40, 39] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from superconducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along superconducting cell membrane space-time sheet (rather than atomic space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Superconducting space-time sheets contain a plan of the biosystem coded to ion densities and magnetic quantum numbers characterizing the super currents. Biocontrol by em fields affects these super currents and one can understand the effects of ELF em fields on biosystem in this framework. The model relies crucially on the liquid crystal property of biomatter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [43]: among other things the circuitry could explain how acupuncture works.

5.2.2 Quantum model for pattern recognition

Time translation invariant pattern recognition circuit can be realized by using two coupled super conductors. The first superconductor contains the reference supra current and second superconductor contains the supra current determined by the sensory input. Supra currents are assumed to have

same spatially and temporally constant intensity. If the supra currents have spatially constant phase difference, also Josephson currents are in the same phase and sum up to a large current facilitating synchronous firing. The temporal phase difference of supra currents does not matter since it affects only the overall phase of the Josephson current. Therefore patterns differing by time translations are treated as equivalent. Quite generally, the requirement of time translational invariance, favours the coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations when the precise timing is important. The pattern to be recognized can be represented as a reference current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is represented by supra current interfering with the reference current. If the interference is destructive, synchronoous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recognition. Obviously the loss of time translation invariance makes this mechanism undesirable in the situations in which the precise timing of the sensory input does not matter. One can however imagine situations when timing is important: for instance, the deduction of the direction of the object of the auditory field from the phase difference associated with signals entering into right and left ears could correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-dimensional quantum brain suggests that sensory input leads by self-organization to a stationary spatial patterns of supracurrents and this process depends only very mildly on initial values. Thus self-organization would generate automatically pattern recognizers.

5.2.3 General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled super conductors and auantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two superconductors provides a manner to realize a biological clock. Josephson current can be written in the form [30]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{5.2.1}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of superconductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [30]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{5.2.2}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of biocontrol and a rhytmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{5.2.3}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector 'wakes-up' into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the instability of the structure. When the supra current in the circuit dissipates below a critical value, instability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second super conductor carriers a supra current. As the time passes the reference current dissipates by phase slippages[31, 30]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to a nonstability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The unstability itself can regenerate the reference current to the clock. If the alarm clock actually 'wakes-up' the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is nonvanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

5.3 Life as symbiosis of MEs, of superconducting magnetic flux tubes, electric flux quanta, and ordinary matter?

The identification of mindlike space-time sheets as 'massless extremals' (MEs) leads to very general vision about bio-consciousness and an explanation for the fact that the effects of ELF em fields on biomatter occur only for certain amplitude windows [48] (these effects are discussed in detail in [J1, J2, J3]

5.3.1 Massless extremals

What MEs are?

Massless extremals (MEs) are an extremely general solution set of field equations associated with Kähler action [B1] and representing various gauge fields and gravitational fields[J4]. Being scale invariant, MEs come in all size scales. The geometry has axial symmetry in the sense that CP_2 coordinates are arbitrary functions of two variables constructed from Minkowski coordinates: lightlike

coordinate $t-z$ and arbitary function of the coordinates of the plane orthogonal to the z-axis defining the direction of propagation. The polarization of the electromagnetic field depends on the point of the plane but is temporally constant. MEs represent waves propagating with velocity of light in single direction so that there is no dispersion: preservation of the pulse shape makes MEs ideal for classical communications.

Electric and magnetic parts of various gauge fields are orthogonal to each other and to the direction of propagation. Classical gauge has as its source lightlike vacuum current. The time dependence of the vacuum current is arbitrary, this is only possible by its lightlikeness. This makes it possible to code all kinds of physical information to the time dependence of the vacuum current. MEs can have finite spatial size and in this case they are classical counterparts of virtual photons exchanged between charged particles and represent classical communication between material space-time sheets. MEs carry gravitational waves and also classical Z^0 fields propagating with light velocity.

MEs can also carry constant electric and magnetic fields but in this case the boundaries of ME contain necessarily the sources of this field. Lightlike vacuum currents or elementary particles in massless phase could serve as sources MEs could also form double-sheeted structures with wormhole contacts serving as effective sources. TGD allows the possibility that the two sheets have opposite time orientations and therefore also opposite classical energies. More generally, the exchange of two or more MEs between material space-time sheets can be such that no net momentum exchange occurs so that the absolute minimum of Kähler action only in a finite region of space-time and gives rise to new degenerate absolute minimum of Kähler action since ME has vanishing action. This kind of structures are obvious candidates for cognitive structures since classical nondeterminism is localized in a finite space-time volume. World should be full of MEs with all possible sizes since they have vanishing action: addition of ME with finite time duration yields new absolute minimum of Kähler action since Kähler action does not change in this operation. This suggests that MEs should be of crucial importance in TGD Universe.

MEs serve as receiving and sending quantum antennae [J4]. Lightlike vacuum current generates coherent light. Also coherent gravitons are generated. MEs serve also as templates for BE condensation of photons and gravitons with momenta parallel to the lightlike vacuum current. Linear structures, say DNA and microtubules, are natural but not the only candidates for structures accompanied by MEs. Since MEs are massless, they carry maximal possible momentum. This makes exchange of ME ideal mechanism for locomotion. The possibility of negative energy MEs is especially fascinating since it suggests 'buy now, pay later' mechanism of energy production: perhaps living matter uses MEs to generate coherent motions [I4, I5].

MEs as Josephson junctions and current junctions

MEs can induce Josephson junctions and more general current carrying bridges between bio-structures. Since the electric field of ME is orthogonal to the direction of the propagation of vacuum current, the Josephson junction with potential difference is formed most naturally when super conductors are joined by join along boundaries bonds to ME in the direction of the electric field associated with ME. MEs can in principle be arbitrary thin so that the thickness of Josephson junction can be much smaller than the dominating wavelength of ME.

ME electric field can contain also constant component.

1. This is possible if there is a vacuum charge density or ordinary elementary particles in a massless phase ("Higgs=0") at the boundaries of ME generating the field.

2. If this charge density is absent, ME is necessary double sheeted with the constant electric and magnetic fields created by the wormhole throats at the boundaries of ME serving as effective charges. Whether the wormhole contacts can propagate with the velocity of light is however not obvious. An attractive hypothesis is that the members of the ME pair have opposite time orientations so that total energy of ME pair can vanish and can be created from vacuum without any energy cost.

   Both single and double sheeted MEs could give rise to the Josephson junctions with a constant potential difference. The coding of the transversal potential difference associated with ME to Josephson frequency could be a fundamental information coding mechanism in living matter. ME can contain also oscillating electric field over Josephson junction at magnetic or some other transition frequency so that MEs are ideal for control purposes.

MEs and the interaction of the classical em fields with biomatter

MEs acting as Josephson junctions and containing oscillating em field at ELF frequency give rise to a harmonic perturbation inducing quantum jumps of the magnetic states of ions and explains the effect of ELF em fields on biomatter. Also the presence of the mysterious intensity windows [47, 48, 49] can be understood. Josephson current paradigm allows to understand this effect if RF or MW MEs associated with the external field act as Josephson junctions.

1. The external electric field oscillating with frequency ω (now radio frequency) defines slowly varying potential difference over Josephson junction of length d acting as Josephson junction provided that the condition

$$\omega \ll \omega_J(max) = ZeV = ZeEd$$

holds true. This gives

$$d \gg \frac{\omega}{ZeE} \ .$$

For $E \sim .1$ V/m and $\omega \sim GHz$ which are typical values used in experiments [48], this condition gives $d \gg 10^{-6}$ meters which is satisfied if Josephson junctions have size not smaller than cell length scale.

2. For fixed length of Josephson junction amplitude window results if the maximal Josephson frequency $\omega_J(max)$ is slightly above some transition frequency since in this case the stationary maxima and minima of amplitude lead to long lasting resonant excitation of quantum transitions. Denoting the relative width of the resonance by $\Delta\omega/\omega = P$, the ratio of the time spent in resonance at $\Omega_J(max)$ to the time spent off resonance at Ω_J is of order

$$\frac{t(max)}{t} \sim \sqrt{1 - \frac{\Omega_J^2}{\Omega_J^2(max)}} \times \frac{1}{\sqrt{P}} \ .$$

For a narrow resonance width this ratio can be very large so that amplitude window results for fixed value of d.

3. Amplitude window results if there is a correlation between the thickness of ME and transversal electric field so that $\omega_J(max) = ZeEd(E)$ satisfies resonance condition for some values of E only, if any. In absence of this correlation Josephson junctions must have discrete spectrum of effective lengths for amplitude window to result.

4. For electric fields in the range .1 V/m the frequencies ω_J are above GHz for d larger than 3×10^{-5} meters and correspond to the frequencies for the conformational dynamics of proteins. There are obviously a large number of frequencies of this kind and several intensity windows. EM fields with these strengths should have special effects on living matter: it could be even that some kind of feature recognition process involving self-organization occurs at these field strengths. Note that the minimal size of Josephson junctions corresponds to the p-adic length scale $L(173) \simeq 1.6 \times 10^{-5}$ meters characterizing structures next to cells in the p-adic length scale hierarchy.

MEs and exotic representations of supercanonical algebra

The exotic representations of p-adic supercanonical and Super Virasoro algebras forming excellent candidate for a hierarchy of lifeforms are associated with both p-adic and real MEs. p-Adic representations have interpretation as cognitive representations but also real counterparts of these representations could be important biologically. For supercanonical representations the scaling operator L_0 is *not* assumed to contribute to the mass squared operator unlike for quaternion conformal representations. Otherwise real massses for exotic representations would be astrophysical and real counterparts of these MEs could occur only as pairs of opposite time orientation and vanishing net energy.

In p-adic context and for $L_0 \propto p^n$, $n = 1, 2, ..$, the real counterpart of the scaling eigenvalue is extremely small, being proportional to $1/p^n$ for R_p. Obviously these states are approximately scaling invariant. Indeed, by Fermat's theorem, the integrated p-adic scalings a^{L_0}, a positive integer, act like identity operator modulo $O(1/p)$ corrections. By the inherent fractality of Super Virasoro and supercanonical algebras, one can indeed construct representations of subalgebras spanned by supercanonical and Super Virasoro algebra for which conformal weights are proportional to p^n.

Mersenne primes $M_n = 2^n - 1$ are especially interesting since for them the action of the integrated scaling 2^{L_0} on the states having $L_0 \propto n$ reduces to that of a unit operator apart from $O(1/M_n)$ corrections. In real context the scaling 2^{L_0} acts in an excellent approximation as a fractal scaling by a power of p which has physical interpretation in terms of the approximate invariance of fractal under scalings by powers of p. This makes Mersenne primes especially interesting. In fact, also Gaussian Mersennes are biologically highly interesting [J7]. For Mersenne primes only integrated p-adic scalings leave states almost invariant. In both cases one can speak about approximate conformal invariance since the states generated by L_n do not have zero norm unlike for the usual representations of the conformal algebra so that L_n act more like oscillator operators and generate new states.

These states are generated by a subalgebra of Super Canoical Algebra in case of MEs since the conformal weight of the vacuum state vanishes (for ordinary elementary particles conformal weight of the vacuum is negative integer). Thus very special representations of p-adic Super Virasoro algebra are in question.

The degeneracy of states (number of states with same mass very small squared) is proportional to the exponent of L_0 and is enormous for the physically interesting values of p-adic prime p. This means that these states provide huge negentropy resources. Thus exotic Super Virasoro representations be interpreted as quantum level articulation for the statement that TGD Universe is quantum critical quantum spin glass. Exotic Super Virasoro representations clearly provide an excellent candidate for an infinite hierarchy of life forms.

The lifeforms defined by $L_0 \propto p^n$ representations are labelled by three integers (k,m,n): physically interesting primes correspond to $p \simeq 2^{k^m}$, whereas k prime and m are integers, and the power n appearing in $L_0 \propto p^n$. Besides this there are lifeforms associated with Mersenne primes. Perhaps it is these lifeforms which make mindlike space-time sheets living creatures and these lifeforms emerge already in elementary particle length scales and become increasingly complex when the p-adic length scale increases. Life could perhaps be regarded as a symbiosis of these lifeforms. These lifeforms ('mind') would interact with each other and ordinary matter via the classical gauge fields associated with MEs. A natural hypothesis is that the quantum phase transitions of the macroscopic quantum phases for the particles of the exotic Super Virasoro representations formed in classical fields of MEs (mindlike space-time sheets) give rise to some (but not all) qualia.

MEs and quantum holography

Sokolov and collaborators [29] have proposed a model of quantum holographic teleportation in which the *classical* photocurrents from the sender to receiver take the role of a dynamical hologram. The connection with MEs is obvious.

1. MEs are carriers of classical lightlike vacuum currents (one of the basic differences between TGD and Maxwell theory). This suggests that MEs could be interpreted also as *classical* holograms, which are *dynamical* as in quantum information theory. Lightlike current would be like a dynamical (four-dimensional) diffraction grating. Lightlike vacuum currents and vacuum Einstein tensor generate also coherent states of photons and gravitons and MEs serve as templates for the topological condensation of photons and gravitons to the Bose-Einstein condensate of photons collinear with ME. The Bose-Einstein condensation of collinear photons and their generalizations to colored configuration space photons should affect the vacuum current by adding to the reference current what might be called evoked response. This condensation process could generate conscious experience and higher level qualia. Thus it would seem that MEs have a triple role as receiving and sending quantum antennae as well as classical holograms.

2. The proposal of [29] generalizes to the case of MEs provided one can device a method of coding quantum states of photon field to the vacuum currents. The high efficiency photodetector matrix is in which each pixel gives rise to a photocurrent [29], is replaced with ME or set of parallel MEs. The neural window hypothesis states that neuronal axons are accompanied by parallel

MEs carrying information between sensory organs and brain and various parts of brain. This is only a less standard manner to say that ME represents classical dynamical hologram. The possibility of local lightcone coordinates allows also MEs which define curved deformations of the simplest cylindrical MEs.

The concrete realization of holographic teleportation proposed in [29] brings strongly in mind the architecture of the visual pathways. Thus one can wonder whether brain is perfoming internal teleportation of photonic quantum states with spike patterns being directly coded to the pattern of the vacuum currents flowing along MEs. If spike patterns code the dynamical hologram, a surprisingly close relationship with Pribram's views about hologrammic brain results. Nerve pulse patterns could be seen as specifying the necessary classical aspects of the quantum teleportation (in TGD classical physics is essential part of quantum physics, rather than some effective theory).

3. The lightlike vacuum current at a 3-dimensional timelike section of ME as a function function of time defines a dynamical 3-dimensional hologram. This is consistent with the fact that our visual experience is two-dimensional: the information is always about outer boundaries of the objects of the perceptive field. The values of the vacuum current at a given point are non-deterministic which means that vacuum current is ideal for coding information. Classical data also propagate without dispersion with light velocity obeying the laws of geometric optics and MEs imply channelling so that MEs are taylor-made for classical information transfer.

4. Space-time sheets can have both positive and negative time orientations and the sign of energy depends on time orientation in TGD framework. This means that classical communication can occur both in the direction of the geometric future and past: this is essential for the classical model of the long term memories as a question commmunicated to the geometric past followed by answe. The dynamical nature of the holograms means that there is no need to combine 2- or 3-dimensional holograms associated with several moments of geometric time to single hologram. To remember is to perceive an object located in the geometric past. Of course, fractality might make possible temporally scaled down versions of the geometric past but the principle would remain the same.

5. Quantum hologram view suggests that the supercanonical representations at the lightlike boundaries of MEs characterized by gigantic almost-degeneracies are the real carriers of biological information. According to the general theory of qualia [K3] this information would become conscious since elementary qualia would correspond to quantum jumps for which increments of the quantum numbers correspond to the quantum numbers labelling supercanonical generators in the complement of Cartan algebra. In this view superconducting magnetic flux tubes could perhaps be seen as intermediate level in the control circuitry controlled by MEs and controlling atomic level.

6. The model for visual qualia leads to the hypothesis that, besides ordinary photons, also colored configuration space photons are possible and characterized by configuration space Hamiltonian which is labelled by orbital spin quantum number J (in two-dimensional sense) and by color quantum numbers. The coherent states of these massless configuration space photons would be responsible for visual colors and polarization sense and the corresponding holograms might be the crux of quantum control in living matter.

5.3.2 MEs and mind

MEs provide a concrete realization of geometric memory. The model for qualia discussed in [K3] and also in [M3, M4, M5, M6] allows to sharpen this model to provide predictions about EEG correlates of memory.

MEs as mindlike space-time sheets

The properties of virtual MEs, in particular finite time duration, vanishing action, and the modification of absolute minimum of Kähler action in finite space-time region, make virtual MEs ideal candidates for mindlike space-time sheets. An atractive hypothesis is that important mindlike space-time sheets

consist of MEs. It was already found that Josephson junctions could correspond to ME pairs consisting of positive and negative energy space-time sheets. The vanishing of the total energy of ME pair makes it an ideal cognitive structure since the creation of these pairs from vacuum changes space-time surface in finite space-time volume only and does not cost energy.

The hypothesis implies that MEs are an electromagnetic lifeform interacting with ordinary bio-matter. As a matter fact, MEs with sizes smaller than the size of organism would make also biomatter living. In particular, classical EM fields interacting with bio-matter should decompose into MEs representing mindlike space-time sheets which are geometric correlates of mental images.

ELF selves as MEs building quantum holograms?

ELF em fields could correspond to MEs or ME pairs having size of order Earth and give rise to levels of collective consciousness responsible for the cultural aspects of our consciousness. M The basic function of MEs would perhaps be the formation of quantum holograms of colored configuration space photons acting as control commands. At DNA level this could be achieved by static ME pairs associated with the nucleotides and tranforming genes to quantum holograms. In case of neuronal axons (Z^0) ELF MEs should propagate with the effective phase velocity of nerve pulse along axon and generate nerve pulse. The propagaton of nerve pulse inducing dropping of ions to magnetic flux tubes, and the consequent generation of EEG MEs would in turn generate code nerve pulse sequence to a quantum hologram and sensory representation. The meaning of the concepts like 'active' and 'passive' hologram and reference wave have been already discussed.

The experiments of Mark Germine [41] provide evidence for the notion of ELF self and associated collective memory. What was studied was the evoked EEG response to a series of random quantum stimuli, which consisted of series of identical stimuli with randomly located deviant stimulus. Two subject persons, A and B, were involved, the first one experienced stimuli as pictures in computer monitor, the second one as sounds. In case that A observed the differing stimulus 1 second before B, the evoked EEG response of B became incoherent. Since evoked stimulus was oscillation at EEG frequency of about 11 Hz in case that A had not observed the stimulus, one could understand the mechanism as a direct evidence for collective 'ELF ME' at this frequency interacting with brains of both A and B. When ELF ME had already heard the stimulus once, it did not react to it in similar manner. Rather interestingly, 11 Hz corresponds to the 10.7 Hz cyclotron frequency associated with Fe_{++} ion in a magnetic field of .2 Gauss (Earth's magnetic field has nominal value of .5 Gauss). Ca^{++} cyclotron frequency in this field is equal to 15 Hz and would explain the effects of ELF fields on vertebrate brain occurring at harmonics of this frequency.

MEs and long term memory

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember classically is to look at a mirror located at a distance of light years. The ends and branching points of magnetic flux tubes are good candidates for the mirrors where MEs are reflected.

In TGD framework synaptic strengths code only cognitive representations and learned associations, not genuine information about events of the geometric past. Long term memory is coded in the classical em field and in coherent light generated by ME in hologram like manner. Any finite space-time region receiving the classical em field of coherent light generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted space-time region (it can be!), the hologrammic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. ELF selves can perhaps control this localization. Note also that the lightlikeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

The fact that memory is stored to the moment of geometric time at which event occurred explains why we know that mental image is memory. It is quite possible that MEs are involved with sensory perception, say vision and auditory experience, and make possible to experience the sources of light as belonging to the external world. Geometric memory allows also understand identification experiences and transpersonal experiences in which person can experience events of the distant past not related to the personal history. Anticipation of future in turn could be also understood as particular kind of

geometric memory, the MEs involved are now p-adic representation intentions, plans, and expectations. Later a more detailed model of long term memories will be developed.

Life as a symbiosis of MEs, superconducting magnetic flux tube structures, electric flux quanta, and of biomatter

The general TGD based vision about life is as a symbiosis involving MEs, superconducting magnetic flux tube structures, and electric flux quanta forming fractal hierarchies and controlling the ordinary biomatter residing at the atomic space-time sheets.

Electric and magnetic flux quanta are actually dual to each other. Indeed, the attempt to understand the non-Hertzian scalar waves of Tesla led to the realization that by the electric-magnetic duality of quantum TGD magnetic flux tube structures have as their duals topological field quanta of electric field carrying essentially constant energy density [I4, I5]. Biosystems are full liquid crystal electrets and electric flux quanta are ideal for their modelling.

Also non-Hertzian scalar waves representing a space-time sheet moving with light velocity and carrying an essentially constant electric field in the direction of propagation are predicted. The non-Hertzian waves could be emitted in the generation of nerve pulses in directions transversal to the parallel axons and negative energy non-Hertzian waves could provide a mechanism of bound state formation between identical nerve pulse patterns representing symbolically thoughts as 'association sequences', that is temporal sequences of spacelike 3-surfaces with timelike separations (made possible by classical non-determinism of the Kähler action).

The basic interaction mechanisms of MEs with superconducting flux tubes are magnetic induction generating supracurrents, the action of MEs as Josephson junctions between magnetic flux tubes, and magnetic quantum phase transitions stimulating radiation of coherent light which in turn BE-condenses on MEs and defines a feedback loop.

Many-sheeted ionic flow equilibrium defines the basic control mechanism with superconducting magnetic flux tubes taking the role of master and atomic space-time sheets taking the role of slave. Magnetic phase transitions could make possible chemical senses based on an endogenous NMR type spectroscopy. Also other than magnetic quantum transitions, such as changes of protein (in particular enzyme-) conformations, could occur coherently at superconducting space-time sheets, so that superconducting space-time sheets could allow an extremely effective high precision quantum control of the biochemistry. Magnetic quantum phase transitions make possible place coding by if the thickness of magnetic flux tube varies and this coding is crucial in the model for how various features are associated with objects of perceptive field at a given position.

MEs allow at their lightlike boundaries representations of super conformal– and supercanonical algebras with gigantic almost-degeneracies of states due to the almost-commutativity of Poincare algebra and supercanonical algebra. Supercanonical states define genuine quantum gravitational state functionals in the space of three-surfaces, the 'world of worlds', and correspond to a higher abstraction level than ordinary quantum states defined in the 'world' (space-time). This 'world of worlds' aspect of quantum gravitational states explains why quantum gravity is crucial for consciousness.

5.4 General ideas about hardware of consciousness

In this section general ideas and metaphors about what quantum brain and quantum brain functioning might be, are summarized. These ideas have developed gradually during last decade and continue to do so. The recent view about brain conforms with the great sixteen years old vision about self as a computer sitting at its own terminal.

This vision, if taken completely seriously, means that the ultimate sensory representation conscious-to-us is outside the brain: that this is the case became clear quite recently (the geometric now when I am writing this is October, 2001). The title of this section is 'General ideas about hardware of consciousness'. rather than 'General ideas about brain'. The reason is that brain and body in TGD Universe form only a tiny part of a system involving hierarchy of MEs and magnetic flux tube structures having astrophysical sizes controlling the matter at the atomic space-time sheets defining brain and body in the usual sense of the world.

I defend this radical deviation from the standard wisdom by the fact that the world 'consciousness' has ceased to be a taboo only during the last decade. It would be really astonishing if the materialistic

view about consciousness as an illusion and brain as a computer would generalize to a general theory of consciousness just by adding one candle to the birthday cake of one century of brain science. Just like the creation of physics at the times of Kepler meant revolution in Earth centered world picture, also the creation of the general theory of consciousness is bound to mean thoroughgoing changes in the basic prejudices about human consciousness.

5.4.1 Brain as a computer

Brain as a computer metaphor in sense of Turing machine has been one of the dominating metaphors about brain functioning. In TGD this metaphor makes sense as far as general functional architecture of modern computer is considered. Programs must be however replaced by self-organization patterns.

Brain as a computer sitting at its own terminal

My personal great experience involved the realization that I am in some sense a computer sitting at its own terminal. It took more than one and half decades to realize what this self-referential idea having deep mystic coloring in it might mean in practice. Actually I realized the connection only after having ended up to this kind of view about brain by quite different routes.

To be precise, 'computer' does not mean in the recent context the abstract Turing machine, but a real world personal computer. The concrete functional and geometric architecture seems to be mimicked by personal computers, not the detailed data processing. the deterministic computer programs are replaced by much more flexible self-organization patterns.

1. Brain corresponds to the central processing unit of this computer. The data in computer memory are typically represented at computer monitor which is outside the central unit, can have much larger size and be located arbitrary far away. In the case of brain this means that the ultimate, conscious-to-me sensory representations are realized outside brain at superconducting magnetic flux tube structures associated with various parts of brain. This view is inspired by very simple observation: when my eyes or my head move, I do not experience that the sensory image of external world moves although its physical representation in brain moves. As if I were an external observed looking the projection of sensory data on canvas inside brain so that the motion of canvas does not matter.

   The standard argument is that the fact that brain constructs sensory representations about the motion of eyes, head, and body, is enough to generate the experience that the world is not moving. At least in TGD framework it is extremely difficult to understand how the sensory image of the external world in motion would not give rise to the experience that the world is in motion. I see the failure to realize this point as one of the fatal consequences of computationalism decoupled from physics: the ability to calculate what really happens does not simply give rise to the experience what really happens in the world of physics.

2. In computer the representation of the data on monitor, printing of data, and even various control actions such as the control of a robot reduces to sending of files to various kinds of receivers: the data is just expressed in various manners. In case of brain this means that that the processes leading to sensory experience or motor action differ only in their last steps. If the last step is not present, imagined motor action or sensory experience is in question. Imagination would involve as a seed p-adic cognitive representation, which is transformed by a p-adic-to-real phase transition to a real form, which in turn serves as initiating cell membrane oscillation pattern leading to an almost sensory experience or almost motor action (also nerve pulse patterns might be involved).

This picture leads to a very general view about sensory representations and motor actions. In this picture also "features" reduce to MEs and this might be too strong an assumption.

1. Brain can be regarded as a collection of standard feature records represented by MEs. These features represent basic features of objects of perceptive field and primitive elements of motor actions. The set of feature MEs is pre-existing and realization of the sensory image or motor action only activates a subset of these MEs. In principle the locations of feature MEs could be more or less random which means extreme flexibility and ability to adapt to new situations.

2. The basic frequency associated with a particular sensory ME codes for the distance of the object of the perceptive field and the direction of ME codes for its direction. Sensory MEs are naturally organized in radial bundles, files, representing various directions for the objects of perceptive field at given distance. Feature MEs with nearly the same frequency generate magnetic quantum phase transitions waking up magnetic self in the desired distance on the magnetic sensory canvas and thus assign to the object of the perceptive field various kinds of attributes. This means nothing but frequency binding and leads to what might be called spectroscopy of consciousness: EEG acts like a spectrogram allowing to deduce information about the functional state of brain.

3. Support for the view that sensory input and motor activities are very similar comes from motor synesthesia in which person can represent the sensory input by dancing it! More concretely, the realization of intention as motor action reduces to generation of Z^0 MEs propagating along axons and generating desired membrane oscillation and nerve pulse patterns. There might be however a crucial difference also: motor action could be a geometric time reversal for the construction of a sensory representation and start from a rough sketch in the geometric now and develop quantum jump by quantum jump to a detailed plan in the geometric past. Time reversed dissipation would polish a sketch to a precise plan. Motor action would start from the motor organs and proceed to the level of brain.

4. Brain can be said to contain a collection of passive sensory and motor features which it activates selectively. This brings in mind computer game containing large number of extremely simple files, for instance sound files producing *Aaaargh*'s and *Auuuch*'s. The activation of ME record could mean that Z^0 ME is color rotated by coherent state of configuration space photons to electromagnetic ME which in turn generates coherent state of photons and configuration space photons acting as a control command; activates magnetic quantum phase transitions; induces supra currents; or something else. Similar mechanism works even at the level of DNA where genes can be coded to various kinds of control commands by activating the associated Z^0 MEs.

What this view implies that there is no need to worry about how brain realizes ultimate sensory representations inside brain as neural activities. What remains to be understood how brain develops into a collection of the standard features; how brain recognizes the standard features from the incoming sensory input; how brain evaluates the distances and orientations and other data related to the objects of the perceptive field; how brain decomposes the perceptive field into objects; and many other things not listed here.

1. Feature recognition might be based on comparison circuits based on supra current circuits. Expected features would be represented as standard patterns of supra currents. When the pattern of supra currents associated with the sensory input and running parallel to those of expected sensory input is sufficiently near to the expected one, a resonant generation of Josephson currents occurs and gives rise to a recognition of the feature.

2. The positions and other geometric data about the objects of perceptive field are presumably estimated by an iterative process in which the sensory input from the virtual world construct of the perceptive field is compared with the real sensory input which could be sustained in the sensory circuits. Cortico-thalamic communications might relate to this iteration. The comparison takes place by comparison circuits and when the two inputs resemble each other sufficiently, a sensory output at the magnetic canvas is generated. The consistency of these two representations should be gained gradually through learning and by the requirement of consistency between different sensory inputs. Similar comparisons are involved with the development of motor action to yield the final action giving rise to the desired goal.

Brain as a motor and sensory organ of higher level selves

Certainly the most dramatic deviation from the standard neuroscience implied by this view is the prediction of an entire hierarchy of MEs and magnetic selves using brain as a generalized sensory and motor organ. We correspond to only one level in this hierarchy making decisions and controlling the behavior of our body in certain time scale. For instance, long term goals and socially acceptable behavior could be seen as forced by selves at the higher levels of the hierarchy. Drives could perhaps seen as activities forced by lower level selves in the hierarchy (amygdala and other parts of paleobrain

contra neocortex). What makes this so dramatic is that the sizes of our magnetic bodies could be astrophysical (here one must of course be very cautious: the realization of long term memories however encourages strongly this view). For instance, EEG ME and corresponding magnetic flux tube structures would both have sizes measured using Earth size as a unit.

A possible mechanism for the motor control from our own sensory canvas as well as from the sensory canvases of higher level selves is provided by Z^0 MEs. The classical Z^0 fields entering to brain and body would represent very high level commands, and might be transformed to endogenous sounds by Z^0-piezoelectric effect identifiable as internal speech (internal speech could also correspond to p-adic Z^0 MEs). This is only one possibility. The construction of the model of nerve pulse and EEG leads to quite general model for the interaction of Z^0 MEs as bridges between two space-time sheets characterized by different p-adic primes, and inducing a flow of Z^0 charge between the two space-time sheets, inducing in turn a flow of em charge, and in case of cell membrane a change of membrane potential leading to the triggering of the nerve pulse. The reduction of the effective phase velocity of Z^0 ME to the conduction velocity of nerve pulse or of some other excitation involves the shift of entire Z^0 ME to future occurring in each quantum jump. If the shift occurs in the direction of geometric past, a super-luminal effective phase velocity results. Both cases might be involved, and would correspond naturally to propagating and standing EEG waves and to the spacelike and timelike soliton sequences predicted by the model for Josephson junctions.

Boolean mind and memetic code

TGD leads to a model of Boolean mind in terms of temporal sequences formed by cognitive neutrino pairs with a vanishing total energy [L1]. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, leads to a prediction of order .1 seconds for the duration of the 'wake-up' period of subself corresponding to the codeword of the memetic code. This codeword consists of 126 bits represented by cognitive antineutrinos such that the two possible Z^0 magnetization directions correspond to two values of Boolean statement. This implies tha the duration of single bit should 1/1260 seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-,5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is .1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.
i) Membrane oscillation/nerve pulse patterns correspond to temporal sequences of Z^0 magnetization directions for cognitive antineutrinos coding for yes/no Boolean statements.
ii) The spin polarization of antineutrinos is changed from the standard direction fixed by the spontaneous Z^0 neutrino magnetization in the direction of axon by Z^0 ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses very probably correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences of Z^0 magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126} - 1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. This expectation seems to be more or less correct. The full memetic code is very probably realized for certain regions of brain only. These regions certainly include auditory pathways responsible for

the comprehension of speech [L1, M2, M4, M5, M6].

5.4.2 Brain, EEG, and quantum holograms

MEs are at the highest level of control hierarchy formed by MEs, superconducting magnetic flux tube structures, and the matter at atomic space-time sheets, and are thus involved with the fundamental control operations. EEG MEs can have also the role as an entangler assigning mental images to the points of the magnetic body with distance to the magnetic body being coded by the length of ME and the direction of the point by the direction of ME.

There are two options for how sensory EEG MEs are realized.

1. EEG MEs would be automatically generated as an outcome of nerve pulse activity, when ions drop to the flux quanta of magnetic field $B \simeq .2$ Gauss (Earth's magnetic field has nominal value .5 Gauss), and entangle mental images with the points of the sensory magnetic canvas. For this option Z^0 MEs parallel to axons would induce nerve pulse activity. Z^0 MEs would result as p-adic MEs representing intentions, and would then be transformed to real MEs representing actions: magnetic body would intend.

2. EEG MEs could be realized as pre-existing sensorily passive Z^0 MEs analogous to recodes. They would be color rotated to em MEs when the sensory representation is activated. The model of nerve pulse and EEG suggests that Z^0 state corresponds to motor action and color rotated em ME corresponds to the subsequent sensory input. There are two problems which make this option less favored.

   i) The first problem is how brain manages to perform the needed color rotation. The record is in a (sensorily) passive state when ME corresponds to Z^0 ME and in an active state when the Bose-Einstein condensation of the configuration space photons on ME generated by another ME induces a color rotation of ME so that it becomes active em ME. The fundamental control operation would be the activation of Z^0 MEs to em MEs which in turn would generate coherent state of photons and configuration space photons acting as a control command, interact classically with the magnetic flux tubes inducing magnetic quantum phase transitions waking up magnetic subselves, and inducing supra currents affecting currents at the atomic space-time sheets via ionic flow equilibrium. The phase congugate of the hologram would correspond to time a reversed command.

   ii) The second problem relates to the interpretation of EEG MEs resulting as a correlate for cyclotron radiation when ions drop to the magnetic flux tubes.

As discussed in [M2], genetic/memetic code could also have translation to control commands represented by pairs of MEs orthogonal to DNA strand/axon. In latter case orthogonal pairs of MEs must move along axon with the same velocity as nerve pulse pattern. Stationary EEG MEs translate the nerve pulse patterns to the patterns of lightlike vacuum currents. TGD based model of EEG and nerve pulse [M2] predicts two kinds of EEG waves: moving and stationary, and it might be that they correspond to these two kinds of codings. The properties of moving/stationary EEG waves suggest their association to left/right brain hemisphere. Left brain might favour the coding of memetic codons to moving EEG ME pairs whereas right brain might favour the coding of nerve pulse patterns to stationary EEG MEs.

The notion of neural window, which was the original form of hologram idea, allows to see information processing in brain from a slightly different point of view.

1. Massless extremals act as quantum antennae and generate coherent light and also provide waveguides along which BE condensed photons can propagate like Cooper pairs in super conductor. The photons radiated by the mindlike space-time sheets representing objects of the perceptive field and propagating along microtubules could provide neurons with a neuronal window. This picture would abstract just the bare essentials of the idea of hologrammic brain: small piece of hologram is like a small window yielding the same picture as larger window but in blurred form.

2. Massless extremals associated with axons could also represent or be accompanied by association sequences making possible geometric memories representing simulations of future and past. What is mysterious from the point of view of the standard neuroscience is that left part of the

body sends sensory stimuli to the right brain hemisphere and vice versa. In TGD framework the mystery disappears: the maximization of the axonal lengths maximizes the durations of the association sequences and hence optimizes geometric memory.

3. Neuronal window idea would perhaps make it possible to realize the idea about iterative computation of conscious experiences involving guesses and comparisons. Neuronal windows would generate representations of various perceptive landscapes in disjoint parts of thalamus (sensory organs feed their input in separate parts of thalamus) and mental imagery would construct guesses for the cognitive representations for the objects of the external world realized in the cortex as mindlike space-time sheets radiating coherent light. The neural pathways from cortex to thalamus would provide thalamus with a neural window to cortex and comparison of the landscapes from cortex and sensory organ would be possible. Simple comparison circuits might be at work: neuron would fire when its neural windows to the cortex and sensory organ give sufficiently similar views.

4. One can sharpen the neuronal window idea by combining it with the music metaphor. This would mean that the massless extremal associated with a given axon would correspond to a Bose-Einstein condensate of photons (or configuration space photons) with one particular frequency. This would mean vision at neuronal level (nothing to do with our vision realized in EEG frequency scale). Thus one can say that each neuronal window is either covered by curtains or provides a view to single sensory landscape at single frequency.

5.4.3 Generalized notions of sensory experiencing and motor activity

The general view about brain is as a system moving of a fractal energy landscape of quantum spin glass containing valleys inside valleys inside... Brain is not only an on observer of the external world but also of its own position in the spin glass landscape. Brain is not only activator of ordinary motor programs but generates also movements in the spin glass energy landscape. Thus the general functional division sensory experience-motor action generalizes and provides completely new insights to the brain circuitry and functioning. For instance, one could perhaps understand why neural loops are bi-directional. The first loop provides sensory information about the position of brain region in its spin glass landscape and the second loop mediates the motor action: just like in case of the spinal chord.

The sensory experiences giving information about spin glass landscape can be interpreted as giving rise to a generalized sensory and emotional input. Emotions correspond to entropy gradients of various types for selves. A mental image with a positive/negative emotional color results from negentropy/entropy feed to subself. If the sign of entropy feed to mental images correlates with the entropy gradient of the system represented by subself, emotions become sensory qualia. Emotions provide perhaps the most important 'Is it going well' type information about the state of brain and body. Entropy gradients can be also used as an active control tool: subselves are rewarded by negentropy feed and punished by a entropy feed. Note that the generalized motor action inducing motion in the spin glass landscape is identifiable as emotional expression and generates entropy gradients and thus emotions.

5.4.4 The paradigm of four-dimensional brain

Four-dimensionality of brain is crucial for the understanding long term memories as multitime experiences receiving contributions from several moments of geometric time. This identification makes it unnecessary to have any memory storage mechanisms. Rather, the activities of the memory circuits can be seen as increasing the probability that memory recall occurs. Reverberating memory circuits in which experience is echoed indeed do this by extending the deep memory valley in spin glass landscape to a long canyon in time direction. This increases the probability that mindlike space-time sheets enter in the region of four-dimensional spin glass landscape representing the memory. The deepness of the spin glass valley correlates with the emotionality of the memory. Childhood memories are especially emotional and therefore stable. Memories are result of creative action and memory circuit involving hippocampus seem to be active in carving out the art works representing geometric memories worth of remembering. TGD based approach solves the basic problems of the neural net approach resulting

from the fact that the formation of new memories destroys old memories and from the fact that it is difficult to understand how the component of experience is known to be a memory.

Four-dimensional brain provides a completely new view about how gemeralized sensory experiences are generated, how generalized motor actions are planned and how memories are constructed. This process is like creating an artwork. *Four*-dimensional spin glass landscape representing a rough scetch is gradually refined by adding details and corrections in increasingly shorter time scales: this corresponds to neural activities of four-dimensional brain generating motion leading to the desired part of spin glass energy landscape. This picture is consistent with the observed $1/f$ noise and fractality of nerve pulse patterns. Absolutely essential is self-organization and related dissipation forcing the Darwinian selection leading to end product which is charicature rather than photo.

5.4.5 Music metaphor and the function of the nerve pulses and EEG

Music metaphor allowing to see brain as a music instrument. gradually changed from a guiding principle to a prediction of TGD inspired theory. In case of brain the music played is EEG and ZEG spectra. EEG frequencies serve as resonant frequencies at which various quantum phase transitions occur resonantly. Various sensory qualia correlate with EEG frequencies and place coding and possibly also temporal coding by cyclotron frequency scale is possible. Stochastic resonance and pendulum metaphor, which are discussed in [M2], allow to understand the mechanisms for the transformation of EEG waves to nerve pulse patterns and vice versa.

The picture about brain as self-organizing system suggests that neurons are subject to strong selective pressures and specialize to produce highly specialized fixed components of our experience so that music metaphor holds true. If music metaphor holds true generally, the nerve pulses involving fast transmitters can be said to pick the strings of the sensory instrument represented by axons and spatio-temporal patterns of nerve pulses determine the overall pattern of the sensory experience. Nerve pulses inducing motor action in sensory landscape represent pushes and pulls in spin glass energy landscape. These pushes and pulls induce motion in the spin glass landscape and generate both neuronal and our emotions. It seems that simplest emotions with no association telling the cause or object of emotion, are determined by the nerve pulse pattern only.

This picture suggests for neurotransmitters two obvious basic functions: they mediate nerve pulses from presynaptic neuron to postsynaptic neuron and modify the properties of synapse and postsynaptic neuron. Fast neurotransmitters controlling directly ion channels are involved with mediation and the relevant time scale is one millisecond: no long term change of the postsynaptic neuron is involved. Sensory experiences and motor actions are mediated by direct neurotransmitters. Slow neurotransmitters involving second messanger action are involved with modulation of the response of the postsynaptic neuron and the time scales can be of order minutes. In this case the properties of the postsynaptic neuron are changed.

Emotional reactions involve typically slow transmitters and the effect of them can be regarded as a generalized motor action inducing motion of neuron in the spin glass energy landscape of the neuron. The large information flows associated with neurotransmitters imply entropic gradients and thus also emotions. Some neurotransmitters such as serotonin and dopamine, which generate sensations of pleasure, should reduce entropy and thus fight against the second law of thermodynamics. This presumably occurs at the neuronal level and could be only represented at the level of the sensory selves, where some other mechanisms of the entropy reduction and generation could be at work. An interesting question relates to the warriors in the war against second law. Could glial cells play key role here as is suggested by the observations that depression (in which mental images becomes very entropic and emotional flatness and emptiness results) involves abnormally small amount of glial cells in forebrain and abnormally strong emotional reactions of amygdala.

One can see associations at neuronal level as formed by the pairs of input and output. Input corresponds to the sensory experiences associated with active presynaptic neurons and output to the activity in the axons. The postsynaptic receptors serve as sensory receptors and each neuron could be specialized to its own sensory modalities which are same for the entire sensory pathway. Alternatively, primary qualia are associated with the sensory receptors or sensory organs: this option provides very elegant understanding of what imagination and dreams are. Boolean axons give rise to 'Boolean modality' representing thoughts. Typically sensory-Boolean associations are associated with the associative regions of brain and are realized as a fusion of mental images. The formation of an association corresponds to the fusion of space-time sheets representing pre- and post-synaptic neurons

to single space-time sheet. The space-time sheets formed by the orbits of synaptic vesicles form the 4-dimensional join along boundaries bond. Fusion to single space-time sheet makes possible conscious association containing both inputs and output as a single experience. This picture also explains the time directedness of association. 'Our' associations are superpositions of neuronal associations associated with various neuronal circuits.

5.4.6 Connection with the functionalistic view about brain

The basic counter argument against quantum theories of consciousness is that the so called classical theories of brain can quite well explain all the relevant aspects of brain functioning whereas quantum theories of consciousness seem to add very little if anything to this understanding. It seems that huge misunderstandings are involved on both camps.

The notion of self is fundamental for consciousness. For some reason the proponents of quantum consciousness (including me hitherto) have however failed to realize that they should perhaps try to formulate this notion as a quantum-physical concept. Indeed, 'What is the quantum counterpart of self' was the bottleneck question in TGD approach and led to the final breakthrough.

Neuroscientists (and also many quantum physicists) in turn seem to have wrong view about what the term 'classical' means. This wrong view reflects the wrong view about time and dissipation, which in TGD framework can be understood elegantly in terms of the subjective time development identified as a sequence of quantum jumps between quantum histories. It is of crucial importance that this development can occur only inside selves! Dissipation is the basic correlate of consciousness and consciousness is the basic prerequisite of 'classicality' understood in the erratic manner. Thus, from the TGD point of view, Hodkin-Huxley equations have nothing to do with genuinely classical world. Rather, they model phenomenologically the development of neurons by quantum jumps between quantum histories. Quantum jumps (and dissipation) inside neurons is possible only because neurons act as subselves and dissipate. Our self can be regarded as a system making something like 10^{38} quantum jumps per second. This implies macrotemporality but this macrotemporality has absolutely nothing to do with classicality in the sense as it appears in the field equations of say General Relativity.

The notion of self as quantum self-organizing system justifies the use of cybernetic notions such as circuits, loops, feedback, feedforward, inhibition and excitation. The general neuroscientist's view about brain as a complex neuronal circuitry finds justification and one ends up with rather concrete identifications for what kind of conscious (not necessary conscious to us –) experiences are associated with various brain circuits. The essentially new elements are 4-dimensionality of brain and realization of qualia and Boolean mind in terms of macroscopic quantum phases and these additional elements lead to genuine understanding of what happens in brain.

5.4.7 Brain as an associative net

Brain can be regarded as an associative net. At neural level association is a pair of incoming axons and outgoing axon: during synaptic transfer the space-time sheets of pre- and postsynaptic neuron fuse to form a larger space-time sheets and the corresponding conscious experience is association formed by the experiences determined by pre- and postsynaptic neurons. Neurons have their own sensory qualia associated with transmitter-receptor combinations: also neuronal seeing and hearing is possible. These qualia are probably not ours. From the point of view of our consciousness, nerve pulse patterns are most important and give rise to symbolic representations of sensory input. Frequency coding is involved and memetic code is reduced to genetic code. Membrane oscillations correspond to full memetic code and higher level cognition. Emission of at least slow neural transmitter gives rise to neuronal emotion. During synaptic firing the association pair becomes conscious. The most elegant option is that sensory qualia are at the level of primary sensory organs.

Also motor actions, in particular the transformation of Boolean statements to speech, can be regarded as associations of this kind. Motor action would be time reversal of sensory perception in appropriate time scales, and the motor actions initiated from some level higher than muscle cells correspond to motor imagination. Speech represents translation of memes to motor actions analogous to the translation of genes to proteins. For instance, logical reasoning develops as associations respecting basic rules of logic. This could explain why we are so poor in performing conscious logical deduction. On the other hand, rules of logic could be unconsciously inherited at the level of experience pairs from the physical world which obeys logic.

The most general possibility is that he output of a complex neuron is some function of the inputs. Music metaphor however suggests much simpler possibility: output is the same always and represented by nerve pulse pattern inducing postsynaptic qualia which depend on the receptor-transmitter combinations involved. This assumption has very strong consequences. Especially interesting are the sequences of associations associated with closed neural loops. The assumption that projections are topographically organized and that given axon is always in the same state mean that all closed circuits are reverbatory. Thus elementary single neuron association sequences associated with various brain circuits would be fixed and nerve pulse patterns should be determined the content of various conscious experiences constructed from these elementary experiences: the analogy with music would be very close. This would have quite strong consequences as far as the general structure of the brain circuits are considered.

1. Memories could quite correspond to asymptotic nerve pulse patterns reverberating in memory circuits. Nerve pulse patterns in closed would determine the content of memory and memories would result as fixed point patterns of self-organization. Very probably also microtubular representations of long term memories are important.

2. Motor plans would be represented by nerve pulse patterns reverberating in motor circuits and selected by self organization and realized as genuine motor actions only in case that the geometrically time reversed process starts from the muscle cells.

3. In case of Boolean thoughts reverberating circuits correspond to tautologies so that one can question the hypothesis that axons are permanently in the same state. Of course, there is no need to assume that thoughts correspond to closed circuits.

5.5 Sensory representations

In this section concrete model for the sensory representations is developed on basis of the general vision already outlined.

5.5.1 Concrete realization of sensory representations

The vision about the concrete realization of the sensory representations conscious-to-us has developed rather slowly. A good measure for the uncertainties involved is that the sizes of the primary sensory organs and EEG ME lengths $L(EEG) = c/f$ have represented the two extreme options for the size scale of the sensory representations conscious-to-us. It seems however more and more clear that TGD forces a dramatic deviation from the prevailing view about cortex as the seat of the ultimate sensory representations. The sensory representations conscious-to-us are outside the body and that the relevant length scale could be most naturally the length scale $L(EEG) = c/f$ defined by the EEG frequencies. In case of long term memories much longer length scales in the range of the light lifetime are necessarily involved and the realization of long term memories forces to conclude that human sensory consciousness is a cosmic phenomenon.

Place coding by cyclotron frequency scale

One of the basic aspects of conscious information processing is concrete geometric representation of even very abstract concepts and information as imagined objects of perceptive field. The observations about geometric qualia suggest to magnetic transition frequencies code for positions of subselves represented by magnetic or Z^0 magnetic flux tubes. Particular EEG frequency wakes-up particular subself in a specific position and orientation and gives rise to a 'feeling of existence' in some part of the virtual world of brain (or possibly outside brain!). Sensation of motion of object of perceptive field results automatically when subself moves inside self. For instance, one could represent coordinate curves as magnetic flux tubes with varying thickness: by magnetic flux conservation thickness codes the coordinate to magnetic field strength to cyclotron frequency.

Where me is?

The motion of eye or head does not induce the sensation that the world is moving although the sensory image moves around the cortex. Rather, brain acts like a (possibly moving) canvas at which the sensory input is projected and monitored by an external observer. This very simple observation is a strong objection against the idea that the ultimate sensory representations reside inside brain, and leads to the view that the magnetic flux tube structures associated with the primary and secondary sensory organs define a hierarchy of sensory representations outside brain. The question is where these representations are realized and one can imagine two alternatives.

1. Are sensory representations realized at the magnetic body?

Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly sensory organs and even neurons. MEs serve as projectors and place coding by magnetic transition frequency associated with ME wakes-up sensory subselves at various positions of magnetic flux tubes having varying thickness and associate thus various sensory qualia and even more complex attributes to the objects of the perceptive field.

This view can be defended also by the neat separation of the information processing from its representation occurring also in case of the ordinary computers as well as by Uncertainty Principle for EEG waves. If primary qualia are at the level of primary sensory organs and entangled with cortex, one can understand why imagination, which involves much the same neural processes as perception, does not give rise to sensory qualia.

EEG MEs correspond to our level in this hierarchy of projections. The simplest possibility is that the sizes of these sensory selves are of the order of EEG ME sizes ($L(EEG) = c/f(EEG)$) and thus can be of the order of Earth size! Thus the ultimate sensory representations are magnetic gigants in TGD and diametrical opposites of the neurophysiological dwarfs of standard neuroscience populating also TGD brain.

The known strange effects of large scale perturbations of Earth's magnetic field on consciousness (say, statistics about the effects of magnetic storms in mental state and tectonic activity inducing UFO experiences) provide a rich palette of anomalies supporting this view. The conservation of magnetic flux makes the magnetic flux tube structures of Earth size (or even larger) very stable: thus physical death presumably means only that our magnetic body redirects its attention to something more interesting. Near death experiences discussed in more detail in [I3] indeed support this view.

Two requirements must be satisfied for this scenario to work.

1. The projectors to the magnetic body cannot rotate when head rotates so that a fixed direction of perceptive field corresponds to the fixed direct at the magnetic body. This can be achieved if the projectors are magnetic structures with a fixed orientation with respect to the Earth's magnetic field.

2. Retinae must act like windows for this scenario to work. This means that the primary qualia mental images (subselves) at retina are entangled with the corresponding cognitive mental images at cortex, keep their attention directed to that part of the perceptive field that they represent as the direction of the gaze changes. Perhaps the retinal mental images are stationary with respect to the liquid phase not comoving with the eye ball. The retina-external world entanglement would also keep retinal attention fixed. This applies also to the saccadic motion, and the loss of visual consciousness when saccadic motion is prevented, could mean simply that retinal mental images lose consciousness when their motor activity with respect to eye ball is prevented: just like we lose our consciousness if not allowed to move!

2. Are the sensory representations realized in the perceptive field?

There is also a more conservative realization of sensory representations (if I had invented it first, I would probably have never considered the representations at the magnetic body!).

1. If retina-external world entanglement is present as suggested by the argument above, sensory canvas for the primary sensory representations could be provided by the perceptive field itself. The series of quantum entanglements from sensory organs to brain to magnetic body would define the entire sensory-cognitive representation involving also the cognitive aspects. There

would be no absolute need for topographic representations at the magnetic body although the appearance of a hierarchy of topographic representations in brain suggest that topographic representations continues. The magnetic representations could however be more abstract higher level representations: somewhat like the manual of an electronic instrument as compared with the photograph of the instrument.

2. One can also imagine that the magnetic body is not involved at all since also in this case the sensory representation would be organized topographically by the entanglement with the objects of the perceptive field. Now brain would entangle to the objects of the external world cognitive mental images. One could say, that me is the entire perceptive field plus physical body. In this case however the function of EEG remains unclear. Also the model of long term memories also suggests that EEG MEs in length scales of light life-time are involved.

Of course, neither of these views about human consciousness is new. In particular, the first one is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically. Here I cannot avoid the temptation to fall for a moment in manifesto mood: what makes me sad is that the materialistic neuroscience so strongly advocates the brain centered view about consciousness with physical death meaning the absolute end. The belief in this world view deprives life from its meaning and reduces it to a vulgar fight for survival or, depending on one's tastes, to a pre-determined performance of a robot. It is also deeply frustrating that the stubborn belief on materialism prevails despite the fact that this dogma contains so many internal contradictions that it would not even deserve to be called world view.

Cortex as a collection of attributes assigned to the objects of perceptive field represented at magnetic canvas

One of the basic problems related to the understanding of the information processing in brain is how various attributes are assigned to the object of the perceptive field. What is known that brain recognizes features and these features/attributes seem to be located in a more or less random looking manner all around cortex. This brings strongly in mind random access memory or computer game in which various little program modules realized as records in random access memory represent collection of standard sound effects. A strong hint is the empirical evidence for the view that the resonance frequencies associated with the autocorrelation functions of nerve pulse patterns, and thus presumably also coding EEG frequencies, are same for the features associated with a given object of the perceptive field. The challenge is to understand how the picture based on a collection of MEs projecting features to the magnetic canvas could allow to understand what is behind these observations.

The view about MEs associating attributes to the object of the perceptive field by waking up subselves in the magnetic flux tube structure serving as a sensory canvas suggests an elegant interpretation for these facts.

1. Cortex can be regarded as a collection of regions specialized to represent various kinds of standard features. Features need not be simple qualia: arbitrary complicated collections of them, such as familiar faces are also possible features. Even entire dynamical processes (selves) could serve as features.

2. Basic feature-regions are like computer records. The information about the position of the feature in perceptive field could be represented by the entanglement of the feature with a particular part of, say, primary sensory area representing a point of the perceptive sphere.

3. The direction of the point of the perceptive field could be coded basically by the direction of the magnetic flux tube emerging from the particular position of the sensory area providing map for solid angles of the perceptive field. The mechanism would be based on resonance with Alfven waves associated with the magnetic flux tubes of personal magnetic body amplifying MEs in the direction of magnetic flux tubes. The length (fundamental frequency) of ME would code for the distance of the point of the perceptive field to the distance of the point of the sensory magnetic canvas. Frequency coding could be achieved by varying the local value of the magnetic field responsible for generating the cyclotron frequency. This coding could be either dynamical or static in which case distance could be most naturally coded to linear structures, most naturally in direction orthogonal to the cortical surface.

4. Features would be basically associated with sensory organs, various neural pathways and brain areas and coded partially by nerve pulse patterns. Features could be practically all kinds of subselves generated by brain activity. Primary qualia could be realized at the level of sensory receptors if entire sensory pathways entangle with the magnetic body.

5. Projector MEs would be orthogonal to the sensory area where they emanate. The Topographic mapping of the perceptive field to sensory areas would guarantee that sensory images would remain stationary under rotations of head: although sensory magnetic sensory canvas would move the image projected to it would be stationary. MEs and magnetic flux tubes must be parallel if Alfwen wave resonance is involved. In this manner the sensory experiences can be private and the contribution from the other brains remains negligible. Note however that people in very intimate contact could gradually share there magnetic sensory canvases: the anecdotes about gradually developing telepathic communications between the teachers and students of the meditative practices could involve this kind of sharing of computer screen between several users.

6. In this coding EEG MES would entangle with essentially all information about the perceptive field and the spectroscopy of consciousness would be realized in a strong sense.

Of course, the extreme flexibility of the entanglement mechanism of binding means that one can imagine almost unlimited number of variants about this basic option and the proposed variant can be defended only as the simplest one found hitherto. One can also allow the possibility that the sequence of entanglements begins from the perceptive field with the primary mental images at the level of sensory organs being entangled with objects of perceptive field.

Fractality suggests that there is a hierarchy of sensory representations. In particular, cortex areas, brain nuclei and even cells could possess their own sensory representations. The inactivity of the primary sensory areas during REM sleep could mean that during dream state sensory representations are non-cortical lower level representations or realized at higher sensory areas. Of course, lower level structures could define the projections to the magnetic sensory canvas also during wake-up consciousness. For instance, relay station like nuclei could act as relay stations for the projections realized at the magnetic body. Any brain area defining topographical map of sensory data is could candidate for defining a sensory representation.

The projector regions would serve as kind of central entanglers. Also the nuclei believed to somehow generate EEG resonance frequencies responsible for the binding of mental images are good candidates for the central entanglers. Thalamus is believed to generate 40 Hz rhytm and is thus a good candidate for the central sensory entangler and projector. Hippocampus generates hippocampal theta and could be the central memory entangler and projector. Frontal lobes generate slow EEG waves during cognitive activities and could act as cognitive entanglers and projectors.

This kind of architecture is expected to be realized at various length scales. Perhaps even at the length scale of genes. The remaining question is how motor activities are realized in this picture. The metaphor for consciousness as a computer sitting at its own terminal, which originally stimulated my personal attempts to understand consciousness, might help here. Computer screen corresponds to the magnetic canvas. The one who sits there presumbly corresponds to our magnetic body (as far as conscious-to-us intentions are considered). The central unit corresponds to the brain. Sensory projector MEs are generated automatically by nerve pulse activity and code the picture on the monitor. Z^0 MEs as active quantum holograms acting as control commands generating nerve pulse patterns would provide a realization of keyboard. Thus it would seem that those aspects of the computer which are usually not regarded as fundamental in Turing machine paradigm are the most crucial for understanding the brain consciousness and computer programmers seem to mimic what happens inside (and outside) their own brain.

Anomalous visual percepts and sensory canvas hypothesis

Sensory canvas hypothesis means that at the perceptual level we see using ELF– rather than visible light. Of course, if primary sensory qualia are at the level of sensory receptors, this seeing has the character of imagination. Even in this case brain could use feedback to the sensory receptors assign sensory qualia with the imagination like perception. This would occur during dreaming and what is regarded as hallucinations.

One can also consider the possibility of "vision" based solely on the ELF input from brain and body having no correlate with the visible light entering into retina or even with neural activity. Even genuinely three-dimensional vision in which own body is seen as it would be seen by the external world suggests itself. The dropping of ions from the atomic space-time sheets to the magnetic flux tubes so that they end up to high n cyclotron states decaying via the emission of photons at frequencies which are harmonics of the cyclotron frequency would generate the projector MEs needed for the sensory representation of the physical body or part of it as seen by the environment.

There is some evidence for this kind of anomalous vision.

1. Yogis have reported altered states of consciousness in which they see their own body three-dimensionally, that is simultaneously from all directions. This might have interpretation as ELF vision involving a feedback from magnetic sensory canvas to brain to "qualiafy" the percept.

2. Becker tells in his book "Cross currents" [29] about a young cancer patient who told that he can see the interior of his own body. The patient could also locate the remnant of the tumour correctly. If sensory receptors are necessary for visual qualia, the needed data must be received from somewhere by brain, and be projected to the visual receptors like during dreaming. The simplest option is that body parts can in some sense "see" each other. In particular, brain can "see" body parts (note that bacteria possess a primitive IR vision based on microtubules). Biohology provides support for the body as a hologram. For instance, an electric stimulation of ear during Kirlian imaging of a finger tip creates a Kirlian photo from which it is possible to abstract a hologram of ear (see [22] and [K2].

3. Also the OBE experiences, for instance those associated with NDEs, could have an analogous interpretation. The sensory input from eyes would be absent but brain would give feedback to visual receptors to "qualiafy" the the input which it might receive from other levels of self hierarchy. If even the input from neural activity is absent during NDEs so that the visual experience should be determined by the background ELF component emanating from the brain and body. The third person perspective associated with OBEs might be always present but be masked by the strong sensory input or by the absence of feedback to visual receptors. It is possible to have experiences about contact with deceased by a therapy based on rhythmic eye movements [21, 60]. The function of eye movements might be to establish a feedback to certain brain regions serving as receivers of input from magnetic bodies of deceased or from magnetosphere.

4. I have proposed thousand and one explanations for the beautiful flow visible when I close my eyes in a calm state of mind. During my "great experience" this background flow was accompanied by extremely vivid visual hallucinations. An additional item to the long list of explanations is following. The information characterizing the flow enters from or via brain to the visual receptors and is in this manner "qualiafied".

What has been said about magnetospheric third person aspect applies also to other senses. Interestingly, I often wake-up partially and realize that I hear my own snoring as an outsider (quite a dramatic experience!). Sometimes I have an experience which might be interpreted by saying that the hearing in the first perspective is superposed with the hearing in the third person perspective. The third person hearing has a time lag so that a kind of double breathing results.

Place coding of features inside brain

Place coding for various geometric parameters characterizing simple geometric 'features' inside brain could be realized using the variation of the cyclotron frequency along a magnetic flux tube of varying thickness. The hierarchy of the sensory canvases allows a modular structure in which a geometric feature such as triangle, line, or ellipse represented at a lower level sensory canvas is projected to a *single* point of 'our' sensory canvas.

Becker tells in his book "Cross Currents" [29] about a technique discovered by Dr. Elizabeth Rauscher, a physicist, and William Van Bise, an engineer. The technique uses magnetic fields generated by two coils of wire, each oscillating at a slightly different frequency and directed so as to intersect at the the head of the subject person. When two energy beams with different frequencies intersect at some point in space, a third frequency, so called beat frequency is formed as the difference

of the frequencies. What Bise and Rauscher found that this ELF frequency (unfortunately, I do not know what the precise frequency range was) generates simple visual percepts like circles, ellipses and triangles and that the variation of the second frequency induces the variation of the shape of the percept.

The simplest interpretation is that the beat frequency is extracted by nonlinear effects in brain and induces a magnetic quantum phase transition at magnetic tubes whose thickness varies and codes for a parameter (say scaling in some direction) characterizing the geometry of the primitive percept (or 'feature'). An analogous phenomenon occurs also for auditory inputs with slightly different frequencies fed into ears and makes it possible to 'hear' sounds below the audible range. The mechanism could be the same.

If primary sensory qualia are realized only at the level of the primary sensory organs, one can make two conclusions. ELF wave wakes up a "feature" analogous to an imagined percept, and presumably realized as a particular nerve pulse pattern. ELF wave also induces a projection from the brain to the retinae "qualiafying" this feature. Blind subjects should not have these extra-sensorily induced percepts.

One can imagine two options concerning the ultimate representation of a simple geometric feature depending on whether the feature corresponds to a *collection* of points or *single* point at 'our' sensory canvas.

1. The visual percept corresponds to a *collection* of activated points at 'our' sensory canvas and activated geometric point corresponds to a standard mental image represented at brain level and assigned to a point of sensory canvas. The magnetic phase transition would initiate a process eventually activating particular projectors and the position of the quantum phase transition at the magnetic flux tube would determine the shape of the feature. One can criticize this option. The brain applies modular hierarchy in the information processing and simple percepts like triangles and circles which are also fundamental in the elementary geometry, are ideal for basic features assignable with a *single* point of 'our' sensory canvas rather than being represented as composites of elementary features (points). The very fact that the place coding for the geometric shape of the feature is involved, suggests the same.

2. The visual percept is represented as a mental image inside brain or, more probably, at some lower level sensory canvas so that the hierarchy of the sensory canvases would directly relate to the modularity of our sensory representations and sensory canvases would be in an intense interaction by quantum entanglement much like various subprograms of a computer program. This geometric mental image is assigned with a *single* point of 'our' sensory canvas by quantum entangling it with a projector ME projecting to a particular point of 'our' sensory canvas. The position of the feature at the sensory canvas might be determined by the position of the volume of intersection for the beams.

The relation of mental imagery to sensory experiences

Mental imagery is something which is difficult to understand in the framework of the standard neuro science. There are empirical results suggesting that mental images correspond to patterns of activity inside cortex, which are three-dimensional and continuous so that neural activation provides a concrete recognizable image about object [50]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [50]. It is also known that imagery uses same regions of the cortex as real sensory experience and the problem is to understand why there is almost sensory experience involved with imagery.

In the framework of the standard neuroscience the obvious question is why the pattern of the imagery activity is not accompanied by a direct sensory experience. Also the boundary between direct sensory experience and imagination is sometimes problematic. For instance, in the state between sleep and awake sensory images often enter into mind. During dreams one can have sensory images and eidetic memory is essentially sensory memory. I have a personal experience about an extended state of consciousness, or rather whole-body consciousness (this experience actually made me consciousness theoretician!). During this state I could see my thoughts as vivid visual images and had also peculiar odour and taste experiences also reported to occur during mystic experiences.

Imagination very probably involves p-adic-to-real phase transitions transforming p-adic imagery to nerve pulse patterns or membrane oscillations. The genuinely p-adic aspect of imagination could

be analogous to a free choice of initial values in a computer simulation, which are then transformed to their real counterparts initiating neural activity.

Why imagination does not involve sensory qualia could be explained in several manners.

1. Primary sensory qualia are realized at the level of sensory receptors and brain constructs only higher level symbolic representations of the sensory input and quantum entanglement binds these representations together. For imagination sensory receptor level is absent. This would also explain rapid eye movements during dreams as being related to the construction of visual qualia. Dreaming is indeed a cognitive activity which is learned gradually (at young age dreamer sees only static images). One could understand why motor activities are not accompanied by sensory experiences associated with motor pathways. The obvious reason for why sensory imagination should not create lively images is that this would lead to a dangerous mixing of the real and virtual. If this interpretation is correct, the study of whether feedback from brain to sensory organs occurs during sensory hallucination, provides a manner to test whether sensory hallucination is a telepathic experience resulting from the sharing of mental images or whether it might be constructed in brain by feedback to sensory receptors.

2. Imagination could rely on membrane oscillations just as higher level cognition. The finding that imagination does involve patterns of activity at visual cortex similar to those associated with ordinary visual perceptions does not support this idea.

3. If sensory representations are realized at the magnetic canvas, the difference between imagination and real sensory experience could result from the absence of the sensory representation, that is projection to the sensory canvas. This state of affairs could have a detectable EEG correlate: presumably in 40 Hz resonance band. The projector MEs responsible for the cognitive representation could be activated but be p-adic and project only cognitive images. One can however wonder why magnetic body is at all conscious about imagined mental images if it does not share these mental images.

Motor output and the ultimate output giving rise to our sensory experience might be very closely related: motor action could be like printing or some control activity and sensory and cognitive representations like pictures at the monitor screen. This picture looks attractive but might neglect some deep differences suggested already by the anatomy of the central nervous system. There are reasons to expect that the construction of sensory percepts and motor activity could be geometric time reversals of each other at some levels of the self hierarchy (MEs in certain time scales). This view would mean that motor action starts from a rough sketch for the outcome of the motor action and quantum jump by quantum jump ends up to the complete performance by a process which might be regarded as a gradual carving of a four-dimensional sculpture relying on both ordinary and time reversed dissipation serving as a Darwinian selectors so that the very many sketches would lead to the same outcome. Both these views might make sense: which view is correct depends on what time scale one is considering.

Are mindlike sheets representing objects of the perceptive field generated automatically?

One of the poorly understood aspects of sensory perception is how objects of the perceptive field are generated at the level of cognitive representations. The problem is especially difficult in the computational approach to consciousness. Natural idea is that the objects of cognitive representation directly reflect the objects of the physical world and that direct physical interaction creates these objects automatically. Various visual illusions demonstrate that also apparent objects are generated by sensory experience which suggests that it is nerve pulse patterns at the level of cortex which give rise to the objects of the perceptive field. In neural net approach to brain consciousness it is however far from trivial what these objects could be.

In TGD approach objects of the perceptive field correspond to mental images and thus subselves. subselves in turn naturally correspond to mindlike space-time sheets. Therefore the problem reduces to that of understanding how sensory input gives rise to mindlike space-time sheets: in particular, how the sensory input or nerve pulse activity induced by it determines the boundaries of the mindlike space-time sheets.

On of the basic laws about sensory experiencing is that only changes are experienced. Quantum model for the contents of consciousness of self implies this law at quantum level: only the averages

of the increments of quantum numbers and zero modes are experienced consciously. By 'Ontogeny recapitulates phylogeny' principles this law should have realization also at the level of dynamics of the space-time surface.

A possible space-time level counterpart of this law is that the primary at the level of primary sensory organ or secondary sensory stimulus at the level of cortex generates Kähler electric field proportional to the gradient of the stimulus. This creates however a problem. Kähler electric flux must be conserved in the approximation that vacuum Maxwell's equations are satisfied (they are not exactly satisfied since vacuum can carry currents of Kähler charge). Suppose that stimulus has a strong gradient: where does the Kähler electric flux go? The answer is simple: mindlike space-time sheet is generated and the flux goes to the mindlike space-time sheet through wormhole contacts! Since sensory stimulus varies rapidly at the boundaries of the objects of the external world, this means that the objects of the perceptive field are automatically represented by mindlike space-time sheets and give rise to selves, mental images in the cognitive representation! Several cognitive representations with different decomposition into objects are possible.

Spectroscopy of consciousness

In [M5] it is found that a simple scaling law $v = \lambda f$ relating the apparent wavelength and phase velocity of EEG wave and more general em waves with its frequency allows to understand the basic anatomical structure of the central nervous system as reflecting evolution regarded as the emergence of new p-adic length scales. Scaling law allows also to predict which frequencies correspond to qualia experienced at a given level of the p-adic self hierarchy for a given conduction velocity of nerve pulses identified as an effective propagation velocity of EEG waves (but actually representing drift velocity of ELF MEs). Scaling law could also relate the sizes $L(magn) \sim L(EEG)$ of the radial magnetic flux tube structures (magnetic canvas or magnetic body) associated with the secondary sensory organs of size $L \sim \lambda$: $L(magn) \sim L(EEG) = c/f = (c/v)L$.

The identification of the quantum correlates of sensory qualia, the realization of the sensory representations using magnetic canvas and frequency coding, and scaling law imply what might be called spectroscopy of consciousness. Spectroscopy of consciousness is described in detail in [M5] and is shown to be consistent with the data about EEG correlates of sensory experience, emotion, cognition and memory (available to me. The model leads to myriads of precise predictions for EEG correlates of primitive building blocks of conscious experience so that the model, although not claimed to be final at the level of detail, is testable.

Especially beautiful is the connection of the theory of the magnetic qualia with atomic and nuclear spectroscopy: the structure of the periodic table reflects directly itself in the spectroscopy of consciousness. Various full electronic shells (He, Ne, Ar, Kr, Xe) correspond to a hierarchy of geometric qualia relating directly with the band structure of EEG. The periods also seem to correspond to the five-layered structure of sensory cortex (primary, secondary, etc... areas).

If one assumes that p-adic length scales define preferred lengths for MEs, then apart from scaling the spectrum of supercanonical transition frequencies is constant of Nature and this leads to extremely powerful predictions and theory is immediately testable. One can indeed identify the basic resonance frequencies associated with EEG as lowest frequencies of this kind. Furthermore, the lower bounds of EEG bands correspond to fundamental frequencies of Super Virasoro transitions. Also now the representations associated with various p-adic length scales seem to correlate with the hierarchy formed by the areas of the sensory cortex.

Spectroscopy of consciousness promises to be for brain science what atomic spectroscopy has been for physics and chemistry. It is somewhat astonishing that this possibility has not been noticed before. After all, spectral lines provide extremely effective, reliable and universal manner to code information and brain is the most refined information processing system we know.

5.5.2 Is the pain in the toe in the toe, in brain, or somewhere else?

The basic question concerns about the seat of the primary sensory experience. There are three options.

1) The apparently very naive view is that sensory experience gets contribution also from the primary sensory organs. Certainly primary sensory organs could be experiencers in TGD framework (and probably are) but this experience need not contribute to our sensory consciousness unless there is entanglement between brain and sensory organs.

2) Standard neuroscience says that our sensory experience can be localized to cortex.

3) The view about ultimate (conscious-to-us) sensory representations as being realized on the magnetic canvases formed by a hierarchy of magnetic flux tubes structures differs in even more radical manner about the view of standard neuroscience. As far as the analysis of the sensory data is considered, this view does not differ in an essential manner from the standard view: magnetic sensory canvas is analogous to a passive monitor screen.

The view 1) is not automatically excluded in TGD framework as it is in standard neuroscience.

1. The experiments of Libet about passive aspects of consciousness [28] could be seen as supporting the hypothesis that subcortical parts of the sensory pathways contribute to our sensory experience [H5].

2. The location of primary qualia to the level of sensory receptors would also allow to understand why sensory pathways are specialized to definite qualia despite the fact that there seems to be no obvious structural or functional differences at neuronal level. As already found, one could also understand the difference between imagination and sensory experience and why feedback to visual receptors (REM) is present during dreaming.

3. The identification of long term memories as multitime experiences containing contributions from the distant geometric past forces to consider the possibility that sensory organs are primary sensory experiencers whereas the standard dogma of the neuro science is that all sensory experiences occur at brain level at geometric now. The idea that also primary sensory organs are seats of the primary sensory experiences, could explain Libet's experiments, explains the observation that persons who have become blind gradually, lose their ability to have dreams and also the rapid eye movements and feedback from brain to auditory organs during REM sleep. It must be emphasized that these phenomena can be understood also in options 2) and 3).

One can represent several objections against the identification of the primary sensory organs as seats of our primary sensory experience (Option 1)[1].

1. The first class of objections is that our sensory perception involves a lot of computation (consider stereo vision as an example) and this computation cannot be performed at the level of the sensory organ. These objections look at first rather convincing but relate only to the cognitive aspects of sensory perception, not the to the primary sensory qualia.

2. The second class of objections is related to the explanatory power of the idea of standard neuroscience that entire sensory pathways containing also neurons of cortex are seats of the sensory experience (For option 2) they are involved with the construction of the sensory experience). This idea allows to regard brain as kind of musical instrument such that each neuron produces its characteristic sensory experience so that our experiences are combinations of the primitive neuronal experiences. For conscious information processing this is a crucial advantage: for instance, incoming nerve pulse patterns in associative regions of brain are consciously differentiated from each other as different modalities so that same nerve pulse pattern can have different meaning as sensory modalities. This objection suggests that the idea of restricting sensory experiences at the level of primary sensory organs is wrong. On the other hand, neuronal pathways and brain could be specialized to build cognitive representations and primary sensory qualia could be at the level of sensory receptors. The feedback from brain to the sensory receptor level could also make possible to manipulate the sensory input.

3. The view about brain as a collection of standard features which are activated by the sensory input and projected to the magnetic canvas and thus associated with the objects of perceptive field is in conflict with the idea that our experience receives a direct contribution from the primary sensory organs. Situation of course changes if one allows entanglement of brain with sensory organs.

4. The phenomena like dreams, hallucinations, synesthesia, phantom limb, and the experiences generated by stimulating neurons of sensory pathways and projected pain are obvious counter

[1]The topic of discussion might look rather academic from the point of view of neuro science but it is not that in TGD framework: it took years to decide whether this idea could make sense or not.

arguments against the idea that sensory organs are primary sensory experiencers (or form parts of them). The identification of the long term memories as multitime experiences allows in principle to overcome these objections, and a more detailed discussion of this point is in order.

In the following the explanations of various strange phenomena of sensory consciousness are studied and the explanations provided by the options 1), 2) and 3) are compared. It must be emphasized that the possibility that even sensory organs (and even neurons) have senses is not excluded by these arguments: what is however clear that *our* sensory landscape is constructed in cortex.

Back projections and cross projections

During REM sleep rapid eye movements occur and are thought to accompany dreaming. It is not however clear to me whether the correlation between rapid eye movements and visual dreaming is one-to-one. The ringing of the ears is a real physical process occurring in ear and these otoacoustic emissions, as they are called, can be sometimes heard by even outsider [M6]. Rapid eye movements during dreams and otoacoustic emissions can be regarded as backprojections from brain to primary sensory organs. These phenomena can be understood without any difficulties in the options 2) and 3). For instance, rapid eye movements could be understood as feedback generated by a visual dream. For the option 1) rapid eye movements could be seen as necessary prerequisite of dreaming and to "qualiafy" imagined mental images.

Synesthesia involves cross-modal associations of form $A \to B$ (say visual to auditory). The simplest view allowed by options 2) and 3) is that this kind of sensory leakage occurs at the level of neuronal connections. In option 1) both dreams, hallucinations, and synesthesia rely on the feedback from brain to sensory organs to "qualiafy" the mental images. The prediction is that there should be a feedback, not only between sensory areas, but between sensory organs or the cross-associated qualia. This prediction is certainly testable. For instance, auditory-visual synesthesia should be lost if eyes are damaged.

Projected pain and phantom leg

For option 1) the explanation of phantom pain as remembered pain and thus as a real pain in the geometric past when the limb still existed, is the simplest one. Projected pain cannot be however interpreted as a remembered pain since the cause of pain is in the geometric now. The assumption that pain is a cortical sensation whereas only pure sensory experiences would be located in the primary sensory organs looks rather strange taking into account the universality of emotions as entropic qualia. What goes wrong with this argument is that the experience of pain is confused with the experience about where the pain is. The wrong location could result when the mental image about pain is projected in a wrong manner to the sensory and cognitive sensory canvases.

For the standard explanation (option 2) one must assume that the experience of pain is localized to the somato-sensory map in brain. The explanation of the projected pain is based on the observation that projected pain is felt in body part which was very near to the body part contain the actual cause during early developmental stages. If somatosensory maps are not updated properly, projected pain becomes possible. This applies also to the Option 1).

For option 3) the explanation of the phantom leg phenomenon would be very simple. The loss of physical limb does not mean the loss of its magnetic counterpart (located perhaps at another side of the globe!). Thus phantom pain might be caused by either sensory input from other parts of leg projected to the magnetic sensory canvas, and much less probably, from external electromagnetic stimulation at magnetic resonant frequency. The reason why the latter option is much less probable is that the radial bundles of MEs and magnetic flux tubes associated with a particular secondary sensory organ are expected to have a large number of wormhole contacts and/or join along boundaries contacts and form single coherent structure. Otherwise it is difficult to understand how the input from MEs of a particular brain could compete with the input from other sources. Phantom pain could result if the nerve pulse patterns from the stump of the limb are such that they are interpreted as pain signals in cortex. One can also consider the view is that phantom pain is geometrically remembered pain from the period when leg still exists and thus would have a real cause.

The phenomenon of projected pain could be also understood in option 3) in the same manner as for option 2). It is also possible that the magnetic map of body coded by MEs is partially out-of-date so that some parts of this map correspond to the structure of body during early developmental

periods. This would mean that the MEs representing by their orientation and activation frequency the positions of parts of body would not be updated after early developmental stages properly. This hypothesis is testable and if somatosensory map is not out-of-date, projected pain could be seen as a support for the notion of magnetic sensory canvas.

Color constancy and sensory organs as primary experiencers

The phenonenon color constancy [36], which forms one of the most important aspects of vision, is a further objection against the identification of sensory organs as primary sensory experiences. At least if one believes that colors are primary sensory qualia. If the object of the visual field is illuminated with a monochromatic light of constant intensity, its color does not change. This is quite contrary to what one might expect on basis of what is expected to happen in the color sensitive cones in retina detecting wavelenghts concentrated around blue, red and green. A particular case of the color constancy phenomenon arises when entire visual field is illuminated with a monochromatic light of a constant intensity: what is experienced is complete darkness. The ability to see the real colors of the objects of the external world, which is made possible by the color constancy phenomenon, is of course extremely valuable for survival purposes.

In option 2) and 3) it can be assumed that the subtraction of the background involves computational processing at the level of brain. If the objects of the perceptive field are generated at the level of brain by nerve pulse patterns, this is probably the case. The subtraction of the background is possible to realize by excitatory and inhibitory projections and mathematically one can regard the sensory image of a colored object of a perceptive field as an integral function for the gradient of the intensity of the sensory input. For a monochromatic constant input the derivative vanishes as also integral function. The task therefore is to realize this integral function in terms of a neural circuit using excitatory and inhibitory inputs and outputs.

For option 1) color constancy is a challenge. Color constancy suggests that retina cannot be the primary sensory experiencers of color qualia since in this case our subjectively experienced world would be changing its colors continually. This conclusion might be too hasty. In fact, one could defend the hypothesis about sensory organs as primary sensory experiencers and use color constancy as a guide line in the attempts to guess how sensory representations for the objects of the external world are generated as mindlike space-time sheets residing in the retina.

The explanation of the color constancy could reduce to the hypothesis that sensory qualia correspond to increments of quantum numbers rather than quantum numbers themselves.

1. If the color perception generated by the illumination at a particular wavelength depends only on the spatial gradient of the illumination, color constancy follows as a consequence. Since the eye is performing saccadic motion, this translates to a temporal gradient of illumination. The temporal change of the illumination at a particular wavelength should thus induce a particular color quale. But this is consistent with the assumption that color qualia correspond to the increments of color quantum numbers in the quantum jump. This model explains also why the saccadic motion is necessary to generate color qualia, and qualia at all. Quite sensory percepts result only when physical change is involved. Saccadic motion maps the gardients of illumination to increments of color quantum numbers.

2. One might also understand why a rotating Benham top containing only black and white regions can produce color sensations. Since both the saccadic motion and the motion of disk are involved, one can imagine that for a rotating disk the proportions of various primary qualia are affected such that a net color is perceived. For instance, the intensity of the perceived color could depend on the velocity with which the eye crosses the intensity gradient and this dependence could depend on wavelength.

All geometric aspects of sensory experiences should reduce to representations generated by zero modes, in particular zero modes characterizing classical Kähler field, which can reduce to pure electromagnetic (vision?) or Z^0 field (auditory experience?). Color constancy could be understood if the incoming light intensities associated with the wavelengths around three basic colors generate Kähler electric fields proportional to the gradient of the intensity. If the gradient is strong, as it is on the boundary of the retinal or neural image of the object, the conservation of the Kähler electric flux forces the generation of mindlike space-time sheet at which part of the flux goes.

Thus retina would automatically create representation for the objects of the visual field as mindlike space-time sheets, which in turn could give rise to subselves representing objects of the visual field as mental images! These objects need not however correspond to our conscious experiences. In fact, the boundaries of all objects of perceptive field should be generated by strong gradients and same principle would apply also to the higher level representations of sensory information. A gradient of Kähler (electric) field proportional to the gradient of primary/secondary sensory stimulus is generated in primary/secondary sensory organ and automatically generates mindlike space-time sheets, which give rise to subselves representing the decomposition of the perceptive field to objects.

Blind sight and Anton's syndrome

In blind sight cortically blind patient claims to be blind but is actually able to locate objects in the visual field when asked to do that. By training the patient can even develop some kind of primitive conscious experience of motion, shape and color.

For option 1) blind sight looks first problematic since the basic assumption is that primary visual qualia are generated at the level of retina. If the entanglement with retina is lost the visual qualia at retina are not assigned with the magnetic sensory canvas and the person is not conscious that his eyes see. The primitive conscious experiences of motion, shape and color would arise at the sub-cortical level make it possible to locate objects in the visual field. Blind sight would be also vision without cortical cognition (such as feature recognition). Training would generate gradually entanglement between sub-cortical areas and the cortical areas responsible for projections to the sensory magnetic canvas.

In option 2) the explanation for the blind sight would be the existence of two separate visual systems. Possible candidates for these systems as regions of cortex have been even identified[24].

In option 3) blind sight has several explanations. There is entire p-adic hierarchy of increasingly refined visions involving retinal vision, amygdalar vision, and various visions corresponding to sensory areas of cortex. There is also the possibility that blind sight results from the lost ability to project the cortical sensory image to the magnetic canvas. In this case blind sight could be purely cognitive seeing. A test for the magnetic canvas hypothesis might be based on the elimination of the MEs responsible for the sensory projection to the magnetic canvas somehow.

The patient suffering from Anton's syndrome is cortically blind but claims that he sees but behaves as if he were blind and confabulates all kinds of explanations for his behavior. The standard explanation (option 2) is that patient is not conscious about being blind: the fact that patent seems to gradually accept the situation that he does not see, supports this explanation.

Option 3) would allow the possibility that the parts of the cortex responsible for projecting sensory data to the sensory magnetic canvas remain intact and that the visual images are hallucinations or visual memories. It would not be surprising that this useless vision would be gradually lost. Note however that lower level visual systems might work.

The advocate of option 1) could argue that patient sees at the subcortical level and hence has pure experience of vision without any cortical cognitive processing of what he is seeing. Person is cognitively blind. There would be no recognition of objects in the visual field, to say nothing about associations and memories related to these objects. Therefore sensory (or subcortical) seeing would not help the patient much and he would behave effectively as a blind person. One could even consider the possibility that patient gradually loses the ability to see because this ability is not useful anymore. A possible test (probably already carried out) for the hypothesis is to check whether patient can show the direction of an intensive light source (even this might require "cognitive seeing").

Woman without body

In his book 'The man who mistook his wife for a hat' [52] Oliver Sacks tells about a tragic situation in which his patient lost totally her body image. Body image is provided by proprioception together with vision and sense of balance. The sensory neurite suffered by the patient destroyed patient's proprioceptive sensory pathways. Patient did not however lose tactile senses. The proprioceptive homunculi in patient's parietal lobes suffered no injury. Patient learned to cope with everyday activities by using vision and sense of balance and all kinds of clever feedback and feedforward mechanisms to compensate the lost proprioception. For instance, patient regained her ability to speak, to keep her

bodily posture and walk. She however lost her balance immediately if she closed her eyes. Patient did not however get back her phenomenal body image in this manner.

The loss of body image is not a problem for option 1) since neural pathways are prerequisites of quantum entanglement between brain and sensory receptors (also these might have been destroyed). Options 2) and 3) can explain the loss of body image without difficulties. These options could even allow to regain the body image artificially, for instance by artificial neuronal stimuli providing a representation for the positions of various body parts. In both cases artificial electric stimulation of cortex should generate tactile sensations of some kind.

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Chapter 6

New Developments in TGD and Their Implications for TGD Inspired Theory of Consciousness

6.1 Introduction

The conflict between the non-determinism of state function reduction and determinism of time evolution of Schrödinger equation is serious enough a problem to motivate the attempt to extend physics to a theory of consciousness by raising the observer from an outsider to a key notion also at the level of physical theory. Further motivations come from the failure of the materialistic and reductionistic dogmas in attempts to understand consciousness in neuroscience context.

There are reasons to doubt that standard quantum physics could be enough to achieve this goal and the new physics predicted by TGD is indeed central in the proposed theory. The developments in quantum TGD during last years have led to a fusion of real and p-adic physics by using generalization of number concept, to the realization of the crucial role of hyper-finite factors of type II_1 for quantum TGD, to the generalization of the imbedding space implying hierarchy of quantized values of Planck constant, to so called zero energy ontology, and to the reduction of quantum TGD to parton level with parton understand as 2-D surface whose orbit is light-like 3-surface, and to the realization that quantum TGD can be formulated as almost topological quantum field theory using category theoretical framework.

These developments have considerably simplified the conceptual framework behind both TGD and TGD inspired theory of consciousness and provided justification for various concepts of consciousness theory deduced earlier from quantum classical correspondence and properties of many-sheeted space-time.

The notions of quantum jump and self can be unified in the recent formulation of TGD relying on dark matter hierarchy characterized by increasing values of Planck constant. Negentropy Maximization Principle serves as a basic variational principle for the dynamics of quantum jump and must be modified to the case of hyper-finite factors of type II_1 The new view about the relation of geometric and subjective time together with zero energy ontology leads to a new view about memory and intentional action. The quantum measurement theory based on finite measurement resolution and realized in terms of hyper-finite factors of type II_1 justifies the notions of sharing of mental images and stereo-consciousness deduced earlier on basis of quantum classical correspondence. A new element is finite resolution of quantum measurement and cognitive and sensory experience. Qualia reduce to quantum number increments associated with quantum jump. Self-referentiality of consciousness can be understood from quantum classical correspondence implying a symbolic representation of contents of consciousness at space-time level updated in each quantum jump. p-Adic physics provides space-time correlates for cognition and intentionality.

6.2 The new developments in quantum TGD

This section summarizes the developments in quantum TGD which have taken place during last few years.

6.2.1 Reduction of quantum TGD to parton level

It took surprisingly long time before the realization that quantum TGD can be reduced to parton level in the sense that fundamental objects are light-like 3-surfaces (of arbitrary size). This identification follows from 4-D general coordinate invariance. Light-likeness in turn implies effective 2-dimensionality of the fermionic dynamics. 4-D space-time sheets are identified as preferred extrema of Kähler action. A stronger form of holography is that modified Dirac action and Chern-Simons action for light-like partonic 3-surfaces defined the Kähler action as a logarithm of the fermionic determinant.

Magic properties of 3-D light-like surfaces and generalization of super-conformal symmetries

The very special conformal properties of both boundary $\delta M^4_{\pm}$ of 4-D light-cone and of light-like partonic 3-surfaces X^3 imply a generalization and extension of the super-conformal symmetries of super-string models to 3-D context [4, 5, C1]. Both the Virasoro algebras associated with the light-like coordinate r and to the complex coordinate z transversal to it define super-conformal algebras so that the structure of conformal symmetries is much richer than in string models.

1. The canonical transformations of $\delta M^4_{\pm} \times CP_2$ give rise to an infinite-dimensional symplectic/canonical algebra having naturally a structure of Kac-Moody type algebra with respect to the light-like coordinate of $\delta M^4_{\pm} = S^2 \times R_+$ and with finite-dimensional Lie group G replaced with the canonical group. The conformal transformations of S^2 localized with respect to the light like coordinate act as conformal symmetries analogous to those of string models. The super-canonical algebra, call it SC, made local with respect to partonic 2-surface can be regarded as a Kac-Moody algebra associated with an infinite-dimensional Lie algebra.

2. The light-likeness of partonic 3-surfaces is respected by conformal transformations of H made local with respect to the partonic 3-surface and gives to a generalization of bosonic Kac-Moody algebra, call it KM, Also now the longitudinal and transversal Virasoro algebras emerge. The commutator $[KM, SC]$ annihilates physical states.

3. Fermionic Kac-Moody algebras act as algebras of left and right handed spinor rotations in M^4 and CP_2 degrees of freedom. Also the modified Dirac operator allows super-conformal symmetries as gauge symmetries of its generalized eigen modes.

Quantum TGD as almost topological quantum field theory at parton level

The light-likeness of partonic 3-surfaces fixes the partonic quantum dynamics uniquely and Chern-Simons action for the induced Kähler gauge potential of CP_2 determines the classical dynamics of partonic 3-surfaces [B4]. For the extremals of C-S action the CP_2 projection of surface is at most 2-dimensional.

The modified Dirac action obtained as its super-symmetric counterpart fixes the dynamics of the second quantized free fermionic fields in terms of which configuration space gamma matrices and configuration space spinors can be constructed. The essential difference to the ordinary massless Dirac action is that induced gamma matrices are replaced by the contractions of the canonical momentum densities of Chern-Simons action with imbedding space gamma matrices so that modified Dirac action is consistent with the symmetries of Chern-Simonas action. Fermionic statistics is geometrized in terms of spinor geometry of WCW since gamma matrices are linear combinations of fermionic oscillator operators identifiable also as super-canonical generators [B4]. Only the light-likeness property involving the notion of induced metric breaks the topological QFT property of the theory so that the theory is as close to a physically trivial theory as it can be.

The resulting generalization of $N = 4$ super-conformal symmetry [27] involves super-canonical algebra (SC)and super Kac-Moody algebra (SKM) [C1] There are considerable differences as compared to string models.

1. Super generators carry fermion number, no sparticles are predicted (at least super Poincare invariance is not obtained), SKM algebra and corresponding Virasoro algebra associated with light-like coordinates of X^3 and $\delta M^4_{\pm}$ do not annihilate physical states which justifies p-adic thermodynamics used in p-adic mass calculations, four-momentum does not appear in Virasoro generators so that there are no problems with Lorentz invariance, and mass squared is p-adic thermal expectation of conformal weight.

2. The conformal weights and eigenvalues of modified Dirac operator are complex and the conjecture is that they are closely related to zeros of Riemann Zeta [B4, C2]. This means that positive energy particles propagating into geometric future are not equivalent with negative energy particles propagating in geometric past so that crossing symmetry is broken. Complex conjugation for the super-canonical conformal weights and eigenvalues of the modified Dirac operator would transform laser photons to their phase conjugates for which dissipation seems to occur in a reversed direction of geometric time. Hence irreversibility would be present already at elementary particle level.

6.2.2 Quantum measurement theory with finite measurement resolution

Infinite-dimensional Clifford algebra of CH can be regarded as a canonical example of a von Neumann algebra known as a hyper-finite factor of type II_1 [16, 18](shortly HFF) characterized by the defining condition that the trace of infinite-dimensional unit matrix equals to unity: $Tr(Id) = 1$. In TGD framework the most obvious implication is the absence of fermionic normal ordering infinities whereas the absence of bosonic divergences is guaranteed by the basic properties of the configuration space Kähler geometry, in particular the non-locality of the Kähler function as a functional of 3-surface.

The special properties of this algebra, which are very closely related to braid and knot invariants [17, 26], quantum groups [19, 18], non-commutative geometry [23], spin chains, integrable models [21], topological quantum field theories [22], conformal field theories, and at the level of concrete physics to anyons [20], generate several new insights and ideas about the structure of quantum TGD.

Jones inclusions $\mathcal{N} \subset \mathcal{M}$ [24, 18] of these algebras lead to quantum measurement theory with a finite measurement resolution characterized by $\mathcal{N}$ [C7, C9]. Quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ interpreted as $\mathcal{N}$-module creates physical states modulo measurement resolution. Complex rays of the state space resulting in the ordinary state function reduction are replaced by $\mathcal{N}$-rays and the notions of unitarity, hermiticity, and eigenvalue generalize [C9, C2].

The notion of entanglement generalizes so that entanglement coefficients are N-valued. Generalized eigenvalues are in turn N-valued hermitian operators. S- and U-matrices become N valued and probabilities are obtained from N-valued probabilities as traces.

Non-commutative physics would be interpreted in terms of a finite measurement resolution rather than something emerging below Planck length scale. An important implication is that a finite measurement sequence can never completely reduce quantum entanglement so that entire universe would necessarily be an organic whole. Topologically condensed space-time sheets could be seen as correlates for sub-factors which correspond to degrees of freedom below measurement resolution. Topological condensation in turn corresponds to the inclusion $\mathcal{N} \subset \mathcal{M}$. This is however not the only possible interpretation.

6.2.3 Hierarchy of Planck constants

The idea about hierarchy of Planck constants relying on generalization of the imbedding space was inspired both by empirical input (Bohr quantization of planetary orbits) and by the mathematics of hyper-finite factors of type II_1 combined with the quantum classical correspondence.

The generalization of imbedding space concept and hierarchy of Planck constants

Quantum classical correspondence suggests that Jones inclusions [24] have space-time correlates [C7, C9]. There is a canonical hierarchy of Jones inclusions labelled by finite subgroups of SU(2)[18] This leads to a generalization of the imbedding space obtained by gluing an infinite number of copies of H regarded as singular bundles over $H/G_a \times G_b$, where $G_a \times G_b$ is a subgroup of $SU(2) \times SU(2) \subset SL(2,C) \times SU(3)$. Gluing occurs along a factor for which the group is same. The generalized imbedding space has clearly a book like structure with pages of books intersecting along 4-D sub-manifold $M^2 \times S^2$,

S^2 a geodesic sphere of CP_2 characterizing the choice of quantization axies. Entire configuration space is union over "books" corresponding to various choices of this sub-manifold.

The groups in question define in a natural manner the direction of quantization axes for for various isometry charges and this hierarchy seems to be an essential element of quantum measurement theory. Ordinary Planck constant, as opposed to Planck constants $\hbar_a = n_a\hbar_0$ and $\hbar_b = n_b\hbar_0$ appearing in the commutation relations of symmetry algebras assignable to M^4 and CP_2, is naturally quantized as $\hbar = (n_a/n_b)\hbar_0$, where n_i is the order of maximal cyclic subgroup of G_i. The hierarchy of Planck constants is interpreted in terms of dark matter hierarchy [C9]. What is also important is that $(n_a/n_b)^2$ appear as a scaling factor of M^4 metric so that Kähler action via its dependence on induced metric codes for radiative corrections coming in powers of ordinary Planck constant: therefore quantum criticality and vanishing of radiative corrections to functional integral over WCW does not mean vanishing of radiative corrections.

G_a would correspond directly to the observed symmetries of visible matter induced by the underlying dark matter [C9]. For instance, in living matter molecules with 5- and 6-cycles could directly reflect the fact that free electron pairs associated with these cycles correspond to $n_a = 5$ and $n_a = 6$ dark matter possibly responsible for anomalous conductivity of DNA [C9, J1] and recently reported strange properties of graphene [33]. Also the tedrahedral and icosahedral symmetries of water molecule clusters could have similar interpretation [35, F9].

A further fascinating possibility is that the observed indications for Bohr orbit quantization of planetary orbits [31] could have interpretation in terms of gigantic Planck constant for underlying dark matter [D6] so that macroscopic and -temporal quantum coherence would be possible in astrophysical length scales manifesting itself in many manners: say as preferred directions of quantization axis (perhaps related to the CMB anomaly) or as anomalously low dissipation rates.

Since the gravitational Planck constant is proportional to the product of the gravitational masses of interacting systems, it must be assigned to the field body of the two systems and characterizes the interaction between systems rather than systems themselves. This observation applies quite generally and each field body of the system (em, weak, color, gravitational) is characterized by its own Planck constant.

In the gravitational case the order of G_a is gigantic and at least GM_1m/v_0, $v_0 = 2^{-11}$ the favored value. The natural interpretation is as a discrete rotational symmetry of the gravitational field body of the system having both gravimagnetic and gravi-electric parts. The subgroups of G_a for which order is a divisor of the order of G_a define broken symmetries at the lower levels of dark matter hierarchy, in particular symmetries of visible matter.

The number theoretically simple ruler-and-compass integers having as factors only first powers of Fermat primes and power of 2 would define a physically preferred sub-hierarchy of quantum criticality for which subsequent levels would correspond to powers of 2: a connection with p-adic length scale hypothesis suggests itself. Ruler and compass hypothesis implies that besides p-adic length scales also their 3- and 5- multiples should be important. Note that in the structure of chromosomes p-adic length scale $L(151) \simeq 10$ characterizes beads-on-string structure of DNA whereas the length scale $3L(151)$ appears in the coiling of this structure.

Implications of dark matter hierarchy

The basic implication of dark matter hierarchy is hierarchy of macroscopic quantum coherent systems covering all length scales. The presence of this hierarchy is visible as exact discrete symmetries of field bodies reflecting at the level of visible matter as broken symmetries. In case of gravitational interaction these symmetries are highest and also the scale of quantum coherence is astrophysical. Together with ruler-and-compass hypothesis and p-adic length scale hypothesis this leads to very powerful predictions and p-adic length scale hypothesis might reduce to the ruler-and-compass hypothesis.

At the level of condensed matter one application is nuclear string model explaining also the selection rules of cold fusion and predicting that dark copy of weak physics with atomic scale defining the range of weak interaction is involved. Note that cold fusion has recently gained considerable support. High T_c super-conductivity is second application of dark matter hierarchy.

The 5- and 6-fold symmetries of the sugar backbone of DNA suggest that corresponding cyclic groups or cyclic groups having these groups as factors are symmetries of dark matter part of DNA presumably consisting of what is called as free electron pairs assignable to 5- and 6-cycles. The model

allows to understand the observed high conductivity of DNA not consistent with the insulator property of DNA at the level of visible matter.

One also ends up with a speculative notion of N-atom providing a mechanism for the emergence of symbolic representations at the level of bio-molecules and a general mechanism of bio-catalysis.

Dark matter and bio-control

The hierarchy of dark matters provides rather concrete realization for the vision about living matter as quantum critical system. This vision will be discussed in more detail later.

The large Planck constants characterize various field bodies of physical system. This gives justification to the notion of (magnetic) field body which plays key role in TGD inspired model of living matter serving as intentional agent controlling the behavior of field body. For instance, the model of EEG relies and of bio-control relies on this notion. The large value of the Planck constant is absolutely essential since for a given low frequency it allows to have gauge boson energy above thermal threshold. Large value of Planck constant is essential for time mirror mechanism which is behind the models of metabolism, long term memory, and intentional action.

The huge values of gravitational Planck constant supports the vision of Penrose [25] about the special role of quantum gravitation in living matter. In TGD framework the proposal of Penrose and Hameroff for the emergence of consciousness known as Orch-Or (Orchestrated Objective Reduction [39]) is however too restricted since it gives a very special role to micro-tubules.

A reasonable guess - based on the hypothesis that transition to dark matter phase occurs when perturbation theory for standard value of Planck constant fails - is that $GMm > 1$ is the criterion for the transition to dark phase for the gravitational field body characterizing the interaction between the two masses so that Planck mass becomes the critical mass for this transition. For the density of water this means size scale of .1 mm, the size of large neuron.

6.2.4 Zero energy ontology

Zero energy ontology has roots in TGD inspired cosmology [D5]. The problem has been that the imbeddings of Robertson-Walker cosmologies have vanishing densities of Poincare momenta identified as inertial momenta whereas gravitational energy density is non-vanishing. This led to the conclusion that one must allow space-time sheets with both time orientations such that the signs of Poincare energies are different for them and total density of inertial energy vanishes. Gravitational momenta can be identified as difference of the Poincare momenta and need not be conserved.

Construction of S-matrix and zero energy ontology

The construction of S-matrix allows to formulate this picture more sharply. Zero energy states have positive and negative energy parts located in geometric past and future and S-matrix can be identified as time-like entanglement coefficients between these states. Positive energy ontology is a good approximation in time scales shorter than the temporal distance between positive and negative energy states. This picture leads also to a generalization of Feynman graphs obtained by gluing light-like partonic 3-surfaces together along their ends at vertices. These Feynman cobordisms become a basic element of quantum TGD having interpretation as almost topological QFT and category theoretical formulation of quantum TGD emerges.

Elementary particles and zero energy ontology

At the level of elementary particles zero energy ontology means that fermionic quantum numbers are located at the light-like throats of wormhole contacts connecting CP_2 type extremals with Euclidian signature of induced metric to space-time sheets with Minkowskian signature of induced metric. Gauge bosons in turn correspond to pieces of CP_2 type extremals connecting positive and negative energy space-time sheets with fermion and antifermion quantum numbers at the throats of the wormhole contact. Depending on the sign of net energy one has ordinary boson or its phase conjugate. Gravitons correspond to pairs of fermion or gauge boson pair with particle and antiparticle connected by flux tube. This string picture emerges automatically if one assumes that the fermions of the conformal field theory associated with partonic 3-surface are free. It is also possible to have gauge bosons

corresponding to single wormhole throat: these particles correspond to bosonic generators of super-canonical algebra and excitations which correspond to genuine configuration space degrees of freedom so that description in terms of quantum field theory in fixed background space-time need not work.

6.2.5 U- and S-matrices

In quite early stage physical arguments led to the conclusion that the universal U-matrix associated with quantum jump must be distinguished from the S-matrix characterizing the rates of particle reactions. The notion of zero energy ontology was however needed before it became possible to characterize the difference between these matrices in a more precise manner.

Some distinctions between U- and S-matrices

The distinctions between U- and S-matrices have become rather clearer.

1. U-matrix is the universal unitary matrix assignable to quantum jump between zero energy states whereas S-matrix can be identified as time-like entanglement coefficients between positive and negative energy parts of the zero energy state. Thus S-matrix characterizes zero energy states.

2. U-matrix is always between zero energy states and the corresponding state function reduction reduces entanglement between zero energy states. State function reduction for S-matrix elements reduces the entanglement between positive and negative energy parts of a given zero energy state and is completely analogous to ordinary quantum measurement reducing entanglement between systems having space-like separation.

3. U-matrix is unitary whereas S-matrix can be unitary only for HFFs of type II_1. In the most general case S-matrix can be regarded as a "square" root of the density matrix assignable to time like entanglement: this hypothesis would unify the notions of S-matrix and density matrix and one could regard quantum states as matrix analogs of Schrö;dinger amplitudes expressible as products of its modulus (square root of probability density replaced with square root of density matrix) and phase (possibly universal unitary S-matrix). Thermal S-matrices define an important special case and thermodynamics becomes an integral part of quantum theory in zero energy ontology.

4. U-matrix can have elements between different number fields. In this case one must however assume number theoretical universality meaning that U-matrix has rational or at most algebraic matrix elements. In the case of HFFs of type II_1 this might imply triviality. U-matrix between p-adic and real number fields would relate to intentional action and the almost triviality would be a blessing meaning that the realization of intentional action occurs in a very precise manner and is restricted only by cutoff due to the algebraic character of number theoretic braids.

S-matrix as time-like entanglement matric is diagonal with respect to number field and number theoretical universality is not absolutely essential for its definition.

Number theoretic universality and S-matrix

The fact that zero energy states are created by p-adic to-real transitions and must be number theoretically universal suggests strongly that the data about partonic 2-surfaces contributing to S-matrix elements come from the intersection of real partonic 2-surface and its p-adic counterpart satisfying same algebraic equations. The intersection consists of algebraic points and contains as subset number theoretic braids central for the proposed construction of S-matrix.

The question is whether also states for which S-matrix receives data from non-algebraic points should be allowed or whether the data can come even from continuous string like structures at partonic 2-surfaces as standard conformal field theory picture would suggest. If also S-matrix is algebraic, one can wonder whether there is any difference between p-adic and real physics at all. The latter option would mean that intentional action is followed by a unitarity process U analogous to a dispersion of completely localized particle implied by Schröndinger equation.

The algebraic universality of S-matrix could mean that S-matrix is obtained as algebraic continuation of rational S-matrix by replacing incoming momenta and other continuous quantum numbers

with real ones. Similar continuation should make sense in p-adic sector. S-matrix and U-matrix in a given algebraic extension of rationals or p-adics are not in general diagonalizable. Thus number theory would allows to avoid the paradoxical conclusion that S-matrix is always diagonal in a suitable basis.

6.2.6 Number theoretic ideas

p-Adic physics emerged roughly at the same time via p-adic mass calculations. The interpretation of p-adic physics as physics of cognition and intentionality emerged. The basic idea was that bosonic p-adic space-time sheets provide representations for intentions and the transformation of intention to action corresponds to a transformation of p-adic space-time sheet to a real one. Gauge bosons identified as pairs of wormhole throats carrying fermion and antifermion numbers so that a a more precise characterization of "bosonic" would be as "purely bosonic" meaning wormhole throat associated with CP_2 type extremal. These bosons would be exotic and correspond to states of super-canonical representations. If one accepts the hypothesis that fermionic Fock algebra represents Boolean cognition, one ends up the idea that fermions and their p-adic counterparts appear as pairs and that p-adic partonic 2-surface has interpretation as cognitive representation of fermion. This picture conforms nicely with interpretation in terms of infinite primes.

Cognition and intentionality would be present already at elementary particle level and p-adic fractality would be the experimental signature of it making itself visible in elementary particle mass spectrum among other things. The success of p-adic mass calculations provides strong siupport for the hypothesis.

This led gradually to the vision about physics as generalized number theory. It involves three separate aspects.

1. The p-adic approach led eventually to the program of fusing real physics and various p-adic physics to a single coherent whole by generalizing the number concept by gluing reals and various p-adics to a larger structure along common rationals and algebraics. This inspired the notion of algebraic universality stating that for instance S-matrix should result by algebraic continuation from rational or at most algebraic valued S-matrix.

   The notion of number theoretic braid belonging to the algebraic intersection of real and p-adic partonic 2-surface obeying same algebraic equations emerged also and gives a further connection with topological QFT:s. The perturbation theoretic definition of S-matrix is definitely excluded in this approach and TGD indeed leads to the understanding of coupling constant evolution at the level of "free" theory as a discrete p-adic coupling constant evolution so that radiative corrections are not needed for this purpose.

2. Also the classical number fields relate closely to TGD and the vision is that imbedding space M^4xCP_2 emerges from the physics based on hyper-octonionic 8-space with associativity as the fundamental dynamical principle both at classical and quantum level. Hyper-octonion space M^8 with space-time surface identified as hyper-quanternionic sub-manifolds or their duals and M^4xCP_2 would provide in this framework dual manners to describe physics and this duality would provide TGD counterpart for compactication.

3. The construction of infinite primes is analogous to repeated second quantization of supersymmetric arithmetic quantum field theory. This notion implies a further generalization of real and p-adic numbers allowing space-time points to have infinitely complex number theoretic structure not visible at the level of real physics. The idea is that space-time points define the Platonia able to represent in its structure arbitrarily complex mathematical structures and that space-time points could be seen as evolving structures becoming quantum jump by quantum jump increasingly complex number theoretically. Even the world of classical worlds (light-like 3-surfaces) and quantum states of Universe might be represented in terms of the number theoretic anatomy of space-time points (number theoretic Brahman=Atman and algebraic holography).

S-matrix as a functor and the groupoid structure formed by S-matrices

In zero energy ontology S-matrix can be seen as a functor from the category of Feynman cobordisms to the category of operators. S-matrix can be identified as a "square root" of the positive energy

density matrix $S = \rho_+^{1/2} S_0$, where S_0 is a unitary matrix and ρ_+ is the density matrix for positive energy part of the zero energy state. Obviously one has $SS^\dagger = \rho_+$. $S^\dagger S = \rho_-$ gives the density matrix for negative energy part of zero energy state. Clearly, S-matrix can be seen as matrix valued generalization of Schrödinger amplitude. Note that the "indices" of the S-matrices correspond to configuration space spinors (fermions and their bound states giving rise to gauge bosons and gravitons) and to configuration space degrees of freedom (world of classical worlds). For hyper-finite factor of II_1 it is not strictly speaking possible to speak about indices since the matrix elements are traces of the S-matrix multiplied by projection operators to infinite-dimensional subspaces from right and left.

The functor property of S-matrices implies that they form a multiplicative structure analogous but not identical to groupoid [30]. Recall that groupoid has associative product and there exist always right and left inverses and identity in the sense that ff^{-1} and $f^{-1}f$ are always defined but not identical and one has $fgg^{-1} = f$ and $f^{-1}fg = g$.

The reason for the groupoid like property is that S-matrix is a map between state spaces associated with initial and final sets of partonic surfaces and these state spaces are different so that inverse must be replaced with right and left inverse. The defining conditions for groupoid are replaced with more general ones. Also now associativity holds but the role of inverse is taken by hermitian conjugate. Thus one has the conditions $fgg^\dagger = f\rho_{g,+}$ and $f^\dagger fg = \rho_{f,-}g$, and the conditions $ff^\dagger = \rho_+$ and $f^\dagger f = \rho_-$ are satisfied. Here $\rho_\pm$ is density matrix associated with positive/negative energy parts of zero energy state. If the inverses of the density matrices exist, groupoid axioms hold true since $f_L^{-1} = f^\dagger \rho_{f,+}^{-1}$ satisfies $ff_L^{-1} = Id_+$ and $f_R^{-1} = \rho_{f,-}^{-1} f^\dagger$ satisfies $f_R^{-1} f = Id_-$.

There are good reasons to believe that also tensor product of its appropriate generalization to the analog of co-product makes sense with non-triviality characterizing the interaction between the systems of the tensor product. If so, the S-matrices would form very beautiful mathematical structure bringing in mind the corresponding structures for 2-tangles and N-tangles. Knowing how incredibly powerful the group like structures have been in physics, one has good reasons to hope that groupoid like structure might help to deduce a lot of information about the quantum dynamics of TGD.

A word about nomenclature is in order. S has strong associations to unitarity and it might be appropriate to replace S with some other letter. The interpretation of S-matrix as a generalized Schrödinger amplitude would suggest Ψ-matrix. Since the interaction with Kea's M-theory blog (with M denoting Monad or Motif in this context) was crucial for the realization of the the connection with density matrix, also M-matrix might work. S-matrix as a functor from the category of Feynman cobordisms in turn suggests C or F. Or could just Matrix denoted by M in formulas be enough?

Number theoretic braids and braid replication

The notion of number theoretic braid is especially interesting from the point of view of quantum biology. Generalized Feynman diagrams obtained by gluing light-like partonic 3-surfaces (whose sizes can be arbitrarily large) along their ends and define what might be called Feynman cobordisms.

A key observation is that number theoretic braids replicate in annihilation vertices. This leads to a general interpretation of generalized Feynman diagrams. Incoming and outgoing "lines" give rise to topological quantum computations characterized by corresponding S-matrices, vertices give rise to replication of number theoretic braids analogous to DNA replication, and internal lines are analogous to quantum communications.

Number theoretic braids are associated with light-like 3-surfaces and can be said to have both dynamical and static characteristics. Partonic 2-surfaces as sub-manifolds of space-like 3-surface can also become linked and knotted and would naturally define space-like counterparts of tangles. Number theoretic braids could define dynamical topological quantum computation like operations whereas partonic 2-surfaces associated with say RNA could define as their space-like counterparts tangles and in special case braids analogous to printed quantum programs. An interesting question is how these two structures are transformed to each other: could this process correspond to a conscious reading like process and how closely DNA relates to language so that reading and writing would be fundamental processes appearing in all scales.

Dark matter hierarchy and hierarchy of quantum critical systems in modular degrees of freedom

Dark matter hierarchy corresponds to a hierarchy of conformal symmetries Z_n of partonic 2-surfaces with genus $g \geq 1$ such that factors of n define subgroups of conformal symmetries of Z_n. By the decomposition $Z_n = \prod_{p|n} Z_p$, where $p|n$ tells that p divides n, this hierarchy corresponds to an hierarchy of increasingly quantum critical systems in modular degrees of freedom. For a given prime p one has a sub-hierarchy Z_p, $Z_{p^2} = Z_p \times Z_p$, etc... such that the moduli at n+1:th level are contained by n:th level. In the similar manner the moduli of Z_n are sub-moduli for each prime factor of n. This mapping of integers to quantum critical systems conforms nicely with the general vision that biological evolution corresponds to the increase of quantum criticality as Planck constant increases. This hierarchy would also define a hierarchy of conscious entities and could relate directly to mathematical cognition.

The group of conformal symmetries could be also non-commutative discrete group having Z_n as a subgroup. This inspires a very short-lived conjecture that only the discrete subgroups of SU(2) allowed by Jones inclusions are possible as conformal symmetries of Riemann surfaces having $g \geq 1$. Besides Z_n one could have tedrahedral and icosahedral groups plus cyclic group Z_{2n} with reflection added but not Z_{2n+1} nor the symmetry group of cube. The conjecture is wrong. Consider the orbit of the subgroup of rotational group on standard sphere of E^3, put a handle at one of the orbits such that it is invariant under rotations around the axis going through the point, and apply the elements of subgroup. You obtain a Riemann surface having the subgroup as its isometries. Hence all discrete subgroups of SU(2) can act even as isometries for some value of g.

The number theoretically simple ruler-and-compass integers having as factors only first powers of Fermat primes and power of 2 would define a physically preferred sub-hierarchy of quantum criticality for which subsequent levels would correspond to powers of 2: a connection with p-adic length scale hypothesis suggests itself.

Spherical topology is exceptional since in this case the space of conformal moduli is trivial and conformal symmetries correspond to the entire $SL(2, C)$. This would suggest that only the fermions of lowest generation corresponding to the spherical topology are maximally quantum critical. This brings in mind Jones inclusions for which the defining subgroup equals to $SU(2)$ and Jones index equals to $\mathcal{M}/\mathcal{N} = 4$. In this case all discrete subgroups of $SU(2)$ label the inclusions. These inclusions would correspond to fiber space $CP_2 \to CP_2/U(2)$ consisting of geodesic spheres of CP_2. In this case the discrete subgroup might correspond to a selection of a subgroup of $SU(2) \subset SU(3)$ acting non-trivially on the geodesic sphere. Cosmic strings $X^2 \times Y^2 \subset M^4 \times CP_2$ having geodesic spheres of CP_2 as their ends could correspond to this phase dominating the very early cosmology.

6.3 TGD inspired theory of consciousness in the new conceptual framework

In this section basic implications of the new view about quantum TGD for TGD inspired theory of consciousness are summarized.

6.3.1 Basic notions and ideas

Quantum jump as moment of consciousness and self represent the fundamental notions of TGD inspired theory of consciousness.

Quantum jump as moment of consciousness and the notion of self

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment: everything is conscious and consciousness can be only lost. This view predicts infinite self hierarchy with the entire Universe at the top.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-subselves) increases.

If one accepts the hierarchy of Planck constants [C9], it seems un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle would correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday.

The standard dogma about consciousness is that it is completely private. It seems that this cannot be the case in TGD Universe. Von Neumann algebras known as hyper-finite factors of type II_1 (HFF) [C7, C9] provide the basic mathematical framework for quantum TGD and this suggests important modifications of the standard measurement theory besides those implied by the zero energy ontology predicting that all physical states have vanishing net quantum numbers and are creatable from vacuum. The notion of measurement resolution characterized in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of HFFs implies that entanglement is defined always modulo some resolution characterized by infinite-dimensional sub-Clifford algebra $\mathcal{N}$ playing a role analogous to that of gauge algebra.

The finite resolution of quantum measurement in degrees of freedom corresponding to HFFs of type II_1 means also finite sensory and cognitive resolution. Fuzzy logic emerges naturally since ordinary spinors are replaced by quantum spinors for which the discrete spectrum of the eigenvalues of the moduli of its spinor components can be interpreted as probabilities that corresponding belief is true is universal [C7].

For ordinary quantum measurement theory separate selves are by definition unentangled and same applies to their sub-selves so that they cannot entangle and thus fuse and shared mental images are impossible: consciousness would be completely private. Space-time sheets as correlates for selves however suggests that space-time sheets topologically condensed on larger space-time sheets and serving as space-time correlates for mental images can be connected by join along boundaries bonds so that mental images could fuse and be shared.

HFFs allow to realize mathematically this intuitive picture. The entanglement in $\mathcal{N}$ degrees of freedom between selves corresponding to $\mathcal{M}$ is below the measurement resolution so that these selves can be regarded as separate conscious entities. They can be said to be unentangled although their sub-selves corresponding to $\mathcal{N}$ (mental images at upper level) can entangle. Fusion and sharing of mental images becomes possible. For instance, in stereo vision right and left visual fields would fuse together. More generally, a pool of shared stereo mental images might be fundamental for evolution of social structures and development of social and moral rules and language (shared mental images make possible common meaning for symbols of language). A concrete realization for this would be in terms of hyper-genome making possible collective gene expression [L2, L1].

The emergence of hierarchy of Planck constants inspired the question whether one could reduce the notion of self to that of fractal quantum jump containing quantum jumps within quantum jumps. It indeed seems that this reduction is possible and that both p-adic time scale hierarchy and hierarchy of Planck constants relate closely to the hierarchy of quantum jumps defining also hierarchy of selves. This reduction conforms with the basic intuitions motivating the original definition of self.

Qualia

Since physical states are labelled by quantum numbers, various qualia correspond naturally to the increments of quantum numbers in quantum jump which leads to a general classification of qualia in terms of the fundamental symmetries [K3]. One can speak also about geometric qualia assignable

to the increments of zero modes which correspond to the classical variables in ordinary quantum measurement theory and non-quantum fluctuating degrees of freedom which do not contribute to the metric of world of classical worlds (WCW) in TGD framework. Dark matter hierarchy suggests that also qualia form a hierarchy with larger values of Planck constant identifiable as more refined qualia. Rather amusingly, visual colors would correspond to increments of color quantum numbers assignable to quarks and gluons in standard model physics. The term "color", originally introduced as an algebraic joke, would directly relate to visual color.

Self-referentiality of consciousness

Quantum classical correspondence is the basic guiding principle of quantum TGD. Thanks to the failure of a complete determinism of classical dynamics, space-time surface can provide symbolic representations not only for quantum states (as maximal deterministic regions) but also for quantum jump sequences (sequences of quantum states) and thus for the contents of consciousness. These representations are regenerated in each quantum jump, and make possible the self referentiality of consciousness: self can be conscious of what it *was* conscious of. The hierarchy of Planck constants and dark matter hierarchy provides a more concrete realization for this vision.

6.3.2 The interpretation of S- and U-matrices from the point of view of consciousness theory

The interpretation of U- and S-matrices from the point of view of consciousness theory is an interesting challenge.

1. There are arguments suggesting that U-matrix in the degrees of freedom characterizable using von Neumann algebra identifiable as a factor of type I (standard QM) would correspond to a so called factorizing S-matrix and be therefore almost trivial [C2]. If so, it would seem that state function reduction in these degrees of freedom does not affect standard model quantum numbers so that the resulting experience would be kind of "that which is" mystic experience and would explain why it seems to be possible to experience state rather than only the change of state. This conforms also with the fact that these state function reductions do not involve reduction of time-like entanglement so that these experiences would be characterized by a kind of "timelessness".

2. The presence of hyper-finite factors of type II_1 is an essentially new element. It is however not clear what one can say about U-matrix associated with HFFs. I have considered the possibility that U-matrix could allow transitions in which entanglement between zero energy states restricted to sub-factor $\mathcal{N} \subset \mathcal{M}$ is replaced with entanglement in factor $\mathcal{M}$ so that unitary process in a well-defined sense could be seen as the reversal of the state function reduction of entanglement in the quantum space $\mathcal{M}/\mathcal{N}$. Since the inclusions define lattice like one-dimensional structure, U-process would be analogous to a dispersion in 1-D lattice.

3. The state function reduction for S-matrix corresponds to a measurement of time-like entanglement and a natural interpretation is in terms of memories. It is not clear whether all state function reductions actually correspond to the reduction of time like entanglement. If this were the case, one could understand the finding of Libet about passive aspects of sensory experience [18] implying that sensory percepts are actually memories corresponding to time scale of fraction of seconds.

4. Interesting questions relate to the interpretation of the complex square root of density matrix character of time like entanglement coefficients define by S-matrix ($\rho_+ = SS^\dagger$ and $\rho_- = S^\dagger S$). If time like entanglement probabilities for the factor of type I are rational or even algebraic numbers, number theoretic entropy is well-defined and negentropic time-like entanglement stable under state function reduction is possible. This kind of entanglement would correspond to memory in which sensory or cognitive mental image of the geometric past is shared. This experience would be analogous to experience of understanding assigned to the negentropic entanglement in general. The near death experiences are reported to involve experiencing of the entire life cycle in single flash: could these experiences correspond to time-like entanglement?

6.3.3 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [H2]) stating that the reduction of entanglement entropy is maximal in quantum jump is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate more to the ageing of mental images rather than physical reality.

Number theoretic Shannon entropy as information

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness. For instance these information measures allow to construct a model of genetic code [L3] as a mapping of 64 genetic codons to primes labelling aminoacids based on the condition that the prime associated with given codon corresponds to minimal number theoretic entropy.

Hyper-finite factors of type $\mathbf{II}_1$ and NMP

Hyper-finite factors of type II_1 bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become $\mathcal{N}$ valued and same is true for eigen states of density matrix. For quantum spinors associated with $\mathcal{M}/\mathcal{N}$ entanglement probabilities must be defined as traces of the operators $\mathcal{N}$.

One of the open questions is whether one generalize the notion of algebraic entanglement to the case of HFFs of type II_1 so that one could have negative number theoretic entanglement entropy as is possible in the case of factors of type I. The density matrices in these degrees of freedom are of form $\sum p_n P_n$ and the question is whether the quantities $p_n Tr(P_n)$ can be assumed to be rationals or at most algebraic numbers.

6.3.4 About the arrow of psychological time and notion of self: a critical discussion

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic. I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation [E10] has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Quantum classical correspondence requires that the flow of subjective time identified as a sequence of quantum jumps should have the flow of geometric time as a space-time correlate. The understanding of the detailed relationship between these two times has however remained a long standing problem, and only the emergence of zero energy ontology allows an ad hoc free model for how the flow and arrow of geometric time emerge, and answers why the relationship between geometric past and future is so asymmetric and why sensory experience is about so narrow interval of geometric time. Also the notion of self reduces in well-defined sense to the notion of quantum jump with fractal structure.

Two times

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which represent basic types for them.

The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

6.3.5 Questions related to the notion of self

I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes

it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configurations space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

Does entanglement mean loss of consciousness?

The ability to avoid entanglement with environment would be essential for the original notion of self and incase of sub-selves it would explain the finite life-time of mental images. One can of however ask whether the assumption about the loss of consciousness in entanglement - that is during sleep - is really necessary. One could however argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday. Furthermore, during topological quantum computation entanglement is absent and thus this state should correspond to conscious experience. Night time is however the best time for tqc since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at some level during sleep and perform quite a long tqc. Perhaps we are!

Could it be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with some system means only diving into the ocean of consciousness as someone has expressed it. We would be Gods as also quantum classical correspondence in the reverse direction requires (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions). This would be the most optimistic view that one can imagine.

What after biological death?

Could the new option allow to speculate about the course of events at the moment of death? Certainly this particular sensory "me" would effectively meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape sooner later brings into the volume of attention (which might also change) a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what she might call enlightment.

6.3.6 Time, memory, and realization of intentional action

What distinguishes between geometric future and past?

One must of course understand why geometric and experienced time correspond to each other so closely that they have been identified. Why geometric future and past are so different?: this might

be the core question. If geometric future contains intentional resources (p-adic space-time sheets) transformed to actions in the phase transition propagating to the geometric future and if geometric future is in a quantum critical state transformed to a non-critical state in this process (a process analogous to freezing or melting critical state of water-ice mixture), one could assign the experienced time with the geometric time characterizing the position of the phase transition front (assignable to sub-selves/mental images).

Also the almost triviality of U-matrix for ordinary transitions might be relevant for the stability of the geometric past. This could also resolve the problem posed by the fact that the contents of conscious experience is only about changes: the state could be represented as changes of internal quantum numbers not related directly to the external world but related to the internal state. For p-adic-to-real transitions representing transformations of intentions to actions almost-triviality does not have meaning.

Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [H6].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [27].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [K6]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [H6]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [18] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$, $k = 0, 1, 2,$, and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

Zero energy ontology and time mirror mechanism

Zero energy ontology gives a justification for the notion of time mirror mechanism essential for the models of remote metabolism, intentional action and long term memory. Negative energy gauge bosons, in particular phase conjugate photons, make possible signals propagating to the direction of geometric past. A second essential element is large value of Planck constant making possible low frequency quanta having energy above the thermal energy.

1. Remote metabolism provides extremely flexible mechanism of metabolism allowing an instantaneous gain of metabolic energy by sending negative energy to some system able to provide

the energy. Population inverted laser or "many-sheeted laser" for which dropping of particles to larger space-time sheet provides zero point kinetic energy as usable energy would define simplest energy storage.

2. The mechanism of intentional action involves sending of negative energy signal from magnetic field body to the brain of the geometric past where it initiates the neural activities giving rise to the desired action. Suppose that one takes seriously the hypothesis that fermions appear as pairs of real fermion and its p-adic counterpart providing a cognitive representation of real fermion and that p-adic bosons represent intentions and their real counterparts actions. If so then the bosons assignable to intentions would not be ordinary gauge bosons but bosonic generators of super-canonical algebra and negative energy signals would be exotic bosons with vanishing electro-weak quantum numbers. This is perhaps too strong a constraint since it would exclude the model of intentional action based on dark $W^{\pm}$ bosons inducing charge density gradients and in this manner neuronal activities such as nerve pulse patterns.

3. There are two mechanisms of long term memory. First mechanism corresponds to episodal or sensory memories in which memories are realized as sharing of mental images by time-like entanglement. Second mechanism would correspond to declarative memories having digital representation. Memory recall would correspond to a pattern of negative energy signals from magnetic body to the brain of the geometric past where it generates the answer as a pattern of positive energy signals. For instance, a code consisting of binary digits is possible to realize in this manner. '1' would correspond to population inverted laser and '0' to same system in ground state. Negative energy signal would drop '1' to '0' and induce positive energy signal and '0' would not generate any signal. Hence the net positive energy signal would tell what the bit sequence in the geometric past is.

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Part II

TIME AND CONSCIOUSNESS

Chapter 7

Time and Consciousness

7.1 Introduction

The identification of moments of consciousness as quantum jumps between quantum histories suggests that our common sense picture about the time evolution of universe might be badly misguided by the restrictions posed by the basic features of our conscious experience. What one can do is to try to develop the most general picture about the cosmology of consciousness consistent with our own conscious experiences and try to identify our position in this picture. Already in its recent form TGD inspired theory of consciousness can give quite restrictive constraints on this Grand Scenario.

The understanding of how psychological time and its arrow emerge has been perhaps the most longstanding problem of quantum TGD and TGD inspired theory of consciousness.By quantum classical correspondence the arrow of subjective time should be mapped to the arrow of geometric time at the level of conscious experience. In similar manner the asymmetry between subjective future and past should be correspond to an asymmetry between geometric future and past. What this means at the level of details has been far from clear and I have proposed many partial answers to the question about the arrow of geometric time. For instance: the geometric future inside light-cone contains much more room than geometric past so that the space-time region about which the contents of conscious experience are about tends to diffuse to the direction of the geometric future defined by light-cone proper time; perhaps the flow of geometric time corresponds to a wave front of intentional action identifiable as a phase transition changing intentions identified as p-adic space-time sheets transformed to real space-time sheets; maybe the space-time sheet assignable to self topologically condensed to a larger space-time sheet shifts in quantum jumps to the direction of geometric future some average temporal distance perhaps defined by CP_2 length scale. All these proposals have provided only partial answers, have led to paradoxes, and failed to give a firm quantitative grasp about the situation.

Also the original wrong view about the correspondence of real and p-adic numbers has generated a lot of confusion. The natural belief of topologist would be that p-adic space-time sheets are mapped to their real counterparts by a continuous map (some variant of what I called canonical identification making sense in p-adic thermodynamics). This map did not however respect symmetries and was inconsistent with field equations. Finally I was able to accept the natural belief of algebraist: reals and various p-adic number fields must be glued to together along rationals and common algebraic numbers to achieve generalization of the number concept and also that of imbedding space. What was difficult to accept was the highly non-intuitive implication that most points of p-adic space-time sheets are at spatial and temporal infinity in real (but not in p-adic) sense so that cognition and intentionality would be literally cosmic phenomena and only cognitive representations would be realized in a finite space-time volume in real sense (causal diamond) in terms of intersections of real and p-adic space-time sheets consisting of rational and some algebraic points.

I have tried to tidy up the chapters so that they would not contain too many mammoth bones. Since I can use only a finite amount of time to documentation purposes, I have not been completely successful and this chapter as also others might contain statements which represent earlier archeological strata. I hope that reader could forgive this. Benevolent reader might even take these chapters as documents about how ideas have developed.

7.1.1 The concepts of self and subjective memory

Self is identified as a subsystem able to remain unentangled during informational "time evolutions" U associated with subsequent quantum jumps. Or putting it differently: self is a subsystem behaving like its own sub-Universe (with respect to NMP). The hypothesis that the experiences of self associated with the quantum jumps occurred after the 'wake-up' sum up to single experience, implies that self can have memories about earlier moments of consciousness. Therefore self becomes extended object with respect to subjective time and has a well defined 'personal history'. If temporal binding of experiences involves kind of averaging, quantum statistical determinism makes the total experience defined by the heap of the experiences associated with individual quantum jumps reliable. Subjective memory associated with sensory mental images has duration of about .1 seconds from the temporal resolution of sensory experience: it is quite possible that our self has much longer duration. The subjectotemporal sequences of sub-selves make possible to remember the digits of a phonenumber.

Subsystem X possessing self behaves essentially as a separate sub-Universe with respect to NMP. An attractive hypothesis is that the experience of self is abstraction in the sense that the experiences of sub-selves X_{ij} of X_i are abstracted to average experience $\langle X_{ij} \rangle$. This implies that the experiences of sub-sub-...selves of X are effectively unconscious to X. This self hierarchy is infinite and has entire Universe, God at the top. Temporal binding with averaging implies that experiences of individual selves are reliable and abstraction brings in the possibility of quantum statistical determinism at the level of ensembles.

7.1.2 Psychological time and its arrow

Quantum classical correspondence requires that the flow of subjective time identified as a sequence of quantum jumps should have the flow of geometric time as a space-time correlate. The understanding of the detailed relationship between these two times has however remained a long standing problem, and I have proposed several models involving ad hoc assumptions. Only the emergence of zero energy ontology allows an ad hoc free model for how the experienced flow and arrow of geometric time emerge, and answers why the relationship between geometric past and future is so asymmetric and why sensory experience is about so narrow interval of geometric time. Also the notion of self reduces in well-defined sense to the notion of quantum jump with fractal structure.

The basic idea about the correspondence between subjective and geometric time is very simple. Configuration space spinor field represents a quantum superposition of space-time surfaces. Assume that the attention of self is directed to a fixed volume of the 8-D imbedding space. Quantum classical correspondence requires that this quantum superposition in the first approximation shifts towards geometric past of the imbedding space so that self experiences effective flow of the geometric time associated with the space-time surface. This explanation works only if macroscopic quantum coherence holds true so that one cannot regard the space-time surface as a fixed arena of dynamics. Also the representability of the space-time surfaces as sub-manifolds of 8-D imbedding space is essential. The identification of the fundamental volume of attention as a causal diamond inspired by zero energy ontology based formulation of quantum TGD provides answers to more detailed questions. This identification means also that causal diamond of imbedding space rather than space-time sheet becomes the space-time correlate of self.

7.1.3 Cosmology of consciousness

The cosmology of consciousness is inspired by the prediction of the infinite self hierarchy and by quantum-classical correspondence principle [H2]. The expectation is that the fractal structure of the many-sheeted space-time should directly reflect the general structure for the cosmology of consciousness. For instance, the p-adic evolution of consciousness should have its counterpart at the space-time level. Indeed, there are good reasons to believe that 4-surfaces have decomposition into real regions and p-adic regions and that one can assign to each real region a finite prime p characterizing the p-adic topology which the real region is near criticality to transform to. Just like configuration space has a decomposition into regions D_P labelled by infinite p-adic primes P, the space-time surface decomposes into real regions labelled by finite primes appearing in the decomposition of P.

Fractality suggests that there are conscious universes within conscious universes and the nested structure of the topological condensate suggests that experiences of universes involve kind of abstrac-

tions about the experiences of the sub-universes they contain. The prediction of infinite hierarchy of selves and summation hypothesis for the experiences of selves is in accordance with this expectation.

Since mind like space-time sheets have a bounded time duration, one cannot assign to a quantum jump a single value of the geometric time. Rather, our psychological time would be associated with one of the infinitely many irreducible sub-experiences associated with mind like space-time sheets and the values of the psychological time range from zero to infinity. Since selves contain sub-selves with various values of psychological time, experiences are actually multitime experiences with respect to both geometric and subjective time. The entire 4-dimensional space-time is a living system: both the geometric future and past are living and participate in each moment of consciousness. Selves have increasingly longer geometric and subjective memories and that at the limit of entire universe selves have infinitely long subjective memory.

7.1.4 Four-dimensional brain

The hypothesis that entire space-time surface is populated by mind like space-time sheets representing systems participating in every moment of consciousness, means also dramatically new manner to understand brain. For instance, the problem of memory trivializes. Geometric memory provides simulations and expectations for what happened and will happen whereas subjective memory has interpretation as immediate short term memory. The most plausible interpretation of long term memories is as geometric memories represented by multitime snapshots. This hypothesis explains the practically unlimited capacity of autobiographical memory and also other basic aspects of long term memories and avoids the counter arguments against the neural net models of long term memory. The paradigm of four-dimensional brain (and body!) forces to reconsider the basic dogma of neuroscience stating that sensory consciousness is associated with brain only and explains nicely the results of Libet's experiments. A concrete model of the long term memory is based on quantum mirror mechanism: experience long term memory means looking at a quantum mirror at a distance of say light years. The attribute 'quantum' means that there is no need to code information to a classical signal, just time like entanglement made possible by the classical nondeterminism of Kähler action and by p-adic nondeterminism is enough.

7.1.5 Good and Evil, Life and Death

Classical-quantum correspondence principle (and also "Ontogeny recapitulates phylogeny" principle in very general form) suggests that the subjective evolution of an organism could be an endless process just like the p-adic evolution of the entire universe is. This inspires the question about what might happen in the physical death. One could also wonder whether the Buddhist ideas about law of Karma, reincarnation and liberation could have physical correlates. The notions of self and mind like space-time sheet; the view about life as a symbiosis of fractal hierarchies of massless extremals (MEs) and magnetic flux tube structures with the ordinary matter, and quantum-classical correspondence principle make it possible to consider possible answers to these questions. Of course, everything to be said is just speculation and should be taken as necessary exercizes needed to learn to work with new concepts and ideas.

7.1.6 Evidence for TGD based time concept

The new concept of time follows from the quantum jump between quantum histories concept so that tests for the latter are indirect tests for the former. Perhaps the strongest support for the new concept of time comes from the requirement of the internal consistency of the world view. The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. Thus the situation is rather scitzophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly, irreversible "real" world, seem to exist simultaneously. Quantum jumps between quantum histories concept solves the paradox and one can understand dissipative world as an effective description forming "almost" envelope for the sequence of reversible worlds understood as entire time evolutions.

Quantum jumps between quantum histories concept explains the peculiar time delays of consciousness revealed in the experiments of Libet and Kornhuber relating to active and passive roles

of consciousness [45, 18] and the causal anomalies revealed by the experiments of Radin and Bierman [35, 36, 41]. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

A further implication is quantum theory of self-organization. Self-organization means the organization of selves leading to fixed point patterns analogous to those generated in Benard flow. This means that dissipation serves as a Darwinian selector of both genes and memes. Dissipation is present also at the elementary particle level and leads to the selection of the p-adic effective topologies of elementary particle space-time sheets. Black-hole elementary particle analogy suggests that the allowed p-adic primes are given the p-adic length scale hypothesis $p \simeq 2^k$, k power of prime.

7.2 TGD based concept of time

TGD based notion of time involves several new aspects. Quantum jump as occurring between entire quantum histories rather than time=constant snapshots of a single history is certainly the most decisive new element. The necessity to differentiate between subjective and geometric time is immediate implication of this identification. The classical non-determinism of Kähler action is second fundamental ingredient: without it time would be lost in the sense that the contents of our conscious experience would not be localized with respect to geometric time and one could not understand the emergence of psychological time and its arrow. The new view about time leads also to the notion of four-dimensional brain implying a new manner to see what long term memories are, and the vision about space-time as a four-dimensional organism. A further new element is related to the possibility of negative energy space-time sheets and classical communications also to the direction of geometric past. The final important ingredient is p-adic physics as physics of cognition and intention having rather exotic implications, such as replication of p-adic memes by time reflection, their instantaneous propagation by the same mechanism, and time reversed cognition. p-Adic physics as physics of intentionality is crucial for understanding of the psychological time as a front of p-adic-to-real phase transition transforming intentions to actions [H8].

7.2.1 'Holy trinity' of time developments

Quantum jump between quantum histories was originally believed to be something irreducible and structureless. Gradually the view about quantum jump has however become more and more structured and as a result a connection the quantum standard measurement theory follows as a prediction of quantum TGD. In what sense quantum jumps remains irreducible is that one cannot build any dynamical model for the non-deterministic steps appearing in quantum jump.

The general structure of quantum jump

It has gradually become clear that TGD involves "holy trinity" of dynamics.

1. The dynamics defined by the absolute minimization of the Kähler action corresponds to the dynamics of material existence, with matter defined as "res extensa", three-surfaces.

2. The dynamics defined by the action of the unitary 'time development' operator U in the space of quantum histories, is the counterpart of the ordinary Schrödinger time evolution $U \equiv U(-t,)$, $t \to \infty$ and can be regarded as "informational" time development occurring at the level of objective existence. It seems however un-necessary and in fact impossible to assign real Schrödinger time evolution with U. U defines the S-matrix of the theory.

3. The dynamics of quantum jumps between quantum histories corresponds to the dynamics of subjective existence.

Quantum jump was originally seen as something totally irreducible. Gradually the structure of quantum jump has revealed itself.

1. The first step in quantum jump is informational 'time development'

$$\Psi_i \to U\Psi_i \ ,$$

where U is the counterpart of the unitary process of Penrose. The resulting state is a completely entangled multiverse state, the entire universe being in a holistic state of 'oneness'.

2. Then follows the TGD counterpart of state function reduction realized as a localization in zero modes:

$$U\Psi_i \to \Psi_f^0 \quad .$$

The assumption that localization occurs in zero modes of the configuration space poses very important consistency condition on U: it must effectively correspond to a flow in zero modes such that there is one-one correlation between the quantum numbers in quantum fluctuating degrees of freedom in some state basis and the values of the zero modes. This together with the fact that zero modes are effectively classical variables, implies that the localization in zero modes corresponds to a state function reduction. All p-adic configuration space degrees of freedom are zero modes so that in this sense cognition is classical. Only so called quaternion conformal fermionic p-adic degrees of freedom are quantal.

3. The state function reduction is followed by a cascade of self measurements in quantum fluctuating degrees of freedom (zero modes do not change during this stage)

$$\Psi_f^0 \to .... \to \Psi_f \quad ,$$

whose dynamics is governed by the Negentropy Maximization Principle (NMP). This process leads to a completely unentangled state (apart from entanglement present in bound states) identifiable as a prepared state. This process can be regarded as an analysis or even decay process.

A good metaphor for quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization in zero modes and subsequent state preparation process). One could formally regard each quantum jump as quantum computation lasting infinitely long time $t \to \infty$ followed by a state preparation of the initial state of the next quantum computation.

Localization in zero modes is necessary

The detailed inspection of what happens in quantum jumps leads to a surprising conclusion that quantum jump involves always compelete localization in zero modes. The argument leading to this conclusion goes as follows.

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of configuration space spinors at given point Y^3 of the configuration space. This suggests that subsystem should be defined as a function of Y^3 and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.

2. Configuration space spinor field can be formally expressed as superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence configuration space spinor field can be formally written as

$$\sum_{Y^3} C(Y^3)(n,N)|n\rangle|N\rangle$$

for any subsystem-complement decomposition defined in Y^3. Clearly, configuration space coordinates appear in the role of additional indices with respect to which entanglement coefficients are diagonal. The requirement that final state is pure state would suggest that quantum jump reducing entanglement must involve complete localization of the configuration space spinor field to some Y^3 plus further quantum jump reducing entanglement in Y^3. Complete localization in the configuration space is however not physically acceptable option since the action of various

gauge symmetries on quantum states does not commute with the complete localization operation. In particular, the requirement that physical states belong to the representations of Super Virasoro and Super Canonical algebras, is not consistent with this requirement.

3. Under rather reasonable assumptions one can however replace complete localization with a localization in the zero modes. Configuration space has fiber space structure. Configuration space metric is non-vanishing only in the fiber degrees of freedom and since the propagator for small fluctuations equals to the contravariant metric, fiber degrees of freedom correspond to genuine quantum fluctuations. Configuration space metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self organization. The requirement that various local symmetries act as gauge symmetries, provides good reasons to expect that *entanglement coefficients in the fiber degrees of freedom are gauge invariants and hence depend on the zero modes only.* If this is really the case then the localization in zero modes leads to a state for which entanglement coefficients and density matrix do not depend on the fiber degrees of freedom.

4. The time development by quantum jumps in zero modes is effectively classical: Universe is apparently hopping around in the space of the zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface. Therefore each quantum jump gives very precise conscious geometric information about space-time geometry and about configuration space in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for localization to given point of zero mode space is given by the reduced probability density Q defined by the integral of the probability density R defined by configuration space spinor field over fiber degrees of freedom. The local maxima of Q with respect to zero modes appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of local maximum.

5. Localization in zero modes is completely analogous to spontaneous symmetry breaking in which scalar field attains vacuum expectation value with the difference that the number of degrees of freedom is infinite unlike in typical models of symmetry breaking. Thus the general structure of the configuration space spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD version (note however that particle massivation results from both p-adic thermodynamics and coupling to Higgs like field of purely geometric origin in TGD framework). TGD Universe is superposition of parallel classical universes (3-surfaces). Therefore quantum entangled state can can be regarded as a superposition of parallel entangled states, one for each 3-surface. Formally entanglement coefficients can be regarded as coefficients containing the configuration space coordinates of 3-surfaces as additional index. The analogy with the spin glass also supports the localization in the zero modes.

6. Localization in the zero modes provides simple explanation for why the universe of conscious experience looks classical: moment of consciousness makes it classical. It also explains why the physics treating space-time as a fixed arena of dynamics has been so successful. As already found, a further important consequence is first principle description of the state function reduction.

7.2.2 Quantum jump as moment of consciousness and the notion of self

If quantum jump occurs between two different time evolutions of Schrödinger equation (understood here in very metaphoral sense) rather than interfering with single deterministic Schrödinger evolution, the basic problem of quantum measurement theory finds a resolution. The interpretation of quantum jump as a moment of consciousness means that volition and conscious experience are outside space-time and state space and that quantum states and space-time surfaces are "zombies". Quantum jump would have actually a complex anatomy corresponding to unitary process U, state function reduction and state preparation at least.

Quantum jump has a complex anatomy since it must include state preparation, state function reduction, and also unitary process characterized by U-matrix. Zero energy ontology means that one must distinguish between M-matrix and U-matrix. M-matrix characterizes the time like entanglement between positive and negative energy parts of zero energy state and is measured in particle scattering

experiments. M-matrix need not be unitary and can be identified as a "complex" square root of density matrix representable as a product of its real and positive square root and of unitary S-matrix so that thermodynamics becomes part of quantum theory with thermodynamical ensemble being replaced with a zero energy state. The unitary U-matrix describes quantum transitions between zero energy states and is therefore something genuinely new. It is natural to assign the statistical description of intentional action with U-matrix.

Intuitively self corresponds to a sequence of quantum jumps which somehow integrates to a larger unit much like many-particle bound state is formed from more elementary building blocks. It also seems natural to assume that self stays conscious as long as it can avoid bound state entanglement with the environment: everything is conscious and consciousness can be only lost. This view predicts infinite self hierarchy with the entire Universe at the top.

If one accepts the hierarchy of Planck constants [C9], it might be un-necessary to distinguish between self and quantum jump. The hierarchy of Planck constants interpreted in terms of dark matter hierarchy predicts a hierarchy of quantum jumps such that the size of space-time region contributing to the contents of conscious experience scales like $\hbar$. Also the hierarchy of space-time sheets labeled by p-adic primes suggests the same. That sequence of sub-selves/sub-quantum jumps are experienced as separate mental images explains why we can distinguish between digits of phone number. The irreducible component of self (pure awareness) would correspond to the highest level in the "personal" hierarchy of quantum jumps and the sequence of lower level quantum jumps would be responsible for the experience of time flow. Entire life cycle would correspond to single quantum jump at the highest(?) level of the personal self hierarchy and pure awareness would prevail during sleep: this would make it possible to experience directly that I existed yesterday. Whether these two definitions of self are in some sense equivalent will be discussed later.

Self is assumed to experience sub-selves as mental images identifiable as "averages" of their mental images. This implies the notion of ageing of mental images as being due to the growth of ensemble entropy as the ensemble consisting of quantum jumps (sub-sub-subselves) increases.

There are thus two definitions of self. The first definition introduces self as a notion separate from quantum jump. Second definition reduces the notion of self to a fractal hierarchy of quantum jumps. The equivalence between two definitions of the notion of self will be proposed later.

7.2.3 Some aspects of classical non-determinism

The general view about the classical non-determinism of Kähler action and its role in TGD and TGD inspired theory of consciousness has developed gradually and still does so. The newest developments relate to the application of quantum gravitational hologram principle in TGD framework. What has been however clear for a long time is that TGD inspired theory of consciousness falls or stands with the classical non-determinism.

Vacuum extremals

Any 4-surface which belongs to $M^4_+ \times Y^2$, where Y^2 is so called Legendre manifold of CP_2 representable as

$$P_i = \nabla_i f(Q_1, Q_2), \quad i = 1, 2 \ ,$$

where f is arbitrary function and (P_i, Q_i) are some canonical coordinates of CP_2, is vacuum extremal of Kähler action. For these vacuum extremals the signature of the induced metric can be either Minkowskian or Euclidian. There are also vacuum extremals with Euclidian signature of the induced metric. The so called CP_2 type extremals are vacuum extremals having light like random curve as light cone projection. These extremals are isometric with CP_2 so that the signature of the induced metric is Euclidian. These extremals provide a model for elementary particle.

The absolute minimization of the Kähler action forces to deform the vacuum extremals to non-vacuum extremals. The remnants of the huge vacuum non-determinism are expected to give rise to the non-determinism required by symbolic representations of conscious experience at the level of space-time dynamics giving rise to language as a special case. Of course, classical nondeterminism of the Kähler action might also relate to the nondeterminism of volition although it seems that p-adic-to-real phase transitions are responsible for the transformation of intentions to actions. It seems that the

CP_2 type extremals representing cognitive neutrino pairs are crucial for our cognitive consciousness and its transformation to symbolic representations.

Mind like space-time sheets as deformations of vacuum extremals

Physical intuition suggests that the gluing vacuum extremals to a material space-time sheet $X^3(Y^3)$ by # (topological sum) contacts, an interaction results and deforms vacuum extremal slightly and that in some cases this leads to a new absolute minimum with slightly larger value of Kähler function and hence a larger value of the vacuum functional making the 3-surface more probable. These deformed vacuum extremals are expected to be still non-deterministic although the non-determinism should be reduced considerably. Via their interactions with the matter like space-time sheets, they provide sensory and symbolic representations for some aspects of the material world. Hence they are excellent candidates for the geometric counterparts of selves. For instance, the time evolution of our body could correspond to this kind of deformed vacuum space-time sheet with a finite time duration. The space-time surfaces $X^4_i(Y^3)$ are expected to be very nearly identical outside the time-interval characterizing the size of the mind like space-time sheet: this in turn implies time localization for the non-determinism of quantum jump and therefore for the contents of conscious experiences associated with the mind like space-time sheet.

Note that the surfaces obtained by gluing vacuum extremals do not anymore correspond to Y^3 at light cone boundary but to association sequences containing besides Y^3 also 3-surfaces not belonging to the light cone boundary. Generalized causality makes it possible to avoid paradoxical situation: assuming that space-time surface $X^4(Y^3)$ is absolute minimum of the Kähler action for Y^3 one might always find a new 4-surface giving rise to a smaller Kähler action by gluing suitable vacuum extremal to $X^4(Y^3)$. Note that it is not at all clear whether one can find absolute minimum surface $X^4(Y^3)$ for Y^3 containing only component on light cone boundary: due to the presence of the vacuum extremals Y^3 might be always accompanied by a set of 3-surfaces not belonging to the light cone boundary.

Are unions of absolute minima and vacuum extremals absolute minima?

There is a peculiar problem, perhaps even paradox, related to the vacuum extremals. It is not obvious whether the unions of absolute minima and vacuum extremals are also absolute minima for some 3-surface? Typically non-determinism could correspond to space-time sheets of a finite duration glued to $X^4(Y^3)$ already found. Indeed, if $X^4(Y^3)$ is absolute minimum, one can form a disjoint union of any vacuum extremal and $X^4(Y^3)$ getting space-time surface with the same value of Kähler action. The generic vacuum extremal [D1]) intersects $X^4(Y^3)$ in a discrete point set but by cutting small spheres from vacuum extremals around intersection points one gets a disjoint union of modified vacuum extremal and $X^4(X^3)$ which is new degenerate absolute minimum. For these vacua the non-determinism is not describable as a discrete sequence of multi-furcations: the only manner is to give entire vacuum extremal to characterize the entire surface.

Something like a continuous version of association sequence seems to be in question and it is not clear whether one should allow not only association sequences but unions of Y^3 belonging to the light cone boundary with vacuum space-time surfaces! The addition of these vacua does not provide cognitive representations for the non-vacuum space-time surface except in purely topological sense as holes created on vacuum extremal at the intersection points. The sensory content of this kind of vacuum would be more akin to a hallucination or completely free imagination or perhaps a state of enlightment with liberation from the determinism of the material world!

Perhaps the simplest manner to get rid of the paradox is to require that all vacuum absolute minima are such that enumerable number of 3-surfaces with time like separations specifies the absolute minimum completely. In this kind of situation deformation to locally non-vacuum extremal having vanishing total classical conserved quantities would occur. It however seems that these absolute minima could be arbitrarily near to vacuum extremals since the temporal interval between two 3-surfaces in association sequence can be arbitrarily small.

Especially interesting are closed vacuum absolute minima of finite temporal duration and possessing no boundaries. These absolute minima could quite well have Euclidian induced metric and non-vanishing action which is automatically negative. These absolute minima can be also non-vacuum extremals locally although the sum of the energies associated with various space-time sheets must

vanish. The solutions of Dirac equation for the induced spinors have also vanishing total energy for these extremals.

Massless extremals as quantum gravitational holograms

Massless extremals (MEs) have turned out to be perhaps the most fundamental solutions of field equations as far TGD inspired theory of consciousness is considered. It has become also clear that they play the role of quantum gravitational holograms. The hologram principle of quantum gravitational theories roughly states that the quantum theory in space-time with boundary reduces to a conformal quantum field theory at the boundary. If Kähler action were deterministic, precisely this would happen. The construction of configuration space geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action does not radically modify the construction based on the assumption of a complete determinism.

It has indeed turned out that the basic construction in which everything reduces to the light like boundary of M^4_+ (moment of big bang) acting as a hologram in quantum gravitational sense and defining conformal quantum theory, generalizes. This construction survives as a template in a more general construction in which also the light like boundaries of MEs having always light like M^4_+ projection are taken into account besides δM^4_+ as surfaces at which initial values can be fixed arbitrarily. This brings in also time absent in a strictly deterministic theory. Thus the quantum gravitational hologram defined by δM^4_+ is replaced by a fractal structure formed by δM^4_+ and Russian doll hierarchy of the light like boundaries of MEs inside MEs. The super-canonical and super-conformal invariances of the light like boundaries indeed generalize in an elegant manner thanks to the basic properties of MEs.

There are good reasons to expect that the light like selves defined by the boundaries of MEs are fundamental in TGD inspired theory of consciousness. The super-canonical quantum states associated with these boundaries are genuine quantum gravitational states defined by configuration space functionals, whose dependence on the bosonic fiber degrees of freedom of the configuration space does not reduce to a mere vacuum functional given by the exponent of Kähler action. This means that these states do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds, so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems. Thus it is the higher abstraction level of quantum gravitational states which connects conscious intelligence and quantum gravitation.

7.2.4 Two times

The notion of quantum jump implies a new view about time. Experienced/subjective time corresponds to a sequence of sub-quantum jumps and cannot be identified with the geometric time defined as the fourth space-time coordinate. This is of course obvious for anyone: consider only the reversibility of geometric time contra irreversibility of experienced time, and the fact that both geometric past and future exist whereas only subjective past exists. The fact that the contents of conscious experience is about 4-D rather than 3-D space-time region, motivates the notions of 4-D brain, body, and even society. In particular, conscious existence continues after biological death since 4-D body and brain continue to exist.

7.2.5 About the arrow of psychological time

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which represent basic types for them.

The third option

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the

space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

7.2.6 Questions related to the notion of self

I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more

general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configurations space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

Does entanglement mean loss of consciousness?

The ability to avoid entanglement with environment would be essential for the original notion of self and incase of sub-selves it would explain the finite life-time of mental images. One can of however ask whether the assumption about the loss of consciousness in entanglement - that is during sleep - is really necessary. One could however argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday. Furthermore, during topological quantum computation entanglement is absent and thus this state should correspond to conscious experience. Night time is however the best time for tqc since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at some level during sleep and perform quite a long tqc. Perhaps we are!

Could it be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with some system means only diving into the ocean of consciousness as someone has expressed it. We would be Gods as also quantum classical correspondence in the reverse direction requires (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions). This would be the most optimistic view that one can imagine.

What after biological death?

Could the new option allow to speculate about the course of events at the moment of death? Certainly this particular sensory "me" would effectively meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape sooner later brings into the volume of attention (which might also change) a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what she might call enlightment.

7.2.7 Memory and time

Do declarative memories and intentional action involve communications with geometric past?

Communications with geometric past using time mirror mechanism in which phase conjugate photons propagating to the geometric past are reflected back as ordinary photons (typically dark photons with energies above thermal threshold) make possible realization of declarative memories in the brain of the geometric past [H6].

This mechanism makes also possible realization of intentional actions as a process proceeding from longer to shorter time scales and inducing the desired action already in geometric past. This kind of realization would make living systems extremely flexible and able to react instantaneously to the changes in the environment. This model explains Libet's puzzling finding that neural activity seems to precede volition [45].

Also a mechanism of remote metabolism ("quantum credit card") based on sending of negative energy signals to geometric past becomes possible [K6]: this signal could also serve as a mere control signal inducing much larger positive energy flow from the geometric past. For instance, population

inverted system in the geometric past could allow this kind of mechanism. Remote metabolism could also have technological implications.

Episodal memories as time-like entanglement

Time-like entanglement explains episodal memories as sharing of mental images with the brain of geometric past [H6]. An essential element is the notion of magnetic body which serves as an intentional agent "looking" the brain of geometric past by allowing phase conjugate dark photons with negative energies to reflect from it as ordinary photons. The findings of Libet about time delays related to the passive aspects of consciousness [18] support the view that the part of the magnetic body corresponding to EEG time scale has same size scale as Earth's magnetosphere. The unavoidable conclusion would be that our field/magnetic bodies contain layers with astrophysical sizes.

p-Adic length scale hierarchy and number theoretically preferred hierarchy of values of Planck constants, when combined with the condition that the frequencies f of photons involved with the communications in time scale T satisfy the condition $f \sim 1/T$ and have energies above thermal energy, lead to rather stringent predictions for the time scales of long term memory. The model for the hierarchy of EEGs relies on the assumption that these time scales come as powers $n = 2^{11k}$, $k = 0, 1, 2,$, and predicts that the time scale corresponding to the duration of human life cycle is ~ 50 years and corresponds to $k = 7$ (amusingly, this corresponds to the highest level in chakra hierarchy).

7.2.8 Cosmology of consciousness

Cosmology of consciousness scenario is inspired by the notion of infinite self hierarchy and by the quantum-classical correspondence principle stating that the fractal structure of the many-sheeted space-time should directly reflect the general structure for the cosmology of consciousness. For instance, the p-adic evolution of consciousness should have its counterpart at space-time level: indeed, there are good reasons to believe that 4-surfaces have decomposition into regions obeying real or finite-p p-adic topology just like configuration space has decomposition into real regions and regions D_P labelled by infinite primes characterizing the appropriate functions space topology. Fractality suggests that there are conscious universes within conscious universes and that the experiences of universes involve kind of abstractions about the experiences of the sub-universes they contain. Summation hypothesis for the experiences of selves indeed states just this.

Each self corresponds geometrically to its own subset of mind like and matter like space-time sheets, separate conscious cosmology. Mind like space-time sheets are bounded in time direction: the sheet of 3-space is born when a tiny energy flows into the sheet from some larger sheet and dies when this energy flows back to the larger background sheet. p-Adic length scale L_p gives a first guess for the typical duration $T_p = L_p/c$ of the space-time sheet. Even human body could correspond to mind like space-time sheet: time duration would be of order of lifetime. Note however that the visible body might be only dip of iceberg, and it indeed seems that our magnetic body could have size for which light life is natural unit of size. Since selves contain sub-selves with various values of psychological time, the experiences are actually multi-time experiences with respect to both geometric and subjective time. The most natural identification of the psychological time is kind of center of mass coordinate associated with the sensory selves.

If quantum entanglement in the direction of time is a relatively rare phenomenon (it is completely absent in standard theories), entangled mind like space-time sheets correspond to nearly the same value of time so that our conscious experience gets dominant contribution from time values around the mean value of the time coordinate for our space-time sheet of finite duration. Entanglement in time direction gives rise to multi-snapshot experiences which would resemble vivid long term memories. The interpretation as genuine memories is however not correct. Rather, multi-time experiences with contents coming from geometric past and recent are in question.

The conclusion would be that the entire 4-dimensional space-time is a living system in TGD universe: both the geometric future and past are living and participate in each moment of consciousness. Each moment of consciousness decomposes into infinite number of sub-moments of consciousness of selves in the self hierarchy with the values of psychological time varying from zero to infinity. The value of our own psychological time of roughly 10^{11} years is just an accident. Entire civilizations can live in different geometric times without knowing anything about each other unless they happen to have entanglement in time direction. If they have, the resulting experiences could be interpreted

as memories, dreams, religious or mystic experiences or simply as hallucinations. The inhabitants of sufficiently but not sufficiently advanced sub-cosmologies tend to believe that they are the only conscious beings in the Universe, construct their own cosmology and try desperately to understand why the value of cosmological time happens to be what it is and, to certain degree quite correctly, conclude that Anthropic Principle is the only explanation.

The civilizations of past could still exist and participate to each quantum jump. Also the civilizations of future coexist consciously with us. The hierarchy of selves implies that selves have increasingly longer geometric and subjective memories. The hypothesis about infinite primes implies a hierarchy of literally infinite values of psychological time and God like conscious beings with infinitely long geometric and subjective memories is possible if infinite primes. At the top of the hierarchy is the entire universe having infinitely long geometric and subjective memories and integrating all experiences at the lower levels of the hierarchy in single abstracted experience. Note that this picture gives hopes to understand how universe is able to construct theory about itself. Notice also that any theory of consciousness should be able to predict its own discovery and the infinite hierarchy of selves gives good hopes in this respect.

One can represent an objection against this picture. p-Adic-to-real phase-transition front should be common to the entire biosphere at our level of self hierarchy at least. It is not clear in what time scale this is true and whether the geometric past can generate intentions which can effectively re-create the geometric past. If p-adic-to-real phase transition occurs in entire cosmology then one could say that there is universal psychological time. A concrete model for p-adic cognition at neuronal level however suggests that there is no deep reason to assume that psychological time would be more than local. The paradoxes related to the transformation of intentions to actions in the geometric past are avoided if the effects of this nondeterminism are bounded to a time scale not longer than p-adic length scale. This would also conform with the hypothesis that the second law of thermodynamics holds true only in time scales longer than the p-adic length scale characterizing the space-time sheet in question.

7.2.9 Communications in four-dimensional society

The idea about four-dimensional society makes sense only if communication between members of this society is possible. It would be even better if communication could occur in "real subjective time". This seems to be possible in principle as the following arguments show.

Communication method

A simple model for real time communication between societies of the geometric future and past is based on the possibility of space-time sheets of negative time orientation having negative energy density. It seems natural to assume that at least classical signals propagate from geometric future to geometric past along these space-time sheets. As suggested in [I3, J4] "massless extremals" could make possible coherent motion of living systems. It seems that they could make possible also "real subjective time" communications in four-dimensional society.

1. Signals to the geometric future propagate along space-time sheets of positive time orientation. These space-time sheets can correspond to ordinary material space-time sheets but also almost vacuum space-time sheets can be considered. In particular, so called "massless extremals" [J4] are possible.

2. Signals to the geometric past propagate along space-time sheets of negative time orientation. Negative energy massless extremals are the optimal choice as far as classical communication is involved. The reason is that signal propagates with maximal signal velocity and consists of Fourier components with same momentum direction so that the shape of pulse is preserved. Polarization direction at a given point of the massless extremal is constant and depends on the transversal coordinates only. Solution involves two arbitrary functions and linear superposition of parallel Fourier components with identical polarization directions is possible. Therefore all possible pulse shapes are possible.

3. What happens in the communication is following. Sender performs quantum jump in which massless extremal of positive/negative energy is generated representing signal propagating to

geometric future/past. Some standardized alphabet formed by the pulse forms for massless extremals: two basic pulse shapes identifiable as binary digits is the simplest choice. Receiver interacts with the massless extremal purely classically to receive the message and generates a massless extremal propagating to geometric past/future as a reply. The difference between sender and receiver is that sender performs quantum jump whereas receiver just acts purely classically to receive the message.

4. The communication is on-line "real subjective time" communication. There is no need to wait for next billion years for reply and members of cultures separated by billions of light years can have real time chat about their family problems! Also communication with effective signal velocity larger than light velocity becomes possible by using a 'radio mast' in the geometric future able to send past-directed signals: the mast receives a signal from the geometric past and sends it to the second receiver in the geometric past.

Anomalies related to spinning astrophysical objects as empirical support for the idea

The proposed communication method could be regarded as mere wild science fiction unless there were some empirical support for the possibility of communication from geometric future to geometric past. In the articles [32, 33] various anomalies related to spinning objects are reviewed. These anomalies are discussed in [G2]. There are also anomalies related to spining astrophysical objects. Kozyrev [30] has conducted astronomical observations using a receiving system of a new type. These observations have been replicated later by other groups [31, 28]. These anomalies give also support for the possibility of the signal propagation backwards in time.

1. When a telescope was directed at a certain star, the detector positioned within the telescope registered the incoming signal even if the main mirror of the telescope was shieded by metal screens. This indicated that electromagnetic waves were accompanied by some waves not shielded by the metal screens.

2. When the telescope was directed to the true position, the signal became stronger. As if there had been almost instantaneous propagation of signal with velocity billions times greater than the velocity of light!

3. When the telescope was directed to a position symmetrical with respect to the visible position, again signal was detected: the imaginative interpretation was that the signal came from future position of the star!

Leaving aside the objections of a typical sceptic and the question whether the effect is real or not, one can ask whether the concepts of many-sheeted space-time concept and classical Z^0 field could somehow give rise to this kind of effect in strong conflict with the conventional wisdom.

1. Propagating photons (extremely tiny 3-surface glued to macroscopic space-time sheet) affect the space-time sheet and could generate propagating classical Z^0 field causing the effect in the detector. Of course, one cannot exclude the possibility of negative energy photons although the experimental arrangement eliminating the ordinary photons should eliminate also these.

2. The strong signal from the true position could have explanation in terms of a coherent classical Z^0 field of astronomical size. This kind of coherence is forced by the imbeddability requirement and was coined as topological field quantization in [D9]. One can intuitively understand it as follows. In TGD elementary particle is replaced with 3-surface, which can have arbitrarily large size and absolution minimization of Kähler action forces 3-surface to behave coherently like single particle (in case that it does not so, it decomposes into disjoint components!). The results of Kozyrev are not the only evidence for this kind of behavior. Total eclipses of the Sun by the Moon reach maximum eclipse about 40 seconds before Sun's and Moon's gravitational forces on Earth align [29]. If gravity is a propagating force, this 3-body test implies that gravity propagates at least 20 times faster than light. The result is consistent with the assumption that the acceleration of Earth is towards the true instanteous direction of the Sun now, rather than being parallel to the direction of the arriving solar photons now. The TGD based explanation is that the changes of the classical gravitational field are not propagating effects but that the

classical gravitational field behaves like single coherent whole (it could of course contain also small propagating part).

3. The signal in the symmetric position could indeed come from geometric future. An attractive possibility is that classical Z^0 field propagated along space-time sheet with negative time orientation: for negative time orientation the propagation is expected to occur backwards in time.

There are also reports about the anomalies related to rotated magnetic systems in laboratory scale and these effects are under intensive study (for instance in Faraday Lab in Russia). The TGD based explanation of the anomalies reported in [17] is developed in [G2]. The model involves in an essential manner the generation of both negative energy space-time sheets and many particle states with negative single particle energies residing at these sheets and some of the observed strange effects involved support the generation of the negative energy particles. The model allows to seriously consider the possibility that even ordinary ions and atoms could have negative energy counterparts.

7.3 Four-dimensional brain

The paradigm of 4-dimensional brain is the most important consequence of the Grand Scenario. The non-determinism of the Kähler action (non-determinism is understood here in the conventional sense of the word) is the quintessential, purely TGD based element of the Grand Scenario: without there would not be any evolution, the contents of conscious experience would be diffused around entire quantum histories and there would be no systems with strongly time-localized contents of consciousness. A second key element is p-adic nondeterminism making possible intentionality and cognition.

7.3.1 The paradigm of four-dimensional brain

The cosmology of consciousness implies that each conscious experience decomposes into separate sub-experiences with the values of the psychological time varying from zero to infinity. Furthermore, the experiences are in general multitime experiences both with respect to both geometric and subjective time. This picture forces the paradigm of 4-dimensional brain having profound consequences concerning the understanding of the brain functioning.

The difficult problems related to the understanding of conscious memory recall could trivialize. No separate mechanisms of memory storage or retrieval are needed and the difficult problems related to the interpretation of the stored memories are circumvented. There are two basic types of memories: geometric and subjective memories. Geometric memories provide as simulation for what happened and will happen provided no quantum jumps occur and has occurred and subjective memories tell what actually occurred. Actual memories are indeed known to be creative reconstructions of past and hence it seems that geometric memories are an essential part of construction. The comparison of expectations and actuality made possible by the two memory types gives rise to the emotions involving comparison aspect.

Subjective memory corresponds to immediate short term memory and the only possible identification of the *genuine* long term memories is as subjective memories at the higher level of self hierarchy, where the time span of subjective memory is longer. One possibility is periodic wake-up of sub-selves representing mental images and giving in this manner rise to long term memories: this requires some kind of periodic neural activity giving rise to the same sub-self periodically. Of course, it is not at all obvious whether long term memories are genuine! It is indeed known that long term memories are a result of a creative process and are not reliable. This would suggest that long term memories are actually geometric memories and are reasonably reliable because our geometric past is rather stable under quantum jumping. Of course, we do not usually test the reliability of our long term memories but take them as granted. The notion of mind like space-time sheet allows multitime experiences containing simultaneous contributions from both geometric present and past and the memories of, say, childhood could be genuine multitime experiences.

The "averaging" associated with the subjective memory implies that volition cannot correspond to the quantum jump occurring in the measurement of the density matrix. Rather, volitional activities must correspond to a localization in zero modes, most naturally selections between degenerate absolute minima of Kähler action. Besides volition associated with the motor activities, also the focusing of

attention and even the selection of premises of logical thought very probably involve this kind of selection. The most probable function of the motor nerve pulses is the generation of multi-furcations in an initial value sensitive system between which the choice occurs. Various motor programs correspond to various branches of the multi-furcation. Just as sensory experience, motor activity is predicted to be a top-down self cascade of quantum jumps starting from the level of the entire body. Each selection of the space-time branch creates self inside which subsystems perform quantum jumps as long as self is awake and these quantum jumps in turn lead to even smaller sub-selves: in this manner a precise and flexible coordination and control of the movement involving volition at all length scales becomes possible whereas in the standard neuroscience picture body would act like a robot with fixed motor programs.

7.3.2 Geometric and subjective memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) geometric time development and the non-deterministic subjective time development by quantum jumps. The memories with respect to subjective time are about previous conscious experiences and "real" whereas geometric "memories" are prophecies giving simulation of geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the space-time surface.

A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure of conscious experience implies that this comparison is a basic function of conscious mind not reducible to anything simpler. It is wellknown that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. This suggests that geometric memories, possibly constrainted by subjective memories, give rise to the "story" about past.

7.3.3 Memories with respect to geometric time as simulations

Geometric memories are about both future and past and are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in past. Geometric memories are also about past: we continually make guesses about the sequences of events which could have led to some event and this is nothing but predicting the geometric past. Of course, geometric memories are simulations rather than real memories. Geometric "memories" are real in the classical limit, when the effect of quantum jumps becomes negligible. In classical physics geometric memory is all that is needed to make predictions of past and future. We can indeed predict rather reliably what will happen in the solar system during the next decade. Also the computational approach to mind assumes only geometric memories. p-Adic geometric memories about future give rise to intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. can be understood in terms of the p-adic geometric memory of future.

Intentionality manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, disappointments, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mind like space-time sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic space-time. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to assume that all aspects of intentionality are made possible the predictions of the expected geometric future and past provided by the mind like space-time sheest.

What is nice is that subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well

possible that all comparisons must be realized as comparisons of the subjective and geometric time developments (it could be that self is also able to compare its sub-selves).

The possibility of this comparison perhaps provides a solution to the paradox raised by the innocent question "How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?". The solution might be simple: mind like space-time sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds between the mind like space-time sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

7.3.4 Are long term memories geometric or subjective memories?

The answer to the question whether long term memories are geometric memories and thus only simulations or genuine subjective memories of higher level self somehow communicated to us, is not obvious.

Long term memories as geometric memories?

Geometric memories realized as multitime experiences involving mind like space-time sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mind like space-time sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing cognitive long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why cildhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mind like space-time sheets located at different values of the geometric time.

Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

Long term memories as subjective memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories (whose existence is questionable) is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory.

Quantum-classical correspondence principle suggests that entanglement could correspond geometrically to temporary join along boundaries bonds between the mind like space-time sheets of self and higher level self. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could perhaps understand how ageing self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this. It would seem that our self must be able to shift the hierarchy level in order to remember details on one hand and to form abstractions on the other hand and that the detailed memories about the wake-up periods of self are unavoidably lost.

There are however serious counter arguments against this identification.

1. It is not at all clear why the experiences of the higher level selves during entangled state could be ours! For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state.

2. The averaging involved with the temporal binding means that the subjective memories of the higher level selves cannot possess the details of our long term memories.

3. It is not obvious how to understand learning and the role of emotions in learning.

The entanglement with the higher level self is not necessary to have genuine long term memories. One could consider also the possibility that higher level self could somehow communicate the long term memories to the lower level selves. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts. The lack of a precise realization of this mechanism makes the realization of the long term memories as geometric memories much more attractive option.

Long term memories as a communication between now and geometric past

The basic challenge is to identify concrete mechanisms of long term memory recall. According to the idea of magnetic sensory canvas discussed in [H4], the positions of objects of perceptive field are coded by the frequency scale of the magnetic transitions occurring at the magnetic flux tube structures having size of wave lengths associated with EEG frequencies. The slowly varying thickness of the magnetic flux tube codes for the position of the object of the perceptive field.

This encourages to consider the possibility that also the temporal position of the object of perceptive field could be coded in this manner. There are however two difficulties involved:

1. Since the time scales are of order life time T , the needed frequency resolution is $\Delta f/f \sim \Delta T/T$, if the time resolution is ΔT. This requires frequency resolutions of order $\Delta f/f \sim 10^{-8}$ at least and this kind of resolution is certainly not achievable in the neuronal circuits.

2. If ELF MEs (massless extremals) are involved it is difficult to understand how one could circumvent the fact that the ME represents geometrically a light ray escaping from the system. This ray should be reflected somewhere. Kind of mirror would be required. Magnetic flux tubes could serve as this kind of mirror and allow the radiation to travel in zigzag curve in space-time to to geometric past.

There is however a much more elegant mechanism of long term memory recall based on MEs. First, of all what makes MEs so interesting from the point of view of long term memories, is that light like selves has a temporal extension, which can be arbitrary long in given rest system. Secondly, the pairs of MEs resulting when ME reflects from some structure such as magnetic flux tube structure serving as a mirror, provide a TGD based model of long term memories relying on the idea that long term memory recall involves a 'question' sent to the geometric past as a classical signal reflected back to brain in a magnetic mirror, and a subsequent quantum entanglement in which the selves of the geometric past and now as well as ME selves entangle to single self so that the self of the geometric now can share the experience of the self of the geometric past. What is so elegant in this mechanism is that there is no necessity of sending the information as a classical signal, only the time like entanglement is needed. In this case the MEs would have a length of order lifetime so that long term memories would be astrophysical phenomena involving magnetic flux tube structures and MEs. The temporal location T of the memory (or rather, shared conscious event) of the geometric past would be coded by the length L of ME: $L = cT/2$. The TGD based notion of time indeed allows geometric time scales of order lifetime to be involved with subjective experiences in psychological time scale of a fraction of second. Certainly this mechanism is completely out of question in standard physics.

7.3.5 Quantum physical model for Boolean mind and cognition

TGD based theory of consciousness has reached such level of well-definedness that one can make serious attempts to construct physical models for Boolean mind and cognitive consciousness. The concepts of mind like space-time sheet, fermionic representation of Boolean algebra, and p-adic physics as physics of cognition are the three basic concepts involved. In this section the p-adic aspects are not considered much (the reason is very mundane: this chapter was written much before the connection between cognition and p-adics became clear!). To avoid confusions it is however worth of making clear in which sense the older picture makes sense in the new framework provided by p-adic physics as physics of cognition.

1. In p-adic context the inherent non-determinism of the p-adic field equations makes mind like sheets ideal as far as geometric correlates of imagination and cognition are considered. Real space-time sheets correspond to matter and symbolic representations. The non-determinism of the real Kähler action makes possible mind like space-time sheets of finite time duration identifiable as sensory and symbolic representations. The p-adic–real phase transitions occurring in quantum jumps and transforming p-adic space-time sheets to real ones and vice versa transform thoughts to actions or symbolic representations and vice versa. This picture provides the geometric counterpart of matter-mind dichotomy and of matter-mind interaction of Descartes.

2. The notion of a cognitive neutrino pair defined as a real zero energy neutrino pair developed before the realization of the p-adic view about cognition and gave rise to realization of Boolean statements as temporal sequences of real zero energy neutrino pairs. According to a more precise definition of cognition, neutrinos can be called cognitive only when p-adic. Both p-adic and real neutrino pairs are crucial and real zero energy neutrino pairs correspond to symbolic representations of thoughts inducing automatically nerve pulse patterns or membrane oscillations (the duration of nerve pulse is slightly longer than the duration of the bit of the memetic codon). In the following I try to follow this definition.

3. An attractive idea inspired by the general theory of qualia [K3] is that real zero energy neutrino pairs correspond to the Boolean counterpart of sensory experience. If so, p-adic-to-real transition would transform a freely imagined, purely formal Boolean statement to an experienced truth of some kind. This brings in mind the the formal statements of abstract propositional logic without fixed truth values contra the models of the logic system assigning definite truth values to these statements. Our beliefs would correspond to p-adic Boolean statements transformable

to real statements just like the repertoire of our motor actions would correspond to intentions transformable to actions.

One can distinguish between two kinds of fermionic degrees of freedom: those associated with the configuration space metric and those accompanying the called quaternion conformal degrees of freedom responsible for the ordinary elementary particles. In the p-adic context only the quaternion conformal fermionic degrees of freedom are present. A possible interpretation is in terms of 'Truth, Beauty, Goodness' trinity. There are three kinds of Boolean statements: logical true/false type statements (p-adic fermions and cognition), aesthetic beautiful/ugly type statements (fermions associated with the configuration space geometry and sensory experience), and ethical right/wrong type statements (real quaternion conformal fermions).

If this is identification has some sense, zero energy neutrino pairs and their real counterparts would contribute to the logical and ethical Boolean mind. The fact that we make also aesthetic judgements would suggest that the fermionic degrees of freedom associated with the configuration space metric and representing genuinely new physics, are present. Of course, also the fact that we have sensory qualia requires that configuration space metric degrees of freedom are present. What is special is that these degrees of freedom do not carry four-momentum but only color and angular momentum-like quantum numbers so that they are not easily detectable by ordinary physical measurements. Note that this makes it easy to generate these fermions from vacuum.

The transformation to real zero energy pairs could be also involved with the symbolic expression of cognition, presumably underlying speech (recall that the members of primitive societies are not able to say that they mother is dead unless this is really the case). More precisely, real zero energy neutrino pairs could correspond to symbolic expression of cognition used in interneuronal communication which need not be directly conscious to us (for instance, the duration of memetic codeword is about .1 seconds so that the duration of single bit is about one millisecond). In this framework the correct interpretation of the memetic codons formed by the real zero energy neutrino pairs would be as basic building blocks of our (or some lower level) belief system.

4. p-Adicity might be absolutely essential for cognition in p-adic sense. p-Adic non-determinism makes possible time like entanglement binding temporal sequences of zero energy fermion pairs to temporal wholes just like the ordinary space like entanglement binds features of sensory experience to spatial wholes. The difference between left and right brain might be that left brain is specialized to temporal and right brain to spatial holism. In real context this binding would be possible only in special cases (zero energy neutrino pairs) and made possible by the non-determinism of Kähler action.

After these preliminaries, let us summarize the basic views about mind like space-time sheets and zero energy fermion pairs.

1. Mind like space-time sheets and the related concept of association sequence provide a geometric model for experiences having time localized content. One can identify psychological time as zero mode and understand its arrow. Mind like space-time sheets are obtained by "gluing" vacuum extremals of finite time duration to a space-time sheet containing matter and the interaction with the material space-time sheet creates the sensory representation in question. One could say that mind like space-time sheet takes a small sample of energy and various gauge fluxes from the material space-time sheet and these tiny (quantized) gauge fluxes create gauge fields giving rise to the needed simulation of the material space-time sheet. Mind like space-time sheets form in a natural manner a geometric hierarchy. One could consider also a direct mimicry of classical fields on material space-time sheets realized in terms of pairs of mind like space-time sheets such that sheets have opposite time orientations so that they can have vanishing net energy. By gluing this kind of sheet pair to the boundary of a material space-time sheet such that space-time sheet with a positive time orientation is joined to the material space-time sheet by join along boundaries bonds, one obtains sensory representation which by continuity argument can be regarded as a direct mimicry. Of course, also mind like space-time sheets can be glued in this manner to the boundaries of real space-time sheets.

2. The fermionic realization of the Boolean algebra provides fundamental model for Boolean mind. The task is to find concrete realizations for the fermionic Boolean algebra and for the quantum

jumps changing the values of the Boolean algebra elements and also to find which of them could correspond to our Boolean mind.

3. Quaternion conformal fermionic state (ordinary elementary particle fermions) should be localized on mind like space-time sheets of finite time duration. Time like entanglement between fermionic states is possible only if fermions exist in finite time interval only since only this makes the required non-determinism of induced Dirac equation possible. This requires that the total quantum numbers of the fermion system vanish. Boolean mind would not carry any energy- This suggest strongly the notion of zero energy fermion-antifermion pair having vanishing total quantum numbers, in particular vanishing total energy. In standard physics context this kind of requirement does not obviously make sense but in TGD framework one can consider two different realizations of zero energy fermion pair. Note that vanishing total energy makes it possible for real zero energy fermion pair to transform to p-adic one and vice versa and would have interpretation as transformation of cognition to symbolic expression and vice versa. Note again, that for fermions associated with the configuration space metric four-momentum vanishes identically.

4. Zero energy fermion pairs give naturally rise to Boolean algebra if fermion and antifermion reside at different space-time sheets. In fact, there are two Boolean algebras involved and the statements at the two space-time sheets can naturally be regarded as negations of each other. The quantum jumps changing Boolean statements involve annihilation or creation of zero energy fermion-antifermion pairs and do not change the total quantum numbers of the system. A unique mechanism creating zero energy fermion pairs is the splitting of a wormhole connecting two space-time sheets.

5. Zero energy boson and fermion pairs resemble virtual particle pairs of the quantum field theories. They are however real particles in the sense that in S-matrix elements they give rise to loops with the weight factors depending on the overlap of the initial and final states in these degrees of freedom rather than being completely determined by the propagator having formal interpretation as density matrix in quantum field theories. Since symbolic representations are virtual worlds, one can say that genuine virtuality is achieved in symbolic sense rather than in the sense of the quantum field theories!

In the following an attempt to understand these concepts at a more detailed level is made. The discussion is in real context, unless explicitly stated otherwise. Two realizations for zero energy fermion pairs will be considered.

1. The first realization is based on the special features of the condensed matter neutrinos a la TGD. The energy of the condensed matter neutrinos is negative since the Z^0 interaction energy of the condensed matter neutrinos with atomic nuclei is negative and much larger than the rest mass of the neutrino. The energy of antineutrinos is positive for obvious reasons. This makes possible to realize zero energy neutrino pairs: a real zero energy neutrino pair is created in the splitting of the Z^0 wormhole connecting the two space-time sheets. There are reasons to believe that this option is realized in bio-systems.

2. Second realization is more exotic. It is a trivial fact that in TGD context the energy associated with a space-time sheet can be positive or negative depending on the time orientation chosen for the space-time sheet. Hitherto the belief has been that this sign-indeterminacy has no physical significance. Along with the construction of the model for the mind like space-time surfaces came the realization that the dependence of the sign of energy on the local time orientation can have highly nontrivial consequences. The point is that for two-sheeted structures with finite time duration, the arrows of geometric time at the two space-time sheets must be opposite and therefore energies at the two sheets can be non-vanishing and are of opposite sign but of equal magnitude since total quantum numbers must vanish!

3. In particular, the absolute minima of the Kähler action which are closed space-time surfaces, with possibly Euclidian signature of the induced metric, have finite time duration and the classical charges associated with various branches of these surfaces must sum up to zero: thus time orientations on various branches cannot be same. [Note that in the first realization time

orientations are same!] This prototype model for a mind like space-time surface is thus nothing but a classical analog for a virtual boson pair created from vacuum!

Similar phenomenon occurs in the fermionic sector. One can construct solutions of the induced Dirac equation for vacuum bubble type double-sheeted space-time surfaces. The solutions describe classical fermion in time loop propagating forwards in time along the first space-time sheet and backwards along the second space-time sheet. At quantum level this timeloop corresponds to a virtual fermion-antifermion pair with vanishing net quantum numbers. The many-fermion states constructed using these pairs are excellent candidates for a fermionic representation of the Boolean algebra.

Zero energy neutrino pairs

In this case the two space-time sheets involved have same time orientation and both can be carriers of ordinary matter. The model for the condensed matter neutrinos implies that the Z^0 binding energy of neutrinos in condensed matter is much larger than the mass of the neutrino so that condensed matter neutrinos have *negative*(!) energy having magnitude more than ten times larger than neutrino mass! For antineutrinos the the interaction with the classical Z^0 field is repulsive so that their energy is positive and much larger than the rest energy. Thus condensed matter neutrinos look as if taylor made for Boolean consciousness! Classical non-determinism is involved since the creation and annihilation of zero energy neutrino pair with zero energy is also geometric process (neutrinos correspond to CP_2 type extremals!). This would mean that our Boolean mind would rely on the classical non-determinism occurring at the level of elementary particles: admittedly against the original expectations.

The most plausible mechanism producing zero energy neutrino pairs is the splitting of Z^0 wormhole contacts (which are CP_2 type extremals connecting two space-time sheets) such that the resulting CP_2 type extremals with holes are carriers of opposite neutrino quantum numbers. Z^0 wormhole contacts feed classical Z^0 gauge field between two different space-time sheets. Because zero energy neutrino pairs can have zero total energy and since CP_2 type extremals themselves are non-deterministically behaving objects, quantum entanglement in time direction is possible for zero energy neutrino pairs. Thus our conscious thinking could be associated with population of zero energy neutrino pairs of finite time duration dispersed around space-time surface representing brain so that the idea about four-dimensional brain is realized. This does not necessary mean that the presence or absence of the pair corresponds to truth value true/false. It turns out that the spin direction of the zero energy antineutrino is more plausible candidate for representing truth value or binary digit.

The space-time sheets associated with the regions, where electronic or neutrino conductivity is broken are the most natural seats of reflective mind [J1, J2, J3]. The pair of sheets in question corresponds to cell and endoplasma membranes (filling the cell in accordance with area maximization!) having $k = 151$ and the sheet at which neutrinos suffer primary condensation, most probably $k = k_Z = 169$. This is the space-time sheet associated with the epithelial sheets consisting of two cell layers and forming sensory organs. The model suggests very strongly that Z^0 wormhole BE condensates associated with $(k = 151, 169)$ space-time sheet might be crucial for the functioning of the brain and play a role analogous to electromagnetic wormhole BE condensates associated with the pair $(k_1 = 149, k_2 = 151)$. Gap junction connected groups of neurons, glial cells and also the epithelial sheets associated with the nuclei of brain would form structures consisting of weakly coupled Z^0 wormhole super conductors and the creation of zero energy neutrino pairs would provide us conscious information about the state of Z^0 super conductor.

The presence of the stripe like structures in cortex resembling defects of super conductor of type I suggests that also the pairs $(k_1 = 169, k_2 > 169)$ sheets appear as defects of neutrino super conductor and that thinking might be possible also at these space-time sheets. Even the entire cortex seems to be a folded membrane like structure maximizing its surface area and hence analogous to a defect in super conductor of type I near criticality (of course, there are many other good reasons for area maximization!). This would make possible physical realization abstractions as association sequences of association.... sequences (thoughts about thoughts). The low density of zero energy neutrino pairs associated with these space-time sheet pairs would explain why abstract thinking seems to be quite rare(!).

Negative energies for condensed matter neutrinos are due to the small mass of the neutrinos: for electrons similar mechanism does not work in condensed matter length scales. Rather remarkably, TGD predicts that all the neutrino species have suffered topological condensation on the p-adic level

and have very nearly equal masses. The nearly equal values of neutrino masses is more or less a surprise since charged leptons and quarks tend to condense on different space-time sheets. The explanation for this peculiar exception from rule is that the condensation on same p-adic level however maximizes the reflective abilities of bio-systems since the number of the possible Boolean statements is 2^{3N} rather than only 2^N if each neutrino possesses effectively N possible states. It might be even that this 3-fold degeneracy makes possible 3-dimensional thinking since $M = 2^N$ values of each spatial coordinate could be represented by 2^N different neutrino states so that $3N$ many neutrino states could provide a coordinatization of M^3 points of a lattice with side $M = 2^N$. The fact that the neutrinos of different generations have slightly different masses, could perhaps bring in the necessary symmetric breaking making it possible to distinguish between different coordinate directions.

There is also a second remarkable exceptional feature related to $k = 169$ space-time sheet. p-Adic length scale hypothesis, which can be deduced from black hole elementary particle analogy by requiring that also the radius of elementary particle horizon is p-adic length scale, predicts that allowed p-adic primes are of form $p \simeq 2^k$, k power of prime. $k = 13^2 = 169$ is the only power of prime in the length scale range extending from electron length scale to length scale of solar system so that the length scale of the epithelial sheets is indeed exceptional! What makes this length scale even more exceptional is that $k = 169$ together with $k = 167$ gives rise to p-adic length scale pair related by scaling by factor two. Twin pairs of p-adic length scales are very common in the range of the biologically interesting length scales and seem to correspond to biologically important length scales. Taking into account that the model predicts correctly the length scale at which reflective consciousness emerges, it is perhaps needless to emphasize how unique the role of the elusive neutrinos, usually thought to be a mere nuisance without any imaginable purpose in the physical world order, would be. Without neutrinos there would be conscious intelligence, at least in the form familiar to us!

The original motivation for identifying neutrinos as associated with the reflective level of our consciousness was based on the metaphor of thinking as inner speech: the motivation was the identification of the quantum correlate of auditory experience as neutrino pair BE condensate. One can however criticize this metaphor. It seems that language can be realized as association sequences related with practically any sensory quale: for instance, sign language is based on vision and persons who are both blind and deaf learn to use direct touch as communication tool. Therefore the conclusion that our thinking is at the fundamental level related to any particular sensory quale, could be too strong. As a matter fact, it turns out that there *is* very close relationship between thought and speech although the original identification of neutrino Cooper pairs as the quantum correlate of hearing is probably wrong.

General model for Boolean mind based on zero energy neutrino pairs

In this picture one ends up to a concrete model for our Boolean mind.

1. A simple model for Boolean mind associated with neutrinos follows as an immediate consequence. The temporal sequences of temporally localized many particle states consisting of zero energy neutrino pairs represent logical statements, which state something about space-time surface in the limit when zero modes determine the many particle state completely (at least in statistical sense). These temporal sequencing does not however correspond to a sequence of logical implications but rules about about the dynamics of space-time surface Rather, logical statements could be regarded as self cascades $A \to B \to C...$ in which self a representing logical statement is created first, then sub-self b of a is created and so on... If sub-selves correspond to different values of p-adic prime, this requires that neutrinos are condensed on several space-time sheets. Logical causation is realized as time ordering for the moments of wake-up for sub-selves and also as set theoretic inclusion: A implies B if b represents sub-self of a. Logical consistency is automatically guaranteed since the premises of logical deduction change at each step.

2. The sequences of many-particle states of zero energy neutrino pairs located around different moments of geometric time (different mind like space-time sheets) could be also regarded as statements about evolution of geometric space-time so that one can say that $A \to B...$ would describe temporal causation and statement about dynamical evolution of 3-surface. The interaction with the surrounding world should gradually lead to a selection of causation sequences appearing in the superposition and to a model for the time evolution of space-time surface. Also

a close connection with the development of linguistic skills is suggestive since neutrino Cooper pairs are the quantum correlate of the auditory experience in TGD framework.

3. The density of the zero energy neutrino pairs is very probably determined by the density of the Z^0 wormhole BE condensate and could characterize the general state of alertness in various parts of brain. The average temporal distance ΔT between zero energy neutrino pairs characterizes the temporal resolution of the conscious experience. In a similar manner, the average spatial distance ΔL between the pairs defines the spatial resolution of the conscious experience. The information content of the conscious experience can be related to the total number of the zero energy neutrino pairs in the region giving rise to the quantum jump. One can immediately understand the differences between right and left brain hemisphere in terms of distribution of the zero energy neutrino pairs. For instance, if ΔT is smaller in the left brain hemisphere than in the right hemisphere, one can understand why left brain is better in task involving precise temporal ordering of events. Similar conclusion applies to ΔL and skills requiring spatial thinking. The fact that right brain has better emotional skills, could be understood if the density of the zero energy neutrino pairs is larger in the limbic system of the right hemisphere.

One can in fact go even further and construct a model for the neutrino based cognition consistent with some basic quantitative facts about brain consciousness [L1].

1. The simplest possible model for the abstraction process leads to the so called Combinatorial Hierarchy of 'genetic codes' labelled by Mersenne primes $M(n+1) = M_{M(n)}$ given by primes $2, 3, 7, 127, ...$ Ordinary genetic code corresponds to the level 127 and next level corresponds to the level $M_{127} = 2^{127} - 1$. This prime corresponds to electron length scale and to secondary p-adic time scale $T_p^{(2)} = p \times T_{CP_2}$, $T_{CP_2} \simeq 10^4$ Planck times. This time scale corresponds to .1 seconds, which is the duration of our self defining the psychological moment of time appearing very frequently as the basic time scale of brain related phenomena!

2. Memetic code consists of sequences of 126 binary digits. If these digits correspond to arrays of zero energy neutrino pairs, the duration of single zero energy neutrino corresponds to $T \simeq .8$ ms. This time scale is the geometric average of the primary p-adic time scales $T(239) \simeq .55$ ms and $T(241) \simeq 1.1$ ms forming a twin pair. Millisecond time scale is indeed the time scale of the nerve pulse!

One must be however be cautious: actually the typical duration of nerve pulse is around 2 milliseconds and nerve pulse patterns seem to code data by frequency coding rather than by a temporally precise binary code. It might be that these time scales relate to neuronal membrane oscillations rather than nerve pulse patterns and that nerve pulse patterns code for a degenerate form of memetic code, most naturally 64 bit genetic code. Be as it may, the basic time scales of conscious brain result as predictions of the model of the abstraction process combined with the p-adic length scale hypothesis.

The first guess is that temporal sequences of zero energy neutrino pairs code Boolean thoughts. In the simplest model the spin of zero energy neutrino codes for the two truth values. A more realistic model assumes that the time varying direction Z^0 magnetization of antineutrinos at the cell membrane space-time sheet represents memetic codons. This model conforms with the general ideas about how quantum cognitive representations are realized.

Zero energy fermion pairs associated with time loops

The second realization of zero energy fermion pairs is based on the possibility of time loops. In this case fermionic degrees of freedom can correspond to interior of the space-time surface and the signature of the induced metric could be either Euclidian or Minkowskian whereas for zero energy neutrinos CP_2 type extremal has Euclidian signature.

1. Mind like space-time surfaces

The original intuitive picture about mind like space-time surfaces was as space-time sheets of finite time duration glued to a material space-time sheet having infinite time duration: gluing was performed by # contacts (tiny wormholes feeding gauge fluxes between the space-time sheets). Also it was thought that space-time surfaces with finite duration are necessarily vacuum extremals and

that gluing to the material space-time sheet changes them to non-vacuum extremals. It came as surprise that also *non-vacuum* extremals of *finite duration* can be considered. The point is that the components of four-momentum currents given by

$$T^{\alpha k} = T^{\alpha\beta}\partial_\beta m^k \sqrt{g}$$

are proportional to the gradients of the standard Minkowski coordinates (m^k denote the standard Minkowski coordinates and $T^{\alpha\beta}$ denotes the energy momentum tensor of the Kähler action). This implies that time components of these currents change sign, when one changes time orientation, that is uses $-x^0$ instead of x^0 as a time coordinate for the space-time sheet. For a two-sheeted space-time surface consisting of two space-time sheets glued together, the global time-orientability implies that time must flow in different directions at the two 4-surfaces involved.

This in turn means that the field equations associated with the Kähler action, which are simply conservation laws for various isometry currents, could allow as their solutions 4-surfaces with a finite time duration and with the property that the two space-time sheets involved carry opposite classical isometry charges. These surfaces are analogous to pairs of virtual bosons of quantum field theories created from vacuum and having vanishing net quantum numbers. A very attractive interpretation of these structures is as a prototype of a mind like space-time surface. Obviously one can glue these sheets to material space-time sheets. It could be also possible to glue single space-time sheet of finite duration to a material space-time sheet to obtain a solution of the field equations: in this case mind like space-time sheet could carry either positive or negative energy depending on its time-orientation.

This scenario makes sense only provided it is possible to satisfy the field equations at the end points of the double sheeted structure. The basic problem is to find mechanisms making possible the transfer of energy and gauge charges between space-time sheets. There are two basic mechanisms.

1.1 Wormholes

Wormhole contacts (# contacts) feeding gauge fluxes between space-time sheets provide a possible realization for the transfer of gauge charges. mind like space-time sheet simply takes a small "sample" of the gauge charge density at the boundaries of the material space-time sheet. This sample of gauge charges and gauge currents serves as a source for gauge fields giving rising to the desired sensory representation. It is not however clear whether energy transfer through wormholes is possible. The reason is that wormholes correspond to space like 4-surfaces whereas energy momentum vector is time like vector and the intuitive picture identifying four-momentum as a vector tangential to the orbit of the particle seems to be in conflict with the possibility of the energy transfer.

In standard Minkowski coordinates energy momentum current is of the form $T^{\alpha k} = T^{\alpha\beta}\partial_\beta m^k \sqrt{g}$.

1. The first problem is that at the throat of the wormhole, defined as the 3-surface at which metric signature changes, $\sqrt{g}$ vanishes if space-time sheet has Minkowskian signature. This requires that some compoments of the energy momentum tensor diverge at this surface. This is what is expected to happen since index raising is performed by the contravariant components of the induced metric tensor and some of them diverge at the throat of the wormhole.

2. Energy current ($T^{\alpha k=0}$) is proportional to the gradient of the Minkowski time coordinate m^0. One can choose the coordinates in such a manner that $m^0 = f(x^0)$. It seems that wormholes can transfer the energy between two space-time sheets having finite time duration for which time flows in opposite direction: the gradient of $m^0 = f(x^0)$ must change sign inside the wormhole and therefore $f(x^0)$ must have vanishing derivative at some 3-dimensional surface X^3 inside the wormhole. The energy densities at different sides of this surface must become infinite with different sign but the magnitudes of the energy densities must become same at X^3. Under these conditions the energy densities sum up to zero at X^3 as they should. If one allows edge in the wormhole then energy densities remain finite and have opposite sign at the edge.

1.2. Gluing two space-time sheets together along their space like boundaries

One can also glue space-time sheets together along regions associated with their boundaries. The formation of join along boundaries contacts, which serves as a necessary prerequisite for the formation of macroscopic quantum systems, provides a representative example of this. One can however consider also the possibility that gluing takes place along *space like* (!) parts of the space-time boundary. For

vacuum extremals with finite time duration the moments of "birth" and "death" indeed correspond to space like boundaries. If isometry currents remain finite everywhere, the surfaces must be glued to each other along space like 3-edges. The discontinuity of the derivative of $f(x^0)$ is not a problem since field equations reduce to the conditions stating that isometry currents are continuous at the edge. If edges are not allowed, isometry currents must become infinite at the surface at which $f(x^0)$ has vanishing derivative just as in the case of wormholes.

Admittedly, in case of Minkowskian signature of the induced metric the unavoidable singularity might make the realization of mind like space-time sheets in this manner impossible. The induced metric can have Euclidian signature also for space-time sheets expressible locally as graphs of maps from M^4 to CP_2. Since Poincare invariance is realized at the level of the imbedding space, there is no deep reason forbidding non-vacuum space-time surfaces of this type. In particular, the space-time sheets can be closed (no boundaries) and in this case they are automatically vacua globally although the classical charge densities associated with various sheets can be (and probably are) non-vanishing. In this case it might be possible to have completely regular time loop like solutions representing pairs of mind like space-time sheets. Since also CP_2 type extremals possess an Euclidian signature of the induced metric, one could consider the possibility that matter and mind quite generally correspond to Minkowskian and Euclidian signatures of the induced metric respectively!

2. Zero energy fermion pairs in time loops

A possible realization of the fermionic Boolean algebra relies on fermion-antifermion pairs such that fermion and antifermion reside on separate space-time sheets. This realization makes possible to change the values of the Boolean statements by the annihilation or creation of fermion-antifermion pairs. The optimal situation is achieved if the net quantum numbers, in particular the total energy of the pair, vanish. In this case the physical realization for the Boolean mind involves no energy in accordance with the intuitive idea that mind is in some sense something "nonphysical". The idea of mind like space-time surfaces as a classical analog for virtual bosons indeed generalizes to the fermionic sector.

For simplicity, consider a pair of space-time sheets glued together to form a double-sheeted structure. In principle, Dirac equation for the induced spinors allows global solutions also in this case. The conservation of the isometry currents for various modes of the Dirac equation at the ends of the space-time sheets can be treated just as it is treated in the bosonic case. Again it can happen that the density of some isometry currents, in particular energy current, associated with a given fermion mode diverges at the 3-surface, where the function $m^0 = f(x^0)$ achieves extremum value. zero energy fermions rotating in time loops are expected also in the case of a mind like space-time sheet glued to a material space-time sheet. Note that for space-time surfaces which are closed (without boundaries) absolute minima of Kähler action with induced metric having Euclidian signature, there are no problems with regions at which signature of induced metric changes and one can have modes of induced spinors satisfying classical Dirac equations.

Quantum mechanically zero energy fermion pairs are analogous to virtual fermion-antifermion pairs created from vacuum and physical representations for the elements of the fermionic Boolean algebra representing thoughts are created by oscillator operator pairs. Rather interestingly, the states for the fermionic representations of the Boolean algebra occur always as pairs with statement and its negation residing at different space-time sheets. One could perhaps say that two-sheetedness is necessary in order to create the idea of the logical negation at the level of conscious experience.

A criticism against above argument is that it is based on classical Dirac equation and not formulated at the configuration space level. The fermions associated with configuration space metric are assumed to have a vanishing four-momentum automatically. It is not clear how this relates to the induced Dirac equation which gives additional constraint and which also at least formally allows to assign four-momentum to the solutions of the Dirac equation.

Second objection is that robustness and stability require a realization of cognitive representations using many-particle systems [H8]. Therefore single fermion should be replaced by a magnetized ensemble of fermions and the direction of magnetization would represent Boolean yes and no.

Is there empirical evidence for negative energy fermions?

Is there any empirical indications for the existence of negative energy fermions? There are several reports about various anomalies associated with rotating magnetic systems, and the TGD based

explanation for the anomalies reported by Godin and Roshchin in [17] involves in an essential manner the generation of negative energy space-time sheets at which a population of negative energy particles is generated. The explanation of the anomalies leads to suspect that, besides negative energy photons and gravitons, also negative energy partners of ordinary ions might be present on negative energy space-time sheets.

7.4 Good and Evil, Life and Death

In principle the proposed conceptual framework allows already now a consideration of the basic questions relating to concepts like Good and Evil and Life and Death. Of course, too many uncertainties are involved to allow any definite conclusions and one could also regard the speculations as outputs of the babbling period necessarily accompanying the development of the linguistic and conceptual apparatus making ultimately possible to discuss these questions more seriously.

Even the most hard boiled materialistic sceptic mentions ethics and moral when suffering personal injustice. Is there actual justification for moral laws? Are they only social conventions or is there some hard core involved? Is there some basic ethical principle telling what deeds are good and what deeds are bad? Second group of questions relates to the physical death. What happens in the physical death? Is self preserved in the physcal death in some form? Is there something deserving to be called soul? Are reincarnations possible? Are we perhaps responsible for our deeds even after our physical death? Could the law of Karma be consistent with physics? Is liberation from the cycle of Karma possible?

In the sequel these questions are discussed from the point of view of TGD inspired theory of consciousness. It must be emphasized that the discussion is chronological sequence of various points of view rather than final summary. Also mutually conflicting points of view are considered.

The localization in zero modes occurring in each quantum jump allows to identify evolution as a gradual increase of the p-adic prime characterizing the Universe: the natural ethics identifies good deeds as the selections promoting evolution and selves act as moral agents.

The cosmology of consciousness, the concept of self and the concept of mind like space-time sheet provide the building blocks needed to construct models for what might happen in the physical death. One can also imagine models for reincarnation. Even the conditions under which the law of Karma could be realized, can be discussed.

One of the purely p-adic aspects of NMP is the possibly of $S \leq 0$ selves (selves whose all subsystems have positive entanglement negentropy). These selves seem to represent "asymptotic selves" and hence could provide a model for "liberated souls" in state of cognitive enlightment. Amusingly, "liberated souls" have a direct geometric counterpart as closed (vacuum) absolute minima of Kähler action in accordance with quantum-classical correspondence principle, which has gradually gained the status of the basic heuristic guiding principle of the TGD inspired theory of consciousness.

The section is concluded with a discussion about what might expect us after the physical death, now from the point of quite recent view about psychological time as characterizing the front of p-adic-to-real transition representing volitional actions. This identification provides rather concrete view about consciousness after death and is forced by very general consistency conditions. The fusion of these ideas with the other views discussed in the section is not even attempted and it remains to find out in which aspects various ideas are mutually consistent and which are not.

7.4.1 Quantum ethics very briefly

Localization in zero modes implies p-adic evolution as a gradual increase of the infinite p-adic prime characterizing the entire universe. This evolution means also the evolution of consciousness. p-Adic evolution has rather surprising consequences. For instance, it seems that one could even understand the origin of moral.

Selves have free will and subjective past and hence can act as moral agents. Volition corresponds basically to the selection between various degenerate absolute minima of Kähler action characterized by different infinite p-adic primes. Infinite p-adic primes decompose in a well defined sense to finite primes characterizing material and mind like space-time sheets and increase or reduction of infinite prime is induced from that of a finite prime so that global evolution is induced by local evolution. The

reduction of evolution to local evolution implies that our choices, although are between finite p-adic primes, affect global evolution, which is much more general concept than biological evolution.

The identification of p-adic space-time sheets as representations for intentions and the identification of p-adic-to-real phase transitions as transformations of intentions to real actions gives additional concreteness to this vision. The identification of the psychological time as the value of the geometric time characterizing the phase transition front at which p-adic-to-real phase transitions mostly occur, allows to understand psychological time as the time value around which volition is strongly concentrated.

The ethics is simple: evolution is the good thing. Therefore the increase of p is good and reduction of p is bad. There are two options for identifying moral choice: either the p:s characterizing initial and final sectors D_p are compared or the p:s characterizing various possible final state D_p:s are compared. The latter option does not look so plausible since it predicts that our moral choices are between infinite number of possible alternatives. In accordance with Hume's law values (in fact all qualities) belong to the realm of subjective existence (quantum jumps) rather than being properties of the objective world (quantum histories).

Moral rules are related to the relationship between indvidual and society and presumably develop via self-organization process and are by no means unique. Moral rules however tend to optimize evolution. There is entire hierarchy of selves and every self has the selfish desire to survive and moral rules develop as a kind of compromise and evolve all the time. The newest progress in this evolution is brought by the cosmology of consciousness, which forces to extend the concept of society to four-dimensional society! The decisions of "me now" affect both my past and future and time like quantum entanglement makes possible conscious communication in time direction by sharing conscious experiences. One can therefore speak of genuinely four-dimensional society. Besides my next-door neighbors I had better to take into account also my nearest neighbors in past and future (the nearest ones being perhaps copies of me!). If I make wrong decisions those copies of me in future and past will suffer the most. Perhaps my personal hell and paradise are here and are created mostly by me.

7.4.2 Ageing and death

Quantum jumps inside self give rise to dissipation so that one can say that physical ageing is the price paid for having self. More concretely, the self representing body image becomes entropic since the corresponding statistical ensemble grows in size quantum jump by quantum jump. The process of ageing could be a process analogous to the process of getting drowsy and falling asleep but in much longer time scales. The process would involve generation of temporal entanglement of sub-selves of self with larger selves. Sub-selves presumably define also conscious clocks. If the average number of quantum jumps per geometric time for sub-selves representing conscious clocks is reduced, geometric time is experienced to flow with increasing rate towards the older age. This could be also due to the increasing role of macro-temporal quantum coherence: periods spend in a state in which quantum jumps effectively fuse to single quantum jump could be experienced as single moment of consciousness. The opposite situation would result in the experience of becoming bored.

Perhaps the process of ageing could be a process of personal growth (in a rather concrete sense!). The temporal entanglements generated between real selves and larger real selves (real self is labelled by the p-adic prime characterizing the p-adic topology which it is near criticality to transform to) would give rise to larger temporal selves and the metaphor "awakening" would thus be much more than a metaphor. Person would spend more and more time in extended state of consciousness and in death finally leave the confines of the physical body. This would make possible the evolution of selves continuing after death to higher levels of conscious existence. This picture is rather optimistic. Of course, one must also consider the possibility that the evolution of self is not continuous growth! The fact that the individual development of many people seems to be a process of continual abstraction indeed that physical death is only one step in the process of abstractions and that our self consciously experiences the final transition to higher level of existence in the physical death.

Universe is full of selves and one cannot say anything definite about the fate of self after death unless one can decide which self can be regarded as the continuation of self before death. Since self has extension with respect to geometric time, it has memories about its earlier history and one could perhaps identify the continuation of self after the death as that self which has the geometric memories of self before death. For instance, mental image of self could entangle with a higher self with subjective

memory of order of lifetime of self. In this extended state of consciousness self could experience the subjective past of self's space-time sheet and associate it with self's recent mind like space-time sheet. Note that this kind of mechanism could also explain why it is possible that I regard it obvious that I existed yesterday although my bodily self slept over night. Of course, the very fact that we can remember our yesterday self although our subjective (short term) memories seem to be of order few seconds, suggests that it is also possible to remember something about previous life, at least for some time after the death: we actually die all the time!

The basic idea of most religions is that people must atone for their sins sooner or later. Something akin to the law of Karma could indeed be realized. The nature of the self carrying my memories after my physical death defines my reincarnation. This self can be either lower or higher in the hierarchy of selves than my self before death depending on the value of the p-adic prime characterizing its space-time sheet. Note that personal p-adic evolution is in accordance with quantum-classical correspondence principle and p-adic evolution at the level of configuration space. Now the personal p-adic prime could however be associated with real space-time sheets in the manner already described. If one accepts that there is an infinite hierarchy of selves with free will, one cannot exclude the possibility that the selves at the same or higher levels of the hierarchy are willing to affect our fate after death just like we can affect the fates of our individual cells ane mental images (however unpleasant this possibility might sound in the ears of the hedonistic modern man!).

Quantum-classical correspondence principle suggests that the endless self-evolution of universe could correspond to an endless self-evolution at the level of individual. If self and mind like space-time sheets are firmly associated with each other, the question about the reality of physical death reduces to the question about the fate of the "personal" mind like space-time sheet after death. Geometrically the fate of the self after death could perhaps be described as a formation of join along boundaries bonds between the mind like space-time sheet of self and the mind like space-time sheet of self at some level of the hierarchy of selves.

7.4.3 Death as disappearance of the mental image representing the physical body?

If one takes seriously the following two assumptions behind the TGD based model of quantum control and coordinate based on the symbiosis of MEs, magnetic flux tube structures, and matter at the atomic space-time sheets, one ends up with rather concrete view about what happens after the bodily death.

1. Our mental images actually correspond to ELF and even ULF MEs of size of order $L \sim \lambda = c/f$, where f is the frequency in question (not above EEG range), so that the sizes of these mental images are measured using Earth size as a unit. Sizes of MEs of order light life are possible.

2. The ultimate sensory representations are realized on the magnetic sensory canvas provided by magnetic flux tube structures of similar size, so that we have magnetic body providing sensory representation of the physical body and external world [H4]. Our magnetic self very probably survives in the physical death simply by the conservation of the magnetic flux and large size of the magnetic selves forbidding the disappearance of the magnetic self.

Under these assumption our afterlife body would consists of the magnetic body plus MEs possibly surviving the death of the so called physical body. The only difference as compared to the life before death would be that the sensory and mental images representing the physical body (sub-selves) would disappear and the attention of our self would be directed to something else. Near death experiences indeed support this view [I3]. In this picture re-incarnation is possible and even plausible and means only that the magnetic flux tube structure representing our bodily self turns its attention to some other physical body and uses it as a sensory and motor organ. This new physical body could be plant, animal, human, or perhaps something else. In this picture the metaphor about physical body as a cloth becomes very concrete.

Since self has an extension with respect to geometric time, it has memories about its earlier history and one could perhaps identify the continuation of self after the death as that self which has the memories of self with respect to geometric time before death. In this extended state of consciousness self could experience the subjective past of self's mind like space-time sheet and associate it with self's recent mind like space-time sheet. Note that this kind of mechanism could also explain why it

is possible that I regard it obvious that I existed yesterday although my bodily self slept over night. This picture is consistent with the reported ability of some children to remember their past lives.

7.4.4 How the law of Karma could be realized?

The existence of self hierarchy means that our deeds are remembered also after our death at higher level of self hierarchy although only as an abstracted summary. One can therefore ask whether the law of Karma or something akin to it might be implied by basic principles of consciousness theory.

First of all, self has two life strategies: be a sinner or saint.

1. Self can fight for the metabolic energy feed giving rise to the self organization of self. This strategy works as long as self is a young, brisk and arrogant sinner. Sinners are not desirable mental images from the point of view of higher level self since they induce a lot of entropic mental images (pain). This strategy is also in conflict with the possible goal of the higher level self to achieve fusion of its own mental images.

2. Self can attempt to share mental images by quantum entangling its sub-selves with the sub-selves of other, possibly, higher level selves. This mechanism gives rise to quantum metabolism and expanded states of consciousness, favors the generation of social structures, and means fusion of mental images from the point of view of higher level self. The cognitive mental images of the saintlike self are highly negentropic and favored by p-adic NMP.

On basis of these findings the policy for higher level selves looks obvious: try to get rid of the unpleasant mental images represented by sinners. Higher level self could apply this policy for purely selfish reasons: too bad sinners might affect like a poison to the moral level of the higher level self and, since the law of Karma is universal, could eventually lead to the decline of the higher level self to a lower level of the hierarchy: the world would seem to be a tough place also after death!

Indirect support for the survival of mind like space-time sheets after death (and for reincarnations) comes from rather unexpected direction. The phenomenon of phantom DNA suggesting that mind like space-time sheets associated with DNA remain in the chamber which contained DNA: in the experiments of Poponin [36] the signature of phantom DNA is its interaction with laser light. For TGD inspired explanation of the phenomenon see [J5]: two peculiar phenomena with a common explanation". The claimed successes of homeopathy could also have explanation in terms of mind like space-time sheets. Homepathic drugs are fabricated by a repeated dilution of the active drug so that the concentration of the drug in solution becomes extremely low. The method of fabrication could however imply that final product contains quite many mind like space-time sheets of the drug molecules and that these mind like space-time sheets are able to affect the sickness. The law of similarities could have something to do with the mechanism involved.

Some support for the extension of self in death is provided by near death experiences. For instance, looking one's body from outside could mean that self is entangled with a larger self formed by the personnel of hospital in the hospital room and sees patient's body with the eyes of the personnel. This experience could be understood as experience of, say self representing hospital room: in this experience the visual experiences of persons in the hospital room would fuse to the experience experienced by patient entangled with the hospital room. Meeting one's relatives and elders could mean entanglement with a larger self formed by the selves of dead and living relatives. This larger self could experience the abstracted experiences of dead and living relatives. Also the ability of subjects of surgical operations to occasionally remember about events occurred during unconscious state, supports this view. Magnetic flux tube structures are the most plausible candidates for the 'body' remaining in physical death: this point is discussed in more detail in [I3].

7.4.5 What 'liberation' might mean?

The strong analogies with Buddhism encourage to ask whether the TGD inspired quantum counterpart for the Buddhist concept of liberation might make sense. Quantum-classical correspondence principle suggests that the endless p-adic evolution at the level of the entire universe corresponds to endless evolution at the level of individual so that the notion of liberation would make sense only as kind of temporal transformation to a higher level of consciousness.

In the real context selves having only single mental image are in state of 'oneness' and experience no divisions and separations since the analysis process represented by state function reductions and self measurements is absent. This kind of state realized at the level of field body is a possible candidate for enlightened state. Certainly it cannot last forever.

Self can have also cognitive mental images or be a cognitive mental image. An attractive identification of these mental images is as p-adic $S \leq 0$ selves discussed in [H2]. $S \leq 0$ selves can be defined as selves for which all subsystems have $S \leq 0$ entanglement. It is easy to see that in case of two entangling p-adic systems $S = 0$ entanglement is unstable unless the number n of entangled states is smaller than p. If it is larger than p, NMP forces quantum jump to a state containing $p^N k < n$ entangled states with identical entanglement probabilities. One might think that 'liberated soul' could possess this kind of cognitive mental image or mental images interpretable giving rise to experience of enlightened understanding. Also this state is in principle unstable against unitary process. Perhaps one could say that 'liberated souls' get at least momentarily rid of the wheel of Karma resulting from attachment to sensory experiences.

Liberation experience as "cosmic consciousness"

Liberation experience might also relate to the experience of "cosmic consciousness". The fear about the loss of consciousness is what gives self an ego, since ego is something which can be lost. This can happen via the generation of bound state entanglement with some other system. This can happen for any subsystem of Universe but not for entire Universe enjoying an eternal state of consciousness. The state of cosmic consciousness thus means being a self without ego. Leaving aside the question whether we are able to experience ideal cosmic consciousness, one can consider the possibility that even human beings could achieve a state of consciousness in which the loss of consciousness is highly un-probable and that this loss of ego is synonymous with the experience of liberation.

The term "cosmic consciousness" looks somewhat pompous notion to anyone identifying himself with his suffering biological body and it would be certainly very difficult to sell this concept to a neuroscientist. This notion might however have a rather literal meaning. If p-adic- and real-rational imbedding space points are related via the identification of common rational points, p-adic space-time sheets typically have an infinite size with respect to the real topology since p-adically infinitesimally small distances necessarily correspond to infinite real distances. In this cognitive sense cosmic consciousness would have surprisingly concrete meaning. On the other other hand, if rationals belonging to various p-adic number fields are identified via the map $r/s \to I(r)/I(s)$, where I is canonical identification, situation changes and p-adic and real sizes correspond to each other. This identification respects rational variants of various symmetries only in the limit $p \to \infty$. These widely different options correspond to two different manners to fuse real numbers and various p-adic number fields to a larger book like structure by gluing these number fields together along common rationals (they gluing could be performed also along common algebraic numbers).

'Liberated souls' as $S \leq 0$ selves

The formulation of NMP in p-adic context is not totally fixed yet.

1. In the original formulation the real counterpart of the p-adic entanglement entropy was defined by canonical identification and was automatically non-negative.

2. It has however turned out that the identification of the real counterpart of p-adic negentropy via the identification by common rationals is much more natural option if entanglement coefficients are rational numbers so that entanglement probabilities are algebraic numbers. Most importantly, entanglement negentropy is positive for p-adic quantum computer type states. Among other things, this allows to understand what it is to understand.

$S = 0$ selves are very interesting limiting case.

1. $S = 0$ selves are defined as p-adic selves for which all subsystem-complement pairs have vanishing entanglement entropy. This means that entanglement probabilities have unit norm. $S = 0$ selves are possible for both definitions of the real counterpart of the p-adic entropy but for the option b) $S = 0$ self is stable against self measurement only provided the number of the entangled states is smaller than p.

2. If the density matrix is the fundamental observable, the allowed quantum jumps of $S = 0$ selves occur to the subspaces of the eigenspaces of the density matrix of some subsystem-complement pair and lead to $S = 0$ a quantum computer type state.

3. If the p-adic entropy operator is the fundamental observable, NMP says nothing about the behavior of $S = 0$ selves. This in principle allows $S = 0$ selves to have extended free will. NMP does not specify the subsystem performing the quantum jump: the density matrix of any subsystem can be measured. $S = 0$ self can also refuse to perform any quantum jump and experience the reality as it is. Using Buddhist terminology, one could call $S > 0$ entanglement as attachment whereas $S = 0$ entanglement could perhaps be identified as a state of pure love and $S < 0$ entanglement as a state of understanding (and pure love).

In the real context NMP forces a complete selection of final state even when the density matrix is degenerate unless bound state entanglement is in question: this has interpretation as a necessity to select between logically inconsistent alternatives. In quantum jumps to entangled state this kind of choice is not performed: final state is like the superposition of dead and living Schrödinger cat. Therefore $S < 0$ entanglement would provide the p-adic loophole allowing to cognitively experience what it is to be entangled. Zen Buddhists experiences are often characterized as states of consciousness in which no selection is made between mutually exclusive alternatives. Hofstadter has described this aspect of Zen in enjoyable manner in his book "Gödel, Escher, Bach". $S \leq 0$ property of self means absence of entropy and this could be interpreted as the absence of illusions and even as genuine cognitive information and understanding. The absence of illusions and of dissipation and many-valued logic of subjective experience, and perhaps even extended cognitive free will in case of $S = 0$ selves, are features which make $S \leq 0$ selves rather special creatures and one could perhaps call them "liberated souls".

What is exciting is that $S \leq 0$ self can correspond to a fixed point of evolution dictated by NMP just as thermal equilibrium is the fixed point of evolution dictated by the second law of thermodynamics. This kind of selves could be generated as a result of repeated quantum jump in which various $S > 0$ subsystems of self quantum jump to a state with $S \leq 0$ entanglement. The probability that this kind of quantum jumps occur is large since the p-adic probabilities involved have unit p-adic norm. Hence $S \leq 0$ selves could quite well correspond to asymptotic selves. Of course, the unitary process U can destroy $S \leq 0$ self or even entangle entire $S \leq 0$ self with a larger self. In case that $S \leq 0$ property is destroyed, self can however perform quantum jumps which re-establish $S \leq 0$ property and by NMP these quantum jumps have high probability of occurrence.

'Liberated souls' geometrically

One can wonder what might be the geometric counterpart for a 'liberated soul'. Buddhas are typically described as jovial persons staring reflectively at their own navel. Amusingly, quantum-classical correspondence principle suggests that $S \leq 0$ selves correspond geometrically to closed (sic!) absolute minima with finite time duration. The fact that these surfaces are vacua suggests that universe could be full of $S \leq 0$ selves in the state of cognitive Nirvana!

1. These absolute minima are automatically classical vacua globally and most naturally possess globally Euclidian metric. Kähler action is negative for Euclidian signature of metric so that absolute minimization of Kähler action favors the formation of these objects. CP_2 type extremals provide simplest examples of this kind of vacua but the size of closed absolute minima can very probably be arbitrarily large. Note that these surfaces are very much like vacuum bubbles of quantum field theory. By vacuum property the inertial mass of liberated soul vanishes. Also the gravitational mass must vanish by a classical, non-relativistic argument: gravitational mass corresponds to a gravitational flux expressible as a surface integral and the gravitational fluxes from the two space-time sheets must cancel each other. Presumably this holds true also for the topologically condensed Buddhas.

2. Extended free will corresponds geometrically to the fact that the association sequences associated with closed absolute minima can contain arbitrary many 3-surfaces with time like mutual separations. $S = 0$ selves can remain selves only if they are able to remain unentangled with the external world. The geometric counterpart of the entanglement is the formation of join along

boundaries bond between boundaries of self and of external world. The fact that closed vacuum absolute minima cannot form join along boundaries bonds, suggests that closed absolute minima, which are automatically vacua, give rise to stable $S = 0$ selves: note that these mind like space-time sheets would be purely "mind like" in accordance with the basic idea about liberation as liberation from confines of material existence. This identification is indeed consistent with the idea that liberated soul should not have painful sensory experiences, should be free of all the daily troubles caused by the gravitational force and dissipation, and be able to preserve the state of $S = 0$ entanglement.

3. Closed absolute minima can also contain zero energy fermion pairs (any solution of induced Dirac equation represents this kind of pair) so that also reflective consciousness is possible and in fact all fermions can contribute to it unlike in case of the ordinary matter-mind type selves for which only zero energy neutrino pairs seem to provide realization of logical thought. The solutions of the induced Dirac equation representing zero energy fermion pairs represent the fermionic counterparts of vacuum bubbles. Physical constraints give no upper bound for the density of the closed absolute minima of Kähler action and this raises the possibility that the Universe is full of enlightened Buddhas and consciousness as we know it is only an exotic and very special form of consciousness!

4. The construction of infinite primes gives additional support for the identification. Infinite primes of form $X \pm 1$ do not correspond to any decomposition of the space-time surface to material and mind like space-time sheets. There is however natural interpretation of 1 as set of closed absolute minima representing enlightened selves in the state of "one-ness"! "1" is factor in the finite part of any infinite prime so that this factor would represent quite generally closed vacuum extremals in Buddha state!

How to observe 'liberated souls'?

Even liberated souls are physical objects and one can ask how to observe them. Liberated souls have vanishing classical charges and extremely weak direct interactions with the material word. The interaction of the coherent photons with the charged # contacts possibly associated with topologically condensed souls could however make possible scattering of the coherent photons from souls such that part of the energy momentum of the topologically condensed photon goes to the material space-time sheet. Charged # contacts couple to the difference of the gauge potentials describing topologically condensed photons of the coherent light on the two space-time sheets [J5]. If soul has charged # contacts with a surface containing matter, one can create a beam of topologically condensed coherent light on the material space-time sheet and allow it to scatter from the soul. Also the interaction of soul's # contacts with matter ordinary matter via classical electromagnetic fields is possible. Of course, liberated souls need not have any em charged # contacts to material space-time sheets so that interaction would reduce to extremely weak gravitational interaction of quadrupole type.

The communication with topologically condensed liberated souls is however possible via the direct subjective experience! A soul which has topologically condensed to the space-time sheet of self, is experienced as a mental image, perhaps even rather enjoyable mental image! Perhaps enlightened souls correspond to memes, pure ideas!

Do liberated souls leave black holes behind them?

Black hole definitely represents a failure of the General Relativity. Thus it should represent also the door to the new physics. Topological evaporation, one of the most obvious implications of TGD, in turn represents something totally new, and it has taken frustratingly long time to decide whether topological evaporation should be taken seriously or not and what it really means. Therefore it would have seemed natural to try to find connection between black holes and topological evaporation. Unfortunately, the logic of discovery does not obey this kind of simple rules and it took twenty four years before I realized the connection.

If the interpretation of gravitational mass as a charge analogous to gauge flux makes sense, the gravitational mass of a completely topologically evaporated space-time sheet must vanish. If one assumes Equivalence Principle this means that also the inertial mass is vanishing and the system is 'feather-light'. Therefore the topological evaporation of a system, if it is possible without the loss of

the identity of the system, would liberate system completely from the constraints posed by gravitation and other classical long range forces. The evaporated system would leave its gravitational and inertial masses to the space-time sheet from which it topologically evaporates as 'surface charges'. The evaporated system itself would carry neutralizing negative gravitational and inertial masses as surface charges at the boundary of the space-time sheet representing the system. Topological evaporation could be also partial and would lead to a partial loss of the gravitational and inertial masses. What would be left in a complete topological evaporation would be only these surface charges which still are 'seen' at the space-time sheet at which the system was topologically condensed. All information possessed by the larger space-time sheet about system's interior would be lost since the evaporated system could easily fleet to another galaxy. This information would be however still there.

This brings in mind black holes: perhaps black hole is left in a complete topological evaporation. Black hole has no hair and is characterized only by mass, angular momentum, and some charges just like also the hole(s) created in topological evaporation. The basic mystery of black hole physics is whether the huge amount of information associated with the physical configuration of the star interior is really lost in the formation of black hole or whether it is somehow preserved. In TGD framework the optimistic option would be realized: the evaporated system liberated from the constraints of gravitation and other classical long range interactions would represent, the information theoretic essence, the 'soul', of the star when it reaches it final stage of evolution. The star would not die in the sense that huge amount of information would be lost. Of course, also other systems than stars might evaporate in a similar manner and become 'liberated souls'.

What kind of mechanism could cause the topological evaporation? If the space-time sheet associated with the system is bound to a larger space-time sheet with the mediation of thread like join along boundaries bonds feeding its gravitational flux to the external world, a rapid rotation of the system might lead to the entanglement of these threads followed by a splitting analogous to what occurs in the reconnection process of magnetic field lines. This kind of process could lead to a partial loss of gravitational and inertial masses and make 'flying saucer' technology possible. There is evidence that spinning magnetic systems can lose part of their gravitational and inertial masses [17], and in [G2] these anomalies are discussed. A typical signature would be spontaneously accelerated spinning due to the angular momentum conservation. These effects depend on the direction of rotation and thus break parity conservation and the explanation of these effects involves also classical weak force in an essential manner.

UFOs might apply this technology. The strange butterfly motion of UFOs is impossible in present technologies if UFOs are really 'copper and steel' as it seems to be the case at least in case of some UFOs. No strong atmospheric recoil effects such as shock waves are observed which suggests that the inertial masses of UFOs are very small. These findings make sense if the reduction of the inertial mass due to a partial topological evaporation induced by a rapid spinning.

The plasma ball like structures often associated with UFOs might represent genuine life forms having very small inertial mass thanks to the proposed mechanism. In [N1, N2, N3] the idea that plasmoidic life forms serve as "mediums" entangling with the observer of ET and with ET is discussed and thus making possible telepathic sharing of mental images between life forms separated by an astrophysical distance. The obvious question is whether these plasmoid like structures might be "liberated souls" in the proposed sense.

7.4.6 What after the physical death?: the vision provided by a more precise view about psychological time

The view about psychological time as the value of the geometric time characterizing the phase transition zone around which volition is strongly concentrated and the identification of volition as p-adic-to-real phase transition was already found to have rather non-nontrivial implications concerning the understanding of psychological time (see section 'More detailed ideas about psychological time'). This vision provides also quite concrete views about the nature of consciousness after the physical death. Recall that the basic concepts and ideas are following ones.

1. 4-D body which grows during the lifetime and becomes fully developed in the physical death. This state can be however unstable against real-to-p-adic phase transitions leading to deconstruction/decay processes.

2. The protein metaphor allowing to relate the growth of the 4-D body in the direction of the geometric future with the growth of a protein in mRNA-protein translation.

3. p-Adic-to-real and real-to-p-adic phase transitions as processes which allow to construct 4-D body gradually like artwork by repeated trial and error process with wrong constructions followed by deconstructions (healing process would be typical example of this). At the level of human consciousness error would mean wrong choice during 4-D growth and to un-ethical behavior.

The basic view is that physical death is only apparently an end. Natural physical death means that personal self-organization pattern becomes completed just like a protein becomes completed during the translation process. Un-natural physical death would mean that part of the plan remains un-fulfilled and the resulting structure is geometro-temporal torso. The contents of consciousness of a bodily dead self would be more or less timeless and radically different from our ordinary highly volitional consciousness getting dominant contribution from the phase transition front. Those in the phase transition front would experience the deceased as long term memories as long as its 4-D body exists.

There are several questions to be answered.

1. Is the mature 4-D body stable or does it possess finite subjective lifetime (note that this 4-D decay process has nothing to do with the physical decay process proceeding towards the geometric future although it could be initiated immediately after this process)? Polymerization metaphor supports this view but also suggests that the mature 4-D body has a finite subjective lifetime. The fact that our long term memories about the deceased are not eternal, suggests that this 4-D body decays sooner or later, at least partially.

2. If 4-D physical body eventually decays completely or partially, what is the mechanism by which it decays? Could this process could occur backwards in the geometric time as a reverse phase transition changin actions to intentions and be followed by a new phase transition giving rise to a new life? Or could it occur simultaneously along the entire geometro-temporal span of 4-D body? Whatever the answer might be, it would seem that this process should be initiated by some seed of the phase transition and proceed then over some region of the 4-D body.

3. Could the phase transitions affect only a finite portion of 4-D body and could one consider a process in which the 4-D body is gradually built-up like an artwork via a trial-and-error process?

4. What is the role of the other selves of the self hierarchy? The stability of a protein depends strongly on its biological environment: in vivo the behavior is quite different from that in vitro. The same might hold for 4-D physical bodies. This brings in mind the fate of a cancer cell in organism. Other selves could induce a partial or complete decay of the 4-D body of self which behaves like a cancer cell and support the the survival of a 'well-behaving' 4-D body.

5. If the phase transition front is common to the members of the society, physical death is experienced by others with its usual meaning. This assumption saves from several paradoxes. But what about the counterpart of the physical death occurring in the geometric past? Is it possible at all or is it like a wound in 4-D body which is healed? It seems that a quantum jump having permanent effects is extremely unprobable since it would be accompanied by infinitely large changes in the geometric future.

Is the subjective lifetime of 4-D body finite?

The reduced non-determinism in the geometric past does not favor the decay process so that the 4-dimensional body could be relatively stable and could perhaps be seen as an approximate geometric correlate for the subjective past which does not change at all. This does not of course exclude the gradual evolution of the 4-D body but the conscious experience during this stage of evolution would be totally different since it would receive its contents from the entire duration of the life cycle.

Quantum criticality of the TGD universe suggests that 4-dimensional self-organization patterns have a finite subjective lifetime which in principle has nothing to with geometric lifetime and could be much longer. Quantum criticality of the TGD universe suggests also that the p-adic-real quantum phase transition defining the front of volitional consciousness can occur also in the reverse direction,

at least temporarily. The phase transitions and their reversals could occur in many manners and be also partial. Life as an artwork view suggests that 4-D body could be build-up gradually by making the reverse phase transition up to the critical moment of life when the wrong choice was made and starting again. One could see the unstability of the 4-D body as the basic cause of reverse phase transition so that the process would automatically lead to an increasingly stable situation leading asymptotically to what might be perhaps called a Buddha state. Of course, there is no guarantee about anything absolutely stable and entire sequence of biological lifes is possible. This sequence of biological lives brings in mind the cycle of Karma and would be the 4-dimensional analog for cell death and regeneration.

The reverse of the p-adic-to-real phase transition would mean that the arrow of the psychological time changes temporarily. From my own 'great experience' during which I was some period of time unconscious in clinical sense I remember the fight against the reversal of time arrow. Perhaps this was actually a fight against the initiation of a process in which some actions transform back to intentions. These temporary reversals of time's arrow would provide an error correction mechanism making possible to refine the carving of the four-dimensional body.

Consider now the arguments in favor and against the view that the subjective lifetime of 4-D body is finite.

1. One signature of the 4-D decay process would be the disappearance or at least the weakening of the long term memories about the deceased resulting from the fact that there exist no 4-D body communicating these memories anymore and only secondary memories resulted in memory recall processes remain. The deceased would rather literally live as our memories. Since the memories about deceased usually tend to fade away this would suggests that 4-D body is indeed unstable. On the other hand, since the long term memories about the deceased do not disappear immediately, it would seem that the decay process does not start immediately and/or that the decay front proceeds to the past with perhaps same velocity (increment of the geometric time per quantum jump) as the growth process. Persons like Buddha who are regarded as immortal in a metaphoral sense would thus be also in a concrete sense, if not immortal, at least very longlived and live as long as the society remembers them. They could even be kept alive by the society.

2. This is not the only possible explanation. The model of long term memory [H6] predicts that there is an upper bound for the length of MEs giving rise to long term memories. The length of ME would actually correspond to the frequency of a transition in which ME is generated. According to the model of long term memory it would be a spin glass transition between two configurations of the classical gravitational field with same induce Kähler field and gravitonic ME would be in question.

3. Wernicke syndrome is a tragic loss of long term memories in which the immmediate past of the patient (often alcoholic) consists only of few minutes: the destruction of mammillary nuclei is involved with this syndrome. The temporal boundary between what is recalled and what is not proceeds gradually to the direction of past during the development of the syndrome and stops to some critical moment of time. Hence the memories of the earlier life are preserved up to some critical moment. Neuroscientists would presumably say that only the ability to build long term memory representations from the sensory input is lost in the Wernicke syndrome since mammillary nuclei are destroyed. This does not however explain why the front of lost memories proceeds to the direction of past.

   A more refined explanation is that some part of the 4-dimensional body of the patient, presumably mammillary nuclei crucial for the build-up process of the sensory and cognitive representations, become unstable and decays. In terms of the protein metaphor, the polymerized protein begins to depolymerize at some moment of time and the depolymerization front proceeds to the direction of the geometric future with the same rate as polymerization. Depolymerization would proceed also to the direction geometric past until it would stop. The explanation for the loss of long term memories suggest that the 4-D body has a finite subjective lifetime.

4. Many people at high age tend to lose their long term memories gradually but the childhood memories are the most stable. This could be interpreted as a partial decay of 4-D body analogous to what could happen also in the Wernicke syndrome.

Saints and sinners, heaven and hell

4-D bodies form a society analogous to a cell population. The fate of the cell in the population depends on its own behavior. The fate of a cancer cell is to die whereas the survival of the healthy cells is supported by the organism. Situation is expected to be the same in the society of 4-D bodies. This suggests one possible interpretation for the Buddhist visions about Karma and for the religious concepts of heaven and hell.

If the member of society is 'saint' enjoying respect and love, it is plausible that other selves support the survival of this 4-D body and catalyze various small scale healing processes helping to stabilize its 4-D body. Thus the saint would live relatively pleasant life in a deep meditation enjoying a timeless state of consciousness and being liberated from the the cycle of rebirths.

If self is 'sinner', that is represents a destructive 4-D subsystem analogous to a cancer cell, one could imagine that the regeneration process must start from the moment when the person made the crucial wrong decision (analogous to an error in the mRNA-protein translation). This requires a thoroughgoing, not necessary pleasant, 4-D decay process analogous to a depolymerization process and proceeding down to this fatal moment of geometric time when the first wrong choice was made. This de-construction process is followed by the reconstruction phase which has as the analog a polymerization process starting again from some point of the protein. The fellow human beings of the sinner would have their psychological nows in the geometric future and from the point of view of the sinner would show very little genuine volition. Thus the geometric past would look for the sinner like a kingdom of dead experienced by a living creature whereas the full-fledged 4-D bodies would experience this kingdom of dead differently, perhaps as a heaven! Heaven and hell would be thus relative concepts.

Are reincarnations in the geometric future possible?

The simplest view assumes that the front of volition does not propagate after the physical death. One could however consider the possibility that the front of volition continues to propagate by transforming p-adic magnetic or Z^0 magnetic mirror structures to real ones: volitional life would continue in electromagnetic form. This would make possible the communications of the deceased with living since the resulting magnetic mirrors could connect the deceased with the living. Since magnetic mirror structures are fundamental for the field realization of the genetic code, one can quite well consider the possibility that this process induces also the self-organization of the ordinary living matter around the magnetic mirror structures. This would have interpretation as a reincarnation. Buddhas able to resist the temptation to reincarnate would continue their life at the field level. Interestingly, the development of physics from Newtonian physics of the material bodies to Maxwellian physics of fields would mirror the evolution of consciousness from concrete biological life to life at the field level.

Are reincarnations in geometric past possible?

Usually reincarnations are thought to occur in geometric future. One could however approach the idea of reincarnation from a completely different view point. The simplest visualization for the cosmology of consciousness is as material space-time sheets populated by mind like space-time sheets drifting gradually to future. Thus also the material space-time sheets representing the life history of my body should be populated by these mind like space-time sheets and unless they are mutually entangled and are at the same level of self hierarchy, this train of mind like space-time sheets wandering through time can be said to represent my re-incarnations as long as the my physical body exists in the geometric past.

The fact that the contents of sensory experiences are sharply localized in geometric time, gives strong constraints on this picture. Sensory space-time sheets can have duration of only few seconds whereas "my" mind like space-time sheet could have much longer duration, even of order lifetime. If sensory space-time sheet populate "my" space-time sheet having much longer time duration, sensory space-time sheets can spend only few seconds in the state of "whole-body" consciousness (pure experiencing). After that sensory self must either fall asleep or go to a mode of "ordinary consciousness" in which it decomposes to sub-selves and analyzes its experience. This analysis period might be related to long term memories.

One could claim that the me's of the geometric past are genuine re-incarnations only if there is continuity of subjective experience involved in the sense that re-incarnation remembers something

about its former life in the geometric future. Some old people relive their childhood and youth. A possible explanation is that the space-time sheet representing new copy of self in the geometric past is entangled with the recent self and makes possible to experience new childhood (time like entanglement is indeed possible in TGD framework). In this process these pseudo "memories" would become more and more real and "reality" would become more and more like memories! This picture would allow the possibility of a smooth transition in which the "center of mass" psychological time of self gradually shifts to geometric past without any gap. Young child could still have subjective memories about the events in the geometric future: these memories would of course be experienced as belonging to subjective past. This sounds somewhat strange but actually it is not obvious which parts of our normal experiences receive their information contents from geometric future. It is the phase transition front for the transformation of intentions to actions which defines psychological time and this picture would mean that a new phase transition front is propagating in the geometric past. This process could occur also after the physical death.

There is an objection against this view: the me of my geometric past cannot possess much volition because this would lead to paradoxical sudden changes of the world geometrically now. Paradoxes are avoided if the volition of the me of the geometric past affects the universe only in a finite interval of geometric time so that the me of the geometric now does not experience these effects. The non-determinism of Kähler action indeed suggests that the net effect of free will cancels in the long run. Paradoxes are thus avoided if there is some minimum distance between the successive p-adic phase transition fronts, presumably given by an appropriate p-adic time scale (of the order of the duration of the life cycle or longer). This would conform with the second law in generalized form stating that volitional effects cancel in time scales longer than the p-adic time scale. These p-adic phase transition fronts should be common to entire biosphere at the same level of self hierarchy.

The fractality of consciousness suggests that the anatomy of the quantum jump reflects what happens during the life cycle. A quantum superposition of potentialities is generated and followed by gradual analysis. This has the decay of 3-D physical body as its physical correlate. The time scale for this kind of cycle corresponds to the lifetime of bound state at relevant p-adic length scale and the process repeats: each lifecycle is effectively single quantum jump in an approriate time scale.

Thus Grand Scenario suggests that the tyranny of time might be an illusion created by the time localization for the contents of sensory experience, the local arrow of psycholocal time and the natural self-centeredness of conscious beings. There would be no real death: or stated otherwise, we die all the time. Even more: that this life was perhaps not a success story is not a too big tragedy: there is great number of lives in store. Various reincarnations of me in my geometric past could subjectively coexist with me and experience a course of life slightly different from mine. My decisions affect also their life since past is changed in each quantum jump and also their decisions affect me. This endless living again is not just boring repetition: p-adic evolution implies that the new version of my life is in statistical sense (one can indeed use this phrase here!) better than the previous ones. In accordance with the quantum-classical correspondence principle and fractal cosmology of consciouness, this is nothing but recreation of the personal cosmology again and again, making possible gradual personal growth.

7.5 Time delays of consciousness and quantum jumps between histories

TGD based concept of time has rather dramatic implications and it would be important to show that the new time concept indeed solves conceptual problems and anomalies. One should also device experiments to test the new time concept. Dissipation is the black sheep in the family of theoretical physics and quantum jump between quantum histories concept explains dissipation in elegant manner. Quantum jumps between quantum histories concept together with the notion of self explains also the peculiar time delays of consciousness revealed in the experiments relating to the active and passive roles of consciousness [45, 18] and described by Penrose in his book [25]. It is also possible to explain the causal anomalies revealed by the experiments of Radin and Bierman [35, 36, 41]. TGD predicts "tribar effect" as a general signature for the quantum jump between quantum histories concept.

7.5.1 Dissipation as evidence for consciousness

TGD based picture about time relies crucially on the notion that quantum jumps occur between quantum histories, objective realities. This hypothesis obviously means giving up the materialistic idea about single objective reality behind our experiences. It took quite long time to realize that our everyday experiences reveals directly the occurrence of quantum jumps between quantum histories! The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally believed that fundamental laws of classical physics are reversible whereas everyday reality is manifestly irreversible. This leads to a rather schizophrenic situation. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and the mathematically horribly ugly "real" world, seem to exist simultaneously. Quantum jumps between quantum histories concept solves the paradox and one can understand dissipative world as an effective description forming "almost" envelope for the sequence of reversible worlds (understood as entire time evolutions).

Dissipation can be also regarded as a direct evidence for the presence of the self hierarchy. One can imagine quite spectacular tests for the idea. NMP predicts that self can be in two modes of consciousness: quantum jumps reduce either matter-mind like entanglement or reduced matter+mind-matter+mind type entanglement leading to an unentangled subsystem giving rise to two new self candidates (sub-system and its complement inside self). The first mode corresponds to "whole-body" consciousness and in this mode matter-mind like dissipation in short length scales should be completely absent. The lowered dissipation should reflect itself as lowered metabolism. The measurement of cell level dissipation occurred during meditative states could provide a test for this picture. TGD explanation for the phenomenon of synesthesia [20] discussed in[H3] relies on the hypothesis that left brain or considerable parts of it get quantum entangled and spends part of time in "whole-body consciousness". Indeed, synesthesia can involve lowering of left brain metabolism by as much 18 per cent [20]: this should lead to paralysis if standard wisdom about brain functioning would hold true!

7.5.2 Experiments related to the active role of consciousness

The first class of experiments [45] is related to the active role of consciousness. For example, the human subject flexes his finger at free will. What happens is that neurophysiological processes (changes in EEG) start about one second before the conscious decision to flex the finger is made. Decision seems to be followed by the action rather than the action by decision! This is in apparent accordance with the point of view that consciousness is indeed a passive spectator and the act of free will is pure illusion.

Quantum jump between histories picture explains the time delays associated with the active aspect of consciousness nicely and also gives an example of two kinds of causalities.

1. The simplest assumption is that the subjective experience of the finger flexing corresponds to the moment, when subject person experiences finger flexing occurs.

2. The new quantum history differs in detectable manner from the old quantum history already before the moment of finger flexing since otherwise the new history would contain an instantaneous and discontinuous jump from non-flexed finger to flexed finger configuration, which is not allowed by field equations. ΔT of order one second seems to be the relevant time scale. It is important to notice that the difference is at the level of classical physics rather than, say, in the form of synchronous neural firing which might involve quantum jumps of lower level selves: in TGD framework EEG activity is indeed classical phenomenon.

3. The attempt of the experimenter to be objective means that in an ideal experiment the observations correspond to the new deterministic history in the associated quantum jump and hence experimenter sees neurophysiological processes as the (apparent) cause of the finger flexing with respect to geometric time. With respect to the subjective time the cause of the finger flexing is the decision of the subject person.

4. This explanation is based on the hypothesis that volitional actions are top-down actions starting from the level of the entire body. A less radical variant of this argument is that the time associated with the conscious decision to flex the finger corresponds to a discontinuous configurational change at the level of brain: the jump from non-flexed to flexed configuration would occur at

the representational level and induce continuous flexing of finger. This does not however change the core of the argument.

7.5.3 Experiments related to the passive role of consciousness

Libet's experiments [18] about the strange time delays related to the passive aspects of consciousness serve as a continual source of inspiration and headache. Every time one reads again about these experiments, one feels equally confused and must start explanations from scratch. The following explanation is based on the model of the sensory representations on the magnetic canvas outside the body and having size measured by typical EEG wave lengths [H4].

The basic argument leading to this model is the observation that although our brain changes its position and orientation, the mental image of the external world is not experienced to move: as if we were looking some kind of sensory canvas inside cortex from outside so that the motion of canvas does not matter. Or equivalently: the ultimate sensory representation is outside brain at a fixed sensory canvas. In this model the objects of the perceptive field are represented on the magnetic canvas. The direction of the object is coded by the direction of ME located on brain whereas its distance is coded by the dominating frequency of ME which corresponds to a magnetic transition frequency which varies along the radial magnetic flux tubes slowly so that place coding by magnetic frequency results.

According to the summary of Penrose in his book 'Emperor's New Mind' these experiments tell the following.

1. With respect to the psychological time of the external observer subject person becomes conscious about the electric stimulation of skin in about .5 seconds. This leaves a considerable amount of time for the construction of the sensory representations.

2. What is important is that subject person feels no time delay. For instance she can tell the time clock shows when the stimulus starts. This can be understood if the sensory representation which is basically a geometric memory takes care that the clock of the memory shows correct time: this requires backwards referral of about .5 seconds. Visual and tactile sensory inputs enter into cortex essentially simultaneously so that this is possible. The projection to the magnetic canvas and the generation of the magnetic quantum phase transition might quite well explain the time lapse of .5 seconds.

3. One can combine an electric stimulation of skin with the stimulation of the cortex. The electric stimulation of the cortex requires a duration longer than .5 seconds to become conscious. This suggests that the cortical mental image (sub-self) is created only after this critical period of stimulation. A possible explanation is that there stimulation generates quantum phase transition "waking up" the mental image so that threshold is involved.

4. If the stimulation of the cortex begins (with respect to the psychological time of the observer) for not more than .5 seconds *before* the stimulation of the skin starts, both the stimulation of the skin and cortex are experienced separately but their time ordering is experienced as being reversed!

   A crucial question is whether the ordering is changed with respect to the subjective or geometric time of the subject person. If the ordering is with respect to the subjective time of the subject person, as it seems, the situation becomes puzzling. The only possibility seems to be that the cortical stimulus generates a sensory mental image about touch only after it has lasted for .5 seconds. In TGD framework sensory qualia are at the level of of sensory organs so that the sensation of touch requires back-projection from cortex to the skin. If the formation of back projection would takes about .5 seconds the observations can be understood. Genuine sensory stimulus creates cortical mental image almost immediately: this mental image is then communicated to magnetic body (time like entanglement).

5. If the stimulation of the cortex begins in the interval $T \in [25 - .5]$ seconds *after* the stimulation of the skin, the latter is not consciously perceived. This effect - known as backward masking - looks really mysterious. It would be interesting to know whether also in this case there is a lapse of .5 seconds before the cortical stimulation is felt.

According to the TGD based vision sensory mental images are at the level of sensory organs and brain constructs symbolic representations about them using intensive back-projections to the sensory organs. These representations give rise to a decomposition of the perceptive field to standardized sensory mental images. The most effective manner to achieve back-projection is by using negative energy signals propagating backwards in geometric time just like in the case of intentional action. Accepting this framework one can at least make questions.

i) Could the stimulation of the cortex induce a negative energy back-projection signal to the skin representing a stimulus effectively interfering to zero with the real stimulus? That the skin stimulus is perceived consciously for $T < .25$ seconds means that the compensating back projection is sent only if cortex has received information about skin stimulation. One can imagine that it takes .25 seconds to form a symbolic representation about the sensory mental images at sensory organ. Why the back-projection would compensate the skin stimulus?

It is known that brain acts like a highly selective gardener applying strong inhibition to certain sensory stimuli and strong excitation to others in order to build percepts. If this principle applies also in time domain - as it should if the paradigm of 4-D brain is accepted- the elimination of the sensory stimulus could be seen as a tendency to build sensory percepts which are sharply localized in time. A precise localization in time is indeed important in the case of sensory percepts.

Second explanation would be based on compensating back-projection. Everyone who has been swimming in windy sea, feels the waves for a long time after coming to the shore. This sensation would correspond to back-projection in TGD framework but it is not clear to me whether this back-projection tends to compensate the actual sensation in order to achieve metabolic economy.

ii) Could it be that the skin stimulus is actually consciously perceived but that this experience is not remembered? In TGD framework the memory about skin stimulus would be realized as a skin stimulus still continuing in the geometric past. If the cortical stimulation for some reason modifies the geometric past by destroying the skin stimulus using back-projection, there would be no memory about the skin stimulus.

1. Two options for the communications to the magnetic canvas

Consider now possible constraints from Libet's experiments on the model of sensory representations based on the notion of magnetic canvas. MEs induce magnetic quantum phase transitions via the classical magnetic field associated with them and oscillating with a multiple of the cyclotron frequency. There are two possibilities.

1) The classical signal is thought to propagate along an existing em ME to the magnetic canvas and induces the magnetic quantum phase transition.

2) MEs behave like topological field quanta. A passive Z^0 ME is replaced with a an active em ME in single quantum jump so that the signal propagates to the magnetic canvas effectively instantaneously.

2. Various time lapses involved

Let us first analyze various time lapses which can be involved in the process leading from the sensory stimulus to the sensory experience.

1. The propagation of the classical signal along ME to the magnetic sensory canvas takes some time. This gives upper bound for the possible sizes L of MEs. The lapse is however for $T_{cl} \sim L/c = 1/f$, which is about .1 seconds for earth-sized MEs and of same order as the time lapse $T_b \simeq .01$ seconds due to the conduction of the nerve pulses from skin to somatosensory cortex.

2. The time T_m for the magnetic quantum phase transition to occur should be $T_m \sim 1/\Gamma$, where Γ is the rate Γ for cyclotron transitions for ions in the harmonic perturbation defined by the classical magnetic field B associated with ME. If the magnetic quantum transitions occur incoherently, Golden Rule implies that the rate Γ should be of order

$$\Gamma \sim N(\frac{B^2}{B_e})^2 f_c \ ,$$

where B is the amplitude of the oscillating magnetic field associated with ME, B_e is Earth's magnetic field, f_c is the corresponding cyclotron frequency, and N is the number of ions participating in the transition.

If T_m indeed represents a lapse of conscious experience then the magnetic field associated with the radial ME inducing the magnetic quantum phase transition should be very strong as compared with the typical intensities in MEG unless N is large. The relative intensity of the fluctuations of Earth's magnetic field is about $\Delta B/B_e \sim 10^{-8}$ and gives an estimate for the intensity of B. The lower bound for the number of ions participating to the quantum phase transition is $N = 10^{16}$. Since the magnetic flux tube has thickness of order cell size, and since there are not much more than about 10^2 ions per cellular volume, the required length of the magnetic flux tube participating in the quantum transition would be longer than 10^8 meters and is definitely too long.

Quantum coherence can however come in rescue here. If the magnetic transitions occur coherently, the rate is given by

$$\Gamma \sim N^2(\frac{B^2}{B_e})^2 f_c \ ,$$

where N is the number of the ions participating in the transitions. For $N > B_e/B$ ($\sim 10^8$ for $B \sim 10^{-8}B_e$) the rate is high enough if the length of the magnetic flux tube participating in which quantum phase transition occurs longer than 10^2 meters. Since the intensity of the magnetic field varies extremely slowly along the magnetic flux tube in the proposed model, the number of the ions participating the transition could indeed be large enough and T_m would become an unimportant factor.

3. The total lapse of time is $T = T_b + T_{cl} + T_m + T_p$, where $T_b \sim .01$ seconds is the time for the signal to propagate to the somatosensory area and T_p is the time used by cortex to estimate the position of the sensory stimulus and activate the MEs taking care of the sensory projection to the magnetic canvas. Since the coding of the position of skin is topographic, there is no need to compute the distance and orientation of the stimulus and one has T_p is minimal. This gives $T = T_b + T_{cl} + T_m + T_p$ for the classical option 1) and $T = T_b + T_m + T_p$ for the quantum option 2).

3. Constraints from Libet's experiments

It is interesting to look what Libet's experiments mean for various options about what precedes the magnetic quantum phase transition giving rise to the sensory experience. The basic observation is that the classical signal propagation time along ME, which is .1 seconds for magnetic flux tube at distance of order Earth circumference, is much shorter than the time .5 seconds between the sensory stimulus and conscious experience. Thus it does not strong constraints on the model based on option 1).

1. If one assumes that the formation of the sensory representations involves the propagation of a classical signals along MEs (option 1)), and that the sensory representation of the skin is at distance of, say, one fourth of Eearth's radius corresponding to the frequency $f = 10$ Hz, the lapse is about $T \simeq T_b + T_{cl} + T_m + T_p = .1 + T_m$ seconds. This allows $T_m + T_p \simeq .4$ seconds. For $T_m \ll T_b$ $T_p \simeq .4$ seconds is allowed. In classical case there are however bounds on the distance of the magnetic canvas, five Earth circumferences is the upper bound.

2. Second option is that the process does not involve classical signalling in the proposed sense so that the distance of magnetic canvas does not matter at all. ME behaves as a single particle and is transformed from passive Z^0 ME to active em ME in single quantum jump. Suppose the arrival of the neuronal signal induced by the electrical stimulation of the skin to the somatosensory area induces this kind of quantum jump, which becomes thus capable of inducing magnetic quantum phase transition. If this is the case, then the sensory representation of the stimulus could result after $T \sim T_b + T_m + T_p$ after the arrival of the neural signal to the cortex. If T_m is negligible one has $T \simeq T_p \simeq .5$ seconds. The fact that the stimulation of cortex by .5 seconds is needed to produce artificially the sensory stimulus suggests that T_m is indeed negligible.

3. The third option is that there is a ME associated with the entire sensory pathway fused with the ME associated with the sensory projection to the magnetic canvas and that already the sensory stimulus at the skin initiates the magnetic quantum phase transition. In this case one has $T = T_m \simeq .5$ seconds.

7.5.4 The experiment of Radin and Bierman as evidence for quantum jump between quantum histories concept

The experiments of Radin [41] and the later experiments by Radin and Bierman [35, 36] gave evidence for anomalous unconscious emotional responses preceding their cause. Radin monitored the sympathetic and parasympathetic behavior of the autonomic nervous system with skin conductance, heart rate and fingertip blood volume measurements. Subjects were asked to look at a computer monitor and press a button to start a trial. Button press caused the display of a blank screen for five seconds, then a randomly selected calm or emotional picture was shown for three seconds, and this was followed by ten seconds of a blank screen. In three studies, Radin found significant differences in autonomic physiology, most notably skin conductance, *preceding* the exposure of emotional vs. calm pictures. Radin examined a number of possible normal explanations for the result and concluded that they did not apply.

Radin and Bierman interpreted the result of the experiment as evidence for a reversal of the arrow of time. The constancy of the arrow of psychological time is by no means obvious in TGD Universe and one of the basic challenges of TGD inspired theory of consciousness is to understand how the (probably statistical) arrow of psychological time emerges. Moment of consciousness as quantum jump between quantum histories concept provides however an elegant explanation of the effect without any need to assume the reversal of the arrow of psychological time. What is important that one can also avoid the poorly defined concept of effects propagating backwards in time, which is needed in explanations based on quantum state as time=constant snapshot concept.

Consider now the TGD based explanation. In quantum jump deterministic quantum history is replaced with a new one: this means that, not only the future, but also the *past* changes. Therefore, if the mean galvanic skin response of the subject person provides a faithful representation for some aspects of subject person's deterministic quantum history, the entire time record about skin response must change to a new one in any quantum jump. If subject person experiences a highly emotional stimulus, the moment of consciousness is expected to be more intensive than for calm stimulus in the sense that the non-determinism associated with the quantum jump is expected to cause observable effects in a larger space-time volume of the quantum history (represented to a good approximation as quantum average space-time surface geometrically). Therefore also the change of the quantum past is expected to be more dramatic as it indeed seems to be according to the results of the experiment.

At first it might seem that there are no means to test whether the past has changed at the moment of consciousness. The experimental arrangement of Bierman and Radin, although certainly not originally planned to test quantum jumps between histories concept, circumvents in an ingenious manner this difficulty by comparing the skin responses associated with calm and emotional trials. Standard physics, which is based on assumption that there is no signal propagation backwards in time, predicts that the average skin responses before the stimulus should be identical for calm and emotial trials. This is not the case so that the results of the experiments indeed support TGD based world view.

One can in fact imagine even more dramatic test based on a modification of Radin-Bierman experiment. In quantum-mind discussion group Stan Klein [23] suggested a modification of Radin-Bierman experiment [35, 36, 41] providing a test for Stapp's and Sarfatti's theories of consciousness [24, 27]. One could perhaps consider the following further modification of Radin-Bierman experiment so that it would simultaneously discriminate between Stapp's and Sarfatti's theories and TGD.

1. It might be possible for computer to perform a comparison of the presponse with average calm and emotional presponses *before* the subject person A sees the picture and, depending on whether the presponse is nearer to calm or emotional average presponse, to print C or E to a computer screen such that the printing result is seen by person B *before* A sees the picture.

2. The theories explaining phenomenon in terms of effects propagating backwards in time (say Sarfatti's theory [27]) would predict that computer record and the sequence of letters remembered

by B are identical and contain both C:s and E:s. According to [23] Stapp's theory would predict that both computer record and B's memories contain only C:s.

3. TGD predicts that B would *see* only C:s. The concept of subjective memory implies that B also *remembers* of seing only C:s whereas computer records would contain both C:s and E:s. This would provide dramatic support for quantum jump between quantum histories concept and for the notion of subjective memory.

In TGD framework one can also consider an alternative explanation for the result of Radin-Bierman experiment. If this explanation is correct, the report of B is consistent with the computer record just as in Sarfatti's theory. The argument goes as follows.

1. Given moment of consciousness contains several irreducible subexperiences besides the experience corresponding to the "real I", which presumably corresponds to "I" able to communicate using language and possessing long term memories. These "I":s are usually collectively identified as subconscious mind. The phenomenon of blind sight and related phenomena [24] give support for the idea that there is second "I", most naturally at the same level of self hierarchy. One can even imagine entire population of selves at some lower level of self hirarchy giving rise to "Zombi within us" or shortly Z. In the latter case the response of Z is dictated by statistical determinism at the level of ensemble. Deterministic response has definite value in fight for survival.

2. The values of the psychological times associated with these various "I":s need not be same in given quantum jump. Suppose that Z has psychological time slightly larger than the psychological time of the ordinary "I" so that Z sees the state of the world at time $t + \Delta t$ whereas "the real I" sees it at time t in given quantum jump. The order of magnitude for Δt is roughly one second. Assume further that Z is able to assign emotional content to the picture. If the decision about what picture is shown is purely mechanical involving no quantum jump (and hence only effectively random) then Z can perceive the picture before the ordinary "I" perceives it with the result that galvanic presponse is created. Galvanic presponse is deterministic in case that Z is an entire population of "I":s.

Some remarks about the model are in order.

1. The criticism against this kind of model is that Z is perhaps not able to assign any emotional content to the pictures. The experiments supporting the existence of Z mildly suggest that Z sees the things "as they are" (for instance Z cannot be fooled by visual illusions) which in turn suggests that emotional response is perhaps not involved.

2. Z could also receive the information about the picture by precognition in principle made possible by the diffuse contribution to the contents of conscious experience coming from entire initial and final quantum histories. If this is the mechanism, one can however wonder why the "real" I is not capable to same so that also "real" "I" would have *conscious experience* about the nature of the picture before seing it.

3. In case of Kornhuber experiments similar explanation would lead to the veto model: the conscious decision to raise index finger is preceded by the conscious decision of Z to raise it and the "real I" can decide whether to allow various neural processes to continue or not.

4. In principle (probably only in principle) one could test the model by allowing the selection of the figure to be shown to A be determined by a quantum jump rather than by deterministic process. If this quantum jump occurs only very short time before A sees the picture, response should disappear.

An effect resembling Radin-Bierman effect might occur in much more conrete situation. There is a legend about the ability of the short distance runners to anticipate the shot of the starting pistol and start already before the gun shot. Perhaps this really occurs but in the following sense. When short distance runners hear the shot they perform a quantum jump to a new history. For obvious reasons they might have developed a skill to jump to a quantum history at which they started before the gun shot. Whether this effect occurs could be tested by using video camera or some more sophicated arrangement (gun shot can be accompanied or even replaced by light signal to make the timing

precise). What could happen is that the man with the gun honestly claims that the runner started after the shot whereas videocamera tells that runner started before the shot. This effect deserves the nickname "tribar effect" (tribar is the famous nonexisting triangle like structure formed from three bars): in its various forms the effect could provide very general hard evidence for TGD based view about space-time.

Notice that the paradox of ping pong game described in the book of Penrose [25] can be resolved in quantum jumps between quantum histories picture. The problem is that the time delays of consciousness are so long that no conscious action seems to be possible in ping pong game. The resolution is simple. The players can quite well miss the ball time on the old history but perform a jump to a new history: on this history they do not miss the ball thanks to the rapid deterministic reflex action.

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Chapter 8

Quantum Model of Memory

8.1 Introduction

The ideas related to the quantum model of memory have developed gradually from very general ideas to reasonably concrete models and a connection with biological quantum computer type systems has emerged. It is good to list the basic ideas and notions briefly to get and idea about this process which is still continuing.

8.1.1 Geometric and subjective memories

The identification of moment of consciousness as quantum jump between histories implies two kinds of time developments, subjective and geometric, and therefore also two causalities and memories. By the 4-dimensional general coordinate invariance of quantum TGD, geometric memories contain information about entire quantum and classical histories. This means that there is no absolute need to store memories of the geometric past to the geometric now. This has dramatic implications for the modelling of brain and allows to get rid of the basic problem of the memory models, namely the fact that the storage of new memories unavoidably tends to destroy the old memories whereas it seem that childhood memories are actually the most stable ones.

8.1.2 p-Adic physics as physics of intentionality

In purely real contex one ends up with the problem that there is no clear difference between memories and intentions: intentions are just memories about the geometric future. Why the memories/predictions of geometric future and past are so different? The solution of the problem came when I realized that p-adic physics is physics of cognition, imagination, and intention. p-Adic spacetime regions represent intentions and are about geometric future. In quantum jumps transforming intentions to actions p-adic regions are transformed to real spacetime regions representing geometric memories and inducing self-organization patterns giving rise to macroscopic actions. This amplification process is possible by the quantum criticality of TGD universe implying initial value sensitivity. Psychological time corresponds to the front of a p-adic-to-real phase transition proceeding to the direction of geometric future.

8.1.3 Spin glass model of memories

One of the relatively early ideas was that the 4-dimensional quantum spin glass property of TGD universe must have fundamental role in the realization of memories. Spin glass property predicts fractal energy landscape in which there are valleys inside valleys inside valleys and memories correspond to self-organization patterns associated with subself having interpretation as processes leading to bottoms of various valleys. In TGD framework energy minima are replaced by the maxima of Kähler function defining configuration space geometry as a function of zero modes which are effectively classical variables in the sense that in each quantum jump a complete localization occurs in these variables. One can also consider the interpretation of 'energy' as binding energy of bound states as function of zero modes. The higher the value of the binding energy, the deeper the valley, and the

higher the probability that system ends up to the bound state and the longer the time spent in the bound state.

One can also regard life as a process of carving a 4-dimensional statue gradually quantum jump by quantum jump. The longer the extension of the valley in the temporal direction and the larger the number of copies of the valley is, the more reliable the memory recall is. The best manner to learn to remember is to remember. The depth of emotion determines how deep and long in temporal direction the valleys representing memories are.

8.1.4 Mirror mechanism

MEs provide a mechanism of long term memory which differs from ordinary sensory perception only in that the ME giving rise to a geometric memory has much longer duration with respect to the geometric time than the ME giving rise to ordinary sensory perception. To remember something at temporal distance T in the past is to look at a mirror with length $L = cT/2$. The mirrors in question must have astrophysical sizes measured in light years typically and this of course raises obvious objections against the model. Although this mechanism as such is too strong an idealization, it can serve as a starting point. For instance, MEs can be also curvilinear and could propagate along closed magnetic flux loops of the personal magnetic body serving effectively as wave cavities and suffer few reflections: this would make possible high precision targeting.

At quantum level remembering means sharing of mental images: this corresponds to the quantum entanglement between the subselves of the geometric now and of the geometric past. The classical non-determinism of Kähler action is essential in making possible entanglement between systems having timelike separation. This would be the mechanism of episodal memory, For non-episodal memories only the the mental image representing the desire to remember would be shared, and the answer from the geometric past could be realized as classical communications using MEs. Commmunication would be based on some code, perhaps memetic code, and would generate a conscious experience in the receiving end, typically verbal memory. Positive energy MEs would propagate with ultra low effective phase velocity inside brain or along magnetic flux tubes of astrophysical size with sub-luminal effective velocity (say alpha wave effective velocity). The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

In this framework synaptic strengths code only cognitive representations and learned associations, not genuine information about the events of the geometric past. Brain can be seen as kind of a collection of standardized features serving as building blocks of sensory and memory representations. Long term memory is coded in the classical em/gravitational fields associated with and in coherent light/gravitons generated by MEs in hologram like manner. Any finite spacetime region receiving the classical em field of coherent light/gravitons generated by it gets hologram like picture containing info about entire geometric time interval spanned by ME. If vacuum current is localized to some restricted spacetime region (it can be!), the hologrammic information is about this region and receiver anywhere along the ME gets more or less the same information since hologram is in question. Note also that the lightlikeness of the boundary of ME implies that ME selves have temporal extension defined by the length of ME.

8.1.5 Third person aspects of memory

Topological quantization implies the notion of field body: field body accompanies any system be it molecule or human body. Field body serves as kind of a manual providing higher level abstract representations about the quantum aspects of the physical body. The model of sensory representations realized at personal magnetic body and at Earth's magnetic body explains both the first and the third person aspects of our sensory experience. Also memories should have third person and transpersonal aspects realized at the magnetic body of Earth. This prediction is testable: moon traveller consciousness should have different third person aspect or this aspect could be even absent. Third person aspect should be crucial for the generation of social structures and the rapid weakening and reversal of Earth's magnetic field predicted to occur within next 2 millenia might have dramatic effects for the future of the civilization.

The sharing of mental images is crucial for the model of the third person aspect of memories. What happens is that subself of brain entangles with with the subself of the magnetic sensory canvas in the geometric past. One could perhaps interpret spontaneous episodal memories as a basic example of memories communicated by some subself of magnetic Mother Gaia to us.

8.1.6 Symbolic and cognitive representations of memories

Most of our memories are not direct re-experiences. In fact, it would be difficult to tell whether memory is really in question if this were the case. Rather, memories are highly conceptual and based on symbolic representations making possible huge filtering and compression of information. Only in some special cases direct re-experiencing occurs. The inherent nondeterminism of the p-adic field equations and the classical non-determinism of Kähler action make possible to represent sequences of quantum jumps determining the contents of consciousness of self at spacetime level in terms of p-adic or real spacetime sheets, that is cognitively and symbolically. Symbolic representations are crucial for memories whereas cognitive representations are crucial for intentions. Symbolic representations allow to store information about geometric past to geometric now: history writing is just this kind of activity. Also brain is doing history writing: to remember is also to form a new memory representation.

It is highly plausible that memory representations are highly abstracted and that the signals from the geometric past do not recreate directly the experience but serve as names for standardized self-organization patterns of neuronal activity, 'features' giving charicature of the experience. This means that it is not easy to distinguish between TGD based model and standard model of memories.

8.1.7 Biosupercomputers and memories

The most recent but certainly not the last step in the development of ideas was the realization of a connection between macrotemporal quantum coherence, quantum spin glass property of the TGD universe, classical and quantum gravitation, and the mirror model of geometric memories.

The interpretation of quantum jump as a creation of a totally entangled holistic state $U\Psi_i$ which is then analyzed to pieces allows to interpret self measurement cascade as a conscious analysis. The temporal fractality of consciousness suggest that the lifecycle of any self can be seen as a generation of multiverse of potentialities followed by analysis (and decay) process. One can see the situation also differently. The conscious experience of self is average over moments of consciousness and the eventual thermalization induced by the quantum jump sequence destroys all conscious information. There must be some mechanism hindering this and making macrotemporal quantum coherence possible.

To achieve macrotemporal quantum coherence self must be irreducible self for which self measurements and analysis do not occur. The self must also have large number of zero modes transformed to quantum fluctuating degrees of freedom and this is achieved if self corresponds at spacetime level to a join along boundaries condensate. In this process the zero modes of the condensing spacetime sheets become quantum fluctuating degrees of freedom. In this 'state of oneness' self is able to carry out quantum computer like information processing which is the diametrical opposite of analysis. The decay of this bound state to its components corresponds to the analysis period at the level of self.

Macrotemporal quantum coherence is possible by the quantum spin glass property of TGD universe making the lifetimes of bound states much longer than in the universe obeying standard physics. Different almost degenerate vacuum spacetimes differ only because they have different classical gravitational energies. The quantum transitions between these almost degenerate states involve emission of MEs representing gravitons. These topological graviton rays are reflected from the curved almost vacuum spacetime sheet acting as a gravitational mirror and self energy diagrams involving emission and absorption of the gravitonic ME have interpretation as correlates for the geometric memory recall. The time scale of human memories is between millisecond and 100 years and this time scale characterizes the gravitational energies for systems having sizes between cell size and cell membrane thickness (the number theoretical miracle is that all p-adic length scales in this reange correspond to Gaussian Mersennes). Microtubules are excellent candidates for realizing long term declarative memories at bit level so that a connection with Penrose-Hameroff views emerges.

8.2 Different types of memories

TGD predicts two kinds of memories corresponding to two different time developments. There is deterministic (in generalized sense) time development with respect to the geometric time and the non-deterministic time development by quantum jumps with respect to the subjective time. The memories with respect to subjective time are about previous conscious experiences and 'real' whereas geometric 'memories' are prophecies giving simulations of the geometric past and future assuming that quantum jumps do not alter the macroscopic properties of the spacetime surface. A good visualization is following: each quantum jump represents particular geometric memory whereas the heap of these memories gives rise to subjective memory. The comparison between expectations and reality is obviously a central part of mentality and the heap structure implies that this comparison is a basic function of conscious mind not reducible to anything simpler. It is wellknown that our memories involve a lot of construction and are more like stories consistent with what we actually have experienced than actual documents of what happened. Perhaps geometric memories constrainted by subjective memories give rise to the 'story'.

One can distuinguish between several memory types such as short term memory and long term memory, episodal memory, procedural memory, implicit memory and associative memory, and it is interesting to try to find whether these memories could be understood in the proposed conceptual framework. In the discussion below concrete mechanisms for the realization of geometric memory are not discussed: the reader interested on this aspect of geometric memory can consult [K3].

8.2.1 Geometric and subjective memories

There are two times in TGD: subjective and geometric. In accordance with this there are also two kinds of memories: subjective and geometric[1].

1. The temporal binding of the experiences associated with quantum jumps occurred after the last "wake-up" of the self gives rise to subjective memory defined as memory about earlier conscious experiences and is identifiable as an immediate conscious memory, "phychological now", presumably of duration of fraction of second in case of sensory experiences. There is infinite hierarchy of subjective memories and if long term memories are genuine subjective memories (this need not be the case!), they could correspond to conscious short term memories of higher level selves somehow communicated to the lower level. An essential element is the possibility of subselves inside self having much shorter lifetime and organized in a subjecto-temporal sequence: without them the average over the quantum jumps would destroy the information and it would not be possible to remember the digits of a phone number. Various rhytmic actions (such as micro tremor of eyes at 80 Hz frequency and muscle tremor) could generate a sequence of subselves with constant duration and thus a clock measuring subjective time.

2. Geometric memories are like a classical physics based model for the universe. They are memories with respect to geometric rather than subjective time and predict what must have happened in the geometric past and what will happen in the geometric future assuming that world is classical (no quantum jumps). The temporal extension of the mindlike spacetime sheets and the notion of the association sequence (3-surfaces consisting of a sequence of spacelike 3-surfaces with timelike separations providing a simulation of classical history) make possible geometric memories. A natural hypothesis is that the macroscopic spacetime associated with the final state of the quantum jump represents the geometric memory. Of course, only part of it becomes conscious and temporal binding implies that self experiences kind of temporal average of the geometric memories associated with the quantum jumps. An attractive possibility is that our long term memories, which have narrative character and are unreliable, correspond to geometric memories. This would mean that there is no need for memory storage mechanisms, four-dimensional brain would take automatically care of memory storage.

Intentionality manifests itself in many ways: as expectations of the future, planning, goals, desires, fears, imagination, intuition etc.. It seems natural, and this is the only possibility given the fact that it

[1]The attribute 'subjective', as it is used in TGD context, does not have quite the same meaning as it usually has as something non-objective and unreliable: 'subjective' derives its meaning from 'subjective time' as consciously experienced time as opposed to the geometric time of physics.

is not possible to know anything about future quantum jumps, to identify all aspects of intentionality with the predictions of the expected geometric future provided by the mindlike spacetime sheet. Geometry as such contains nothing intentional. Rather, the intentional aspects of the conscious experience reflect the attitudes towards the expectations provided by the geometric memory.

'Memories' with respect to geometric time as simulations

Geometric memories are predictions/simulations for what would happen if no further quantum jumps would occur and what would have happened if no quantum jumps had occurred in the past. Simulations and expectations rather than real memories are in question. Geometric memories become reliable in the classical limit, when the effect of quantum jumps becomes negligible. In the deterministic world of classical physics geometric memories would be absolutely reliable. It is indeed possible to predict rather reliably what will happen in the solar system during the next decade. Geometric memories are a prequisite of the intentionality often regarded as a basic characteristic of conscious mind: beliefs, expectations, plans, etc. involve geometric memory in an essential manner. The computational approach to mind assumes only geometric memories.

The memory with respect to geometric time is possible even assuming that single quantum jump determines the contents of conscious experience completely. However, if the contents of conscious experience are determined completely by the initial and final quantum histories of single quantum jump, it is in principle impossible to have genuine memories about previous conscious experiences. This does not make it impossible to have a model for the most probable subjective life history through simulation. Quantum statistical determinism could make these simulations possible. One must however admit that the hypothesis about subjective memory, naturally identifiable as a short term immediate memory defining the duration of psychological moment, makes things extremely simple and natural. One could also argue that in a universe without subjective memory it would not be possible to discover the notion of quantum jump so that internal consistency of the theory of consciousness requires genuine memory about earlier conscious experiences.

Mindlike spacetime sheets and simulations

It is a fact that we can plan future in the time scale of life time. We can also quite reliably extrapolate to the past without direct memory of what happened. The simplest explanation is that the time extension associated with those mindlike spacetime sheets, which we have access to, is of the order of lifetime or perhaps even longer. The simplest model for the simulation would be based on an ensemble of thoughts scattered around entire material spacetime history defined by, say, my body. Cognitive neutrino pairs would realize thoughts as Boolean algebra of statements and could be present everywhere in condensed matter, in particular in water, which is expected to have very rich hierarchy of spacetime sheets. Self would experience the sum of the abstracted experiences of ensemble members and experience a simulation about what happens in future and what happened in past assuming that quantum jumps will not occur in future and did not occur in past.

Of course, selves could also do what computers do, namely mimick other selves by building cognitive representations about them at their own spacetime sheets. This would make it un-necessary to jump between the levels of the self hierarchy. These representation could have quite different temporal and spatial scales and the presence of the time scaled versions about time development of other selves would realize the fractality aspect related to the idea about Universe as a hologram. DNA could be an example of this kind of simulation of the entire lifespan of individual in molecular length and time scales. Monte Carlo simulation of elementary physics experiment could be also regarded as a simulation of this kind.

The difference between intentions and geometric memories

Intentionality, understood here as time-directedness, manifests itself in many ways: as expectations of future, planning, goals, desires, fears, imagination, etc.. The basic element of mentality is the comparison between the expectations of future and what actually occurred. In TGD framework this tension between potential and actual can be understood. The temporal extension of the mindlike spacetime sheet makes possible expectations of what happens in the future assuming that no quantum jumps occur or at least that quantum jumps do not change the macroscopic spacetime. Single quantum jump contains information about this kind of expectations. Subjective memory in turn tells what

happened actually. Therefore it seems natural, and this is the only possibility given the fact that it is not possible to know anything about future quantum jumps, to identify the predictions of the expected geometric future provided by the mindlike spacetime sheet as a basic prequisite of intentionality.

Subjective memory makes it possible to compare the expectations with what really occurred since subjective memory is kind of a heap of predictions of future arranged with respect to the value of the psychological time. The origin of at least some emotions, which often involve a comparison of what happened and what was expected to happen, is perhaps here. It is quite well possible that all comparisons must be realized as comparisons of the subjective and geometric time developments. It seems that self can also compare its subselves, which correspond to simultaneous mental images.

The possibility of this comparison provide a solution to the paradox raised by the innocent question 'How do I know that the me of today is the same as the me of the yesterday? How do I even know that I existed yesterday?'. The solution might be simple: mindlike spacetime sheets have extension which can be much longer than the duration of the subjective memory. Therefore subjective memories contain information about the geometric me of the yesterday and geometric me of today and since these me's resemble each other quite a lot, the conclusion is that also the yesterday's me was a conscious self living in this same body. It is however quite possible that temporal entanglement with higher selves still remembering my past wake-up states is also involved and realized as a formation of join along boundaries bonds between the mindlike spacetime sheets of my self and of higher level self. Higher level self could also communicate directly the subjective memories about my existence to me.

The difference between intentions and memories remained a puzzle for a long time. The answer was finally provided by the view about psychological time as a value of the geometric time characterizing the position of the p-adic-to-real phase transition front propagating to the direction of the geometric future. The MEs representing intentions are p-adic whereas those representing memories are real.

What is the temporal extension of mindlike spacetime sheets?

With respect to subjective time self and its subselves can be characterized by the typical durations of the wake-up state. With respect to the geometric time self (or rather, mindlike spacetime sheet) can be characterized by its own duration and the durations of the mindlike spacetime sheets which it contains. The time span for the predictions and memories provides an estimate for the duration of mindlike spacetime sheets. mindlike spacetime sheets can have timelike separations. mindlike spacetime sheets of geometric past could represent memories so that conscious memories could be regarded as multitime experiences and the distances between mindlike spacetime sheets could be quite large, of order lifetime.

Durations of mindlike spacetime sheets representing subselves

Sensory experiences seem to correspond to a well defined geometric now having perhaps duration of order .1 seconds. Thus it seems that mindlike spacetime sheets representing my sensory subselves have rather short time extension, of order .1 seconds. 'Ontogeny recapitulates phylogeny principle' (ORP) suggests that the extension is of same order as the duration of the immediate subjective memory, something like .1 seconds. This prediction is certainly consistent with the typical resolution of the sensory experience, say the ability of the visual system to discriminate subsequent pictures as separate pictures. Quite generally, the p-adic time scale $T_p = L_p/c$ characterizing the mindlike spacetime sheets gives the first guess for the duration of the mindlike spacetime sheet and duration of geometric memory provided by it. Note that .1 seconds gives for the p-adic length scale L_p and estimate which is about circumference of Earth!

The fact is that we have childhood memories, plan future and make reliable predictions. This is not in contradiction with the duration of the mindlike spacetime sheets associated with sensory subselves. The mindlike spacetime sheets representing subselves (mental images) can be located in geometric past or future so that multitime experiences with mindlike sheets of past and future contributing to the experience are possible.

The duration of .1 seconds is the duration of typical subselves representing our mental images. The geometric duration of the mindlike spacetime sheet representing our 'main self' should be much longger since it contains mindlike spacetime sheets distributed along entire life span.

The subselves which have fallen asleep, wake-up again generating new wave of sensory experience. For instance, mental images (after images) typically re-appear periodically. We are also mental images of larger self in the hierarchy and the periodical appearenc e of of our mental images suggests that

also we appear periodically as mental images of this larger self. This would mean reincarnation in the geometric past so that our life would be lived again and again. Entire trains of mindlike spacetime sheets could wander through time again and and experience what it is to live in a particular body. Therefore my body could live again and again: by p-adic evolution each life would tend to be slightly better than the previous one. The civilizations of past could be still well and alive and even more civilized! This picture could perhaps explain why persons in their old age sometimes begin to live their childhood again.

What is the subjective duration of 'our' self?

Our conscious experience is some kind of an averaged sum over all conscious experiences associated with the quantum jumps occurred after the last 'wake-up'. If the averaging is completely democratic, the only possibility is that our sensory subselves have duration not much longer than the the time resolution of the sensory experience of order .1 seconds. Contrary to the original beliefs, this does not in principle pose any limitation to the duration of 'our' self.

There are thus several options concerning the duration of our self.

1. Our self could have duration not much longer than the duration of immediate short term memories of order .1 seconds. The ability to remember digits of a phone number requires that the duration is indeed longer. For this option it is not at all obvious how the subjective experience of personal continuity is possible.

2. The duration could also correspond to the wake-up period. Also now the problem is how we know that this self existed already yesterday. Note that the gradual thermalization of subselves means that subjective memories represented by subselves get gradually fuzzy so that the digits of a phone number are forgotten even if our self has duration of order wake-up time.

3. Our self has a duration of order lifetime, or even longer and only the mental image representing our physical body has duration of order lifetime. A possible objection is that the mental image representing our self becomes gradually more and more entropic unless it manages to fight against second law. This might of course correspond to ageing.

Third option deserves a more detailed consideration.

1. The geometric duration of our 'main' mindlike spacetime sheet should be of the order of life span if geometric memory explains long term memories. 'Ontogeny recapitulates phylogeny' principle would suggest that also the subjective duration of our 'main' self is of order life time. This option would explain elegantly the fact that we possess subjective identity: this kind of subjective identity would be a logical deduction in case that our main self has duration shorter than life time.

2. This option would mean that we are not actually unconscious during sleep but are only unable to remember anything about what happened during sleep. This would be rather natural since various sensory and cognitive subselves are not conscious during sleep periods so that also multitime experiences in which sensory subselves wake-up in night time are rare! It might be also possible to remember events occurred during sleep state only during sleep.

3. Note that the claims about near death experiences in which entire life is experienced as a kind of film, could be interpreted as very intensive experiences in which mindlike spacetime sheets along the entire life span 'wake-up' and give rise to multitime geometric memories. Alternatively, if bodily self with a duration of order lifetime is a subself of our self (perhaps identifiable as the self associated with our magnetic body), the bodily self representing entire life cycle could be experienced as a mental image. Also shorter bodily subselves forming a subjectotemporal sequence, 'film', could be experienced in the absence of the ordinary sensory input.

8.2.2 Habits, skills, associations

The universe of TGD is quantum spin glass [I1]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/asso- ciations are formed.

1. Mental images (in particular memories) correspond to subselves undergoing self-organizing time development by quantum jumps leading to self-organization patterns selected by dissipation. Thus both memes and genes, in particular long term memories, can be regarded as winners in the fight for survival in which dissipation is the ultimate Darwinian selector. Inhibitory and excitatory nerve pulses might physically realize "frustrations" which make possible large number of almost degenerate energy valleys.

2. The universe of TGD is quantum spin glass characterized by a fractal "energy" landscape having valleys inside ... inside valleys (directories inside...inside directories). This structure is ideal for a hierarchical representation of memories. Memories must correspond to valleys of the spin glass "energy" landscape into which dissipation takes the system. Memory formation is active process and memories are charicatures rather than photos and deep valleys of the energy landscape represent these charicatures. Hippocampus, known to be involved with the formation of the long term memories, could control the rate of motion in these control variables. The plastic regions of the brain are the most spin-glassy ones and are the most probable seats of the long term memories.

3. System has some territory in the energy landscape. The motion in the zero modes serving as control variables causes a slow shift of the entire territory. Synaptic strengths corresponds naturally to the slow control variables characterizing the position of the territory. In the presence of a metabolic energy feed and sensory input system moves around this territory.

8.2.3 Spin glass model of learning and long term memories

The universe of TGD is quantum spin glass [I1]. This provides extremely general conceptual framework for understanding how memories/habits/learned skills/associations are formed.

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One can consider two general models of learning and memory recall in this framework, the TGD version of the neural network model and the genuinely TGD based mechanism on the notion of the geometric memory. Consider first the TGD based version of the neural network model of memory.

1. The possible memories of the system correspond its territory in the "energy" landscape. Learning means slow change of the shape of the territory so that memory valleys get gradually deeper and system ends up to them with larger probability in future.

2. Repeated simulated annealing provides a promising memory recall mechanism. The feed of energy from metabolism kicks the system into a motion and dissipation leads it into some valley.

If the valley is quite not correct (correct subdirectory but wrong subsubdirectory), a smaller kick leads the system to the bottom of some nearby valley which might be correct. By applying a sequence of increasingly smaller kicks system finally finds the correct memory valley. The conscious attempt to remember corresponds naturally to an external force forcing the system to move in a correct direction.

There are several objections to this scenario. The first mystery is how system knows that the experience is a memory: there seems to be nothing which would distinguish memory from the experience occurring for the first time. Second problem is that the formation of the new memories tends to destroy the old ones: the new territory is simply not the old one. Even if one could circumvent this paradox, it is difficult to understand why the lively episodal memories of childhood are the most stable ones.

If long term memories are geometric memories then memory recall mechanism corresponds to multitime experiences involving generation of mindlike spacetime sheets in both geometric now and past.

1. Learning by repetition means keeping some subsystem in some deep valley for a long period of geometric time (system is still in that valley in the geometric past!). This corresponds to reverberating patterns in neuronal circuits generated automatically or by learning by repetition. In this picture the modification of synaptic strengths is not learning of memories but just what it seems to be: a modification of responses to sensory inputs necessary for survival.

2. The attempt to remember creates mindlike spacetime sheets located in the geometric past. The probability that a newly created mindlike spacetime sheet is located in the memory valley of long time duration is high and thus conscious memory recall becomes probable. Also very emotional and 'catchy' experiences generating long lasting memory valleys are easily remembered. Childhood memories are often very emotional ones and therefore also the most stable ones.

No final vision about what memories are in TGD framework exists yet. What is certain is that one can distinguish between geometric and subjective memories. The idea that episodal memories are ordinary sensory experiences with the object of the perceptive field in the geometric past is very attractive and speculative hypothesis which might work in TGD Universe, but more conventional explanation sounds more realistic in the context provided by the standard neuroscience. What is lacking still is a clear vision about the precise physical realization of long term memories.

8.2.4 Long term memories

An important question is whether our long term memories correspond to either geometric or subjective memories or whether they involve both aspects somehow.

Long term memories as geometric memories?

The unreliability and narrativeness of the long term memories would support strongly the interpretation of at least episodal long term memories as geometric memories, that is multitime experiences involving active mindlike spacetime sheets scattered along entire life span. This option is consistent with the short duration of subjective memories, which can be even of order .1 seconds characterizing the duration of immediate sensory memories.

Geometric memories could be realized as multitime experiences involving mindlike spacetime sheets located around several moments of the geometric time, provide the simplest realization for the long term memories.

1. The model solves the basic difficulties of the neural net models of long term memory. In the neural net models long term memories are represented by synaptic strengths. The problem is that the learning of new memories destroys old memories. In particular, the stability of the childhood memories is difficult to understand. It is also hard to understand how brain knows that the experience represents memory. One cannot avoid the difficulty by saying that novelty detection tells that experience occurs for the first time since the notion of novelty does not make sense if conscious experience contains only information from single moment of geometric time.

2. TGD model is consistent with neural net models and actually generalizes them. Neural net in the spirit of TGD corresponds to brain as system moving in spin glass energy landscape. Self-organization by quantum jumps leads the system to a bottom of an energy valley representing memory. This model is consistent with the fact that there is no upper bound for autobiographical memory. One can also understand how learning occurs. The repetition of an experience means that energy valley becomes a canyon in time direction so that mindlike spacetime sheets in the geometric past have a large probability to end up to the region representing memory. In particular, reverberating nerve pulse patterns are ideal for representing long term memories.

3. Highly emotional experiences generate deep valleys and increase the probability of the system of the geometric past to stay at the bottom of valley. This explains why cildhood experiences are so stable. In fact, one could identify primitive emotions of pleasure and pain as related to the motion in the spin glass energy landscape. Pleasure and pain could even directly correlate with the sign of the increment of the Kähler function in the hopping motion in the spin glass energy landscape. Note that primitive pleasure and pain are are very much like sensory experiences and one could regard them as sensory experiences of brain about its own motion in spin glass energy landscape. This leads to the generalization of the notions of sensory experience and motor action to include the motion in spin glass energy landscape and to a considerably new insight about the meaning of the brain architecture.

There are also perinatal experiences, memories about previous lives and transpersonal experiences having natural explanation in terms of geometric memory realized as multitime experiences associated with mindlike spacetime sheets located at different values of the geometric time. Transpersonal experiences suggests that self is dynamical: if prenatal experiences, memories about previous lives and transpersonal experiences are really what they seem to be, the geometric time extension of self should dramatically increase during these experiences.

If 'our' self has duration of order lifetime, also subjective memories can contribute to our long term memories. As already found, this option does not exclude the possibility that our long term memories correspond to subjective memories.

Geometric memories as sensory experiences with the object of the perceptive field in the geometric past?

The general theory of qualia to be developed in [K3] leads to the conclusion that geometric memories could be regarded as special kind of sensory experiences for which some objects of the perceptive field located in the geometric past. One also ends up with a concrete models for the mechanism making long term memories possible by 'waking up' subselves of the geometric past in selective manner by EEG frequencies. The unavoidable conclusion is that massless extremals (MEs) with durations of order lifetime, and hence with sizes which are measured in light years, are necessarily involved. Needless to say, one must give up the idea that we are nothing but our brains.

The fact that the lightlike boundaries of MEs serve as quantum holograms and have gigantic information storage capacities by the almost degeneracy of the states fits nicely with view. Lightlikeness means that 3-dimensional time=constant slice of Minkowski space is replaced with a slice which can have arbitrary long temporal duration so that memories become indeed possible. The fact that at least vision represents directly information about outer surfaces of 3-dimensional objects rather than objects themselves but contains information about time development over an interval of order .1 seconds fits nicely with this view.

The realization of long term memories in terms of magnetic quantum phase transitions induced by ME frequencies requires incredibly high frequency resolution. The resolution is of order $\Delta f/f \sim \Delta T/T$ giving $\Delta f/f \sim 10^{-9}$ for time resolution of about $\Delta T = 1$ seconds. An unrealistically high frequency resolution is required if temporal coding by EEG frequencies is assumed. There is also another problem: if the signal to the geometric past and back is between parts of brain, one cannot avoid zigzag type MEs effectively representing a repeated reflection between two mirrors. In the p-adic context these zigzag MEs are allowed by conservation laws (this might relate with the fact that long term memories are mostly cognitive) but not in the real context.

These observations suggests that one should allow MEs and magnetic flux tube structures with length scales of order light lifetime and try to invent a more elegant mechanism of long term memory. One might start from the mirror idea and consider the possibility that memory recall involves a

question sent to the geometric past as a classical signal reflected back to brain in a mirror formed by a magnetic flux tube: perhaps passive Z^0 MEs are involved at this stage. Thus MEs with lengths of order of light lifetime ($L = cT$) would be required. The answer presumably involves a transformation of Z^0 MEs to active em MEs and the generation of quantum entanglement unless it is present already: the recalled experience is shared by the experiencer now and experiencer in the geometric past. The mechanism involves several purely TGD based features: the lightlike character of the boundaries of MEs making possible lightlike selves; spacetime sheets with a negative time orientation allowing classical signals to propagate backwards in time; the magnetic flux tube structures associated with brain having sizes of order light years making possible MEs to form mirrors. Precognition is the temporal mirror image of this mechanism.

If long term memories are in some sense sensory experiences with the object of the perceptive field in the geometric past, the notion of the magnetic canvas should work also in these astrophysical length and time scales. Consider first the constraints on this mechanism.

1. The sensory experiences at different levels of the magnetic hierarchy cannot be identical. This means that standard sensory representation using magnetic canvas must be applied to realize the episodal memory. This leaves only two possibilities. Either the experience is coded to a lightlike vacuum current and this information, when sent into future, regenerates the sensory experience there. Alternatively, future self could entangle with the self of the geometric past and share its experience.

2. Since MEs correspond to 3-surfaces moving with light-velocity, the only possible realization of the communications between geometric past and geometric now is in terms of 'laser mirrors' connected by MEs representing geometrically the light reflected in the mirror. The length of ME is given by $L = cT$: $2T$ is the moment of the geometric past which gives rise to the memory. Interestingly, Peter Gariaev has suggested that laser mirrors are involved also with DNA [33]. This means that a ME extending from the brain of the geometric now to the geometric past and the ME from the brain of the geometric past fuse with the same magnetic flux tube to form a representation for light reflected in a cosmic mirror. The MEs and magnetic flux tube structures associated with the relevant parts of brain must form pre-existing, tightly correlated structures since the probability for the formation of this kind of mirrors accidentally is extremely small and there is no guarantee that they connect parts of the same brain. Second mirror would be obviously defined by the join along boundaries contact of ME with the magnetic flux tube. Hippocampus is a natural candidate for the brain structure, at which the first mirror is located. The fact that MEs represent channelled energy means that distance is not a problem as far as energetics is considered.

3. Active memory recall must involve a question sent to the geometric past followed by an answer communicated to future in some manner. There must be some difference between precognition and memory recall so that the question and answer cannot be realized in the same manner. This serves as an important guideline. Various arguments lead to the view that the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

   Sharing of mental images if time-like quantum entanglement is generated between the selves of the geometric past and geometric now. This is possible in TGD framework, thanks to the non-determinism of Kähler action making also MEs quantum holograms in quantum gravitational sense. The fact that MEs represent lightlike selves, would be essential for this realization. The beauty of this realization is that the information need not be transferred classically. This realization is actually a special case of the realization in terms of zigzag ME in much shorter length scale: in this case a huge number of reflections in the mirror pair would be required and it is difficult to understand how one could control the temporal position of the self of the geometric past in this kind of situation.

This picture deserves some further comments.

1. If the higher levels of the magnetic self hierarchy are intelligent as one might expect (and even more intelligent than us), one can also consider the possibility that the step in which the

interaction of ME representing a question sent to the geometric past with the magnetic flux tube at the higher level of the hierarchy is far from a mechanical interaction. Rather, the magnetic flux tube structure could act as an intelligent conscious system rather than a mechanical relay station.

2. The process could also have interpretation as an exchange of two virtual MEs between brain and magnetic flux tube structure: kind of a very low frequency counterpart of self energy Feynmann diagram realized as a generalized Bohr orbit. The Feynmann diagrams for the emission of parallel photons are infrared divergent. This encourages the expectation that the probability for the presence of MEs parallel to the magnetic flux tubes is very high and increases with the increasing length of ME. The spontaneity of the episodal memories is in accordance with this view. An interesting question is how these MEs relate to $1/f$ noise.

3. The assumption that the lengths scales of MEs and magnetic structures are identical implies that the frequency of EEG ME equal to the magnetic transition frequency f_m fixes the length of the two MEs involved and thus the temporal location of the long term memory in the geometric past:

$$T = \frac{2}{f_m} \quad .$$

This represents a frequency coding for the temporal location but in a manner different from the one proposed originally. In particular, this coding does not require ME frequencies to be in EEG range and defined with a relative accuracy of order $E - 9$. In standard physics the idea about brain generating MEs with a frequency scale of the order of the inverse of lifetime does not make sense: in TGD context situation is different since this process occurs in subjective time.

If this picture has captured something essential from the nature of the long term memories, the conclusion is that we are not at the top of the magnetic sensory hierarchy. Human body and brain generates extremely weak magnetic fields and the corresponding magnetic flux tube structures could serve as a sensory canvas making possible long term memories. Near death experiences [I3] could be understood in this framework if the weak magnetic fields associated with the higher levels of the fractal hierarchy of magnetic structures utilize brain and body as kind of sensory and motor organs. Note that there is flux tubes inside flux tubes structure so that ordinary sensory experiences can be associated also with these flux tubes.

Long term memories as memories of higher level self?

The natural identification of the immediate short term memory as subjective memory predicts that the life time of a human sensory self cannot be much longer than .1 seconds, the duration of psychological moment of time. Our long term memories correspond to much longer time interval and cannot thus correspond to our subjective memories. Entire hierarchy of subjective memories is however predicted and a possible model for *genuine* long term memories is as resulting from temporary entanglement with selves belonging to the higher level of the hierarchy. Also this identification is consistent with the fact that there seems to be no upper bound on autobiographical memory. Summation hypothesis implies that our genuine long term memories would be sums over a large number of wake-up periods of self in the subjective past of the self. Therefore one could perhaps understand how ageing self gains gradually wisdom from experience: also the identification of the long term memories as geometric memories explains this.

Higher level selves could communicate their subjective and geometric memories as well as the emotions generated by their comparison to us. The first idea to come into mind is that communications occur during totally entangled state, sleep or trance. For this option it is not at all clear how the experiences of the higher level selves during entangled state could be ours! In fact, we should lose our selves during entanglement with self characterized by larger p-adic prime. For instance, during sleep without dreams entanglement with some higher level self should occur and we do not remember anything about this. Trance is a second example of this: subject person does not remember anything about the trance state. Thus it seems that this mechanism cannot give rise to conscious long term memories. This does not however exclude the possibility that cognitive representations are formed

during the communication and lower level self experiences them later as memories. One function of sleep might be the generation of the entanglement with higher selves making in turn possible the communication of genuine memories of subjective past to our mind. This communication could realize these memories as thoughts about the experiences of past realized as nerve pulse patterns regenerating these thoughts.

The so called semitrance mechanism [N5] avoids the objections against communications occurring in totally entangled state. During semitrance parts of brain are entangled with some higher level self. These selves can communicate their memories to that part of brain which is awake (communication means generation of mental images). Ancient men received these communications as sensory hallucinations ('God's voice'), very much like schizophrenics, whereas modern man experiences them as thoughts and emotions which are often 'hallicinatory' in the sense that they are not automatic reactions to the sensory input. The TGD based vision for the development of language and civilization modifies Jaynes's vision about bicameral man as a schizophrenic of modern society and relies on the notion of semitrance. Semitrance mechanism is extremely general and could be present in all length scales. For instance, semitrance could provide the inhabitants of cell societies (organisms) and protein societies (cells) with a personal self narrative (genetic determination of cell as self narrative!).

Semitrance mechanism survives the most obvious counter arguments.

1. The general objection is that the memories of the higher level selves are rather abstract. The assumption communication mechanism is restricted to thoughts and emotions is however consistent with the abstract nature of the non-episodal long term memories. The most natural identification of episodal memories is indeed as personal geometric memories or possibly as artificially generated sensory hallucinations stimulated by higher level self during semitrance.

2. Since semitrance mechanism is only a communication method, geometric and subjective memories remain the fundamental memory mechanisms. Therefore the nice features of the geometric memory are not lost. For instance, one can understand learning and the role of emotions and repetition in learning.

More complicated scenarios

One can consider also more complicated scenarios for realizing long term memories.

1. Ensemble of mindlike spacetime sheets could generate continuously cognitive representations remaining in ideal case unchanged and memories as ability to re-experience would be carried by mindlike spacetime sheet when it wanders to the direction of future. This would require that mindlike spacetime sheets replicate just as material spacetime sheets (DNA, cells, members of species) do. If mindlike spacetime sheets responsible for memories of this kind have finite lifetime, say of order one second, short term memories could be realized in this manner without cognitive population explosion. In fact, cell division might realize long term memories in cell populations. Perhaps also DNA replication might be regarded as this kind of memory.

2. The realization of long term memory and communication relying on replication is rather primitive and the fact is that neurons do not replicate. A natural explanation is that neurons have discovered procedural memory, which means that long term memories could be realized dynamically: standardized nerve pulse patterns generate standardized temporal patterns of antineutrino Z^0 magnetization. This implies ability to regenerate the thought stimulated by the primary experience and associative learning would associate memories to experiences as thoughts. This picture would correspond to that of ordinary associative nets and is subject to the standard counter arguments such as the loss of old memories caused by the learning of the new ones.

3. Sustainment of the mental images is indeed one of the basic mechanisms behind human intelligence and can be also seen as a manner to enhance the probability that a geometric memory in the past is recalled. Sustained mental images are analogous to the icons of the computer screen, which in fact supports the idea that the evolution of computers mimics in many respects the evolution of the brain. At program level icons correspond to program loops. At neural level to periodic neural process generating again and again the same mental image (not necessarily directly conscious to us).

4. Written language and symbols are the next step to the internal sustainment and make possible to achieve a given sensory and cognitive experience in a controlled manner. Program files are obviously analogous to the written language (the electronic control systems preceding the computer era were effectively computer programs but were not written as computer code, externalized). DNA could be seen also as ROM type memory of living systems.

8.2.5 Implicit memories

A possible definition of implicit memories is as memories which exist but are not created in conscious experience of the subject person. Also implicit learning could be defined in this manner. A good example of implicit memory is provided by a situation in which unaesthetized patient can quite accurately remember what has been said during the operation [21]. An example of implicit learning is the learning of grammatical rules without any explicit (conscious) representation for them. The status of the implicit memories and learning is not established. A possible reason for this is that it is not easy to understand them in computational paradigm of consciousness. Connectionism explains implicit learning and memories as unconscious formation of associations and mathematically modelled by the dynamics of the neural networks.

In TGD framework implicit learning and memories could correspond to learning and memories at the lower levels of the self hierarchy not usually conscious to us. In case that the mindlike spacetime sheet corresponding to our subself forms join along boundaries bond with a lower level self so that lower level self fuses with the subself in question, its memories can become our conscious memories. ORP suggests that this process involves also the formation of quantum entanglement and this indeed must occur. Biofeedback could be understand as a special case of this process. In the TGD based model for the quantum correlates of the sensory qualia this process is key role. The memories communicated by semitrance mechanism can indeed be and probably often are implicit.

One can consider also formation of join along boundaries bonds between our subselves and subselves of other persons. This is quite possible if our subselves indeed correspond to topological field quanta representing ELF photons associated with the EEG frequencies having size of even size of Earth. Formation of join along boundaries contacts between topological field quanta of this size would make for us to experience the memories of other persons. This kind of mechanism could explain the memories of anesthetized patient about what happened during the operation as memories of subselves of the persons participating the operation. An open question is whether the mechanism could also explain also out-of body experiences, in which patient looks himself from outside, sometimes involved with this kind of situations.

Implicit learning could also correspond to the development of various cognitive skills realized as self-organized self cascades so that no explicit representation of the skill is needed: when initial value self wakes up, the cascade proceeds with highly predictable manner due to quantum statistical determinism. Even the ontogeny could be regarded as this kind of skill implicitely coded in DNA!

8.2.6 Procedural memories

Procedural memories seem to be mostly stabilized sequences of thoughts and mental images and the proposed model for cascade like generations of selves provides therefore a model for procedural memory. Procedural memories could be simple cognitive acts occurring again and again as a reaction to some specific stimulus. mindlike spacetime sheet would carry them while drifting into the future. For an ensemble of selves with each self initiating cognitive acts is in question, reliability of memories would result.

Quantum spin glass model of brain explanains for formation of the procedural as resulting from quantum self-organization. Dissipation caused by quantum jumps would automatically select skills, habits and eigen behaviours as surviving self-organizing patterns. These patterns would correspond to deep valleys in the fractal energy landscape of the spin glass landscape, which is effectively four-dimensional. Repetition would automatically lead to the learning of procedural memories since it would extend the valleys in time direction so that mindlike spacetime sheets would have larger probability to enter to the valley and give rise to memory. For instance, reverbrating nerve pulse patters in the memory circuits of brain would realize this repetition.

8.3 Quantum computation in biological length scales, Penrose Hameroff hypothesis, and mirror model of long term memory

Penrose and Hameroff have proposed that microtubules could act as quantum computers. The quantum states involved would be quantum superpositions of tubulin conformations and quantum gravitation would somehow make these quantum superpositions stable. Long enduring quantum superpositions of the conformations of (say tubulin) molecules would allow to perform a multiverse simulation for the conformational behaviour of the molecules and this would certainly have evolutionary value.

Penrose-Hameroff hypothesis is highly interesting from TGD point of view since TGD Universe is quantum spin glass in the sense that there is an infinite number of different configurations of spacetime sheets whose energies differ only by the gravitational interaction energy. Also the generation of coherent gravitatons by MEs might have a role to play in the quantum physics of living matter. Especially so because genuine quantum gravitational states are state functionals in the space of 3-surfaces, that is world of worlds: therefore they should correspond to higher abstraction level of consciousness than ordinary elementary particles. Furthermore, the gravitational constant associated with the energy of the induced gauge fields is by a factor 10^8 larger than the gravitational constant associated with elementary particles. The task is to put these pieces together.

In the following I will discuss Penrose-Hameroff hypothesis in more detail from the point of view of TGD.

1. TGD Universe indeed allows quantum computing under natural assumptions and the huge quantum spin glass degeneracy broken only by classical gravitation is crucial for the preservation of quantum coherence.

2. Quantum computation occurs optimally for irreducible selves which are in the 'state of oneness' and have no subselves (mental images) so that there are no dissipating subsystems. The paradoxal statement of mysticism that completely empty mind is source of infinite wisdom has therefore a precise content. Second prequisite is that all but center of mass zero modes of 3-surface representing say join along boundaries condensate of tubulin molecules (microtubule) transmute to quantum fluctuating degrees of freedom when 3-surfaces topologically condenses to a larger spacetime sheet. Otherwise a complete localization in zero modes meaning state function reduction would occur in each quantum jump and quantum computation would not be possible in time scales longer than CP_2 time about 10^{-39} seconds defining the average duration of a single quantum jump (quantum jump corresponds to 'elementary particle of consciousness' having duration of CP_2 time).

3. The problem is that standard physics predicts too short life times for the bound states so that quantum computations would still last for too short time. The huge spin glass degeneracy associated with the join along boundaries bonds however implies that there is an immense number of bound states with almost degenerate energy. This means that the branching ratio for the decay to unbound states is reduced dramatically and bound state lifetime increases.

4. An unexpected connection with the mirror model of long term memories emerges: it is the topological correlates of gravitons which are mirrored from curved almost vacuum spacetime sheet. The reason why for gravitons is that they have so weak interaction with background. What is especially fascinating is that classical gravitational binding energies in the range spanned by the cell membrane thickness and cell length scale (all p-adic length scales in this range correspond to Gaussian Mersennes) correspond to time range 1 millisecond- 100 years, the span of human memories. In particular, microtubule conformations could code for declarative long term memories. Also a connection with the idea that so called $1/f$ noise (now gravitonic) is crucial for consciousness and long term memory emerges.

8.3.1 Is quantum computation possible at all in TGD universe?

In TGD framework each quantum jump can be interpreted as quantum computation performed by entire universe. Unitary process $\Psi_i \to U\Psi_i$, where Ψ_i is a prepared maximally unentangled state,

corresponds to the quantum computation. Then follows state function reduction and state preparation involving a sequence of self measurements and given rise to a new maximally unentangled state Ψ_f.

The problem is that simplest estimate for the increment of the psychological time in single quantum jump is about 10^{-39} seconds from the idea that single quantum jump is a kind of elementary particle of consciousness and thus corresponds to CP_2 time. This would mean that 10^{39} quantum computations occur during single second and conscious experience is average over these quantum computations and the result of the computation would be averaged out completely. This would look like another manner to say that quantum computation is not possible.

That Nature would not allow quantum computation in time scales much above CP_2 time scale looks strange and there sould be ways to get out of the problem.

1. The estimate, which is just a dimensional guess, could be simply incorrect and the average increment of psychological time could be dynamically determined and be much longer. The question is about how long average time interval the p-adic-to-real phase transition front shifts towards geometric future in single quantum jump. There are good reasons to believe that this time interval is common for living organisms: otherwise one ends up with strange paradoxes. It seems however difficult to believe that this interval is as long as say .1 seconds: we would not experience a continuous stream of consciousness if this were the case and 10 Hz would be natural time scale for the rate of all quantum transitions.

2. Situation changes if the quantum entanglement associated with the quantum computer is bound state entanglement stable against self measurements and if the quantum computer self is in a state of 'irreducible selfness' and therefore stable against self measurement. Paradoxally, in mystics this corresponds to the state of oneness without any mental images: the total emptiness of mind would be crucial for quantum computation which is the most effective manner to perform information processing! In this case quantum jumping could preserve bound state for quite a long time. The halting would be caused by an external perturbation destroying the bound state. The properties of the bound state plus interaction with environment would allow to estimate the typical duration of the quantum computation. This time would take the role of coherence time. This would suggest connection with the standard approach to quantum computation.

Irreducible selfness is not enough for quantum computation. Macrotemporal quantum coherence in the sense that zero modes for the three-surface cease to be zero modes under some conditions, is also necessary for quantum computation. The reason is that localization in the zero modes corresponds to state function reduction spoiling the quantum coherence.

One can imagine two alternative mechanisms transmuting zero modes to quantum fluctuating degrees of freedom.

1. Topological condensation transforms zero modes to quantum fluctuating degrees of freedom quite generally. In this case one would effectively have no zero modes at all. This looks utterly unphysical conclusion.

2. The formation of join along boundaries bonds between 3-D space sheets implies that only the 'center of mass' zero modes remain whereas relative zero modes become quantum fluctuating degrees of freedom. This option looks realistic and is very natural in the case of tubulins and water molecules, which indeed form join along boundaries condensates. The formation of join along boundaries bonds is indeed the basic mechanism for the formation of macroscopic quantum states and the correlate for bound state quantum entanglement. This would explain why water is so important for life.

Whether one can one approximate quantum jump sequence as unitary Hamiltonian time evolution in case of a bound state is an open question. Fractality of consciousness would suggest that one can in case of quantum coherence effectively treat long quantum jump sequence as a single quantum jump (just like one can treat molecules as pointlike particles in a reasonable approximation) so that Hamiltonian description might make sense. Hamiltonian time evolution would more or less correspond to a unitary operator resulting as a product of the actions of the unitary operators U associated with the quantum jumps of the sequence. Discretized time development would emerge automatically in this framework. Schrödinger equation at infinitesimal level would not make sense but this is of course not a practical problem.

The fact that oxidative metabolism is anomalously low during a neuronal syncrony supports the view that neuronal synchrony might give rise to bound-state entangled multineuron states in 'state of oneness'(the liberated binding energy would be usable energy). The quantum computations performed by the neuronal groups might last the typical duration of 'feature', which is about .1 seconds, typical time scale of alpha rhytm.

8.3.2 Macrotemporal quantum coherence and molecular sex

The formation of bound states is a generic mechanism for generating new quantum fluctuating degrees of freedom and could make possible quantum computation like processes and multiverse states of consciousness containing large amounts of conscious information. At macrolevel sexual organism could be basic example of multiverse state of oneness generated by the formation of quantum bound state between partners. Neuroscientists use to talk about rewards and punishments and one might argue that life involves kind of sexual pleasure as a reward for the formation of bound states at all levels of hierarchy. Spiritual experiences would represent a more abstract experiences of this kind involving the formation of bound states of the field bodies by MEs serving as field bridges.

Some examples are in order.

1. The binding of molecules by lock and key mechanism is a fundamental process in living matter and could generate large number of quantum fluctuating degrees of freedom and generate conscious intelligence. This could explain why long linear macromolecules are so important for life. From the viewpoint of classical chemistry it is not obvious why DNA is arranged into long chromosomes rather than separate short threads. In TGD universe the reason why would be that for chromosomes the number of quantum fluctuating degrees of freedom and thus the amount of conscious intelligence is maximized.

2. The Ca^{++} ions binding to microtubules and molecules like calmodulin could act as switch like bridges between water clusters and microtubules and thus able to dramatically increase the number of quantum fluctuating degrees of freedom and initiate quantum computation like process. The de-attachment of Ca^{++} ions would halt the process.

3. The binding of the information molecules to receptors is a universal control mechanism in living matter. In TGD universe information molecule would initiate genuine quantum information processing lasting for the lifetime of the information molecule-receptor complex. In particular, neurotransmitters could induce molecular states of oneness in receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters have join along boundaries bonds to other neurons mediated by magnetic flux tube structures, they could act as conscious quantum links in quantum web and induce quantum computation like processes involving distant neurons just as link links in the web induce classical computations involving distance computers.

4. One could see information molecules and receptors as representatives of opposite sexes: information molecules being active quantum binders free to move from flower to flower whereas receptors would be the passive party attached to some structure. The binding of the information molecule to the receptor would be the analog of sexual intercourse. Usually the receptors are bound to larger structures such as cell membrane and also the zero modes for some parts of these larger structures could become quantum fluctuating in the process.

8.3.3 Do quantum superpositions of tubulin molecule conformations last for a time longer than CP_2 time?

In TGD quantum superpositions of molecular(say tubulin) conformations correspond quantum superpositions of 3-surfaces representing protein conformations and the question is whether they could last more than CP_2 time.

Naive argument: No

The first guess is that the conformational degrees of freedom of protein correspond in TGD framework to effectively non-quantum fluctuating zero mode degrees of freedom (zero modes do not contribute

to the line element defining the metric of the configuration space of 3-surfaces). In each quantum jump a complete localization in the zero modes must occur by mathematical consistency. Standard quantum measurement theory results if there is entanglement between zero modes and quantum numbers associated with quantum fluctuating degrees of freedom: just like between spin of electron and its classical orbit in magnetic field in Stern-Gerlach experiment.

In each quantum jump the unitary process U generates a multiverse in which different protein conformations are in quantum superposition and state function reduction selects a quantum superposition of the spacetime surfaces such that zero modes have same values for all these surfaces and state looks completely classical. If the average increment of the psychological time in quantum jump is CP_2 time about 10^{-39} seconds, this means that the quantum superposition lasts only for 10^4 Planck times and is what standard quantum gravity would also suggest apart from 10^4 factor. Thus TGD would not support Hameroff-Penrose view if the simplest assumptions are correct.

Could gravitational interaction transform zero modes to quantum fluctuating degrees of freedom?

The situation changes if the interaction of the tubulin molecule with the external world, say other tubulin molecules, somehow transforms zero mode degrees of freedom characterizing the shape of free tubulin to quantum fluctuating degrees of freedom, or rather the relative shape degrees of freedom. The mechanism would be simply the formation of join along boundaries bonds between tubulins of microtubules which would transmute all but the overall 'center of mass zero modes' to quantum fluctuating degrees of freedom. I do not know whether molecular chemistry allows examples in which molecule can be said to be in quantum superposition of different conformations or whether molecules behave effectively classically as assumed in Born-Oppenheimer approximation for calculating electronic states. In translational degrees of freedom situation is certainly different.

Quantum fluctuations in the shape of the spacetime sheet belonging to a join along boundaries condensate characterized by prime p would be of the order p-adic length scale $L_p \propto \sqrt{p}$. The ratio of this length scale to the length scale of the larger spacetime sheet at which molecules are condensed topologically, would be typically a small power of 2: $\sqrt{p/p_1} \simeq 2^{(k-k_1)/2}$, k and k_1 primes or powers of prime. Typically the factor would be $1/2, 1/4, ...$ Interestingly enough, in biological length scales twin pairs $k, k_1 = k + 2$ of primes are very abundant: in this case the value of the factor would be $1/2$ so that quantum fluctuations in shape would be maximal. Perhaps this maximation of quantum fluctuations is something deep.

Could classical gravitation stabilize irreducible bound state entanglement?

Bound state entanglement gives rise to a 'state of oneness' in which quantum computing system is totally bound-state entangled and does not decay into subselves in self measurement process and can thus behave effectively as a non-dissipating system and quantum compute. The estimates for the duration of this kind of bound states tend to be much shorter than required [24]. The question is whether classical gravitational interaction could somehow stabilize these bound states.

The extremely low value of the gravitational binding energy is an objection against the view that gravitational interaction could help to stabilize the bound states. The huge degeneracy of the bound states could however change the situation.

1. Suppose that spin glass degeneracy gives rise to a huge number of almost degenerate bound states for which only the classical gravitational energy is different and that for non-bound states this degeneracy is much smaller. The dominant part of the binding energy is of course something else than gravitational. If this is the case, the number of the bound states is so large as compared to the number of unbound states that the branching ratio for the decay to unbound state is very small and bound state entanglement can last for much longer time as usually. Although the lifetime of an individual bound state need not increase, the time spent in bound states and defining decoherence time become much longer than predicted by standard physics.

2. If the join along boundaries bonds are sufficiently near to vacuum extremals, they indeed allow immense spin glass degeneracy with slightly different gravitational interaction energies and the desired situation can be achieved.

3. This argument can be refined by using unitarity. If the net rate for the transitions to bound states is enhanced by the degeneracy of the bound states, probability conservation implies that the probability for the occurrence of decohering decays is reduced correspondingly.

A rough order of magnitude estimate for the gravitational binding energy for a cubic blob of water (that is living matter) having size given by p-adic length scale $L(k)$ is

$$E_{gr}(cubic,k) \sim \frac{GM^2}{L(k)} = G\rho^2 L^5(k) \sim \frac{Gm_p^2}{L(137)}\frac{L^5(k)}{L^5(137)} \simeq 2^{-127}2^{5/2(k-137)}\frac{1}{L(137)} \quad .$$

Gravitational binding energy is larger than the p-adic energy $2\pi/L(k)$ for $L(k=179) \simeq .169$ mm. In the range $L(163) = 640$ nm and $L(167) = 2.56$ μm gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. If the binding energy gives estimate for the lifetime of the gravitationally bound states, this might fit nicely with EEG energies in typical cell length scales!

For $k = 157$ and $k = 151$ (the range from cell 10 nm-80 nm, microtubules are at the lower end of this range) the gravitational binding frequency corresponds to a time scale of 8.5 hours and 32 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. What sounds paradoxal is that short length scales would correspond to long time scales but this indeed follows from the inverse square law for the gravitational force.

One can perform a similar estimate for linear structures. Parametrizing the microtubular transversal area to be $d = x^2L^2(151)$, $L(151) = 10$ nm, one has

$$E_{gr}(lin,k) = x^5 \times E_{gr}(cubic,151)\frac{L(k)}{L(151)} \quad .$$

This gives for $L(k) \sim 1$ meter, the frequency of $.1 \times x^5$ Hz. The time scale varies between $10/x^5$ seconds and $32/x^5$ years and certainly covers the time scale for human long term memories. Of course, this rough estimate involves numerical factor which can increase the upper bound.

Note that the increments of the gravitational energy between transitions between almost degenerate bound states are some fraction of the gravitational binding energy. Also the gravitational interaction energy associated with the classical em fields could contribute significantly to the density of the gravitational energy in TGD framework and tend to increase the overall energy scale. The reason is that the gravitational constant associated with classical fields is roughly 10^8 times larger than the ordinary gravitational constant [G1]. Thus, if the energy of classical fields is more than $10^{-8}m_p \sim 10$ eV per proton the classical field energy of, say, join along boundaries bonds becomes significant factor. Since hydrogen ground state binding energy is about 13 eV, this kind of energy density per atomic volume looks quite reasonable in case of water.

TGD universe is quantum critical system in the sense that spacetime sheets representing magnetic and electric fields with arbitrary large sizes are present and correspond to two phases in equilibrium (compare with ice and water at melting point). Electric-magnetic duality is second fundamental symmetry of quantum TGD. Magnetic flux tubes carrying constant magnetic field (in lowest order approximation) have as their duals spacetime regions carrying electric fields (constant in lowest order approximation). In biosystems various electrets and magnetic flux tube structures are the concrete realization of these two phases. Classical gravitational effects generate vacuum 4-currents near the boundaries of these structures serving as sources of magnetic resp. electric fields. The boundaries of these structures are singularities of the classical gravitational fields and these gravitational fields are good candidates for generating gravitional MEs responsible for long term memories.

8.3.4 Long term memory and gravitational MEs

Interestingly, MEs (topological light rays) with fundamental frequencies with time scale measured using year as a unit are needed in the mirror model of long term memories (to remember event at a distance of T in past is to look in mirror at a distance $L = cT/2$). The gravitational transitions between huge number of almost degenerate spin glass states could be coded to the fundamental frequencies of MEs. In particular, structures with sizes slightly above cell membrane thickness, such as microtubules, could generate these MEs as the topological correlates of graviton emission with frequency equal to the increment of the gravitational binding energy in quantum jump involved. Thus there would be a

direct correlation with long term memories and microtubules: microtubule conformations could code for long term memories.

The mirror mechanism of long term memory has beautiful interpretation in terms of topological correlates for virtual graviton exchange with vacuum.

1. The light reflected in mirror corresponds to topological light rays assignable to gravitons and is reflected from the curved vacuum. Topological counterpart of virtual graviton is emitted by (say) tubulin, absorbed by vacuum and and emitted again by vacuum, and finally absorbed by tubulin. Curved vacuum acts as a mirror for gravitons and you see yourself in this mirror.

2. Why gravitons are the only possibility in time scale of years is simply that they interact so weakly that they can propagate light years before absorbed by curved vacuum. Time scales come out correctly and microtubules are known to be crucial for long term memories (Altzheimer's disease involves changes at microtubular level).

3. There are also genuine vacuum extremals interpretable as topological graviton rays. These graviton rays could reduce to vacuum MEs except in the turning point. This would mean 'self-reflection' without scattering from background and interpretable as an absorption and emission of a virtual graviton. In case of nonvacuum extremals, classical momentum conservation however requires that the topological graviton exchanges momentum with the background spacetime surface and thus is mirrorred from it.

4. One could interpret the low energy topological graviton rays responsible for long term memory as a particular kind of $1/f$ noise accompanying all critical systems, in particular TGD Universe, which can be regarded as a quantum critical quantum spin glass. Gravitonic $1/f$ noise would be emitted in the transitions between almost degenerate spin glass states and would be kind of analog for gravitational brehmstrahlung.

5. Gravitonic MEs carry also classical em and/or Z^0 fields. The requirement that memory MEs interact weakly with the environment suggests that Z^0 MEs are in question.

If this view is correct, the time scales of long term memory at DNA level would correspond to very long time scales characterizing consciousness at the level of species. As a matter fact, the gravitational binding energy associated with $L(139) \sim .1$ nm (atomic physics) corresponds to the age of the universe: perhaps this explains why Schröedinger equation applies to the description of atom. $1/R$ dependence of the gravitational interaction energy would explain why very short length scales code biological information about very long time scales rather than vice versa.

8.4 Model for long term memories

In the following an attempt is made to understand how long term memories could be realized at neuronal level. I hope that my fragmentary knowledge about the details of brain science would not mask from the reader the beauty and simplicity of the general mechanism. The model is constructed first at general level and then basic facts about long term memory are discussed in the framework of the model.

8.4.1 General ideas

In TGD framework one can make a precise distinction between genuine memories and apparent memories such as procedural and implicit memories, associations, feature recognition, and standardized neuronal 'features' serving as building blocks of memories. The basic question is whether the representations of the long term memories are realized in the brain geometrically now or in the brain of the geometric past. In TGD the latter option is allowed by timelike quantum entanglement made possible by the non-determinism of Kähler action. The very fact that the memory storage of past memories to the geometric now is not needed, means that there is no need to carve long term memories to associative structures so that geometric now would contain representations about moments of the geometric past. Only the representation of the event at time when it occurred is needed. For example, this implies that long term potentiation (LTP) is just learning and adaptation to a new situation and

can only be related to the modification of memory representations and possibly the construction of new standardized features.

Mirror mechanism

Mirror mechanism is the simplest quantum mechanism of episodal memories and involves only a sharing of mental images by entanglement. The brain hemisphere sends a negative energy ME to the geometric past reflected at a large distance and returning back to the hemisphere and induces a sharing of mental images. The desire to remember something and the memory of the past fuse to a single mental image shared by the brains of the geometric past and now. The desire to remember would be communicated to the geometric past also in case of non-episodal memories whereas memory itself would be communicated classically by positive energy MEs.

In a more realistic situation multiple reflections for a curvilinear negative energy ME along a closed magnetic flux loop would occur and guarantee precisely targed communications to the geometric past. The sizes of these loops would be measured in light years. Z^0 Mes and Z^0 magnetic flux loops associated with the personal Z^0 magnetic body are the most realistic candidates since in this case the interaction with matter is minimized.

The notion of memory field supports this idea. Retrograde amnesia leads to a selective loss of memories in some time interval, and the notion of memory field provides a possible explanation. This means that brain structures with a given memory field entangle with those events of the geometric past which are located in some time interval ΔT at temporal distance T in the past. A closed Z^0 magnetic flux tube with a given length $L(T)$ would obviously be a correlate for a memory field with a given time span T.

The sharing of mental images mechanism requires only that gravitational/Z^0 MEs take care of only quantum entanglement and because it allows arbitrary kinds of episodal long term memories. The electric stimulation of neurons can induce complex episodal memories. This can be understood if the episodal memory recall involves only the entanglement by the negative energy ME and the field pattern associated with ME does not matter at all. The unique experimental signature of the quantum entanglement mechanism is that no direct correlates for the memories themselves are necessary in the brain geometrically now. One can wonder what distinguishes the resulting experience from precognition by the self of the geometric past: could it be that to precognize now is to remember in the geometric future?

The direct sharing of sensory experience is non-economical in the sense that the amount of the irrelevant information is very high. The conceptualization involved with the symbolic representation allows to represent only the absolutely essential aspects. In case of classical communications symbolic representations is of course the only practical possibility. Since the brain of the geometric past serves as a passive entangler and does not have the possibility to process the communicated information, the sharing of the mental images is not flexible enough and does not allow an active precisely targeted memory recall. It is also very difficult to tell whether sensory experience represents memory or a genuine experience.

Classical communications and non-episodal memories

For non-episodal memories classical communication mechanism suggests itself as a more appropriate mechanism. Classical signalling requires the coding of the data to the shape of the field pattern propagating along positive energy ME, which could be curvilinear and analogous to a radiation propagating in a wave cavity defined by a magnetic loop of the magnetic body.

MEs are indeed optimal for the coding of the classical signal since the vacuum current for given moment of geometric time is non-deterministic. Classical communications would allow and also require the minimization of the data communicated. These memories would not be sensory unless back-projection to the sensory organs is involved at the receiving end. The formation of the symbolic representation is subject to errors: for instance, temporal order of events can change. It is known that declarative memories can often involve changes of the temporal order. It must be emphasized that declarative need not be synonymous with non-episodal. Declarative memories could be also episodal and correspond to sharing of a symbolic mental images of the geometric past.

A dramatic reduction of the phase velocity is required, and is also assumed to occur for Z^0 MEs in the model of nerve pulse and it could occurs for EEG MEs because of the interaction with brain.

The phase velocities of EEG waves in brain provide a good estimate for the effective phase velocities of MEs. The mechanism reducing the velocity is quantal: positive energy ME drifts to the direction of geometric future quantum jump by quantum jump and this reduces the effective phase velocity. Thus it would seem that classical communications might rely on positive energy EEG and ZEG MEs in EEG frequency range. Z^0 cyclotron frequencies are quite generally in alpha band so that Z^0 MEs could be responsible for the communication of the long term memories using memetic code whereas EEG MEs might be responsible for various sensory representations at the personal magnetic body and even magnetosphere. Note that the "features" of Freeman [26] having during of about .1 seconds are good candidates for the representation of the classical signals. If EEG MEs are involved, the modulation of hippocampal theta frequency is a candidate for the representations of classical signal.

There are are two basic options for how the classical communication could occur.

1. Positive energy ME would not leave brain at all and would therefore have ultra slow effective phase velocity along the brain structure in question, say axon, so that it would not leave brain during its travel to the geometric future.

2. Positive energy ME would be curvilinear and parallel with magnetic flux loop of the personal magnetic body serving effectively as a wave guide. In this case the reduction of the phase velocity to EEG wave phase velocity would be enough. For instance, for the phase velocity of alpha waves propagating along loops with the size of the order of the Earth's circumference, the time span of the memory would be of the order of one year. In this picture one of the functions of the part of EEG and ZEG representing evoked responses could be classical communications making possible non-episodal memories. Only part of these memories would be conscious to us. The length of the magnetic loops is expected to directly correlate with the period of EEG frequency involved with the classical communication via the relationship $L = vT$ would provide a second correlate for the notion of the memory field. There are indeed reasons to expect that the structures communicating signals to the geometric future are specialized to communicate signals to a certain distance.

The most plausible neurophysiological excitations associated with the received signal are Ca^{++} waves known to have extremely wide velocity spectrum. For the option a) the required velocity would be of order neuronal sizes per year, and this is perhaps unrealistically low velocity. It is also difficult to see how the neuronal noise would not spoil the signal. For the option b) the positive energy ME entering brain at the moment of memory receival would induce Ca^{++} waves in turn inducing neural activity.

For classical signalling the transformation of the classical signal to a conscious experience is needed. Positive energy Z^0 MEs could directly generate membrane oscillations and nerve pulse patterns via the general mechanism of nerve pulse and EEG discussed in [M2]. EEG MEs could in turn induce cyclotron transitions at the magnetic flux tubes of the Earth's magnetic field and induce modulations of Z^0 MEs in turn affecting nerve pulse generation. Also a transformation of the signal to Ca^{++} waves could be possible. The conscious experience does not involve sensory component unless there is back-projection to the level of sensory organs involved.

Interesting questions relate to the interpretation of the ultraslow effective phase velocity of MEs acting as bridges connecting two space-time sheets.

1. The classical fields from a larger spacetime sheet A can be transferred to a smaller spacetime sheet B topologically condensed on A by inducing the motion of the wormhole contacts, which in turn generate classical fields at the smaller space-time sheet. The fields can also penetrate along join along boundaries bonds connecting the boundaries of two space-time sheets.

2. Quite generally, the "topological" half of Maxwell's field equations implies that tangential component of E and normal component of B are continuous at the junctions connecting the boundaries of two space-time sheets. One could assume that quantum effects can be modelled phenomenologically by introducing the phenomenological D and H fields introduced also in the Maxwell's theory. In the Maxwell's theory the discontinuity of the normal component of the D field equals to the density of the free surface charges and the discontinuity of the tangential component of the H field equals to the free surface current. These conditions can be assumed also now, at least as the first approximation.

3. One could model the propagation of MEs topologically condensed at a spacetime sheet labelled by a p-adic prime $p \simeq 2^k$, k prime or power of prime, by introducing the di-electric constant $\epsilon(k)$ and the relative permeability $\mu(k)$ satisfying the condition $\epsilon(k)\mu(k) = 1/v^2 > 1/c^2 = 1$, where v is the effective phase velocity of ME depending in general on its fundamental frequency. The fields D and H would be defined as $D = \epsilon(k)E$, $H = B/\mu(k)$: this condition generalizes to that for the Fourier components of the fields. The reduction of the effective velocity for the propagation of the topologically condensed MEs to say alpha wave phase velocity does not seem plausible.

4. The propagation of MEs which serve as bridges between boundaries of two spacetime sheets (say cell membrane spacetime sheet and cell exterior spacetime sheet) must be modelled differently. One could introduce a generalized di-electric constant $\epsilon(k_1, k_2)$ and permeability $\mu(k_1, k_2)$ characterizing the pair of spacetime sheets such that the effective phase velocity $v(k_1, k_2)$ of MEs acting as bridges satisfies $\epsilon(k_1, k_2)\mu(k_1, k_2) = 1/v^2(k_1, k_2)$, and also now depend on the fundamental frequency of ME. A very large value of $\epsilon(k_1, k_2)$ implying the needed very small value of the effective phase velocity would mean that the orthogonal component of the electric field does not appreciably penetrate inside ME from either spacetime sheet. Since MEs are the fundamental topological field quanta, this looks a natural assumption. The extremely low effective phase velocity should be due to the replacement of the wormhole contact coupling with the join along boundaries coupling causing the "stucking" of MEs. Note that the join along boundaries coupling is topological sum coupling for boundaries whereas wormhole contacts represent topological sum coupling for interior. Furthermore, join along boundaries contacts can have a macroscopic size whereas wormhole contacts are CP_2-sized: this could explain the huge reduction of the effective phase velocity for the boundary MEs.

Negative energy Z^0 MEs as ideal entanglers with the geometric past

Gravitational, or equivalently Z^0-, MEs with negative energies are especially favoured for quantum communications. The reasons are many-fold. The interaction with the matter is very weak in long length scales but strong in cellular length scales, negative energy implies that ME is identifiable as a virtual particle and analogous to a part of a Feynmann diagram so that no dissipation is involved and quantum communication is possible. The reversal of the arrow of geometric time means also that there is not macroscopic dissipative dynamics which would spoil the quantum coherence.

The requirement that the entanglement process is highly selective suggests a resonance mechanism. This requires that receiving and sending structures are similar and generate ULF MEs with fundamental frequencies measured typically in cycles per year. If negative energy energy ME is in question, as suggested by the idea that a classical communication to the geometric past is involved, it cannot be emitted unless there exists a receiver absorbing the negative energy and in this manner providing energy for the sender by buy now-let others pay mechanism. For negative energy MEs resonance mechanism plus a simple classical signal serving as a a password could also guarantee that correct part of the brain receives the signal.

Negative energy MEs represent time reversed level of the p-adic length scale hierarchy so that the dissipative effects associated with the space-time sheets with the normal arrow of time should not interfere with the quantum communication. This at least, when the energy of the negative energy ME has a magnitude larger than the thermal energy associated with the space-time sheets with which it interacts: there is simply no system which could make a transition to a lower energy state by the absorption of a negative energy ME. Furthermore, since the systems with reversed arrow of geometric time are expected to have extremely low density, the dissipative effects in the reversed direction of time are expected to be small.

Since the generation of negative energy MEs does not require energy feed, the memory recall to the geometric past occurs more or less spontaneously, and the scanning of the geometric past becomes possible. The intentionality of the memory recall would be realized as generation of a p-adic Z^0 transforming to a negative energy Z^0 ME, when the real system jumps to a higher energy state. This process makes possible precisely targeted intention also in the case of memory recall since the transitions in question cannot occur spontaneously. In the case of precognition precognizer must intentionally receive negative energy MEs from the geometric future so that energy feed is needed. This perhaps explains why precognition is so rare. Note that p-adic variant of pre-cognition having

interpretation as intentionality occurs easily since p-adic energy is conserved only in a piecewise manner.

The most often needed non-episodal memories, say short term memories, could be communicated automatically: in this case the memory recall would be a geometro-temporally local operation, much like taking a sample from a data stream representing particular kind of memories with a particular time span. The option is probably not realized for all non-episodal memories since this would require large energy expenditure.

8.4.2 Is the right brain hemisphere the quantum entangler?

There are some reasons to suspect that the quantum communications with the geometric past occur more dominantly in the right brain hemisphere whereas classical communications would occur in the left hemisphere. This would explain among other things the holistic aspects of right brain consciousness. Left brain hemisphere is specialized more to symbolic processing of information and would indeed be more suitable to classical communication of this information.

Clearly, right brain would be passive receiver whereas left brain would be active expresser. DNA strands would be an example of this dichotomy at molecular level. This dichotomy would be realized also at the level of gene expression using em and Z^0 MEs as the model of biophotons involving in essential manner negative and positive energy MEs suggets. Of course, this statement must be take only in the spirit of fractality and wuold hold true only in certain range of p-adic time scales.

The following arguments lend some support for the proposed division of labour between right and left brain hemispheres.

Synesthesia as a key to the mechanism of episodal memory

What forces brain region to send negative energy Z^0 MEs and thus to remember? "Hunger!" is the possible answer! During synesthesia the metabolism in the left cortex is reduced by by 18 per cent due to the abnormally high metabolism in memory circuit (for the model of synesthesia see [H3]). Perhaps the generation of the negative energy Z^0 MEs is forced by the starvation of the neurons of the left cortex induced by the over-activity of the neurons of the memory coordination circuit. The starving cortical neurons of the left hemisphere would send massive amounts of negative energy Z^0 MEs to the direction of the geometric past inducing entanglement bridges by the mirror mechanism with the brain of the geometric past in turn inducing episodal long term memories by the sharing of the mental images. Thus the miraculous ability of synesthetes to remember episodally could be understood to result as a by-product of a neuronal emergency reaction.

There are good reasons to expect that same mechanism might be at work also in the normal situation but involve a less dramatic artificial starvation of the neurons of the right brain hemisphere. Clearly, the role of hippocampus is dramatically different from what is usually believed and also forces to question the naive belief that neuronal activity is a measure of the contribution of brain area to the conscious experience. While building long term memory representations as classical signals hippocampus and memory circuit would steal energy from certain areas of cortex, and the resulting metabolic starvation would force them to send negative energy MEs to gain energy in this manner. This in turn would lead to the generation of long term episodal or non-episodal memories as a side product. Quite generally it is known that limbic brain and cortex tend to work in complementary modes: when the cortex is in a high state of arousal, limbic brain is in a state of low arousal and vice versa. Perhaps the passive brain region is involved with memory recall and the active one with the construction of sensory or memory representations.

Left-handedness and episodal memory

It is known that persons with many left-handed family members have better ability for episodal memory recall and that this probably relates closely to the communication between left and right hemispheres. We begin to have verbal memories only after the age of four: at this time also the connection between right and left hemispheres has matured. The proposed mechanism of non-episodal memories requires that the right brain hemisphere shares the mental image representing the desire to remember and the left brain hemisphere communicates the memory classically. Als the communication between right and left hemisphere is necessary for this process to occur. Children before the age of four

could live in a kind of a dream time experiencing mostly sensory episodal memories and presumably not being able distinguish memories from genuine experiences. This would also explain why we do not have declarative memories dating to the time before the age of four.

How could one understand the tendency of persons with many left-handed family members to have better episodal memory recall? The ability to have sensory memories can appear also when a damage occurs to the regions of the left hemisphere. It could be that classical communications between the hemispheres are worser than usually when episodal memory recall is favoured, and are replaced by quantum communications. The mental images in the left brain hemisphere would entangle with those in the right hemisphere entangling in turn with the geometric future and give rise to episodal memories. Thus the quantum communications between hemispheres might be better than usually. This kind of persons would be more "holistic" than ordinary persons.

NDEs and long term memories

That negative energy Z^0 MEs could be responsible for episodal long term memories is supported by near death experiences. Persons having near death experiences are clinically dead: in particular, EEG is absent. If these persons indeed have conscious experiences and if they are able to remember them as it seems, and since EEG signals are out of question, only the Z^0 MEs generated during NDE remains as a viable alternative in TGD framework. Brain or possibly body should be involved with the receival of geometric memories if spin glass degeneracy is essential for the entanglement by Z^0 (gravitational) MEs.

Life review is one important aspect of the NDE experiences: entire 4-dimensonal body is experienced simultaneously. The starvation of neurons forcing them to generate negative energy Z^0 MEs could explain the episodal memory feats of synesthetes and the eidetic memory, and would naturally be at work also during NDE experience. This is not the only possibility. This experience might also be partially due to the absence of the dominating p-adic-to-real phase transition changing intentions to actions. This life review memory could be interpreted as geometric memories not masked by the normal contributions to the contents of consciousness. An interesting possibility is that this contribution is generated by theta and delta bands of EEG during lifetime and is present also normally but, being strongly masked, is not recognized.

Dejavu experiences and memory feats

Dejavu experiences provide a challenge for any realistic model of memory. In Dejavu the sensory experience is accompanied by the feeling 'I have experienced this already earlier'.

A natural working hypothesis is that purely sensory memories, sensory re-experiences, do not contain information about the value of the geometric time associated with the sensation. This means that sensory memories cannot be distinguished from real experiences. On the other hand, cognitive and symbolic memories differ so radically from the sensory experiences that there is no difficulty of distinguishing them from genuine experiences. Therefore one knows that the experience represented by this kind of memory occurred in geometric past or represents an expectation of future. Symbolic (real) and cognitive (p-adic) representations are very probably continually transformed to each other. If this view is correct, then the simultaneous occurrence of the sensory and cognitive memories implies dejavu experience. The event giving rise to the sensory and cognitive memories might have occurred only few seconds earlier.

This view has some nontrivial implications concerning the character of conscious experience of children. Cognitive abilities are thought to appear only after the age of four or five years. If also symbolic memories are absent, small children might live in a kind of dream time, as also members of primitive cultures, such as aboriginals, are believed to live in. Also dream consciousness could involve in an essential manner sensory memories as suggested by temporal acontinuity of dream consciousness. One could also see dreams as transformations of cognitive representations to sensory ones and such reverse to what occurs in wake-up consciousness so that surreal dream logic could basically result from p-adic non-determinism. The back projection to the sensory organs would be an essential element of the mechanism.

The absence of a temporally organized consciousness would explain why we do not possess memories from the age before four. Perhaps also the bicameral consciousness, which according to Jaynes preceided modern consciousness, was kind of dream time consciousness in which memories were direct

sensory experiences, like voices experienced as voices of gods and visual hallucinations. According to Jaynes, also schizophrenics are modern bicamerals.

Some time ago I saw a TV document about some autistic persons, who have very serious cognitive defects like inability count the number of objects if it exceeds two, are capable of miraculous memory feats. One of these fascinating individuals was an artist who could draw in full detail a picture about an area of London containing thousands of buildings after havin seen the area once from a helicopter. Another autistic artist, virtuoso pianist, could reproduce every piece he had heard with highly personal style. Perhaps also great musical wunderkinds like Mozart have had similar direct sensory memory for music. Also a brain damage spoiling cognitive abilities can lead to the blossoming of exceptional artistic gifts. If the neuronal metabolic starvation forces the generation of negative energy Z^0 MEs in turn giving rise to long term episodal memories then one could indeed understand how brain damage could have this kind of positive consequences.

The explanation suggesting itself is that the loss of cognitive memory is compensated by sensory memory in this kind of situations. A plausible reason for why average human being has dominantly cognitive memories is simple. Sensory memory contains huge amounts of un-necessary data: symbolic and cognitive memories have much higher survival value since only the relevant data are stored. Sensory genii have very hard time in the modern society unless they work as artists!

In light of foregoing, the poor cognitive abilities of animals suggest that also animals remember predominantly sensorily and live in dream time (note however that rats have hippocampal theta). For instance, dogs might have sensory memory dominated by odours. The challenge is to invent tests for this hypothesis. One could also try to device a non-destructive method leading to a temporary loss of cognitive consciousness and making possible to spend a day as a dog.

8.4.3 Going to the neuronal level

The following attempt to develop the model of long term memory at the neuronal level is made involves many uncertainties and must be taken as an exercise in order to get accustomed with the ideas involved.

Which parts of the brain are the quantum entanglers?

It is known that the electrical stimulation of amygdala, hippocampus, and temporal lobes can generate lively sensory memories. The simplest explanation is that quantum entanglement with the sensory representations of the geometric past is in question. The role of the electric stimulation would be only the generation of time like entanglement, not providing any information characterizing the memory. This would mean that large portions of brain can participate to the generation of episodal memories.

The fact that the part of body must be able to generate negative energy Z^0 MEs with a proper ULF time scale, poses constraints on the system involved. Cellular sub-systems and microtubules are good candidates in this respect since the transition frequencies for the transitions involving change of classical gravitational are in the required range. Since resonance mechanism is probably involved, there are good reasons to believe that similar system is is involved with both the receival and sending of the message. Microtubular structures are good candidates adn accompany both neurons and glial cells.

Energetics poses also constraints. The receivers of negative energy MEs should have an easy access to the metabolic energy resources compensating the negative energy. In fact, the receiver must be in an excited state, which decays when negative energy Z^0 ME is received (dropping ions to a larger space-time sheet could be also involved). Glial cells serve as metabolic resources of the brain and interact with neurons via Ca^{++} waves and are the first guess for the system entangling with negative energy MEs. Other parts of brain and body, even sensory organs, can get metabolic energy by entangling with astrocytes via negative energy MEs so that the desired sharing of mental images would indeed result.

The notion of memory field [18] was derived from the study of short term memory and applies to the neurons of the frontal lobes at least. The span T of the memory field is essentially the time span of the long term memory. T correlates strongly with the fudamental frequency associated with the negative energy ME if quantum entanglement is involved, and the length of magnetic loop and curvilinear negative energy Z^0 ME satisfies $L \sim cT = c/f$, where f is a frequency related to a transition in which gravitational energy of the system is question changes.

When f is expressed in terms of the size of the water blob generating gravitational negative energy Z^0 ME in spin glass transition this gives $T \propto L^{-5}$, where L is the size of the water blob serving as a gravitational quantum antenna. Z^0 MEs with T varying in the range 8.5 hours- 32 years in the length scale range 80 nm-10 nm are generated. One day (24 hours) would correspond to a length scale 33 nanometers: 3.3 times the thickness of the cell membrane. In case of neurons only the intracellular structures having much larger sizes and much higher gravitational binding energies might serve as entanglers (larger spacetime sheets would be in question) and give rise to short term memory. The time scale of 1 minute corresponds to about .3 micrometers, millisecond corresponds to $L(167) \simeq 2.3$ micrometers, whereas $L(163)$ corresponds to a time scale of 1 second. This would suggests that sub-neuronal water blocks larger than the size of cell nucleus could generate short term memories which need not be conscious-to-us. Perhaps the flux loops of the magnetic body of the cell nucleus are involved.

For linear structures like microtubules one has $T \propto 1/L$. Even in this case a rather strong dependence on the time span of the long term memory on the system generating negative energy Z^0 MEs results. The fact that microtubules are ideal for representing conscious information symbolically, suggests that neuronal/astrocytic microtubules serve as the entanglers at sending/receiving end of the quantum communication line responsible for long term memories. This picture also suggests that the Z^0 magnetic flux loop of a given astrophycal length scale is associated with a microtubule of a given length.

Where the classical signals are generated and received?

There are several bits of information helping to guess how long term memories might be realized.

1. The damage of the hippocampus leads only to a loss of the ability to generate new declarative memories but does not lead to a loss of long term memories from the period when hippocampus was intact. Thus it seems that hippocampus plays essential role in the communication of our non-episodal declarative memories to the geometric past and that at least a dominant part of the receivers are somewhere else than in hippocampus. Since the stimulation of both amygdala, hippocampus and temporal lobes induces long term episodal memories, it would seem that all these structures can serve as quantum entanglers.

2. New neurons and glial cells are regenerated in hippocampus and the regeneration is especially intense during ischemia which can destroy a lot of neurons [16]. This would suggest that both glial cells and neurons are essential for the realization of long term memories.

These pieces of data give some guide lines in the attempt to build a more detailed model of long term memories.

1. The generation of classical signals requires metabolic energy and this suggests that the generation occurs as near as possible to energy resources. Glials cells are known to be the providers of the metabolic energy. Synchronously firing neuron groups are accompanied by astrocytes forming gap junction connected structures. For a long time it was believed that astrocytes play only the role of passive energy storages but it has become clear that there is signalling between astrocytes and neuronal groups based on Ca_{++} waves. Astrocytes couple also strongly to sounds: for instance, it is known that very mild blow in head inducing sound waves can lead to a loss of consciousness. Perhaps the astrocyte structures associated with hippocampal neurons generate positive energy MEs responsible for the classical communications making our non-episodal memories possible.

2. The receival of the classical signal does not require metabolic energy. If astrocytes are involved with the sending of the classical signal, then neurons would be naturally the receivers of the signal and the energy received with the signal would partially explain why synchronous firing of neuronal groups seems to require less metabolic energy than expected. Of course, quantum entanglement by negative energy MEs wither energy sources could also explain this.

Is memetic code used to code declarative long term memories?

Memetic code is a good candidate for the coding of declarative long term memories. The duration of single memetic codeword would be about .1 seconds and the duration of a single bit would be about 1 millisecond. This hypothesis fits nicely with the facts that the Z^0 cyclotron frequencies are around 10 Hz; that the frequency of neuronal synchronal firing is about kHz; and that there seems to be no direct electromagnetic counterpart for the synchronous firing.

Quite recently it became clear that TGD predicts counterpart of Tesla's scalar waves [I4, I5]. These waves represent a pulse of electric field propagating with a velocity of light and an electric field in the direction of propagation. These waves corresponds in TGD to spacetime sheet of finite length and duration ($L = cT$) carrying constant electric field and propagating with velocity of light to the direction of the field. This solution type is extremely general and dual to the magnetic flux tubes. Electrets (and also zelectrets) are one manifestation of these structures in living matter (membrane potential is one example of this kind of structure).

One could consider the hierarchy of Z^0 MEs representing geometrically a hierarchical structure of commands and that memetic code corresponds to the lowest level with bit represented by a electric pulses whose polarity determines whether '1' or '0' is in question: very much like in case of computers. Zelectret sequences would ultimately give atomic nuclei kicks in a direction depending on the value of the bit.

What about other synchronous EEG frequencies?

Genuine theta (hippocampal theta which spans both theta and alpha bands) and delta bands could correspond to more abstract levels of consciousness not directly experienced by us usually. During slow wave sleep theta and delta bands dominate and the interpretation in terms of the binding of the mental images to memory representations is highly suggestive. Hence these bands would contribute to our consciousness in the geometric future rather than in the geometric now.

1. Theta band might relate to long term memory consolidation by a construction of temporal replicas of ordinary long term memory representations generated already during the wake-up period. Sleep state is certainly ideal in this respect.

2. Naive extrapolation suggests that delta band memories correspond to a rather long temporal distance T (that is very low frequency $f = 1/T$ for gravitonic MEs). Delta band memories would be therefore generated by structures with sizes below the thickness of cell membrane. One could understand why delta band is strongest in childhood and weakens towards old age. If delta band memories correspond to very long temporal distances T, it is useless to generate these memories at the old age since there would be no brain receiving these memories. The long time span of the delta band memories would explain why childhood memories are stable and why some persons 'return' to their childhood at the old age. The return to the sensory world of childhood at old age suggests that delta band memories must be sensory memories. Delta band representations might even give rise to transpersonal memories experienced during the later lives. The absence of ordinary sensory input masking delta band memories would explain why earlier life cycles can be recalled in meditative states.

3. The contribution of theta and delta band memories to our consciousness could also relate to the third person aspect of consciousness. Theta and delta waves could be associated with the magnetospheric sensory representations giving rise to multibrained selves. The entanglement between sleeping brains inducing a loss of personal consciousness would induce a kind of collective stereo consciousness in which a large number of invididual views about world fuse together would be in question. The search for correlations between the EEGs of sleepers having a close personal relationship might be rewarding. For istance, DNA could quantum entangle and give rise to conscious memories in very long time scale at the level of species.

Note that the presence of synchronous or asynchronous EEG correlate of memory generation is present also during memory recall does not seem to be necessary since the memory is indeed in the geometric past.

Questions

One important question is whether positive energy EEG MEs are involved with long term memories or only with sensory representations (assuming that sensory representations are realized at the magnetic body). The idea that Z^0 MEs take care of memories and EEG MEs of sensory representations is attractive idea at least.

Fascinating questions relate to cognitive representations since these involve p-adic physics. Frontal lobes are known to be the seat of planning, volition and cognition. Therefore p-adic cognitive representations, p-adic entanglement and the p-adic selves characterized by positive entanglement negentropy should be realized in the neural circuits involving frontal lobes. These circuits have been even proposed to be 'conscious circuits' but this probably reflects the erranous identification of consciousness as cognitive consciousness only. Cognitive representations could be realized at magnetic cognitive canvas using beta frequencies as resonant frequencies and beta MEs would entangle with the points of the cognitive magnetic canvas p-adic mental images representing intentions and plans. The transformation of these p-adic mental images to real ones would somehow generate generalized motor actions, in particular ordinary motor actions. That frontal lobes contain motor areas conforms with this view.

8.4.4 Hippocampus and long term memories

The findings about hippocampal system provide a good test for the general ideas about long term memory. For a review about the role of hippocampus in long term memory see [23].

Anatomy of hippocampal system

The anatomy of hippocampus is discussed in [19]: here only very rough summary is given: possible inaccuracies are due to my amateurish knowledge of brain science.

Hippocampus is located with the inferior medial wall of the temporal lobe posterior to the amygdala. Hippocampus decomposes into anterior and posterior regions. Hippocampus consists of a number of subcomponents, and adjoining structures, such as the parahippocampal gyrys, entorhinal and perirhinal cortex and uncus. The main body of the hippocampus consists of the detante gyrus (here brain cells are regenerated), the subiculum and the sectors referred to as CA1,CA2,CA3 and CA4. The uncus is a bulbar allocortical protrusion located in the anterior-inferior medial part of the temporal lobe.

There are three major neural pathways leading to and from the hippocampus. These include the fornix-fimbrial fiber system, and a supracallosal pathway which passes through the cingulate, and via the entorhinal area: this is the mesocortical gateway to the hippocampus. Through the fornix-fimbrial pathways hippocampus makes major interconnections with the thalamus, septal nuclei, medial hypothalamus, and exerts either inhibitory or excitatory influences on these nuclei.

The entorhinal cortex acts to relay information to and from the hippocampus. The hippocampus maintains via the entorhinal cortex interconnections with the neocortical multi-modal associations areas of the temporal, frontal, and parietal lobes, including surrounding structures, e.g., the parahippocampal gyrus, and allocortical tissues, the perirhinal cortex, septal nuclei and amygdala. The parahippocampal gyrus, entorhinal and perirhinal cortex, being directly interconnected with the hippocampus and the neocortex, act to relay input from the neocortical association areas to this structure.

The entorhinal cortex consists of 7 to 8 layers rather than only 6 layers. The entorhinal cortex maintains massive interconnections with all multi-modal neocortical association areas (as well as with the amygdala, hippocampus, septal nuclei, olfactory bulb, etc.) but none of the primary sensory areas which presumably relates to the fact that hippocampus is responsible for declarative rather than sensory memories.

Memory deficits and hippocampus

Memory deficits provide important information about the role of hippocampus with respect to the memory. In anterograde amnesia the ability to generate new long term declarative memories is lost and it is known that a damage to the hippocampus can cause this defect. Thus it seems that hippocampus is crucially involved with the construction of long term memories. Also the damage to the medial temporal lobes and subcortical structures such as medial thalamus and mammillary bodies

can destroy the ability to generate long term memories. This supports the view that hippocampus is kind of a central entangler binding together mental images from various parts of brain: most naturally entanglement occurs along the three neuronal pathways going through hippocampus and presumably associated with toruslike magnetic flux tubes.

In retrograde amnesia memories about some period of time in past are lost. It seems that this deficit does not correlate with the damage of hippocampus. Thus the cautious conclusion is that long term memory recall occurs also elsewhere in brain. The selectivity of the retrograde amnesia suggests that the notion of the memory field applying in the case of short term memory [18] generalizes. The brain structures responsible for the receival of long term memories are specialized in the sense that they entangle with the mental images of the geometric past located only in an interval around certain temporal distance T. If the memories involve only few reflections along a closed magnetic flux loop, the corresponding Z^0 (gravitonic) MEs have fundamental frequency $f = 1/T$ and correspond to spin glass transition for microtubules or for 3-dimensional sub-neuronal structures at a length scale between cell size and cell membrane thickness if the simplest estimate makes sense. This kind of resonant selectivity might be possible to achieve if the receiving system is driven to the bottom of the spin glass landscape with a depth which corresponds to the gravitonic energy $E = 2\pi f$ If memories involves large number of reflections, it is difficult to imagine, how this kind of selectivity could be achieved.

Hippocampus and declarative memory

It is known that there are several memory types and hippocampus is responsible for the construction of only declarative memories, which are verbal and highly symbolic representations of the geometrical aspects external world. Hippocampus is not essential for the recognition of familiar objects nor for procedural/motor memories which are implicit memories. The natural identification of declarative memories is as memories communicated classically using some coding but one cannot exclude sharing of mental images. Memetic code or its scaled up/scaled down is a good candidate in this respect. The modulation of hippocampal theta might provide the coding.

Sensory memories can be induced by the electric stimulation of both hippocampus, amygdala and temporal lobes. This suggests that lower levels of self hierarchy which we do not experience directly can have sensory memories. The entanglement by negative energy Z^0 ME with the geometric past giving rise to an episodal memory is the most natural interpretation for the effect. Neural loops are the geometric correlates for entanglement at the level of CNS, and timelike quantum entanglement of parts of the electrically stimulated structures with primary sensory areas with the mediary of these loops should be involved. If the stimulation is too strong, hallucinations result. In this case the sensory representations in thhe brain geometrically now are presumably activated and back projection to the sensory organs would occur. An interesting possibility is that the strength of stimulation correlates with the temporal distance of the sensory representation in the geometric past activated in the stimulation.

Hippocampus provides spatial and temporal context

The right hippocampus of the taxi drivers in London is enlargened. This supports the view that hippocampus provides kind of a symbolic map of the spatial layout of the environment. Studies in animals suggest that hippocampus adds a spatial context to the mental images from cortex entangled with mental images in subhippocampal structures entangled with the mental images in hippocampus. The spatial map is based on various spatial cues serving as landmarks. Left hippocampus is in turn involved with the verbal memories and this suggests that it is responsible for providing a temporal context and time ordering of events. This suggests that hippocampus is responsible for the temporal and spatial organization of conscious experience besides generating memory representations. Perhaps a high level sensory representations at the magnetic body is in question.

Hippocampus is known to contain place cells providing cognitive representations for the objects of perceptive field. These place cells are pyramidal cells containing magnetic crystals which suggests that they act as projectors to the magnetic memory canvas. All kinds of features could be associated with these landmarks, and more generally, with the symbolic objects of the memory field.

Long term potentiation (LTP) does not occur in hippocampus but hippocampus is highly dynamical with synaptic contacts being generated all the time and even the size of hippocampus continually changing. It would seem that hippocampus provides by its own dynamical structure a context for

various data coming from cortex, kind of a geometro-symbolic model for the external world. The mental image associated with this model of external world quantum entangles with the mental images in cortex, amygdala, hypothalamus, etc...

Not only spatial but also temporal context is important and hippocampus should provide also this. Purely sensory memories do not carry any information about whether memory is in question or not. For symbolic representations the situation is different. Symbolic representations would be realized as association sequences, perhaps in the time scale of hippocampal theta such that each 3-surface of association sequence contains lower level association sequences contains.... Memetic code words of duration .1 seconds would be at the lowest level and perhaps correspond to mesoscopic features of Freeman [26].

The intronic portion of DNA could provide the fundamental hardwave representation of memes in terms of sequences of 21 DNA triplets: spoken language would be only a tip of an iceberg if this picture is correct [L1]. Positive energy em and Z^0 MEs could realize these memes in the shape of vacuum current, which at given moment of time is non-deterministic and therefore optimal in this respect. Memetic code realized in terms of Z^0 magnetization direction for cognitive antineutrinos is a further candidate for realizing the symbolic representations. This highest level representation adding context to the other data located in the geometric past would entangle via Z^0 MEs with the brain of the geometric now in case of episodal memories. The fact that hippocampus is thought to be involved with the trassfer of items in short term memory to long term memory in cortex conforms with the mirror mechanism.

Entorhinal cortex serves as somekind of a relay station between hippocampus and neocortex. Entorhinal cortex has very special structure being 7-to-8 layered rather than 6-layered. Entorhinal cortex maintains rich connections to various multimodal regions in temporal, parietal and frontal cortices but not to the primary sensory areas. This is consistent with the idea about three-leveled hierarchy *multimodal areas→ entorhinal → cortex-hippocampus*, with the fact that the mental images associated with hippocampal memory representations are symbolic rather than sensory, and with the assumption that multimodal areas, entorhinal cortex, and hippocampus entangle.

Hippocampal theta corresponds to EEG frequency range varying from about 4 Hz to 12-14 Hz and thus spans both theta and alpha bands. Hippocampal theta can be seen as a correlate for the binding of various cortical and subcortical mental images to a single mental image representing both that aspect of consciousness which makes possible organized view about space and time and declarative memory. MEs at hippocampal theta frequencies could project to the magnetic memory canvas providing an abstract representation about world analogous to sensory representation but without sensory qualia. It must be emphasized that the memory representation should provide an essential part of our everyday consciousness making possible space and time categories of everyday conscious experience. Novel and painful stimuli indeed induce hippocampal theta as well as orienting reactions, learning, selection and discrimination.

Remote emotions and associations?

Amygdala seems to be responsible for the formation of emotional aspects of the memories in accordance with entanglement paradigm. Amygdala is known to be sensitive to emotional contextual cues which can trigger perceptive experiences similar to previous ones. Associative memories seem to be in question.

Whether the associative memory is in the geometric now or past is not obvious and timelike quantum entanglement might perhaps allow to induce remote associations in the geometric past. If the cue is entangled with the cue in the geometric past, the activation of this cue by quantum entanglement could activate neural process generating the memory in the geometric past. This kind of mechanism would provide a general mechanism of active memory retrieval. The active scanning of memory neurons with memory fields characterized by different values of T would be a second mechanism of this kind. In fact, there need not be any sharp difference between ordinary associations and associations in past.

Memory consolidation and long term potentiation

The notions of memory consolidation and long term potentiation relate to the more standard views about long term memory and it is interesting to try to interpretthem in TGD framework. Memory

consolidation means the strengthening of memories by 'replaying' them. Certainly a repetion of mental image provides a manner to learn and establishing a long term memory also in TGD. The mere generation of gravitational MEs associated with a given mental image means consolidation: no modification of the existing neural connectivity is needed. Of course, standardized mental images are probably generated but this is not construction of memories in the strict sense of the word.

Memory consolidation involves hippocampal theta. In TGD framework hippocampal theta is a correlate for that part of consciousness which gives rise to an organized view about space and time: not necessarily in the geometric now however. Mirror mechanism implies that this process defines automatically memory representations about the state of brain so that memory consolidation is an automatic side effect.

It has been proposed that during REM sleep hippocampus is 'replaying' the memories unconsciously [25]. The fact that there is no sensory input at night time would suggest that sleeping brain is like an empty magnetic tape freely usable for the memory construction. Theta and delta bands could relate to the memory representations replayd during sleep period but could be also responsible for the construction of higher level sensory representations important for non-episodal memories.

There are however objection against the idea that REM sleep is specialized with the replaying. First, hippocampal theta, believed to be crucial for the formation of long term declarative memories, is not synchronous during REM sleep. Secondly, during dreams only the posterior portion of the hippocampus is active whereas during learning the active part is the anterior portion of the hippocampus.

TGD based vision suggests a first principle explanation for the activity of hippocampus during sleep and dreams. Both classical communications to the geometric future and the receival of negative energy MEs from the geometric future require metabolic energy feed. Since the metabolism related to the motor activity and sensory preception is absent during sleep, the optimal realization of the long term memories is based on the entanglement with the sleeping brain of the geometric past. This would also explain why we do not have conscious experiences about memory recalls from the geometric future. Sleeping brain can also help the situation by performing memory recalls itself. REM sleep would not be in any special role except that it could make possible episodal sensory memories.

The memories about dream experience fade out rapidly after wake-up. This suggests that the lengths of the magnetic flux tubes along which classical communications occur during dreams, are short and therefore also the time span of the resulting declarative memories is brief. This as it should be since otherwise dreams would make possible pseudo memories. We could be conscious during dreams but would not remember it since long term memories would not be generated during this period. Alternatively, dream memory representations could be generated by the larger self to which we are fused during sleep. The above mentioned findings about the hippocampal activity during dreams could mean that magnetic flux loops of declarative memory get longer in posterior-anterior direction: this would mean a concrete identification for the neurophysiological correlates of the declarative memory fields. Also the dominating frequency of EEG/ZEG would become lower in this direction.

The basic question relates to the intepretation of the hippocampal theta. There are two options.

1. Hippocampal theta is associated with the EEG MEs responsible for the classical communications to the geometric future making possible long term memories.

2. Z^0 MEs take care of the classical communications to the geometric future (memetic code) whereas hippocampal theta contributes to the conscious experience of the geometric now by generating high level sensory representations at the personal magnetic body.

For the latter option hippocampal theta could be also involved with the generation of entanglement between various parts of brain crucial for the construction of long term memories making possible an organized view about space and time. This assumption conforms with the idea that EEG rhytms are responsible for the synchrony and entanglement. This would not happen during REM sleep since hippocampal theta is asynchronous during dreaming and during cortical synchrony (not much sensory input). Visual dream consciousness is indeed sensory consciusness without an organized view about space and time categories. This applies also to the non-REM verbal dreams. Furthermore, the desynchronization of both hippocampal and cortical EEGs implies a confused state of mind. This would suggest that hippocampus indeed contributes also to our consciousness in the geometric now, and makes possible the organized view about space and time by constructing higher level sensory representations.

Long term potentiation (LTP) has been suggested as a mechanism by which hippocampus generates long term memories by strengthening the synaptic communications between neurons. In TGD framework this interpretation does not make sense: rather LTP can be seen as a special case of associative learning which is just gradual modification of the brain structure as a response to the conscious experience. Of course, LTP modifies gradually memory representations but these memory representations do not contain information about past.

As noticed, LTP does not occur in hippocampus itself. Instead, hippocampus grows rapidly in neuron number and synaptic connections during long term memory generation. This conforms with the view that hippocampus is more or less a real time dynamical representation for what might be called changing context. In particular, new neurons generated in hippocampus could be essential in representing the context and could generate gravitonic MEs crucial for the entanglement.

Relationship between cortical and hippocampal EEGs

Cortical desynchronization accompanies hippocampal synchronization and vice versa. The simultaneous desynchronization of cortical and hippocampal EEGs involves distractability and hyperresponsiveness so that person becomes owerwhelmed, confused, and may orient to and approach several stimuli.

These findings can be understood in TGD framework.

1. During cortical asynchrony there are good reasons to build long term memories so that hippocampus should be in synchronized state and bind various mental images to long term memories.

2. During cortical synchrony there is nothing to represent as long term memories and hippocampus can do something else. Perhaps participate in imagination and day dreaming as suggested by the fact that also during REM sleep hippocampal theta is asynchronous.

3. When both cortical and hippocampal theta are desynchorized, not only the long term memory representations fail to be generated but also the construction of spatial and temporal context and this leads to confusion and difficulties with orientation to various stimuli.

8.4.5 Microtubuli and long term memory

When I began consciousness theorizing whole-daily around about 1994, I became deeply fascinated about microtubuli (as probably most others in the field of quantum consciousness). I launched off by developing a rudimentary model about how microtubuli could act as quantum antennae in the TGD universe: massless extremals were the key element of the model. Needless to say, too much of the general theory of consciousness and of biosystems as macroscopic quantum systems needed for a deeper understanding was unconscious-to-me at that time.

After the rapid self-organization of the theory during this year and still continuing (I am living last days of August 2002 while writing this), it occurred to me that it might be a good idea to take a fresh look on the role of the microtubuli. While re-reading the wonderfully inspiring article of Nanopoulos dating back to 1995 [40], I realized that the TGD based view about macrotemporal quantum coherence, the mirror mechanism of long term memory, and the quite recent discovery of cognitive codes and their physical realization, provide the tools for developing a view about the role of microtubuli in long term memory.

What made me somewhat skeptic about the importance of the microtubuli for *our* consciousness was the naive view that the size L of the system system generating the memory increases when the geometrotemporal distance T of the long term memory increases. Microtubuli would be conscious but from our point of view this would represent something analogous to bit level in computers.

The understanding of how the macrotemporal quantum coherence is generated however challenged this view. TGD Universe is quantum spin glass and spin glass degeneracy is broken only by the classical gravitational binding energy. Quantum transitions between almost degenerate quantum spin glass states correspond to frequencies defined by the differences of the classical gravitational binding energy and generate gravitational MEs responsible for the quantum mirror mechanism. Gravitational binding energy increases with the system's size and this means an effective inversion of the length scale hierarchy, so that systems like microtubuli can contribute to our conscious experience much more signicantly than some subsub....subself level at the bottom of the self hierarchy might be expected to do.

Basic findings about the correlation between long term memory and microtubuli

A basic difference between ordinary cell and neuron is that the microtubuli associated with the T shaped centriole in case of the ordinary cell, are in neuron replaced by long microtubule bundles starting in a region near nucleus and connecting it to dendrites and axonal ends. The natural guess is that at least these microtubuli are closely involved with the brain consciousness.

What happens in microtubuli is indeed very intimately related to what happens in synapses. The minimal modification of the standard neuroscience belief system is that microtubuli control how synapses, still assumed to be responsible for the memory representations, are modified during learning identified as generation of long term memories. In [40] a lot of basic facts about microtubuli plus the evidence for the correlation between microtubuli and long term memory is discussed and references can be found in this article. Here I just summarize the basic points of the discussion of [40].

1. The production of tubulin and MT activities correlate with peak learning, memory and experience in baby chick brains. Experiments with baby rats show that when they first open they eyes, neurons in their visual cortex begin producing vast quantities of tubulin.

2. The experiments with trained goldfishes show that the drug colchicine produces retrograde amnesia. The interference with MTs responsible for the structural modification of certain synapses is believed to affect memory fixation. In TGD framework one must carefully distinguish between learning and memory: microtubuli could provide both the long term memory representations and also control learning by controlling synaptic strengths.

3. The selective dysfunction of animal brain MTs by the drug colchicine causes defects in learning and memory which mimick the symptons of Alzheimer's disease (AD). It has been reported that in rats a continuous MT disruption induced by a chronic colchicine administration results in a dose-dependent learning deficit, and memory retention is also impaired. It has also been stressed that these colchicine-induced cognitive defects resemble those of AD, e.g., amnesia of the recent learning and loss of formerly established memories. These findings encourage to think that that microtubuli are involved both with the generation of the memory representations and long term memory recall by mirror mechanism in accordance with the idea that microtubuli act as both receiving and sending quantum antennae in the sense that they generate MEs making possible timelikequantum entanglement. MEs generate coherent photons or gravitons according to the original definition of quantum antenna [J4]. Certainly, the antenna which sends is also optimal for receiving.

4. It has been suggested and also supported by detailed experimental studies that the impairment of MTs, leading to tangled and dysfunctional neural cytoskeleton, may be one explanation for the pathogenesis of AD.

5. In specific hippocampal regions of the brain of schizophrenic patients, distorted neuronal architecture has been found due to a lack of 2 MAPs. This suggests that the splitting of consciousness characterizing schizophrenia has a geometric correlate already at the microtubular level: macroscopic bound state entanglement responsible for the binding to longlived holistic microtubular mental images and the generation of memory representations would not occur as they should.

How microtubuli could relate to declarative long term memories?

For several reasons microtubuli are taylor-made for the realization of long term declarative memories in TGD Universe (the structure of microtubuli is discussed in some detail in [H8], where the realization of cognitive codes is discussed). Microtubuli are however not the only candidates: also 2-D membrane like structures and genuinely 3-D structures could be involved and correspond to different types of long term memories.

1. Microtubuli can entangle with each other and with the surrounding world in conformational degrees of freedom to yield macrotemporal quantum coherence. Also cognitive neutrinos could be present. Microtubule associated proteins (MAPs) can mediate naturally bound state entanglement between conformational patterns of different microtubuli. This makes possible macrotemporal quantum coherence and processes resembling quantum computation when bound states

are formed. MAPs can act as switches initiating quantum computation and halting it. The simplest possibility is that MAP protein becomes just disconnected at some levels of the hierarchy of spacetime sheets.

2. Tubulin dimers allow two different conformations and the patterns of tubulin conformations are ideal for binary representations of data natural for the representation of long term declarative memories. In [H8] a cognitive code explaining the numbers associated with microtubular geometry is discussed and a model for how the conformational patterns are coded into conscious experience in the phase transition in which spontaneus electric polarization occurs and forces all tubulin dimers to the ground state conformation. That microtubuli allow the realization of the symbolic counterparts of cognitive representations realized using cognitive neutrinos and possibly also by p-adic MEs, conforms with the fact that colchicine which affects MTs, induces cognitive defects characteristic of Alzheimer's disease. The linearity of microtubuli would be obviously essential and at least parts of the sensory pathways could be responsible for the representations of these memories.

3. In the standard view about long term memories one cannot identify microtubuli as seats of long term memory representations. The reason is simply that microtubule conformations are quite too short-lived for this purpose. This leaves only the identification of the synaptic strengths as a representation of long term memories. In TGD the situation is just the reverse and flexibility requires fast enough dynamics. The time scale defining sensory resolution is obviously a bottle neck time scale. The time scale for the phase transition leading to ground state of tubulin dimer in an external electric field and the time scale related to the control of the external electric field at the microtubular spacetime sheet are the most obvious guesses. The first time scale should be of order of the time scale of conformational dynamics, about nanosecond. The latter time scale would be basically the duration of nerve pulse if nerve pulses are responsible for the phase transition in question. In TGD framework the modification of synaptic strengths can be more naturally seen as representing generation of new 'habit routines' rather than memory representations which are much more involved and information rich.

4. Microtubuli are ideal for quantum mirror mechanism of long term memories. As already found, in case of spherical structures the dependence of gravitational binding energy on size of the structure is $E_{gr} \propto L^5$, whereas the gravitational binding energy depends on the length L of a linear structure as $E_{gr} \propto L$. For membrane like structures $E_{gr} \propto L^3$. Since microtubule lengths vary in the range 10 nm- 1 mm, this means that the temporal distance $T \propto 1/L$ of long term memory varies between 32 years 2.8 hours (very roughly; increase of the overall time scale due to the fact that increment of the gravitational binding energy in the transition is smaller than the gravitational binding energy itself). Inside axons microtubuli can bind to longer structures by MAPs and even meter sized structures associated with sensory pathways are possible. This lowers the lower bound for the time span to 10 seconds. The longest microtubuli are responsible for the representation of the shortest term memories realizable in this manner. Of course, memory circuits should regenerate again and again microtubular memory representation and in this sense synaptic strengths become an essential part of the memory representation.

5. Colchicine affects both memory recall and memory generation. This inspires the working hypothesis that microtubuli of a given length $L \propto 1/T$ in the geometric past entangle with a microtuble of same length in the geometric now during memory recall. For instance, the receiver in the geometric now could correspond to a postsynaptic microtubule whereas the sender in the geometric past corresponds to a presynaptic tubule. This is not the only alternative, receiving cells could be even glial cells.

6. That the memories of childhood are the most stable ones could be interpreted as reflecting the fact the microtubuli act both as receiving and sending quantum antennae, and that the long microtubuli responsible for generating the short term memory representations and for receiving them deteriorate towards the old age with much higher probability than the shorter ones. It could be possible to induce selective amnesiae restricted to memories with a temporal distance $\sim T$ by a treatment which affects microtubuli of given length $\sim L \propto 1/T$.

7. Microtubuli could be also ideal for the communication of non-episodal memories involving classical communication by ultra slow Z^0 MEs perhaps accompanied by Ca^{++} waves known to have an extremely wide velocity spectrum. Ca^{++} ions are associated with the outer surface of the microtubuli and dynamically comparable to a crop field in a wind. Ultra-slow orientational waves for these Ca^{++} ions representing sensory inputs and propagating along axons could make possible a classical communication of data from the geometric past as declarative memories. For sensory pathways the sequences of microtubuli could have a total length of order one meter. For the average length $L_0 = 10\ \mu m$ of the microtubule in brain, the time span $T_0 = 10$ seconds would give $v_0 \sim 1\mu m/s$, a typical velocity of in cellular level. In this case 10 nm length of microtubule would correspond to 10^{-2} seconds of time. This would mean that roughly 13 parallel sequences of 13 bits of information about 10 millisecond period. The bit rate of one bit per millisecond corresponds to the information storage capacity of the memetic code. For longer time intervals T and microtubule lengths L the bit rate would scale like $(L/L_0) \times (T_0/T) = v/v_0$. For $T = 1$ year and $L = L_0$ one would have roughly one bit per hour. It seems that this mechanism can be at work only for short term memories whereas long term memories would involve closed magnetic loops.

Relation to the general model of long term memories

It is interesting to relate the proposed model with the general model of long term memories.

1. Long term memory is lost when tubulins return to ground state unless there is some mechanism regenerating the conformational state. In brain the function of neuronal loops generating the nerve pulse patterns repeatedly would take care of regenerating the memory representation. If this view is correct, then also memories of childhood involve this kind of continual regeneration. Sensory pathways do give rise to long term memories unless the feedback from brain to primary sensory organs (otoacoustic sounds and the movement of eyes during REM sleep) regenerates these memory representations. During dream long term memories correspond to small value of T: does this allow to conclude that the feedback to the primary sensory organs during dreams results in long term memories with T about few minutes? The maximation of the lengths of the sensory pathways (left side of the body is connected to right brain hemisphere and vice versa) would relate to the maximization of the representational capacity if this mechanism is at work. Notice that the continual regeneration of memories with say temporal distance of $T = 15$ minutes does not seem sensical since these memories would not be received by that part of the 4-D brain which corresponds to the p-adic-to-real phase transition front. The most natural assumption is that sensory representations are regenerated for time interval of order T so that the maximal values of T and stablest memories correspond to relatively short microtubuli in the interior of neuron.

2. Hippocampus is believed to be crucial for the generation of long term declarative memories and responsible for spatio-temporal organization of perceptive field. Hippocampus could act as a kind of entanglement center entangling with 'features' at various brain areas and project them to the sensory magnetic canvas (the episodal component representing spatial relationships might accompany also non-episodal memories!). Feature subselves would have microtubular selves as subselves: this would mean entanglement between hippocampal and other microtubular memory representations. The microtubuli acting as central entanglers in hippocampus should be relatively short, with lengths not much longer than the length determined by the lower bound for temporal distance T for long term memories. The maximal length L of hippocampal axons should correspond to this T and $L \sim 10^{-2}$ meters from the size of the hippocampus might be a reasonable guess giving a time scale of about 15 minutes (these estimates are just orders of magnitude).

3. The recall of long term memories could basically correspond to a transition of a neuronal microtubule to a higher energy state by an emission of negative energy Z^0 ME. The process would be preceded by the emission of a p-adic Z^0 ME representing the intention to remember and transformed to a real negative energy MEs in the jump to a higher energy state. The neuronal/astrocytic microtubules of the right brain hemisphere could be specialized to send/receive negative energy MEs, whereas the astrocytic/neuronal microtubules of the left hemisphere would

be specialized to send/receive positive energy MEs. Of course, this is just a naive guess inspired by the right/left–holistic/reductionic dichotomy. What is however clear that microtubuli with abnormally small metabolic energy feed would be responsible for generating long term memory recalls and those with abnormally large energy feed responsible for generating long term memories.

4. Tubulin dimers correspond to the Mersenne prime $p = M_k = 2^k - 1$, $k = 13$, and the n-ary 13-adic time scale nearest to p-adic prime nearest to .1 second time scale of the memetic code word is $T(20, 13) \simeq .8$ seconds whereas single bit lasts for $T(20, 13)/13 \simeq 61$ milliseconds. .8 seconds is rather natural time scale from the point of view of human consciousness. Corresponding frequencies are 1.25 Hz in delta band, and 16.25 Hz in the lower end of the beta band which conforms with the fact that cognition correlates with the beta band activity of EEG. That delta frequency alone does not give rise to conscious experience would be due to the fact that no phase transition giving rise to a conscious experience occurs if all tubulins possess same ground state conformation. The facts that delta band weakens during ageing and also memory generation mechanisms deteriorate towards the old age, conform with the idea that this band is responsible for the generation of memory codewords. If this view is correct, hippocampal theta should be responsible for the binding of mental images rather than coding of our long term memories. Of course, also a lower level representations in time scale of hippocampal theta could be in question.

5. At this stage it is not possible to answer the question whether microtubuli correspond to subselves or subsub....selves. If the entangled microtubuli correspond to our subselves, the microtubuli belonging to different neurons should be able to entangle with each other. This requires the presence of join along boundaries bond contacts between pre- and postsynaptic microtubuli. MEs with lengths of neuron length scale could serve as this kind of contacts and generate time like entanglement between the microtubuli of neurons along the neural pathway.

What about effectively 2-D and 3-D memory representations?

Microtubuli need not be solely responsible for our long term memory representations. The fact that microtubuli seem to correlate with cognition and declarative memories which involve typically representations linear with respect to time suggests that the effective dimension D of the structure involved determines the character of the long term memory and also that of sensory experience. Moreover, it is quite possible that a large number of entangled neurons results in a kind of 'stereo consciousness' fusing a large number of slightly different views about the same sensory input. This would mean large number of entangling Grandmother neurons.

1. Cell membranes consist of a large number of parallel rather than serially ordered units. Hence cell membranes could be responsible for the storage of sensory memories, which are 2-dimensional at the basic level, say visual images. The neuron size of 10^{-4} meters corresponds to the lower bound of about millisecond for $T \propto L^3$.

2. Three-dimensional blobs of biomatter in length scale range 1 micron-10 nanometers span the range 1 millisecond-32 years for temporal distance T. This allows to consider the possibility that 3-D structures could be also responsible for long term memory representations. If one takes seriously the dimensional rule, 3-D structures should give to genuinely three-dimensional sensory memories and make 3-D spatial imagination and sensory experience possible. It is not obvious whether neurons contain any 3-D lattice like structures besides liquid crystal blobs of ordered water. Effectively 3-D structures could also result as composites of 2-D structures.

8.5 Hyper-finite factors of type II_1, dark matter hierarchy, and long term memories

This section is devoted to the progress that has occurred during the period 2004-2006 and represents new material which has not yet been fully integrated with the older material. The realization that the von Neumann algebra known as a hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and

these algebras provide a justification for several ideas introduced earlier on basis of physical intuition. One of the most important outcomes is a prediction of a hierarchy of quantum phases with arbitrarily large values of quantized Planck constant identified as dark matter and assumed to be the quintessence of living matter.

8.5.1 Hyper-finite factors of type II_1 and quantization of Planck constant

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of the configuration space of 3-surfaces ("world of classical worlds"). As a matter fact, it seems that the infinite-dimensional character of this algebra implies the rest of TGD. 4-D space-time, imbedding space $M^4 \times CP_2$, and the entire quantum TGD could emerge from the extension of the hyper-finite factor of type II_1 to a local algebra. This extension is local with respect to an octonionic coordinate whose non-associativity guarantees that the algebra does not reduce back to a mere hyper-finite factor of type II_1. The dynamics of quantum TGD would follow from the associativity condition: in particular, space-time surface would be maximal associative or co-associate sub-manifolds of imbedding space.

The quantization of Planck constants assignable to M^4 and CP_2 degrees of freedom as integer multiples of the ordinary Planck constant is strongly suggestive in this framework and the phases with large Planck constant are interpreted as a dark matter quantum controlling ordinary matter in living matter. The average geometric durations of quantum jumps are naturally quantized as multiples of the integer characterizing M^4 Planck constant. This allows the reduction of the notion of self to that of quantum jump at higher level of hierarchy. A strong quantitative prediction for the preferred geometric durations of quantum jumps emerges.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled sub-systems. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a justification from the quantum measurement theory for hyper-finite factors of type II_1.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II_1 and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II_1 and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

8.5.2 Dark matter hierarchy

The identification of dark matter as phases having large value of Planck constant [D6, J6, C7] led to a vigorous evolution of ideas still continuing while I am writing this addendum to the original text. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [C7]. Also a good educated guess for the spectrum of Planck constants emerges. The implications are non-trivial already at the level of hadron physics and nuclear physics and imply that condensed matter physics and nuclear physics are not completely disjoint disciplines as reductionism teaches us. One condensed matter application is a model of high T_c superconductivity predicting that the basic length scales of cell membrane and cell as scales are inherent to high T_c superconductors.

Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [M3]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [L2, M3]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [M3].

It seems safe to conclude that the dark matter hierarchy with levels labelled by the values of Planck constants explains the macroscopic and macro-temporal quantum coherence naturally. That this explanation is consistent with the explanation based on spin glass degeneracy is suggested by

following observations. First, the argument supporting spin glass degeneracy as an explanation of the macro-temporal quantum coherence does not involve the value of $\hbar$ at all. Secondly, the failure of the perturbation theory assumed to lead to the increase of Planck constant and formation of macroscopic quantum phases could be precisely due to the emergence of a large number of new degrees of freedom due to spin glass degeneracy. Thirdly, the phase transition increasing Planck constant has concrete topological interpretation in terms of many-sheeted space-time consistent with the spin glass degeneracy.

Jones inclusions and quantization of Planck constant

The Clifford algebra spanned by gamma matrices of infinite-dimensional space defines standard example of a von Neumann algebra known as hyper-finite factor of type II_1. The characteristic property of this algebra is that unit matrix has unit trace. Jones inclusions of hyperfinite factors of type II_1 combined with simple anyonic arguments turned out to be the key to the unification of existing heuristic ideas about the quantization of Planck constant [C9].

1. Quantum TGD emerges from the infinite-dimensional Clifford algebra extended to an analog of a local gauge algebra with respect to hyper-octonionic coordinate [C7]. In particular, the notions space-time as a hyper-quaternionic four-surface of imbedding space emerges.

2. One can understand how and why Planck constant is quantized and gives an amazingly simple formula for the separate Planck constants assignable to M^4 and CP_2 and appearing as scaling constants of their metrics as integer multiples of standard value $\hbar_0$ of Planck constant: $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$. This in terms of a mild generalization of standard Jones inclusions [C7]. The emergence of imbedding space means that the scaling factor of these metrics given by the scaling factor of Planck constant have spectrum: their is no landscape as in M-theory. Also the fusion of real and various p-adic variants of imbedding space along common rational (algebraic) points is involved.

3. In ordinary phase Planck constants of M^4 and CP_2 are same and have their standard values. Large Planck constant phases correspond to situations in which a transition to a phase in which quantum groups occurs. These situations correspond to standard Jones inclusions in which Clifford algebra is replaced with a sub-algebra of its G-invariant elements. G is product $G_a \times G_b$ of subgroups of $SL(2,C)$ and $SU(2)_L \times \times U(1)$ which also acts as a subgroup of SU(3). Space-time sheets are $n(G_b)$-fold coverings of M^4 and $n(G_a)$-fold coverings of CP_2 generalizing the picture which has emerged already. An elementary study of these coverings fixes the values of scaling factors of M^4 and CP_2 Planck constants to orders of the maximal cyclic sub-groups. Mass spectrum is invariant under these scalings.

4. This predicts automatically arbitrarily large values of Planck constant and assigns the preferred values of Planck constant to quantum phases $q = exp(i\pi/n)$ expressible using only iterated square root operation: these correspond to polygons obtainable by compass and ruler construction with integer n expressible as $n = 2^k \prod_i F_{s_i}$, where $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes: the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. In particular, experimentally favored values of $\hbar$ in living matter should correspond to these special values of Planck constant. This model reproduces also the other aspects of the general vision. The subgroups of $SL(2,C)$ in turn can give rise to re-scaling of $SU(3)$ Planck constant. The most general situation can be described in terms of Jones inclusions for fixed point subalgebras of number theoretic Clifford algebras defined by $G_a \times G_b \subset SL(2,C) \times SU(2)$.

5. These inclusions (apart from those for which G_a contains infinite number of elements) are represented by ADE or extended ADE diagrams depending on the value of index. The group algebras of these groups give rise to additional degrees of freedom which make possible to construct the multiplets of the corresponding gauge groups. For $\beta \leq 4$ the gauge groups A_n, D_2n, E_6, E_8 are possible so that TGD seems to be able to mimick these gauge theories. For $\beta = 4$ all ADE Kac Moody groups are possible and again mimicry becomes possible: TGD would be kind of universal physics emulator but it would be anyonic dark matter which would perform this emulation.

8.5.3 Dark matter hierarchy and the notion of self

The introduction of dark matter matter hierarchy forces to also reconsider the definition of self and in the following the original definition and modified definition are discussed. The vision about dark matter hierarchy as a hierarchy defined by quantized Planck constants leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [J6, M3].

The hierarchy of dark matter levels is labelled by the values of Planck constant having quantized but arbitrarily large values. It seems that the most important hierarchy comes as $\hbar(k) = \lambda^k \hbar_0$, where $\lambda \simeq 2^k$ is integer. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T(k) \propto \lambda^k$ of the quantum jump.

Dark matter hierarchy suggests a modification of the notion of self, in fact a reduction of the notion of self to that of quantum jump alone. Each self involves a hierarchy of dark matter levels, and one is led to ask whether the highest level in this hierarchy corresponds to single quantum jump rather than a sequence of quantum jumps. This indeed looks extremely natural and the hypothesis that self remains un-entangled for a longer duration than single quantum jump un-necessary. It is perhaps un-necessary to emphasize that the reduction of the notion of self to that of quantum jump means conceptual economy and somewhat ironically, would also a return to the original hypothesis but with a quantized Planck constant.

The averaging of conscious experience over quantum jumps would occur only for sub-selves at lower levels of dark matter hierarchy and these mental images would be ordered, and single moment of consciousness would be experienced as a history of events. One can ask whether even entire life cycle could be regarded as a single quantum jump at the highest level so that consciousness would not be completely lost even during deep sleep. This would allow to understand why we seem to know directly that this biological body of mine existed yesterday.

The fact that we can remember phone numbers with 5 to 9 digits supports the view that self corresponds at the highest dark matter level to single moment of consciousness. Self would experience the average over the sequence of moments of consciousness associated with each sub-self but there would be no averaging over the separate mental images of this kind, be their parallel or serial. These mental images correspond to sub-selves having shorter wake-up periods than self and would be experienced as being time ordered. Hence the digits in the phone number are experienced as separate mental images and ordered with respect to experienced time.

If one accepts the hypothesis that CP_2 time defines the typical geometric duration of quantum jump then moments of consciousness with duration longer than CP_2 time would be associated with dark matter. This would require quite huge value of n for human consciousness and does not seem a plausible option since the time scale of .1 seconds corresponds to integer $n \simeq 2^{256} \simeq 10^{38}$. A more reasonable looking option is that n-ary p-adic time scales $T(n,p)$ for a given value $\hbar = m\hbar_0$ define the typical geometric duration so that for a given prime p one would have the hierarchy $T(m,n,p) = mT_p(n) = m\sqrt{p}^n T_{CP_2}$ of geometric durations of moment of consciousness, with favored values of m given by $m = 2^k \prod_i F_{s_i}$: as already explained, $F_{s_i} = 2^{2^{s_i}} + 1$ are distinct Fermat primes and the lowest Fermat primes are given by $3, 5, 17, 127, 2^{16} + 1$. $m = 2^{11}$ seems to be favored in living matter [M3]. T_{CP_2} corresponds to CP_2 time about 10^4 Planck times. The geometric durations give a natural first guess for the duration of long term memories. Second interpretation is as the increase of geometric time coordinate in single quantum jump in the drift towards geometric future which should accompanying quantum jump making possible to understand the experience about flow of time.

8.5.4 The time span of long term memories as signature for the level of dark matter hierarchy

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Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. The integer $n = 2^{k11}$, $k = 0, 1, 2, ...$ seem to define favored values of Planck constant in living matter. This means a hierarchy in which time and length scales are zoomed up by a factor of 2048 in the transition to the next level of hierarchy. This integer represents also fundamental constant in TGD Universe [D6].

Higher levels of dark matter hierarchy provide neat quantitative view about self hierarchy and its evolution. For instance, EEG time scales corresponds to $k = 4$ level of hierarchy and a time scale of .1 seconds [J6], and EEG frequencies correspond at this level dark photon energies above the thermal threshold so that thermal noise is not a problem anymore. Various levels of dark matter hierarchy would naturally correspond to higher levels in hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question.

The level would determine also the time span of long term memories as discussed in [M3]. $k = 7$ would correspond to a duration of moment of conscious of order human lifetime which suggests that $k = 7$ corresponds to the highest dark matter level relevant to our consciousness whereas higher levels would in general correspond to transpersonal consciousness. $k = 5$ would correspond to time scale of short term memories measured in minutes and $k = 6$ to a time scale of memories measured in days.

The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [L2, M3]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible social rules and moral.

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open. Also the notion of self is problematic.

8.5.5 How the arrow of psychological time emerges?

Quantum classical correspondence predicts that the arrow of subjective time is somehow mapped to that for the geometric time. The detailed mechanism for how the arrow of psychological time emerges has however remained open.

Two earlier views about how the arrow of psychological time emerges

The basic question how the arrow of subjective time is mapped to that of geometric time. The common assumption of all models is that quantum jump sequence corresponds to evolution and that by quantum classical correspondence this evolution must have a correlate at space-time level so that each quantum jump replaces typical space-time surface with a more evolved one.

1. The earliest model assumes that the space-time sheet assignable to observer ("self") drifts along a larger space-time sheet towards geometric future quantum jump by quantum jump: this is like driving car in a landscape but in the direction of geometric time and seeing the changing landscape. There are several objections.

   i) Why this drifting?

   ii) If one has a large number of space-time sheets (the number is actually infinite) as one has in the hierarchy the drifting velocity of the smallest space-time sheet with respect to the largest one can be arbitrarily large (infinite).

   iii) It is alarming that the evolution of the background space-time sheet by quantum jumps, which must be the quintessence of quantum classical correspondence, is not needed at all in the model.

2. Second model relies on the idea that intentional action -understood as p-adic-to-real phase transition for space-time sheets and generating zero energy states and corresponding real space-time sheets - proceeds as a kind of wave front towards geometric future quantum jump by quantum jump. Also sensory input would be concentrated on this kind of wave front. The difficult problem is to understand why the contents of sensory input and intentional action are localized so strongly to this wave front and rather than coming from entire life cycle.

There are also other models but these two are the ones which represent basic types for them.

Arrow of time in zero energy ontology

The third explanation for the arrow of psychological time - which I have considered earlier but only half-seriously - looks to me the most elegant at this moment. This option is actually favored by Occam's razor since it uses only the assumption that space-time sheets are replaced by more evolved ones in each quantum jump. Also the model of tqc favors it.

1. In standard picture the attention would gradually shift towards geometric future and space-time in 4-D sense would remain fixed. Now however the fact that quantum state is quantum superposition of space-time surfaces allows to assume that the attention of the conscious observer is directed to a fixed volume of 8-D imbedding space. Quantum classical correspondence is achieved if the evolution in a reasonable approximation means shifting of the space-time sheets and corresponding field patterns backwards backwards in geometric time by some amount per quantum jump so that the perceiver finds the geometric future in 4-D sense to enter to the perceptive field. This makes sense since the shift with respect to M^4 time coordinate is an exact symmetry of extremals of Kähler action. It is also an excellent approximate symmetry for the preferred extremals of Kähler action and thus for maxima of Kähler function spoiled only by the presence of light-cone boundaries. This shift occurs for both the space-time sheet that perceiver identifies itself and perceived space-time sheet representing external world: both perceiver and percept change.

2. Both the landscape and observer space-time sheet remain in the same position in imbedding space but both are modified by this shift in each quantum jump. The perceiver experiences this as a motion in 4-D landscape. Perceiver (Mohammed) would not drift to the geometric future (the mountain) but geometric future (the mountain) would effectively come to the perceiver (Mohammed)!

3. There is an obvious analogy with Turing machine: what is however new is that the tape effectively comes from the geometric future and Turing machine can modify the entire incoming tape by intentional action. This analogy might be more than accidental and could provide a model for quantum Turing machine operating in TGD Universe. This Turing machine would be able to change its own program as a whole by using the outcomes of the computation already performed.

4. The concentration of the sensory input and the effects of conscious motor action to a narrow interval of time (.1 seconds typically, secondary p-adic time scale associated with the largest Mersenne M_{127} defining p-adic length scale which is not completely super-astronomical) can be understood as a concentration of sensory/motor attention to an interval with this duration: the space-time sheet representing sensory "me" would have this temporal length and "me" definitely corresponds to a zero energy state.

5. The fractal view about topological quantum computation strongly suggests an ensemble of almost copies of sensory "me" scattered along my entire life cycle and each of them experiencing my life as a separate almost copy.

6. The model of geometric and subjective memories would not be modified in an essential manner: memories would result when "me" is connected with my almost copy in the geometric past by braid strands or massless extremals (MEs) or their combinations (ME parallel to magnetic flux tube is the analog of Alfwen wave in TGD).

This argument leaves many questions open. What is the precise definition for the volume of attention? Is the attention of self doomed to be directed to a fixed volume or can quantum jumps

change the volume of attention? What distinguishes between geometric future and past as far as contents of conscious experience are considered? How this picture relates to p-adic and dark matter hierarchies? Does this framework allow to formulate more precisely the notion of self? Zero energy ontology allows to give tentative answers to these questions.

8.5.6 Questions related to the notion of self

I have proposed two alternative notions of self and have not been able to choose between them. A further question is what happens during sleep: do we lose consciousness or is it that we cannot remember anything about this period? The work with the model of topological quantum computation has led to an overall view allowing to select the most plausible answer to these questions. But let us be cautious!

Can one choose between the two variants for the notion of self or are they equivalent?

I have considered two different notions of "self" and it is interesting to see whether the new view about time might allow to choose between them or to show that they are actually equivalent.

1. In the original variant of the theory "self" corresponds to a sequence of quantum jumps. "Self" would result through a binding of quantum jumps to single "string" in close analogy and actually in a concrete correspondence with the formation of bound states. Each quantum jump has a fractal structure: unitary process is followed by a sequence of state function reductions and preparations proceeding from long to short scales. Selves can have sub-selves and one has self hierarchy. The questionable assumption is that self remains conscious only as long as it is able to avoid entanglement with environment.

   Even slightest entanglement would destroy self unless on introduces the notion of finite measurement resolution applying also to entanglement. This notion is indeed central for entire quantum TGD also leads to the notion of sharing of mental images: selves unentangled in the given measurement resolution can experience shared mental images resulting as fusion of sub-selves by entanglement not visible in the resolution used.

2. According to the newer variant of theory, quantum jump has a fractal structure so that there are quantum jumps within quantum jumps: this hierarchy of quantum jumps within quantum jumps would correspond to the hierarchy of dark matters labeled by the values of Planck constant. Each fractal structure of this kind would have highest level (largest Planck constant) and this level would corresponds to the self. What might be called irreducible self would corresponds to a quantum jump without any sub-quantum jumps (no mental images). The quantum jump sequence for lower levels of dark matter hierarchy would create the experience of flow of subjective time.

It would be nice to reduce the original notion of self hierarchy to the hierarchy defined by quantum jumps. There are some objections against this idea. One can argue that fractality is a purely geometric notion and since subjective experience does not reduce to the geometry it might be that the notion of fractal quantum jump does not make sense. It is also not quite clear whether the reasonable looking idea about the role of entanglement as destroyer of self can be kept in the fractal picture.

These objections fail if one can construct a well-defined mathematical scheme allowing to understand what fractality of quantum jump at the level of space-time correlates means and showing that the two views about self are equivalent. The following argument represents such a proposal. Let us start from the causal diamond model as a lowest approximation for a model of zero energy states and for the space-time region defining the contents of sensory experience.

Let us make the following assumptions.

1. Assume the hierarchy of causal diamonds within causal diamonds in a sense to be specified more precisely below. Causal diamonds would represent the volumes of attention. Assume that the highest level in this hierarchy defines the quantum jump containing sequences of lower level quantum jumps in some sense to be specified. Assume that these quantum jumps integrate to single continuous stream of consciousness as long as the sub...-sub-self in question remains unentangled and that entangling means loss of consciousness or at least that it is not possible to remember anything about contents of consciousness during entangled state.

2. Assume that the contents of conscious experience come from the interior of the causal diamond. A stronger condition would be that the contents come from the boundaries of the two light-cones involved since physical states are defined at these in the simplest picture. In this case one could identify the lower light-cone boundary as giving rise to memory.

3. The time span characterizing the contents of conscious experience associated with a given quantum jump would correspond to the temporal distance T between the tips of the causal diamond. T would also characterize the average and approximate shift of the superposition of space-time surfaces backwards in geometric time in single quantum jump at a given level of hierarchy. This time scale naturally scales as $T_n = 2^n T_{CP_2}$ so that p-adic length scale hypothesis follows as a consequence. T would be essentially the secondary p-adic time scale $T_{2,p} = \sqrt{p}T_p$ for $p \simeq 2^k$. This assumption - absolutely essential for the hierarchy of quantum jumps within quantum jumps - would differentiate the model from the model in which T corresponds to either CP_2 time scale or p-adic time scale T_p. One would have hierarchy of quantum jumps with increasingly longer time span for memory and with increasing duration of geometric chronon at the highest level of fractal quantum jump. Without additional restrictions, the quantum jump at n^{th} level would contain 2^n quantum jumps at the lowest level of hierarchy. Note that in the case of sub-self - and without further assumptions which will be discussed next - one would have just two quantum jumps: mental image appears, disappears or exists all the time. At the level of sub-sub-selves 4 quantum jumps and so on. Maybe this kind of simple predictions might be testable.

4. We know that that the contents of sensory experience comes from a rather narrow time interval of duration about .1 seconds, which corresponds to the time scale T_{127} associated with electron. We also know that there is asymmetry between positive and negative energy parts of zero energy states both physically and at the level of conscious experience. This asymmetry must have some space-time correlate. The simplest correlate for the asymmetry between positive and negative energy states would be that the upper light-like boundaries in the structure formed by light-cones within light-cones intersect along light-like radial geodesic. No condition of this kind would be posed on lower light-cone boundaries. The scaling invariance of this condition makes it attractive mathematically and would mean that arbitrarily long time scales T_n can be present in the fractal hierarchy of light cones. At all levels of the hierarchy all contribution from upper boundary of the causal diamond to the conscious experience would come from boundary of same past directed light-cone so that the conscious experience would be sharply localized in time in the manner as we know it to be. The new element would be that content of conscious experience would come from arbitrarily large region of Universe and seing Milky Way would mean direct sensory contact with it.

5. These assumptions relate the hierarchy of quantum jumps to p-adic hierarchy. One can also include also dark matter hierarchy into the picture. For dark matter hierarchy the time scale hierarchy $\{T_n\}$ is scaled by the factor $r = \hbar/\hbar_0$ which can be also rational number. For $r = 2^k$ the hierarchy of causal diamonds generalizes without difficulty and there is a kind of resonance involved which might relate to the fact that the model of EEG favors the values of $k = 11n$, where $k = 11$ also corresponds in good approximation to proton-electron mass ratio. For more general values of $\hbar/\hbar_0$ the generalization is possible assuming that the position of the upper tip of causal diamond is chosen in such a manner that their positions are always the same whereas the position of the lower light-cone boundary would correspond to $\{rT_n\}$ for given value of Planck constant. Geometrically this picture generalizes the original idea about fractal hierarchy of quantum jumps so that it contains both p-adic hierarchy and hierarchy of Planck constants.

The contributions from lower the boundaries identifiable in terms of memories would correspond to different time scales and for a given value of time scale T the net contribution to conscious experience would be much weaker than the sensory input in general. The asymmetry between geometric now and geometric past would be present for all contributions to conscious experience, not only sensory ones. What is nice that the contents of conscious experience would rather literally come from the boundary of the past directed light-cone along which the classical signals arrive. Hence the mystic feeling about telepathic connection with a distant object at distance of billions of light years expressed by an astrophysicist, whose name I have unfortunately forgotten, would not be romantic self deception.

This framework explains also the sharp distinction between geometric future and past (not surprisingly since energy and time are dual): this distinction has also been a long standing problem of TGD

inspired theory of consciousness. Precognition is not possible unless one assumes that communications and sharing of mental images between selves inside disjoint causal diamonds is possible. Physically there seems to be no good reason to exclude the interaction between zero energy states associated with disjoint causal diamonds.

The mathematical formulation of this intuition is however a non-trivial challenge and can be used to articulate more precisely the views about what configuration space and configurations space spinor fields actually are mathematically.

1. Suppose that the causal diamonds with tips at different points of $H = M^4 \times CP_2$ and characterized by distance between tips T define sectors CH_i of the full configuration space CH ("world of classical worlds"). Precognition would represent an interaction between zero energy states associated with different sectors CH_i in this scheme and tensor factor description is required.

2. Inside given sector CH_i it is not possible to speak about second quantization since every quantum state correspond to a single mode of a classical spinor field defined in that sector.

3. The question is thus whether the Clifford algebras and zero energy states associated with different sectors CH_i combine to form a tensor product so that these zero energy states can interact. Tensor product is required by the vision about zero energy insertions assignable to CH_i which correspond to causal diamonds inside causal diamonds. Also the assumption that zero energy states form an ensemble in 4-D sense - crucial for the deduction of scattering rates from M-matrix - requires tensor product.

4. The argument unifying the two definitions of self requires that the tensor product is restricted when CH_i correspond to causal diamonds inside each other. The tensor factors in shorter time scales are restricted to the causal diamonds hanging from a light-like radial ray at the upper end of the common past directed light-cone. If the causal diamonds are disjoint there is no obvious restriction to be posed, and this would mean the possibility of also precognition and sharing of mental images.

This scenario allows also to answers the questions related to a more precise definition of volume of attention. Causal diamond - or rather - the associated light-like boundaries containing positive and negative energy states define the primitive volume of attention. The obvious question whether the attention of a given self is doomed to be fixed to a fixed volume can be also answered. This is not the case. Selves can delocalize in the sense that there is a wave function associated with the position of the causal diamond and quantum jumps changing this position are possible. Also many-particle states assignable to a union of several causal diamonds are possible. Note that the identification of magnetic flux tubes as space-time correlates of directed attention in TGD inspired quantum biology makes sense if these flux tubes connect different causal diamonds. The directedness of attention in this sense should be also understood: it could be induced from the ordering of p-adic primes and Planck constant: directed attention would be always from longer to shorter scale.

Does entanglement mean loss of consciousness?

The ability to avoid entanglement with environment would be essential for the original notion of self and incase of sub-selves it would explain the finite life-time of mental images. One can of however ask whether the assumption about the loss of consciousness in entanglement - that is during sleep - is really necessary. One could however argue that if consciousness is really lost during sleep, we could not have the deep conviction that we existed yesterday. Furthermore, during topological quantum computation entanglement is absent and thus this state should correspond to conscious experience. Night time is however the best time for tqc since sensory input and motor action do not take metabolic resources and we certainly do problem solving during sleep. Thus we should be conscious at some level during sleep and perform quite a long tqc. Perhaps we are!

Could it be that we do not remember anything about the period of sleep because our attention is directed elsewhere and memory recall uses only copies of "me" assignable to brain manufacturing standardized mental images? Perhaps the communication link to the mental images during sleep experienced at dark levels of existence is lacking or sensory input and motor activities of busy westeners do not allow to use metabolic energy to build up this kind of communications. Hence one can seriously ask, whether self is actually eternal with respect to the subjective time and whether entangling with

some system means only diving into the ocean of consciousness as someone has expressed it. We would be Gods as also quantum classical correspondence in the reverse direction requires (p-adic cognitive space-time sheets have literally infinite size in both temporal and spatial directions). This would be the most optimistic view that one can imagine.

What after biological death?

Could the new option allow to speculate about the course of events at the moment of death? Certainly this particular sensory "me" would effectively meet the geometro-temporal boundary of the biological body: sensory input would cease and there would be no biological body to use anymore. "Me" might lose its consciousness (if it can!). "Me" has also other mental images than sensory ones and these could begin to dominate the consciousness and "me" could direct its attention to space-time sheets corresponding to much longer time scale, perhaps even to that of life cycle, giving a summary about the life.

What after that? The Tibetan Book of Dead gives some inspiration. A western "me" might hope (and even try use its intentional powers to guarantee) that quantum Turing tape sooner later brings into the volume of attention (which might also change) a living organism, be it human or cat or dog or at least some little bug. If this "me" is lucky, it could direct its attention to it and become one of the very many sensory "me's" populating this particular 4-D biological body. There would be room for a newcomer unlike in the alternative models. A "me" with Eastern/New-Ageish traits could however direct its attention permanently to the dark space-time sheets and achieve what she might call enlightment.

8.5.7 Remote metabolism, long term memory, and zero energy ontology

The notion of negative energy signals and time mirror mechanism emerged before zero energy ontology. Since the mechanisms of remote metabolism, of memory, and of intentional action rely on time mirror mechanism, one should check that this mechanism is indeed consistent with zero energy ontology. Zero energy ontology could also yield new insights to these mechanisms.

Zero energy ontology

Zero energy ontology states that physical states have vanishing net conserved quantum numbers and states decompose to positive and negative energy state and that the latter one can be said to be located in the geometric future with of the positive energy state at the time-like boundary of the space-time sheet representing the system. It is possible to speak about energy of the system if one identifies it as the average positive energy for the positive energy part of the system.

The matrix ("M-matrix") representing time-like entanglement coefficients between positive and negative energy states unifies the notions of S-matrix and density matrix since it can be regarded as a complex square root of density matrix expressible as a product of real squared of density matrix and unitary S-matrix. The system can be also in thermal equilibrium so that thermodynamics becomes a genuine part of quantum theory and thermodynamical ensembles cease to be practical fictions of the theorist. In this case M-matrix represents a superposition of zero energy states for which positive energy state has thermal density matrix.

1. If the positive energy parts of zero energy states appearing in the superposition have only single value of energy, the notion of remote metabolism is certainly well-defined. Even in the case that the system is thermalized remote metabolism makes sense since average energy can be increased by remote metabolism. One can even imagine a statistical variant of the process in which the temperature increases.

2. The critical question is whether crossing symmetry prevails in the sense that the positive energy signal propagating to the geometric future is equivalent to a negative energy signal propagating to geometric past. The eigen modes of the modified Dirac operator appearing in the first principle formulation of quantum TGD are characterized by the eigenvalues λ, which are complex. $|\lambda|^2$ has interpretation as a conformal weight mathematically analogous to a vacuum expectation value of Higgs field. There are reasons to believe that the eigenvalues relate closely to the zeros of Riemann zeta and/or its generalizations. If the eigenvalue and its complex conjugate correspond

to a state and its phase conjugate, crossing symmetry fails and would mean also breaking of time reversal symmetry.

Is zero energy ontology consistent with time mirror mechanism

Energy conservation and geometric arrow of time poses strong conditions on the mechanism. If positive energy part of state sends negative energy signal, then negative energy part of state must send a compensating positive energy signal. Furthermore, positive (negative) energy signals propagate towards geometric future (past).

1. If only single space-time sheet is involved, either negative energy signal S_-: $X^4_- \to Y^4_-$ or positive energy signal S_+: $X^4_+ \to Y^4_-$ is possible. The energy of both states is reduced in magnitude. For instance, this process tends to reduce destroy long term memories represented as bit sequences with bit represented by population inverted laser system.

2. Second possibility is that X^4 are Y^4 are disjoint and X^4 is in the geometric future of Y^4.

   The first possibility is S_+: $X^4_+ \to Y^4_-$ and negative energy signal S_-: $X^4_- \to Y^4_-$: the energy of both X^4 and Y^4 is reduced in this case.

   Second possibility is S_-: $X^4_+ \to Y^4_+$ and S_+: $Y^4_- \to X^4_-$. X^4 would suck energy from Y^4 in the geometric past. This option could correspond to both remote metabolism, memory recall, and intentional action. The presence of topological light ray connecting two systems would be also a correlate for time-like quantum entanglement making possible sharing and fusion of mental images and creating a sensation about flow of time just like it creates sensation of depth in stereo vision by fusion of right and left visual fields. Depending on the sign of the energy of the signal one would have memory or precognition. Precognition would require use of metabolic energy and this might be one reason for why it is rather rare.

3. Suppose next that the zero energy space-time sheet, call it X^4, is inside larger space-time sheet, call it Y^4: $X^4 \subset Y^4$. In this case one can have S_-: $X^4_+ \to Y^4_+$ accompanied by S_+: $X^4_- \to Y^4_-$. $X^4 \subset Y^4$ would suck energy from a larger system Y^4. It is of course possible to replace signals with signals of opposite energy in opposite time direction.

   A possible interpretation is as a metabolic charging of smaller space-time sheets by sucking energy from longer scales or by active pumping of energy to shorter scales. The transformation of long wavelength photons with large Planck constant to short wavelength photons with smaller Planck constant is an analogous process and might realize metabolic charging in biology. For instance, Sun-Earth system could correspond to Y^4 and biosphere to X^4.

To sum up, zero energy ontology completes the picture in the sense that it also provides a process making possible metabolic charging.

Thermodynamical considerations

It is not at all obvious whether the proposed picture is consistent with the standard thermodynamics. The transfer of energy from long to shorter length scales making possible to gain metabolic energy and realize the mechanism of long term memory indeed seems a genuinely new element. This process resembles dissipation in the sense that energy is transferred from long to short length scales. In an approach to thermal equilibrium temperature gradients are however reduced whereas remote metabolism favors the active generation of "hot spots".

These considerations relate closely to the notions of entropy and syntropy by Italian mathematician Luigi Fantappie [29] assigned with the two arrows of time. I learned from the work of Fantappie in SSE conference held in Röros from Antonella Vannini [30] and Ulisse Di Corpo [31].The discovery of Fantappie was that in living systems entropic processes seem to be accompanied by syntropic processes which seem to be finalistic. He assigned these processes to the advanced solutions of wave equations.

It would seem that entropy and syntropy do not relate directly to the notion of remote metabolism.

1. Syntropy growth would indeed be the mirror image of entropy growth associated with negative energy mirror image of positive energy dynamics. This dynamics could be seen as sequences of downwards scalings leading from long time scale to short time scale. This sequence would define

time sequences proceeding in opposite directions of time for positive and negative energy parts of states. Thus entropy growth would be accompanied by syntropy growth.

2. Syntropy growth could be also seen as a consequence of generalized second law applying with respect to subjective time and growth of syntropy would be growth of entropy but manifesting itself at space-time level in reversed direction of geometric time. For instance, the spontaneous assembly of bio-molecules from their parts could be seen as a decay process in the reverse direction of geometric time controlled by phase conjugate control signals.

3. Remote metabolism as generation of "hot spots" does not seem to reduce to these notions and might represent a genuine breaking of standard thermodynamical view about the world.

One must also distinguish the notions of entropy and syntropy from the notion of number theoretic entanglement negentropy N assignable with quantum entanglement with algebraic entanglement probabilities.

1. N is defined as the maximum of the p-adic entanglement negentropy $N(p)$ as a function of the p-adic prime p and thus assigns to an entangled system a unique prime p_{max}. $N(p)$ is obtained by replacing in the definition of the Shannon entropy the argument of logarithm with its p-adic norm. N is in general positive and thus defines a genuine measure of information.

2. The non-negative negentropy defined in this manner characterizes entanglement as a carrier of information rather than the state of either of systems and has nothing to do with the ordinary (non-positive) entropy characterizing the lack of knowledge about the state of either subsystem. Negentropy Maximization Principle [H2] favors the increase of the number theoretic negentropy and thus formation of entanglement quantum systems and generation of quantum coherence. Depending on the character of entanglement negentropic entanglement might be interpreted as a correlate for some conscious experience with positive content: say experience of understanding (time-like entanglement implying causal structure), of love (space-like entanglement), etc...

It is not obvious to me whether the remote metabolism as a manner to build hot spots and diversity could be reduced to NMP or whether it should be regarded as something completely independent.

8.5.8 Applying computer analogy to the model for long term memories

The general model for long term memories does not say anything detailed about how memory recall can take place effectively. Taking seriously the idea that we made computers as our images, one can try to see whether the basic facts about memory storage and recall in the case of computers could help to guess how the memory recall is realized in TGD Universe.

The basic metaphor is 4-D brain as a kind of magnetic tape in time direction carrying memories as a text consisting of letters with fixed width (temporal duration) and decomposing into paragraphs, sections, etc... just like written text. Rhythms of generalized EEG would realize the decomposition to letters, and larger sub-units.

Computer analogy suggests also the analog of directory system allowing an easy and rapid access to a particular record in a particular file. Fractality would automatically make possible fractally scaled down variants of the system with life span scaled down to a second but details absent or not visible in the cognitive resolution available.

Web suggests a link system in temporal direction realizing temporal associations automatically and topological light rays which would be vacuum extremals in passive state could realize the link system.

The two kinds of memories seem to be closely related

There are two kinds of memories. The proposal is that the sharing of mental images of the geometric past gives rise to episodal memories, re-experiences. These memories would correspond to mental images identified as quantum jumps containing quantum jumps containing... for zero energy states. This hierarchy would correspond to dark matter hierarchy and hierarchy of Planck constant.

One can criticize this idea.

1. Does the quantum entangled zero energy state of the magnetic body and brain of the geometric past really give rise to the episodal memory as sharing of mental images? The sharing aspect would certainly give rise to experience of time as analog for the depth experience in stereo vision assumed to result from the sharing of left and right visual mental images. But why not interpret this kind of state as a representation for a "law of nature" telling that state pairs in the superposition of states are causally related? Isn't state function reduction reducing entanglement necessary to experience sharp sensory qualia? The answer to these questions is that it is entangled system whose qualia are in question, not either of the individual systems. In quantum context this would mean that the sum of observables giving rise to the qualia of separate systems are measured in quantum jump.

2. What it really means to have an episodal memory? For sharing of mental images by space-like entanglement of sub-selves the space-time correlate is the join along boundaries bonds connecting the space-time sheets condensed at larger disjoint space-time sheets. In the case of episodal memories it would seem that the experiencer-now and and experiencer-then must correspond to disjoint space-time sheets and containing smaller space-time sheets connected by a topological light ray. Hence also classical communications would be an essential part of the mechanism of memory and the distinction between episodal and declarative memories does not seem so sharp as thought originally.

3. The mere re-experiencing of events of the geometric past by quantum entangling with a subsystem representing sensory mental image is not very effective mechanism. A more effective manner to remember is to represent memories symbolically as bit sequences with bits represented as population inverted state and ground state of laser (say many-sheeted laser). In this case metabolism is required to keep the representations intact.

Memory recall as communications between magnetic body and brain of geometric past

Memory recall would be communications between magnetic body and brain of the geometric past. Magnetic body can be visualized as a kind of onion with several layers: the larger the radius of layer the longer temporal distance T to the geometric past it corresponds. In memory recall the size of the active layer would correspond naturally to the temporal distance to the brain of the geometric past where the memory is stored. The frequencies of large Planck constant photons involved with communications would correspond to this distance ($f \sim 1/T$) and a de-coherence to photons with much shorter wavelength would take place in the process.

Neuroscience suggests that theta waves, which still have wavelength of order Earth size scale, are involved. They could result in de-coherence of waves with wavelength of order $\lambda = cT$ reducing the value of Planck constant.

The most primitive memory recall would rely on the scanning of brain of geometric past by using negative energy signal with a slowly varying carrier frequency. One can however consider MEs which are present permanently as vacuum extremals and activated to non-vacuum extremals during memory recall: this would mean a realization of a link system.

How could one realize links in time-like direction?

Links are certainly one of the most powerful functions of the web. Links are always present and activated when used. The obvious counterpart for the web link would be a topological light ray connecting two subsystems with a time-like separation. Topological light rays can also reduce to vacuum extremals and the activation of the the link could correspond to a feeding of energy to a topological light ray deforming it to a non-vacuum extremal. This kind of links would be naturally associated with long term memories and would make it un-necessary to scan the entire geometric past in the search of a particular episodal or declarative memory.

Dreams and building up of copies of memories

Important memories should be stored in several copies since would increase the probability that the scanning of the geometric past allows to build ME bridge to the subsystem representing the memory

mental image. Memories represented as bit sequences can be also lost in a repetitive recall since they might fail to receive metabolic energy feed.

Dreams might be a manner to build this kind of copies. The copies built up in this manner can involve a considerable processing and it could even happen that for painful memories large number of less painful variants are constructed. Also the original memory could be transformed to less painful during the period of time-like entanglement. When it is important that memory remains unchanged, PS might in fact be not favorable and it is known that PS deprivation can help of keeping memory intact [32].

There is a lot of evidence that memory processing indeed occurs during sleep (memory consolidation): in particular during paradoxical sleep (PS, REM periods with dreams) and during periods of deep slow wave sleep (SWS) preceding them. The sequential model for memories [32] assumes that both periods are necessary. The first guess is that dreams and preceding SWS periods could build copies of both episodal and declarative memories.

The sensory experience associated with a dream possibly resulting partially by sharing of sensory mental image of geometric past (say previous day) could give rise to a symbolic representation realized as a kind of record. If also a copy of sensory mental image is created, the dream would involve virtual visual input generated by sending signals from brain to retina and other sensory organs involved (in TGD sensory organs carry fundamental sensory qualia). This back projection is present also during wake-up state and essential part of building sensory representation from the raw sensory data. The fact that dreams are by no means direct copies of the sensory inputs of the geometric past suggests that an active buildup of sensory mental images indeed takes place. One could however stretch the limits of imagination and argue that the dreams could be composed of sequences of shared mental images from different times: this would conform with the short time range of "dream logic".

If the brain can be regarded as a kind of magnetic tape in the temporal direction, SWS period might be interpreted as a kind of empty interval in the tape telling that a memory record comes next (kind of silence before concert). Second function of SWS pattern would be to divide the time axis to frames analogous to letters appearing as units in computer memory. The SWS interval might also contain a temporal pattern defining among other things what might be regarded as a name of the record in question. The temporal pattern of the negative energy signal used in memory recall should have such a pattern that it would "resonate" with this pattern. Note that vacuum extremal MEs could define "static" links to memory mental images activated during memory recall to non-vacuum extremals and one can imagine also sequences of these extremals building a sequence of links.

Directory system, holograms, and p-adic fractality

Directory system is necessary in order to handle computer memory effectively. Basically the directory would be a scaled down fractal variant of the geometric past with a reduction of details leaving only titles of sections and subsections, so to say. These directories would make possible an effective scanning of the brain of the geometric past by going directly to the correct directory coded roughly by the temporal distance. The fact that we can construct mentally fractally scaled down memory representations about what happened during day and even during lifetime without effort suggests that this kind of fractal representation indeed is there.

The obvious idea is that the items of directories serve as links to subdirectories so that it is possible to active link in each directory item leading to a subdirectory associated with that item.

The fact that p-adically small is large in the real sense would automatically realize small time scale representations of long temporal intervals. This would suggest that the memory storage mechanism is hologram like so that copies of memories in various time scales are present. Effective p-adic topology would indeed suggest the presence of this kind of representation with various copies appearing as p-adically scaled variants of basic pattern for given p. For this option declarative memory recall would not require a precisely targeted signal to a particular moment of geometric past whereas sensory memories would require it (note however the possibility that dreams build more or less faithful copies of sensory memories).

One could imagine a fractal coding of names of directories and subdirectories by temporal distances in various p-adic length scales. Here effective p-adic topology giving rise to a hierarchy of p-adic length scales might play key role in the coding. Also dark matter hierarchy and hierarchy of Planck constants would be involved in an essential manner and code for various scales of long term memory. The fact that favored value of Planck constants and p-adic length scales come in octaves suggests a close

interaction between the two hierarchies.

The p-adic view about cognition suggests that p-adic numbers give a representation for the addresses of records and that effective p-adic topology for real space-time sheets is essential. Their space-time counterparts would be discrete intersections field bodies and p-adic space-time sheets having literally infinite size. The density of points of intersection would reduce as one moves away from biological body both in temporal and spatial direction and the fact that p-adic numbers correspond always to non-negative real numbers would conform with the fact that memories are about geometric past and the memories of nearest past are the most precise and for time scales which are fractions of second become sensory experiences which are actually very short term memories as findings of Libet demonstrate.

What is the role of generalized EEG rhythms from the point of view of memory?

TGD predicts entire hierarchy of EEG rhythms which are predicted to correlate with various biorhythms. One challenge is to understand the precise role of EEG rhythms, in particular theta band known to be involved with memory consolidation. Functional magnetic resonance imaging led to the discovery of so called so called spontaneous fluctuations in BOLD (blood oxygen level dependent) signal having 1/f spectrum in average sense [33] (I am grateful for Vesa Kiviniemi (who is also working in this field [34]) for sending me this review article). The frequency spectrum of these fluctuations is in the range range $.1 - .001$ Hz.

This activity is regarded as spontaneous in the sense that it is not induced by stimulus, motor output, or task but is something independent and thus conflicts with the paradigm that EEG corresponds directly to the brain state dictated by the input to brain and motor output and by cognitive tasks. For this reason spontaneous BOLD fluctuations were originally interpreted as noise but it has become clear that the fluctuation patterns possess both spatial and temporal coherence and that it is possible to assign regions of spatial coherence with brain functions in various brain areas.

The variation of spontaneous BOLD fluctuations explains also the variation of responses in experimental situations involving fixed stimulus or tasks. Spontaneous BOLD fluctuations seem to superpose linearly with the effect due to stimulus or task. BOLD fluctuations seem correlate with the slow fluctuations in EEG known to modulate the power spectrum in various EEG bands. Interestingly, there are also ~ 1 Hz slow fluctuations of membrane potential, which could be related to the cyclotron frequencies of DNA nucleotides (carrying constant negative charge density).

These findings conform with the fact that TGD predicts a fractal hierarchy of EEGs corresponding to the hierarchy of values of Planck constant. A further prediction would be that scaled variants of alpha band and its harmonic should appear in BOLD fluctuations as also the counterparts of beta and theta bands whose positions cannot however predicted without further assumptions.

EEG and its generalization would allow to interpret EEG rhythms as dividing the magnetic tape in time direction to a linear lattice of separate frames which each could represent a record in turn containing further records. This would be much like a fractal variant for the decomposition of a written text to letters with an approximately constant width. SWS would define kind of empty lines between paragraphs in this text and during wake-up state similar empty lines might be present.

Of course, the strict linear lattice is an idealization. It could be perturbed by insertions just like written text by pictures. These insertions could represent sensory mental images due to sensory input. Another analogy for sensory input would be as external force inducing kicks to the harmonic oscillator changing the amplitude of oscillation and inducing phase increments.

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Chapter 9

About the Nature of Time

9.1 Introduction

The notion of time remains one of the most problematic concepts of physics. In classical physics the different properties of the time of Newton's equations and thermodynamical time are puzzling. In special relativity and general relativity the notion of simultaneity becomes a problematic concept and challenges the naive Newtonian view about time flow as a motion of 3-D time=constant snapshot of 4-D space-time. The replacement of time=constant 3-surface with past directed light-cone assignable to the world-line of observer resolves this problem. In general relativity the problem is that past light-cones need make sense only locally. In quantum measurement theory the localization of the state function reduction process into a finite space-time volume is in conflict with the determinism of Schrödinger equation. In biology the presence of self-organization processes like self assembly challenge second law of thermodynamics in short time scales. In neuroscience the finding of Libet suggesting that neural activity seems to precede conscious decision forces to give up the notion of free will or the naive identification of experienced and geometrical time.

In this essay I will consider a new view about time based on Topological Geometrodynamics [13], which can be regarded as an attempt to unify fundamental interactions assuming that space-times are representable as 4-dimensional surfaces of certain higher-dimensional space-time $H = M^4 \times CP_2$ (M^4 denotes 4-D Minkowski space and CP_2 complex projective space of 2 complex dimensions) fixed by the requirement that the theory explains standard model symmetries and provides a geometrization of classical gauge fields and gravitational fields.

The construction of quantum TGD leads to a radical revision of space-time concept (many-sheeted space-time and topological field quantization), and forces also to generalize the original view about imbedding space. p-Adic physics as physics of cognition and intentionality is part of TGD inspired theory of consciousness and the need to fuse real and p-adic physics to single coherent whole forces to revise the notions of number and space-time. It has been also necessary to replace the standard positive energy ontology with what I call zero energy ontology. These generalizations are of special importance in TGD inspired theory of consciousness and of quantum biology.

There are several first principle approaches to quantum TGD and following gives only a very concise summary of them.

1. Generalization of Einstein's program of geometrizing classical physics so that quantum theory can be seen as a theory of *classical* spinor fields in the world of classical worlds (WCW) consisting of light-like 3-surfaces and possessing Kähler geometry [4, 5, B4]. By general coordinate classical physics becomes an exact part of quantum theory in a well-defined sense. A geometrization of Fermi statistics is obtained, and the Clifford algebra associated with the spinors of WCW can be regarded as a direct sum of von Neumann algebras known as hyper-finite factors of type II_1 (HFFs) closely related to quantum groups and non-commutative geometry;

2. Quantum TGD as almost topological field theory (TQFT) with fundamental objects identified as light-like 3-surfaces and having generalized super-conformal symmetries as symmetries [C1, C2]: the notion of braid is the basic building block of this approach;

3. There are two kinds of conformal symmetries corresponding to the boundary of light-cone of Minkowski space and light-like 3-surfaces, and these symmetries alone dictate to high degree the physics. Quite recently it turned that also a symplectic analog of conformal field theory emerges naturally in TGD framework (super-canonical symmetries) and this led to a concrete proposal for how to construct n-point functions needed to calculate M-matrix [13];

4. Physics as a generalized number theory involving three different threads corresponding to need fuse real and various p-adic physics to single coherent whole by using a generalization of number concept obtained by gluing reals and various p-adic number fields and their extensions together along rationals and common algebraics [E1]; the observation that standard model symmetries and dynamics of quantum and classical TGD are to high degree dictated by classical number fields [E2]; and the ideas inspired by the notion of infinite prime [E3];

5. The identification of WCW Clifford algebra elements as hyper-octonion (subspace of complexified octonions spanned by real unit and octonionic imaginary units multiplied by the commuting additional imaginary unit) valued conformal fields having values in HFF provides a justification for the concept of number theoretic braid needed both in the fusion of real and p-adic physics and in TGD as almost TQFT approach;

6. The hierarchy of Planck constants realizing quantum criticality [C9] forces a generalization of the notion of imbedding space by replacing it with a book like structure having as its pages singular coverings and factor spaces of H and allowing to realize geometric correlates for the choice of quantization axis in quantum measurement: the particles at different pages of this book are "relatively dark" since they do not possess local interaction vertices which means a radically new manner to interpret dark matter;

7. Zero energy ontology and the notion of finite measurement resolution formulated in terms of inclusions of HFFs fix quantum dynamics highly in terms of Connes tensor product allowing to interpret quantum theory as a square root of thermodynamics [13, C2]: finite measurement resolution has number theoretic braid as its space-time correlate so that various approaches to TGD are closely related;

8. Quantum theory of consciousness as a generalization of quantum measurement theory to include observer to the theory [14].

The notion of number theoretic braid is a common denominator of various approaches to quantum TGD and leads to effective discretization of the imbedding space which is however due to the finite measurement resolution and number theoretic constraints rather than being something fundamental so that there are no problems with standard conservation laws.

The article series about TGD and its applications to biology and consciousness [13, 14, 15, 16, 17, 18, 19, 20] gives an overall view about quantum TGD. In the following I will concentrate only on the aspects of quantum TGD relevant for the notion of time. I will first describe zero energy ontology and p-adicization program and after that consider the problem of time.

9.2 The most recent vision about zero energy ontology and p-adicization

The generalization of the number concept obtained by fusing real and p-adics along rationals and common algebraics is the basic philosophy behind p-adicization. One must be able to speak about rational points common to real and various p-adic variants of H. The basic objection is the necessity to fix some special coordinates in turn implying the loss of a manifest general coordinate invariance. The isometries of the imbedding space could save the situation provided one can identify some special coordinate system in which isometry group reduces to its discrete subgroup. The loss of the full isometry group could be compensated by assuming that WCW is union over sub-WCWs obtained by applying isometries on basic sub-WCW with discrete subgroup of isometries.

The combination of zero energy ontology realized in terms of a hierarchy of causal diamonds (CDs) and hierarchy of Planck constants providing a description of dark matter and leading to a generalization of the notion of imbedding space suggests that it is possible to realize this dream. The

article [13] provides a brief summary about recent state of quantum TGD helping to understand the big picture behind the following considerations.

9.2.1 Zero energy ontology briefly

1. The basic construct in the zero energy ontology is the space $CD \times CP_2$, where the causal diamond CD is defined as an intersection of future and past directed light-cones with time-like separation between their tips regarded as points of the underlying universal Minkowski space M^4. In zero energy ontology physical states correspond to pairs of positive and negative energy states located at the boundaries of the future and past directed light-cones of a particular CD.

2. CDs form a fractal hierarchy and one can glue smaller CDs within larger CDs. This construction recipe when combined with TGD inspired theory of consciousness allows to understand the asymmetry between positive and negative energies and why the arrow of experienced time corresponds to the arrow of geometric time and why the contents of sensory experience is located to so narrow interval of geometric time. One can imagine evolution to occur as quantum leaps in which the size of the largest CD in the hierarchy of personal CDs increases in such a manner that it becomes sub-CD of a larger CD. p-Adic length scale hypothesis [13] follows if the values of temporal distance T between tips of CD come in powers of 2^n: $T = 2^n T_0$. All conserved quantum numbers for zero energy states have vanishing net values. The interpretation of zero energy states in the framework of positive energy ontology is as physical events, say scattering events with positive and negative energy parts of the state interpreted as initial and final states of the event.

3. In the realization of the hierarchy of Planck constants $CD \times CP_2$ is replaced with a Cartesian product of book like structures formed by almost copies of CDs and CP_2s defined by singular coverings and factors spaces of CD and CP_2 with singularities corresponding to intersection $M^2 \cap CD$ and homologically trivial geodesic sphere S^2 of CP_2 for which the induced Kähler form vanishes. The coverings and factor spaces of CDs are glued together along common $M^2 \cap CD$. The coverings and factors spaces of CP_2 are glued together along common homologically non-trivial geodesic sphere S^2. The choice of preferred M^2 as subspace of tangent space of X^4 at all its points and interpreted as space of non-physical polarizations, brings M^2 into the theory also in different manner. S^2 in turn defines a subspace of the much larger space of vacuum extremals as surfaces inside $M^4 \times S^2$.

4. Configuration space (the world of classical worlds, WCW) decomposes into a union of sub-WCWs corresponding to different choices of M^2 and S^2 and also to different choices of the quantization axes of spin and energy, color isospin and hyper-charge for each choice of this kind. This means breaking down of the isometries to a subgroup. This can be compensated by the fact that the union can be taken over the different choices of this subgroup.

5. p-Adicization requires a further breakdown to discrete subgroups of the resulting sub-groups of the isometry groups but again a union over sub-WCWs corresponding to different choices of the discrete subgroup can be assumed. Discretization relates also naturally to the notion of number theoretic braid.

Is it really possible to speak about zero energy states for a given sector defined by generalized imbedding space with fixed M^2 and S^2? Classically this is possible and conserved quantities are well defined. In quantal situation the presence of the light-cone boundaries breaks full Poincare invariance although the infinitesimal version of this invariance is preserved. Note that the basic dynamical objects are 3-D light-like "legs" of the generalized Feynman diagrams glued together along their ends at generalized vertices.

9.2.2 Definition of energy in zero energy ontology

The approach relying on the two super conformal structures of quantum TGD gives hopes of defining the notion of energy for positive and negative energy parts of the state.

1. Since light-like 3-surfaces assignable to incoming and outgoing legs of the generalized Feynman diagrams are the basic objects, one can hope of having enough translational invariance to define the notion of energy. If translations are restricted to time-like translations acting in the direction of the future (past) then one has local translation invariance of dynamics for classical field equations inside $\delta M^4_{\pm}$ as a kind of semigroup. Also the M^4 translations leading to interior of X^4 from the light-like 2-surfaces surfaces act as translations. Classically these restrictions correspond to non-tachyonic momenta defining the allowed directions of translations realizable as particle motions. These two kinds of translations have been assigned to super-canonical conformal symmetries at $\delta M^4_{\pm} \times CP_2$ and and super Kac-Moody type conformal symmetries at light-like 3-surfaces. Equivalence Principle in TGD framework states that these two conformal symmetries define a structure completely analogous to a coset representation of conformal algebras so that the four-momenta associated with the two representations are identical [C1].

2. The condition selecting preferred extremals of Kähler action is induced by a global selection of $M^2 \subset M^4$ as a plane belonging to the tangent space of X^4 at all its points [C1] and interpreted as a plane of nonphysical polarizations so that direct connection with number theory and gauge symmetries emerges. The M^4 translations of X^4 as a whole in general respect the form of this condition in the interior. Furthermore, if M^4 translations are restricted to M^2, also the condition itself - rather than only its general form - is respected. This observation, the earlier experience with p-adic mass calculations, and also the treatment of quarks and gluons in QCD encourage to consider the possibility that translational invariance should be restricted to M^2 translations so that mass squared, longitudinal momentum and transversal mass squared would be well defined quantum numbers. This would be enough to realize zero energy ontology. Encouragingly, M^2 appears also in the generalization of the causal diamond to a book-like structure forced by the realization of the hierarchy of Planck constant at the level of the imbedding space.

3. That the cm degrees of freedom for CD would be gauge like degrees of freedom sounds strange. The paradoxical feeling disappears as one realizes that this is not the case for sub-CDs, which indeed can have non-trivial correlation functions with either upper or lower tip of the CD playing a role analogous to that of an argument of n-point function in QFT description. One can also say that largest CD in the hierarchy defines infrared cutoff.

9.2.3 p-Adic variants of the imbedding space

The need to fuse p-adic physics with TGD emerged originally from the discovery that p-adic mass calculations based on p-adic thermodynamics give excellent predictions for elementary particle masses if one assumes p-adic length scale hypothesis stating that primes near integer powers of 2 are physically favored [13]. Later came the interpretation of p-adic physics as cognition cognition and intentionality. The following somewhat technical construction of p-adic variants of the imbedding space provides new insights concerning the understanding of the arrow of geometric time.

1. Rational values of p-adic coordinates are non-negative so that light-cone proper time $a_{4,+} = \sqrt{t^2 - z^2 - x^2 - y^2}$ is the unique Lorentz invariant choice for the p-adic time coordinate near the lower tip of CD. For the upper tip the identification of a_4 would be $a_{4,-} = \sqrt{(t-T)^2 - z^2 - x^2 - y^2}$. In the p-adic context the simultaneous existence of both square roots poses additional conditions on T. For 2-adic numbers $T = 2^n T_0$, $n \geq 0$ (or more generally $T = \sum_{k \geq n_0} b_k 2^k$), would allow to satisfy these conditions, which would be one additional reason for $T = 2^n T_0$ implying p-adic length scale hypothesis. The remaining coordinates of CD are naturally (hyperbolic) cosines and sines of the spherical coordinates θ and ϕ (hyperbolic angle $\eta_{\pm,4}$).

2. The existence of the preferred plane M^2 of un-physical polarizations would suggest that 2-D light-cone proper times $a_{2,+} = \sqrt{t^2 - z^2}$ $a_{2,-} = \sqrt{(t-T)^2 - z^2}$ can be also considered. The remaining coordinates would be naturally $\eta_{\pm,2}$ and cylindrical coordinates (ρ, ϕ).

3. The p-adically transcendental values of a_4 and a_2 are literally infinite as real numbers and could be visualized as points in infinitely distant geometric future so that the arrow of time might be said to emerge number theoretically.

4. The selection of the preferred quantization axes of energy and angular momentum unique apart from a Lorentz transformation of M^2 would have purely number theoretic meaning in both cases. One must allow a union over sub-WCWs labeled by points of $SO(1,1)$. This suggests a deep connection between number theory, quantum theory, quantum measurement theory, and even quantum theory of mathematical consciousness.

5. In the case of CP_2 there are three real coordinate patches involved [21]. The compactness of CP_2 allows to use cosines and sines of the preferred angle variable for a given coordinate patch.

$$\begin{aligned} \xi^1 &= tan(u)exp(i\frac{(\Psi+\Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= tan(u)exp(i\frac{(\Psi-\Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{9.2.1}$$

   The ranges of the variables u, Θ, Φ, Ψ are $[0, \pi/2], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively. Note that u has naturally only positive values in the allowed range. S^2 corresponds to the values $\Phi = \Psi = 0$ of the angle coordinates.

6. The rational values of the (hyperbolic) cosine and sine correspond to Pythagorean triangles having sides of integer length and thus satisfying $m^2 = n^2 + r^2$ ($m^2 = n^2 - r^2$). These conditions are equivalent and allow the well-known explicit solution [22]. One can construct a p-adic completion for the set of Pythagorean triangles by allowing p-adic integers which are infinite as real integers as solutions of the conditions $m^2 = r^2 \pm s^2$. These angles correspond to genuinely p-adic directions having no real counterpart. Hence one obtains p-adic continuum also in the angle degrees of freedom. Algebraic extensions of the p-adic numbers bringing in cosines and sines of the angles π/n lead to a hierarchy increasingly refined algebraic extensions of generalized imbedding space. Since the different sectors of WCW directly serve as correlates of selves, this means a direct correlation with the evolution of the mathematical consciousness. Trigonometric identities allow to construct points which in the real context correspond to sums and differences of angles.

7. Negative rational values of the cosines and sines correspond as p-adic integers to infinite real numbers and it seems that one use several coordinate patches obtained as copies of the octant $(x \geq 0, y \geq 0, z \geq 0,)$. An analogous picture applies in CP_2 degrees of freedom.

9.3 Zero energy ontology, self hierarchy, and the notion of time

Consider now the formulation of TGD inspired quantum theory of consciousness [14] and quantum biology [15] in terms of zero energy ontology.

One should understand the asymmetry between positive and negative energies and between two directions of geometric time at the level of conscious experience, the correspondence between experienced and geometric time, and the emergence of the arrow of time. One should explain why human sensory experience is about a rather narrow time interval of about .1 seconds and why memories are about the interior of much larger CD with time scale of order life time. One should have a vision about the evolution of consciousness: how quantum leaps leading to an expansion of consciousness occur.

Negative energy signals to geometric past - about which phase conjugate laser light represents an example - provide an attractive tool to realize intentional action as a signal inducing neural activities in the geometric past (this would explain Libet's classical findings), a mechanism of remote metabolism, and the mechanism of declarative memory as communications with geometric past. One should understand how these signals are realized in zero energy ontology and why their occurrence is so rare.

In the following I try to demonstrate that TGD inspired theory of consciousness and quantum TGD proper indeed are in tune.

9.3.1 Causal diamonds as correlates for selves

Quantum jump as a moment of consciousness, self as a sequence of quantum jumps integrating to self, and self hierarchy with sub-selves experienced as mental images, are the basic notions of TGD inspired theory of consciousness. In the most ambitious vision self hierarchy reduces to a fractal hierarchy of quantum jumps within quantum jumps.

It is natural to interpret CDs as correlates of selves. CDs can be interpreted either as subsets of the generalized imbedding space or as sectors of WCW. Accordingly, selves correspond to CDs of the generalized imbedding space or sectors of WCW, literally separate interacting quantum Universes. The spiritually oriented reader might speak of Gods. Sub-selves correspond to sub-CDs geometrically. The contents of consciousness of self is about the interior of the corresponding CD at the level of imbedding space. For sub-selves the wave function for the position of tip of CD brings in the delocalization of sub-WCW.

The fractal hierarchy of CDs within CDs is the geometric counterpart for the hierarchy of selves: the quantization of the time scale of planned action and memory as $T(k) = 2^k T_0$ suggest an interpretation for the fact that we experience octaves as equivalent in music experience.

9.3.2 Why sensory experience is about so short time interval?

CD picture implies automatically the 4-D character of conscious experience and memories form part of conscious experience even at elementary particle level. Amazingly, the secondary p-adic time scale of electron is $T = 0.1$ seconds defining a fundamental time scale in living matter. The problem is to understand why the sensory experience is about a short time interval of geometric time rather than about the entire personal CD with temporal size of order life-time. The explanation would be that sensory input corresponds to subselves (mental images) with $T \simeq .1$ s at the upper light-like boundary of CD in question. This requires a strong asymmetry between upper and lower light-like boundaries of CDs.

The localization of the contents of the sensory experience to the upper light-cone boundary and local arrow of time could emerge as a consequence of self-organization process involving conscious intentional action. Sub-CDs would be in the interior of CD and self-organization process would lead to a distribution of CDs concentrated near the upper or lower boundary of CD. The local arrow of geometric time would depend on CD and even differ for CD and sub-CDs.

1. The localization of contents of sensory experience to a narrow time interval would be due to the concentration of sub-CDs representing mental images near the either boundary of CD representing self.

2. Phase conjugate signals identifiable as negative energy signals to geometric past are important when the arrow of time differs from the standard one in some time scale. If the arrow of time establishes itself as a phase transition, this kind of situations are rare. Negative energy signals as a basic mechanism of intentional action and transfer of metabolic energy would explain why living matter is so special.

3. Geometric memories would correspond to the regions near "lower" boundaries of CD. Since the density of sub-CDs is small there geometric memories would be rare and not sharp. A temporal sequence of mental images, say the sequence of digits of a phone number, would correspond to a temporal sequence of sub-CDs.

4. Sharing of mental images corresponds to a fusion of sub-selves/mental images to single sub-self by quantum entanglement: the space-time correlate could be flux tubes connecting space-time sheets associated with sub-selves represented also by space-time sheets inside their CDs.

9.3.3 Arrow of time

TGD forces a new view about the relationship between experienced and geometric time. Although the basic paradox of quantum measurement theory disappears the question about the arrow of geometric time remains.

1. Selves correspond to CDs. The CDs and their projections to the imbedding space do not move anywhere. Therefore the standard explanation for the arrow of geometric time cannot work.

2. The only plausible interpretation at classical level relies on quantum classical correspondence and the fact that space-times are 4-surfaces of the imbedding space. If quantum jump corresponds to a shift for a quantum superposition of space-time sheets towards geometric past in the first approximation (as quantum classical correspondence suggests), one can understand the arrow of time. Space-time surfaces simply shift backwards with respect to the geometric time of the imbedding space and therefore to the 8-D perceptive field defined by the CD. This creates in the materialistic mind a temporal variant of train illusion. Space-time as 4-surface and macroscopic and macro-temporal quantum coherence are absolutely essential for this interpretation to make sense.

Why this shifting should always take place to the direction of geometric past of the imbedding space? Does it so always? The proposed mechanism for the localization of sensory experience to a short time interval suggests an explanation in terms of intentional action.

1. CD defines the perceptive field for self. Selves are curious about the space-time sheets outside their perceptive field and perform quantum jumps tending to shift the superposition of the space-time sheets so that unknown regions of space-time sheets emerge to the perceptive field. Either the upper or lower boundary of CD wins in the competition and the arrow of time results as a spontaneous symmetry breaking. The arrow of time can depend on CD but tends to be the same for CD and its sub-CDs. Global arrow of time could establish itself by a phase transitions establishing the same arrow of time globally by a mechanism analogous to percolation phase transition.

2. Since the news come from the upper boundary of CD, self concentrates its attention to this region and improves the resolution of sensory experience. The sub-CDs generated in this manner correspond to mental images with contents about this region. Hence the contents of conscious experience, in particular sensory experience, tends to be about the region near the upper boundary.

9.3.4 Can selves interact and evolve?

Interesting questions relate to how dynamical selves are.

1. Is self doomed to live inside the same sub-WCW eternally as a lonely god? This question has been already answered: there are interactions between sub-CDs of given CD, and one can think of selves as quantum superposition of states in CDs with wave function having as its argument the tips of CD, or rather only the second one since T is assumed to be quantized.

2. Is there largest CD in the personal CD hierarchy of self in an absolute sense? Or is the largest CD present only in the sense that the contribution to the contents of consciousness coming from very large CDs is negligible? Long time scales T correspond to low frequencies and thermal noise might mask these contributions. Here however the hierarchy of Planck constants and generalization of the imbedding space could come in rescue by allowing dark EEG photons to have energies above thermal energy.

3. Can selves evolve in the sense that the size of CD increases in quantum leaps so that the corresponding time scale $T = 2^k T_0$ of memory and planned action increases? Geometrically this kind of leap would mean that CD becomes a sub-CD of a larger CD - either at the level of conscious experience or in absolute sense. The leap can occur in two senses: as an increase of the largest p-adic time scale in the personal hierarchy of space-time sheets or as increase of the largest value of Planck constants in the personal dark matter hierarchy. At the level of individual organism this would mean emergence of new lower frequencies of generalized EEG and levels of personal dark matter hierarchy with larger value of Planck constant.

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Part III

INTELLIGENCE, INFORMATION, AND COGNITION

Chapter 10

Conscious Information and Intelligence

10.1 Introduction

This chapter is a fusion of two separate chapters, the first one devoted to information measures for conscious experience and second summarizing a quantum model for intelligent systems. This reflects in its own way the fact that the development of the related ideas has not been a linear process and has involved many weird twists typical for a mathematical thinking without strong connection with empiria.

Much of the latest progress relies crucially on the developments in basic quantum TGD occurred during only one year (I am writing this towards the end of January, 2003). In the following I shall summarize different quantum views about information, intelligence and consciousness. Needless to add that all these memes live still their infancy and are only starting their development to social members of the meme society defining TGD inspired theory of consciousness: only time will show which of these friends of mine will survive to the adult age.

10.1.1 The notions of association sequence and mindlike sheet

"Ontogeny recapitulates phylogeny" metaphor, or better to say quantum-classical correspondence principle, relates the concepts of self and mind-like space-time sheet. Self can be defined as a subsystem able to avoid generation of bound state entanglement with the environment. Self has subjective memory and can be regarded simply as a heap of moments of consciousness occurred after the wakeup. Subjective memory is assumed to be kind of abstraction or sum about experiences associated with moments of consciousness. Self is assumed to experience the experiences of its subselves as somekind of abstractions: this implies infinite hierarchy of selves having increasingly abstract views about world.

Association sequence concept is inspired by the classical nondeterminism of Kähler action. Association sequence is minimal number of spacelike 3-surfaces having timelike separations and fixing uniquely one of the absolute minima of Kähler action associated with the 3-surface Y^3 at lightcone boundary. Both mind-like and material space-time sheets give rise to association sequences: in case of material space-time sheets the non-determinism involved has macroscopic and long lasting consequences. Association sequences appear in all p-adic length scales. p-Adic slaving hierarchy suggests a mechanism for how the association sequences could form a cognitive hierarchy based on the formation of association sequences of association sequences of....

Quantum non-determinism is expected to be important only in the p-adic length scales of the order of the size of the system whereas in shorter p-adic length scales it should be possible to regard the system as an ensemble of association sequences obeying statistical determinism. Quantum entanglement between the association sequences provides a possible model of association and a model for how wholes are formed from parts at the level of subjective experience. The replication of association sequences in turn makes possible competition and struggle for survival leading to the evolution of cognitive abilities. The interaction of the association sequences with the space-time sheets containing ordinary matter or with lower mind-like space-time sheets gives rise to the cognitive counterparts of

the evolutionary pressures.

10.1.2 Boolean logic and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number $=1/0\leftrightarrow$ yes/no). In this manner ordinary Boolean algebra is extended to vector space spanned by fermionic states. When cognitive fermion pairs are used instead of fermions, fermion number conservation does not pose any constraints and full linear superposition of the Boolean algebra elements is possible. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary 'this is true' experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates.

An alternative, and as it has turned out a more realistic option, corresponds to the identification of the Boolean truth values with spin directions for fermions, anti-neutrinos in case of biosystems. In this case fermion number conservation does not pose any constraints and a the macrosopic realization replaing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust. Both p-adic and real variants of cognitive antineutrinos seems to be needed and p-adic-real entanglement with positive definite number theoretical entanglement entropy gives to the experience of understanding and makes possible cognitive quantum computation like processes.

10.1.3 Connections with computationalism and hologrammic brain

Classical computationalism dominates cognitive science. The traditional AI models brain as symbol processor whereas connectionism provides a realization for associationism. TGD Universe is quantum computer in a very general sense and one can understand intelligent system as a quantum computer like system performing one quantum computation per CP_2 time about 10^4 Planck times. Macrotemporal quantum coherence binds long sequences of quantum jumps to effetively form a single quantum jump and decoherence times become much longer than CP_2 time. Quantum computationalism is shown to reproduce the relevant aspects of computationalism and connectionism without reducing conscious brain to a deterministic machine.

Holographic brain is also one of the dominating ideas of neuroscience. TGD based realization of memory allows to reduce hologram idea to its essentials: what matters is that piece of hologram is like a small window giving same information as larger window but in less accurate form. This inspires the concept of neuronal window: each neuron has small window to the perceptive landscape and is typically specialized to detect particular feature in the landscape. Coherent photons emitted by mind-like space-time sheets and propagating along axonal microtubules serving as wave guides, realize neuronal windows quantum physically. The notion of massless extremal (ME) gives a rigorous foundation for the idea that quantum holograms are involved with consciousness. The most advanced and detailed formulation of the hologram idea hitherto is based on the notion of conscious hologram.

10.1.4 The paradigm of four-dimensional brain

An important element is effective four-dimensionality of brain making possible to understand long term memories, planning and motor activities in a completely new manner. Further important ideas are music metaphor already described and the vision about brain as an associative net such that each neuron represents some sensory quale or 'Boolean quale'. The memetic code, with codons consisting 126 bit sequences, is the key essential element of brain as cognitive system. Codons can be interpreted either as elements of a Boolean algebra or as bits in the binary expansion of an integer in the range $(0, 2^{126})$ so that memetic code makes brain able to assign numbers with qualia. An attractive and testable identification for the memetic codons is as phonemes of language.

The newest development associated with the paradigm of 4-dimensional brain is the realization that brain hemispheres could have different arrows of the geometric time at appropriate p-adic time scales. For instance, negative energy MEs would make possible quantum communications to the direction of the geometric past. The model of non-episodal memory call would involve quantum communication of the question to the geometric past (time-like entanglement and sharing of mental images), and a

classical (dissipative) communication of the answer to the geometric future. Negative-positive energy dichotomy could be be realized in an extremely wide range of time scales and to explain, besides the basic mechanism of long term memory, also precisely targeted realization of intentions, sensory-motor dichotomy, and biocycles as dissipation-healing cycles.

10.1.5 The meanings of sensory, cognitive, symbolic

With my physicist's background I have used the attrivutes sensory, cognitive and symbolic somewhat sloppily and the precise meanings of these become only gradually clear. The classical non-determinism of Kähler action quite generally implies that space-time surfaces are symbolic representations whereas p-adic space-time sheets provide cognitive representations for the subjective existence and also serve as correlates of intentions. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuro-science). Sensory experience is always a multiverse experience since sensory qualia have quantum jump increments as quantum correlates, and is thus not reducible to the level of space-time.

10.1.6 Information theoretic interpretation of Kähler action

An important stimulus in the development of ideas was the Jan 30, 1999 issue of New Scientist [23], in which the work of Roy Frieden [21, 22] about information theoretical interpretation of the variational principles of physics was discussed at popular level. The work of Frieden relies on the concept of Fisher information. One can find a precise definition of the Fisher information in Mathematical Handbooks but this definition does not help too much without any further knowledge about Frieden's work. There is also a book available about Frieden's work [22].

Although the article in New Scientist [23] does not give any mathematical details about Frieden's work, it becomes clear that Fisher's theory as such does not apply to TGD framework. Frieden's basic idea seems however extremely attractive. Indeed, TGD inspired theory of consciousness leads to a hypothesis concerning the information theoretic interpretation of the Kähler function.

1. Absolute minimization of Kähler action and maximization of negentropy gain are the two 'great' variational principles of quantum TGD. Both variational principles of TGD have information theoretic interpretation. The negative of the Kähler function for quantum critical universe serves as a classical information measure for the Universe and entanglemement entropy (quantum version of Shannon entropy) tells how interesting potential conscious experience is but does not tell anything about its real information content. As explained in the introduction, one can define much more general information measures of conscious experience.

   It is important to notice that the p-adic version of Kähler action does not make sense nor is needed at all at configuration space level. All that is needed is that the p-adic variants of the field equations stating the absolute minimization of Kähler action are satisfied. At quantum level this means that each quantum jump involves a complete localization in p-adic configuration space degrees of freedom: p-adic physics at the space-time level is completely classical. Cognition has no colors.

2. The negative of the Kähler function for the critical value of the Kähler coupling strength, $-K_{cr}$ is by the absolute minimization of Kähler action non-negative entropy type variable. Hence it could somehow measure the classical information content of the space-time surface. A natural guess is that the information content is essentially due to the presence of the mind-like space-time sheets making it possible to have conscious information about classical time development with contents of separate conscious experiences located in bounded space-time sheets. If this interpretation is correct, the absolute minimization of the Kähler action maximizes the information content of the symbolic representations provided by the space-time surfaces in the superposition defined by the final state of the quantum jumps (zero mode degrees of freedom have same values for all space-time surfaces in the superposition).

3. A new view point to the precise meaning of the quantum criticality emerges. The degeneracy caused by the non-determinism to the configuration space functional integral is characterized by a degeneracy factor N_d assumed to be describable in a good approximation by $N_d \simeq exp(-K_{cr})$

for the critical value of the Kähler coupling strength. The requirement that degeneracy factor and vacuum functional compensate each other fixes, the value of Kähler coupling strength to have the critical value. Thus arbitrarily large negative values of K and arbitrarily large sensory information contents of the space-time surface become possible at quantum criticality. Complexity of the Universe is maximized. Below quantum criticality only configurations for which K is near zero contribute and sensory information content for allowed space-time surface is finite. Above criticality theory becomes ill defined since configuration space integrals diverge. Thus quantum criticality is necessary for maximally intelligent and maximally interesting conscious universe.

4. Altogether this means that absolute minimization of Kähler action and Negentropy Maximization Principle, the basic variational principles of quantum TGD, can be regarded as basic laws for a quantum theory of consciousness: physics reduces to a a theory of consciousness! This is not perhaps so surprising when one realizes that physics is nothing but an attempt to identify lawlike regularities governing the contents of conscious experiences.

10.1.7 Measures for the information content of conscious experience

The concept of information is expected to be a crucial ingredient of any theory of consciousness. The problem of assigning information measures to conscious experience looks however formidable and it took long time before concrete ideas emerged.

1. The first impulse came from the already mentioned work of Frieden related to the information theoretic interpretation of action principles. Second impulse came from the intensive discussions with Stephen King [38] and other members of *Time* discussion group. The first information measures were assigned with single quantum jump identified as a moment of consciousness. The realization that the quantum jump can be regarded as a TGD counterpart of state function reduction followed by a state preparation realized by an entire cascade of self measurements, made possible further developments related to these information measures along with a more precise formulation of NMP.

2. Already the discovery of the notion of self made it obvious that the information measures associated with single moment of consciousness are not enough, and could be even obsolete as far as macrotemporal aspects of consciousness are considered. Clearly, one should be able to ascribe information measures to selves defined by quantum jump sequences.

   The interpretation of self as a growing statistical ensemble defined by the moments of consciousness implies a deep connection of information theory, statistical physics, and theory of qualia [K3]. It also leads to the identification of concrete information measures associated with the distributions of various quantum number and zero mode increments defined by the sequence of quantum jumps characterizing various primary qualia. Information measures can be identified simply as differences between various kinds of entropies associated with the asymptotic thermal self and 'self now' since self in a thermal state should correspond to a completely fuzzy mental image carrying no information. One cannot deny that these information measures are very practical.

3. The last step of progress (I am writing this paragraph 30th January, 2003) was the realization that p-adic-real cognitive entanglement in the so called quaternion conformal fermionic degrees of freedom makes sense if the entanglement coefficients are algebraic numbers and therefore can be regarded as being common to reals and algebraically extended p-adics. To an algebraic entanglement one can assign a number theoretic entanglement entropy, which can have also negative values, and NMP guarantees that this kind of entanglement is stable under state preparation. In this case sub-self would give rise to an experience of understanding. Algebraic entanglement might be possible also between real systems forming bound states. Needless to say, the possibility to assing genuine positive definite information to selves, could mean a revolution in the understanding of the conscious information processing in the living matter.

10.1.8 p-Adic physics as physics of cognition and intention

One of the latest newcomers in the bundle of ideas related to intelligent systems is p-adic physics as physics of cognition. p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious looking interpretation for the solutions of the p-adic field equations is as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic space-time sheets as their geometric correlates. This in the sense that p-adic spacetime sheets somehow initiate the real neural processes providing symbolic counterparts for the cognitive representations provided by p-adic spacetime sheets and p-adic fermions. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

p-Adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one. This process has interpretation as a topological correlate for the mind-matter interaction in the sense of transformation of intention to action and symbolic representation to cognitive representation. Also the notion of p-adic teleportation makes sense: what happens that p-adic massless extremals (MEs) suffer repeated time reflection so that zigzag curve in space-time is generated (p-adic piecewice conservation of energy allows this). This makes possible effectively superluminal communication as well as replication of p-adic cognitive representations. Also time reversed versions of p-adic cognitive representations are generated in this manner. p-Adic cognitive representations could provide the physical correlates for the notions of memes [32] and morphic fields [53].

p-Adic real entanglement makes possible makes possible cognitive measurements and cognitive quantum computation like processes, and provides correlates for the experiences of understanding and confusion.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as 'thoughts' unlike the 'real' reality which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences. The developments related to the p-adic view about cognition are left to [H8].

10.1.9 The number theoretic view about information

In the p-adic context one must modify Shannon's definition of entropy by replacing the ordinary logarithm based on p-adic norm. This definition gives rise to a real valued entropy in both real and p-adic contexts if entanglement coefficients are rational/algebraic numbers. For irrational/non-algebraic entanglement standard Shannon formula and its p-adic variant must be used and gives rise to non-negative entropy. Unlike Shannon entropy, the p-adic entropies (one for each p) can be also negative so that the entanglement entropy defines a genuine information measure whose sign tells whether the system contains information or dis-information. For the p-adic entropies Negentropy Maximization Principle tends to preserve the quantum coherence if p divides the common denominator of the entanglement probabilities. Thus the states with rational/algebraic entanglement can be regarded as bound states, which are not at all fragile like the states with irrational/non-algebraic entanglement are. This leads to a purely number-theoretic characterization of life: life corresponds to islands of rational/algebraic numbers in the seas of real and p-adic continua. The new views about quantum coherence and information have testable implications at the level of fundamental physics, quantum computation, biology, and consciousness.

Before continuing I must apologize the lab notebook like character of this chapter. The notion of information has developed gradually through various side tracks, and I have not yet had time to go all the material through to see which ideas are consistent with each other and which are not. The birth of TGD inspired theory of consciousness has been an enormous explosion of ideas and Darwinian selection must operate for years to eliminate the non-survivors. In any case, one can safely state that the number theoretic view described above is essentially correct, and provides also a deep vision about the role of p-adic numbers in TGD and implying the fusion of physics and information theory with number theory.

10.2 How to define measures for the information content of consciousness?

In this section my aim is to discuss different views to the problem how to define the information contents of conscious experience rather than advocating any final truth. Of course, just at this moment the statistical information measures associated with self seem to be the most realistic ones to me personally, but during these 24 years of TGD I have learned that it it is better to tolerate all views about the solution of the problem even when their mutual consistency is not obvious.

10.2.1 How to assign information measures with a moment of consciousness?

The concepts of information, information flow and information gain of conscious experience would seem to have a natural place in theories of consciousness. It seems intuitively obvious that configuration space spinor fields must contain information. Configuration space spinor fields have indeed interpretation as both objective realities and Platonic Ideas, the latter interpretation being suggested strongly by the possibility to interpret fermionic Fock state basis as a Boolean algebra of statements about statements. The basic statements are most naturally statements about space-time geometry since fermionic oscillator operators for X^3 are determined by the second quantized free quantum field theory for the induced spinors on space-time surface $X^4(X^3)$ [H1].

Information gain as difference of informations for initial and final state of quantum jump

The basis idea is that any measure for the information gain of quantum jump is essentially difference of information measures for the initial and final states of the quantum jump. Configuration space spinor field is a well defined geometric object so that the entire machinery of the classical information theory are available. It would be unrealistic to believe that there is only single information measure: rather each type of information is expected to give rise to its own information measure.

To proceed further, notice that quantum jump decomposes to a localization in zero modes representing state function reduction followed by a cascade of self measurements giving rise to state preparation. One can assign information gains both to the localization of zero modes stage and to the state preparation stage. Internal consistency requires that the action of U in zero modes is effectively a flow correlating quantum numbers characterizing configuration spinor to the values of zero modes.

1. If the information gain associated with the quantum jump is defined as the difference of the informations associated with Ψ_i and Ψ_f it vanishes, since these states are localized in zero modes and completely unentangled as outcomes of state preparation process. If this is the correct option, one can assign information measures only to the self defined by the sequence of quantum jumps.

2. An alternative interpretation is that part of the information content of the configuration space spinor field is transformed in the process $U\Psi_i \to \Psi_f$ to conscious information in quantum jump so that the information content of the configuration space spinor field is reduced.

The option 2) is the only sensical one if one wants to assign information gains with single moment of consciousness.

Information measures associated with localization in zero modes and state preparation

As found quantum jump decomposes to a localization in zero modes followed by state preparation. Separate information measures can be associate with these two stages.

1. It is natural to assign this kind of information gain to the localization in zero modes identifiable as information gain associated with the state function reduction. The task is to assign well defined measures of information to the dependence of the configuration space spinor field on zero modes, and identify the information gain of state function reduction as the difference of information measures for $U\Psi_i$ and Ψ_f. The information measures in question ought to be well defined since $U\Psi_i$ is a discrete superposition of states localized in zero modes. For instance, one can assign entanglement entropy to the subsystems defined by quantum fluctuating degrees of freedom and zero modes and this entropy becomes zero in quantum jump: obviously the reduction of entanglement entropy represents simplest measure for information gain.

2. Second class of information measures can be assigned to the sequence of self measurements leading to the final prepared state: during this stage zero modes remain constant. The sum over the total information gains associated with the steps of self measurement cascade seems to be the the proper notion. The total information gain associated with a given step is sum over the information gains associated with various mutually unentangled subsystems performing a self measurement. Entanglement negentropy gains associated with the formulation of NMP are especially natural quantities here.

There are natural constraints on information measures. Since conscious experience decomposes into separate sub-experiences and this decomposition follows closely the decomposition of the space-time surface to p-adic regions characterized by finite values of p-adic prime, one expects that also the information gain of conscious experience has similar decomposition. This indeed turns out to be the case for local information measures expressible as integral of information density

$$i = RX$$

over the configuration space. Here R is the Fock space norm squared of configuration space spinor for given 3-surface Y^3 and X is a measure for local information. X can measure information about the local geometry of configuration space, about configuration space spinor at Y^3 or about the properties of the space-time surface $X^4(Y^3)$. The constraints coming from the formulation of NMP fix essentially uniquely the information gains associated with various irreducible sub-selves.

Examples of especially interesting information measures are entanglement entropy, information measure for the position of Universe (3-surface) in zero modes and information measures giving information about the geometry space-time surface and classical gauge fields defined on it.

The information gains associated with the cascade of self measurements giving rise to state preparation

State function reduction is followed by a sequence of self measurements in quantum fluctuating fiber degrees of freedom ultimately leading to a competely unentangled state (bound states can of course be entangled and can appear in the product state). It should be possible to assign measures of information also to this cascade of self measurements.

The cascade means decomposition of the system resulting in localization to zero modes to two unentangled subsystems: which pair of subsystems is in question is determined by NMP. The entanglement probabilities defined by the density matrix for either subsystem characterize the probabilities for the outcomes of the self measurement. Both unentangled subsystems resulting in the first step are again subject to self measurements and the process continues until an unentangled state results.

It seems natural to assume that the information measures are associated with the entire cascade and that they are additive in the sense that information gain is sum over the information gains of the steps of the cascade and that a given step contributes by the sum of the information gains associated with unentangled subsystems which are subject to self measurement in a given step of the cascade:

$$\begin{aligned} \Delta N &= \sum_i \Delta N(step\ i) \ , \\ \Delta N(step\ i) &= \sum_{k=1,..,k(i)} \Delta N(system\ k) \ . \end{aligned} \tag{10.2.1}$$

10.2.2 Information measures associated with selves

With the discovery of the notion of self it became clear that information measures associated with single moment of consciousness are not enough to define realistic information measures for selves. The crucial observation in this respect was that the sequence of final states of quantum jump defines a statistical ensemble growing in size quantum jump by quantum jump. If the averages of the increments of zero modes and quantum number increments in quantum jumps are experienced consciously, then the distributions for these increments determine the information content of conscious experience of self. The entropies associated with these distributions characterize the fuzziness of the qualia associated with various quantum number and zero mode increments. Since subselves (mental images) are expected to approach thermal equilibrium asymptotically, it is natural to define information measures associated with these increments as differences of the entropies associated with the asymptotic thermal selves and selves. A word of warning here however relates to the possible problems related to the precise definition of 'thermal self'. Without the notion of thermal self one can only define measures for the lack of information as entropies (which is of course in accordance with the Buddhist notion of Maya).

This approach applies does not necessate the assignment of information measures to the quantum jumps themselves. It is however possible to define also statistical variants of these information measures. Since conscious experience involves an averaging over quantum jumps, it seems natural to consider averages of the information measures associated with the state function reduction and state preparation states over the quantum jump sequence. Again the differences of these measures for self and for asymptotic thermal self would seem to provide the natural information measures. It must be however admitted that it is not at all clear whether these information measures have any practical utility.

10.2.3 Information measures associated with cognitive representations

p-Adic physics as physics of cognition suggests how to measure the information contents of cognitive representations. The basic hypothesis is that at the fundamental level cognitive representations are provided by the p-adic space-time sheets. One can even say that these space-time sheets mimick the physics of the real space-time sheets representing matter.

One can model these cognitive representations in terms of mappings of real space-time sheets to p-adic space-time sheets. The so called canonical identification is the basic building block of these maps. It maps p-adics and reals to each other continuously but does not respect differentiability. One can define canonical identification with some pinary cutoff and use the inherent non-determinism of the p-adic differential equations to complete the discrete image of the real space-time region to a continuous and differentiable solution of the p-adic counterparts of the field equations associated with the absolute minimization of the Kähler action. Thus p-adic physics simulates real physics.

The so called phase preserving canonical identification is a variant of this map respecting various fundamental symmetries. It must be emphasized that these maps are not fundamental and unique element of quantum TGD as I believed earlier: rather, they are simple models for how intelligent systems build cognitive representations. Especially interesting feature of these maps is that typically inside of system is mapped to outside and viceversa (say, external world to the p-adic world of brain).

The necessary pinary cutoff associated with the cognitive mappings of the real space-time regions to p-adic space-time regions allows to assign unique information measure to the values of the geometric quantities (say imbedding space coordinates as function of space-time coordinates) as the number of pinary digits present in the pinary expansion of the geometric quantity. A natural hypothesis is that the coarse graining characteristic for cognitive experience (world consists of objects) corresponds to the pinary cutoff associated with real-to-p-adics cognitive mappings.

10.2.4 Information gain related to the localization in zero modes

The simplest local information measure gives information about the position of the classical universe in the zero modes. Only the localization in zero modes is possible since complete localization in configuration space would mean quantum jump to a completely classical world with unique space-time surface rather than quantum superposition of parallel classical space-times and would mean the breaking of basic symmetries. Neither does complete localization make sense mathematically. Since positional information in zero modes measures the deviation of $U\Psi_i$ from the classicality, it relates to the parallel universe aspect of quantum TGD and is very natural from the view point of quantum TGD. For these reasons positional information deserves a detailed discussion.

1. Positional information measure in zero modes relies on Shannon formula giving measure for the information gain associated with a complete localization of configuration space spinor field in zero modes and is the same as used in the kinetic theory of gases based on probability distributions for single particle states. Definition works also in ordinary single particle wave mechanics but has no obvious generalization to quantum field theory context. Note that the positional information gain in zero modes is maximal.

2. Unitarity is consistent with the localization in zero modes only if the action of U is such that it induces effective flow in zero modes such that quantum numbers of the initial state are in one-one correlation with the values of the zero modes in the final state. This assumption about U implies standard state function reduction aspect of quantum measurement. In general U produces discrete superposition of states localized in zero modes and the positional information measure in zero modes becomes discrete. In the simplest case this measure reduces essentially to Shannon entropy defined by the probabilities that localization occurs for various discrete values of zero modes.

3. Without discretization in zero modes positional information measure would contain an infinite part, which does not however depend on the state. Thus, even without localization in zero modes it is possible to compare the information contents of different quantum histories and the information gain associated with conscious experience is well defined, positive and at least formally finite. A beautiful information theoretic interpretation for the evolution by quantum jumps results. If U acts as a flow the general information gain can be expressed as an average information gain with weighting over the probabilities of various values of zero modes.

4. Since local information measure with respect to zero mdoes is in question, one can assign to each subsystem its own information gain. It is now however obvious whether this picture works in p-adic context.

Definition of the positional information measure in zero modes

If Kähler action were deterministic, configuration space spinor field would be determined once its values on the lightcone boundary are fixed. Thye non-determinism of Kähler action implies that given 3-surface Y^3 on the lightcone boundary corresponds to several absolute minima $X^4(Y^3)$. In fact, it seems that one must introduce infinite number of massless extremals (MEs), whose lightlike boundaries having lightlike M^4_+ projection take mathematically the role of lightcone boundary. It is not yet clear how to formulate the theory consistently using lightlike boundary and the collection of MEs: presumably one must extend the configuration space to include all these MEs. At practical level it is however obvious that MEs located in laboratory become the basic objects.

There is presumably also a discrete non-determinism involved and this forces also a generalization of the concept of 3-surface. The space of 3-surfaces on $X^3 \times CP_2$ is like a many-sheeted like Riemann surface with various sheets corresponding to various absolute minima $X^4(Y^3)$ fixed by choosing some minimal number of 3-surfaces from a particular absolute minimum. The earlier view was that these 'association sequences' provide a geometric representation for thoughts [H1]: the vision about p-adic physics as physics of cognition however suggests that association sequences give for sensory experience the character of multitime snapshot.

Contrary to the original beliefs, the non-determinism of Kähler action implies that it is not possible to reduce everything to the lightcone boundary. Rather, the inner product for the configuration space spinor fields can be expressed using integrals over the spaces of the 3-surfaces Y^3 belonging to

$X^3 + \times CP_2$, where the surfaces X^3 denote lightlike projections of MEs to M^4_+ with moment of big bang ($X^3 = \delta M^4_+$) included. There is also a summation over the degenerate branches of $X^4(Y^3)$ for given X^3. Effectively it would seem that each ME defines its own information theory with MEs inside this ME possibly included.

The definition of information to be discussed is used also in the kinetic theory of gases and relies on the idea of the selection of the configuration space point defined by localization of the configuration space spinor field and on Shannon entropy.

1. The probability that 3-surface Y^3 in volume element dV of configuration space is selected is

$$dP = R(Y^3) \times dV \ , \tag{10.2.2}$$

where R is 'modulus squared' for the configuration space spinor field at Y^3, which is essentially the norm of the state of fermionic Fock space.

2. The information about the position of Universe in configuration space associated with the configuration space spinor field is defined as the negative of the Shannon entropy measuring *the information gain in a complete localization of the configuration space spinor field.* Using division into volume elements dV

$$\begin{aligned} I &= -\sum_{Y^3} dP \times log(dP) \\ &= -\sum_{Y^3} R \times log(R) \times dV - \sum_{Y^3} R \times dV log(dV) \\ &\to -\int R \times log(R) \times DX^3 - log(dV)_{|dV \to 0} \ . \end{aligned} \tag{10.2.3}$$

The first part gives, at least formally, a well defined integral over the configuration space. Second term is infinite unless dV becomes effectively discrete. That the information contained by quantum history would be infinite, is not at all surprising. Note however that the infinite term does not depend on state!

3. Since it is only information differences which matter, one could therefore forget the infinite contribution and define information as

$$I \equiv -\int R \times log(R) \times DX^3 \ . \tag{10.2.4}$$

This kind of formula of course applies also in ordinary single particle wave mechanics. One should perhaps call I as *available information.* The degeneracy of the absolute minima brings in summation over branches $X^4(X^3)$ but this is only a minor complication and is included in the definition of integral.

The dropping of the infinite background contribution ($log(dV)$) from the definition of information measure implies that the positional information in zero modes is not positive definite anymore. This is of course a questionable feature and contradicts the intuitive view about what information is.

4. If the localization in zero modes occurs and U acts effectively as a flow, then $U\Psi_i$ is localized in the set of discrete points of configuration space. If one replaces R which integral over the quantum fluctuating degrees of freedom, the definition of I reduces to a sum over zero modes

$$\begin{aligned} I &= -\sum_{z_i} p_i log(p_i) \ , \\ p_i &= \int_{qf,} R(z_i, qf) dV_{qf} \ . \end{aligned} \tag{10.2.5}$$

Here z_i denotes for the discrete values of zero modes in one-one correlation with quantum numbers associated with fiber degrees of freedom (this corresponds to the correlation of quantum numbers with classical variables in state function reduction). qf denotes quantum fluctuating degrees of freedom. This expression is nothing but entanglement entropy for the entanglement between quantum fluctuating degrees of freedom and zero modes. Thus the effective flow property of U in zero modes guarantees both the finiteness and the positivity of the positional information measure.

Note that more general information measures are obtained as averages

$$\begin{aligned} I &= -\sum_{z_i} X_i(z_i) p(z_i) log(p(z_i)) \ , \\ p(z_i) &= \int_{qf} R(z_i, qf) dV_{qf} \ , \end{aligned} \tag{10.2.6}$$

where X_i is average over fiber degrees of freedom characterizing what kind of information is in question.

The localization in zero modes implies that information for the final state of the quantum jump vanishes so that the positional information gain is maximal possible and equals to the information associated with the state $U\Psi_i$. In the sequel the basic properties of the positional information gain are discussed.

Connection with the information measure defined by Kähler action

One can decompose configuration space spinor field as

$$\Psi = exp(\frac{K}{2}) f \ , \tag{10.2.7}$$

where K is Kähler function. This makes it possible to express information in the form

$$I \equiv - < K > - < log|f|^2 > \ , \tag{10.2.8}$$

where the first term is expectation value for the negative of the Kähler function. Averaging involves integration over quantum fluctuating degrees of freedom with fixed values of zero modes plus discrete averaging over the zero modes.

What is remarkable that first term is a direct generalization of the purely classical hypothesis that Kähler function gives entropy type measure for the representative resources of the 3-surface measured by the number N_d of the degenerate absolute minima assumed to be proportional to $exp(-K_{cr})$, where K_{cr} is Kähler function at quantum criticality. This suggests that 'ontogeny recapitulates phylogeny' principle is at work also here in the sense that vacuum expectation for the classical measure for representative resources equals to the quantal information of the vacuum state (apart from infinite state dependent term).

Boolean and non-Boolean components of consciousness

Local information measures decompose quite generally into several parts. Kähler function represents vacuum contribution to information, f can in turn decompose to a product of zero mode functional and fermionic part giving an additional bosonic contribution to the information. The purely fermionic Fock space part of the f can be interpreted as the information related to Boolean mind, whereas bosonic contribution has interpretation as the information related to the proto level of consciousness [H1] which includes sensory experiences and emotions.

The original identification of the fermionic contribution was as reflective level of consciousness, "consciousness about consciousness". One the other hand, summation hypothesis telling how self hierarchy gives rise to a hierarchy of abstractions, follows by "Ontogeny recapitulates phylogeny" principle from the geometric model of the abstraction process as a formation of association sequences of association sequences. Hence the natural looking identification of the reflective thought as abstraction favours the identification of the reflective and proto levels of consciousness in terms of self and and its subselves. In case that there are no subselves, only reflective level is present and would correspond to pure self-awareness without cognitive and sensory content, if latter identification is correct.

The fermionic part of f describes all fermions associated with the 3-surface representing universe: note that in TGD framework elementary bosons are regarded as fermion antifermion bound states in length scale of CP_2 so that all matter in the form of elementary particles corresponds to the reflective contribution to information. If f decomposes into a product of unentangled states then also information reduces to a sum of the informations associated with these subsystems.

Dispersion creates positional information in zero modes

By definition I measures the information gain in the localization of the configuration space spinor field in zero modes. Completely localized configuration space spinor field does not carry (potential) information whereas the delocalized field carries a lot of it.

This picture provides a beautiful information theoretic interpretation for the time evolution by quantum jumps. The action of the operator U implies dispersion from sector D_{p_i} to entire configuration space and generates information (Djinn leaves the bottle!) and localization to the sector D_{p_f} means reduction of information (Djinn fullfills the wish (free will) and returns to a possibly new bottle). Therefore the information gain about classical universe associated with conscious experience is non-negative. Also the measurement of subsystem density matrix generates information and NMP maximizes this information gain.

Positional information in zero modes provides a general insight into the quantum physics of biosystems. Since living systems are known to be very (conscious) information rich systems, time development operator U must generate very large information, which means that the states $U\Psi$ for biosystems are very unclassical having wide distribution in configurations space. Hence the modelling of biosystems treating space-time as a fixed arena of dynamics, need not be a good approximation.

10.2.5 Combining number theory and information theory

TGD approach to consciousness forces to reconsider also the notion of information itself, and this leads to a new, number-theoretic view about information. This view might have radical implications for quantum computation. The view described in this section represents the latest (December 2002) view about information in TGD framework and is certainly nearest to the truth.

Number theoretic information measures

The notion of information in TGD framework differs in some respects from the standard notion.

1. At the microtemporal level qualia correspond to the increments of various quantum numbers/zero modes in a quantum jump. Selves can be seen as ensembles of quantum jumps, and one can identify experienced qualia as ensemble averages qualia. Therefore one can assign entropy to a given quale. Usually entropy increases quantum jump by quantum jump and qualia get fuzzy. Formation of macroscopic quantum bound states changes the situation and mental image can stay clear as long as the bound state lasts.

2. The definition of the entropy in p-adic context is based on the notion p-adic logarithm depending on the p-adic norm of the argument x only ($x = p^n r/s$, r and s not divisible by p; $Log_p(x) = log_p(|x|_p) = -n$) [H2]. For rational- and even algebraic number valued probabilities this entropy can be regarded as a real number. The entropy defined in this manner can be negative so that the entanglement can carry genuine positive information. Thus p-adic bound state entanglement giving rise to a fusion of cognitive mental images is a natural correlate for the experience of understanding, and one can assign to heurekas a well defined amount of information. Rationally entangled p-adic system has a positive information content only if the number of the entangled state pairs is proportional to a positive power of the p-adic prime p.

3. This kind of definition of entropy works also in the real-rational and even real-algebraic cases and makes always sense for finite real world ensembles and for entanglement between real (p-adic) systems. Entanglement probabilities are indeed algebraic numbers for both rational and algebraic entanglement coefficients. Here the problem is how to fix the value of the prime p and the only reasonable criterion is maximization of information.

4. The modified definition of entropy would have deep implications. For the ordinary definition of the entropy NMP [H2] states that real entanglement is minimized in the state preparation process. For the number theoretic definition of entanglement entropy NMP stabilizes the entanglement with positive information content. The fragility of quantum coherence is the basic problem of quantum computation and the good news would be that Nature itself (according to TGD) tends to stabilize quantum coherence if entanglement is rational/algebraic.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

The possibility to define entropy differently for rational/algebraic entanglement raises the question about which kind of systems can possess this kind of entanglement. There are several options.

1. Only the entanglement between different number fields is rational/algebraic

This option is maximally conservative and would bring nothing new into the real physics. $R - R_p$ and $R_{p_1} - R_{p_2}$, $p_1 \neq p_2$ entanglement is indeed necessary algebraic (and rational unless one allows an algebraic extension of p-adic numbers, which is however forced by the diagonalization of the density matrix in the general case). For $R_{p_1} - R_{p_2}$ entanglement there are two natural entropies S_{p_1} and S_{p_2}. One can define the total entropy uniquely as the sum $S = S_{p_1} + S_{p_2}$: similar definition applies to $R - R_p$ case. This definition generalizes to the situation when more than two systems belonging to different number fields are entangled.

This kind of entanglement could be called cognitive, and it would be natural to assign a positive or negative information with cognitive entanglement. Cognition could be seen as a quantum computation like process, more approriate term being quantum problem solving. Intelligent life would metaphorically reside at the rational/algebraic intersection of reals and p-adics/algebraic extensions of p-adics. Quantum-classical correspondence suggests that life is a boundary phenomenon at the space-time level: real and p-adic space-time sheets, action and intention, meet along common rational/algebraic points at the boundaries of the real space-time sheets so that these regions are indeed space-time correlates for the presence of cognitive entanglement.

Since intentionality (and thus p-adicity) is an essential aspect of life, one could say that living-dead dichotomy corresponds to rational-irrational or to algebraic-transcendental dichotomy. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua.

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of

rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

2. Other options

There are also other options besides the maximally conservative option.

1. Physics could be quite generally rational/algebraic at Hilbert space level. This would mean that the state space has algebraic numbers as coefficient field. In this case everything would be living. A milder constraint is that $R_p - R_p$ entanglement is always algebraic. For non-algebraic $R_p - R_p$ entanglement the entanglement entropy is p-adic valued and must be mapped to real number by canonical identificiation $x = \sum x_n p^n \to \sum x_n p^{-n}$: the resulting entropy is non-negative. If only algebraic $R_p - R_p$ entanglement is allowed, one can use $I = -S_p$ as an information measure.

2. Bound state entanglement is rational/algebraic. If this view is correct, one is led to ask whether life corresponds to rational or algebraic entanglement. The algebraic option would maximize the size of the living sector of the state space. Rational numbers are common for reals and all p-adics: in algebraic case this holds true only if one introduces algebraic extensions of p-adics. This might make rationals preferred.

   The objection against both options is that in the case of algebraic $R - R$ entanglement it is not clear which prime p should define the information measure. The only reasonable looking criterion fixing the value of p is the maximation of information. One could also argue that information is associated with only cognitive entanglement which by definition is between different number fields. Also the hypothesis that all entanglement/bound state entanglement is always algebraic, might pose too strong restrictions on quantum dynamics. For instance, S-matrix elements would be rational- or algebraic number valued.

Quantum computation and quantum problem solving in TGD Universe

Macrotemporal quantum coherence makes also quantum computation like processes possible since a sequence of quantum jumps effectively binds to a single quantum jump with a duration, which corresponds to the lifetime of the bound state. Quantum computation like process starts, when the quantum bound state is generated and halts when it decays. Spin glass degeneracy increases the duration of the quantum computation to time scales which are sensical for human consciousness. In case of cognitive quantum computation like processes the quantum coherence is stabilized by NMP.

1. Spin glass degeneracy provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along boundaries bonds and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis emerges.

2. Bio-systems would be especially attractive candidates for performers of both non-cognitive and cognitive quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes would involve new physics not taken into account in the standard physics based biochemistry.

3. The possibility of cognitive quantum computation like information processing forces generalize the standard quantum computer paradigm also because ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic $R - R_p$ entanglement two-state systems are naturally replaced with p-state systems and for $R_{p_1} - R_{p_2}$ entanglement with $p_1 \times p_2$ state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which means gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127} - 1$ M_{127}-qupits making about 254 bits. The idea about neuron as a classical bit might be a little bit wrong!

4. It might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macrotemporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing

units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

Information concept at space-time level

Quantum-classical correspondence suggests that the notion of information is well defined also at the space-time level. The non-determinism of Kähler aciton and p-adic non-determinism plus algebraic information measures suggest a natural approach tot the problem of defining the information concept. This approach provides also a new light to the problem of assigning a p-adic prime to a given real space-time sheet.

1. How to assign an information measure to a space-time sheet

In the presence of the classical non-determinism of Kähler action and p-adic non-determinism one can indeed define ensembles, and therefore also probability distributions and entropies. For a given space-time sheet the natural ensemble consists of the deterministic pieces of the space-time sheet regarded as different states of the same system. The probability for the appearance of a given value of observable is of the general form $p_i = m_i/N$, $m_i < N$, where N is the number of deterministic pieces and S_p is always negative, when p divides N.

Obviously the primes dividing N define natural candidates for the information measures but the problem is which criterion selects one of them. There are three options.

1) Require that the information measure corresponds to the prime p for which S_p is smallest. Obviously p must divide N.

2) Define the information as sum

$$I = -\sum_{p|N} S_p \ ,$$

(here $p|N$ means that p divides N) so that all contributions are positive.

3) Include all primes dividing N or m_i in $p_i = m_i/N$:

$$I = -\sum_{p|N \ or \ p|m_i} S_p \ ,$$

In this case also negative contributions are present. This defition is actually equivalent with a definition

$$I = -\sum_{p} S_p \ ,$$

in which the summation appears over all primes. One could say that the information decomposes into different kinds of informations labelled by primes.

What is interesting is that, the ordinary Shannon entropy S for rational probabilities can be expressed as a sum of all p-adic entropies using the adelic decomposition $|x| = \prod_p |x|_p^{-1}$:

$$S = -\sum_p S_p = I \ .$$

The sum of real and p-adic entropies vanishes. Real dis-information and the p-adic information would compensate each other completely. Whether the adelic formula for information theory might have some deeper interpretation remains open.

2. How to assign p-adic prime or primes to a real space-time sheet?

A long-standing problem of quantum TGD is how to associate to a given *real* (not only p-adic) space-time sheet a unique p-adic prime (or possibly several of them) as required by the p-adic length scale hypothesis.

1. One could achieve this by requiring that for this prime the negentropy associated with the ensemble is maximal. The simplest hypothesis is that a real space-time sheet consisting of N deterministic pieces corresponds to the p-adic prime defining the largest factor of N.

2. One could also consider a more general possibility. If N contains p^n as a factor, then the real fractality above n-ary p-adic length scale $L_p(n) = p^{(n-1)/2}L_p$ corresponds to smoothness in the p-adic topology. This option is more attractive since it predicts that the fundamental p-adic length scale L_p for a given p can be effectively replaced by any integer multiple NL_p, such that N is not divisible by p. There is indeed a considerable evidence for small p p-adicity in long length scales. For instance, genetic code and the appearance of binary pairs like cell membrane consisting of liquid layers suggests 2-adicity in nano length scales. This view means that the fractal structure of a given real space-time sheet represents both an integer N and its decomposition to prime factors physically. This would also mean that one can assign several p-adic information measures to the real space-time sheet. This obviously conforms with the physics as a generalized number theory vision.

3. Intuitively it seems obvious that there must be a physical mechanism selecting one prime amongst all possible primes which characterizes the information measure associated with the ensemble of the deterministic pieces associated with the real space-time sheet. Conscious information requires the presence of cognition: the real space-time sheet must be entangled with a p-adic space-time sheet. Quantum-classical correspondence means that the ognitive entanglement of the real system with p-adic system has as a space-time correlate join along boundaries bond connecting the real and p-adic space-time sheet and glued to the boundary of the real space-time sheet along common rational points. One could argue that the p-adic join along boundaries bonds are most probable when the p-adic prime is such that it defines an effective p-adic topology for the real space-time sheet. This would mean that the prime-power factors of N define preferred p-adic length scales to the real space-time sheet.

4. The hypothesis that the prime factorization of N determines the effective p-adic topologies associated with the real space-time sheet inspires the hypothesis that the rational (or algebraic) p-adic-real entanglement necessary for cognitive quantum measurements is probable/possible only for the p-adic primes dividing N.

3. Does classical space-time physics represent factorization of integers?

Quantum-classical correspondence suggests that quantum computation processes might have counterparts at the level of space-time. An especially interesting process of this kind is the factorization of integers to prime factors. The classical cryptography relies on the fact that the factorization of large integers to prime factors is a very slow process using classical computation: the time needed to factor 100 digit number using modern computer would take more than the recent age of the universe. For quantum computers the factorization is achieved very rapidly using the famous Shor's algorithm. Does the factorization process indeed have a space-time counterpart?

Suppose that one can map the integer N to be factored to a real space-time sheet with N deterministic pieces. If one can measure the powers $p_i^{n_i}$ of primes p_i for which the fractality above the appropriate p-adic length scale looks smoothness in the p-adic topology, it is possible to deduce the factorization of N by direct physical measurements of the p-adic length scales characterizing the representative space-time sheet (say from the resonance frequencies of the radiation associated with the space-time sheet). If only the p-adic topology corresponding to the largest prime p_1 is realized in this manner, one can deduce first it, and repeat the process for N/p_1^n, and so on, until the full factorization is achieved. A possible test is to generate resonant radiation in a wave guide of having length which is an integer multiple of the fundamental p-adic length scale and to see whether frequencies which correspond to the factors of N appear spontaneously.

Seeing the prime factorization might be also possible via a direct sensory perception. Oliver Sacks tells in his book 'The man who mistook his wife for a hat' [52] about twins, John and Michael, who had a mysterious ability to 'see' large numbers and their prime factorizations despite the fact that their intelligence quotient was about 60 and they did not have any idea about the notions of integer and prime. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately '111!'. Then John mumbled '37', Michael repeated it and John said '37' third time. Obviously this was their sensory representation for the decomposition $111 = 3 \times 37$ of number 111 to a product of primes! The explanation of these strange feats suggested in [H3] is a less general idea about physical representation of the factorization. The proposed mechanism

could indeed explain prime factorization as a sensory perception involving no algorithmic cognition at all.

10.3 Information theoretic interpretation of quantum TGD

Frieden's hypothesis [21, 22, 23] that the action principles of physics have information theoretic interpretation inspired the idea that Kähler action has information theoretic interpretation. It must be emphasized that this section represents kind of an archeological layer in the development of TGD based view about information, and I have not yet tried to relate it to the latest (December 2002) TGD based view about information described in the previous section.

10.3.1 Information theoretic interpretation of action in Frieden's theory

Frieden [21, 22, 23] introduces two kinds of information concepts. Fisher information, usually denoted by I, is defined as the information which can extracted from a physical phenomenon by measurements of a specific type. Information J is defined as the information contained by the phenomenon and in general $J - I \geq 0$ holds true.

The action defining the dynamical equations of a physical theory decomposes into a difference $I - J$, where J is the total information contained by the state and I is the available information. I and J depend on what is measured. Minimization of $I - J$ for position measurement leads to classical Newton's equations.

In classical mechanics J corresponds typically to the integral of potential energy V and I corresponds to the integral of kinetic energy I, in accordance with the decomposition

$$S = \int L dt, \quad L = T - V \ .$$

Maxwell action is obtained by considering position measurement in presence of charge. For Maxwell action

$$S = \int (B^2 - E^2) d^4x \ ,$$

the entire integral of B^2 corresponds to I whereas total information J is non-vanishing only provided there is coupling to external currents.

This interpretation does not look promising from the point of view of TGD.

1. The total information J is identically zero whereas absolute minimization of Kähler action implies that the available information I is negative. It is difficult to assign physical meaning to negative available information.

2. Frieden's approach puts position measurement in a special role and the idea that every measurement type defines its own physical law, looks peculiar. A more natural interpretation for the Kähler function would be a measure for some kind of classical information associated with the space-time surface.

3. Frieden's interpretation has no connection with the TGD inspired ideas about symbolic and cognitive representations.

10.3.2 Kähler function is unique from the requirement that temporally localized conscious experience is possible

The properties of the Kähler action are unique from the requirement that the information given by conscious experience is maximized. The crucial property of the Kähler action is its vacuum degeneracy, which implies classical non-determinism and makes possible mindlike space-time sheets. As a consequence, it becomes possible to have time localized conscious information about quantum histories and sensory experience becomes possible (note that cognition is possible already by the inherent non-determinism of the p-adic field equations). Also the arrow of the psychological time is generated.

Thus the requirement that temporally localized conscious experience is possible, selects Kähler action uniquely.

Some of the consequences are matter-mind decomposition for the space-time surfaces resulting as a decomposition to mind-like and material space-time sheets. Similar decomposition applies at the level of the configuration space spinors. Spin glass analogy and the notion of infinite primes,... are also consequences of the classical non-determinism.

Note that this argument is a strong argument in favour of the information theoretic interpretation but does not involve the assumption about $I - J$ decomposition of the Kähler function. Furthermore, whatever the information theoretic interpretation of the Kähler function is, it must be consistent with this interpretation. An attractive guess is that the negative of the Kähler function could be identified as a measure for the amount of potential information contained by the classical space-time surface. It seems that this information must be symbolic information rather than cognitive since real mind-like sheets seem to be geometric correlates of symbolic rather than cognitive representations.

10.3.3 Information theoretic interpretation of Kähler function

The $I - J$ decomposition of the Kähler function in the manner suggested by Frieden's theory does not make sense in TGD context. On the other hand, the formal similarity of the vacuum functional with thermodynamical partition function suggests the interpretation of the vacuum functional as an exponent for the negative of some kind of entropy type variable so that the negative of the Kähler function would correspond to entropy.

The exponent $exp(-K_{cr})$ of the negative of Kähler function, for a suitable choice of the value α_{cr} of the Kähler coupling strength, should somehow measure the number of some kind of microstates. A natural identification of the 'microstates' is as a degeneracy caused by the classical non-determinism of the Kähler action, which implies that configuration space integration over 3-surfaces Y^3 at the light cone boundary involves summation over all possible association sequences going through the same 3-surface Y^3 on the light-cone boundary and having the same value of the Kähler function. This summation brings in a degeneracy factor, which will be referred to as N_d.

An educated guess is that the degeneracy factor N_d is in a good approximation proportional to the exponent of the negative of the Kähler function, when Kähler coupling strength has critical value α_{cr}:

$$N_d \simeq exp(-K_{cr}) \ . \tag{10.3.1}$$

Note that α_{cr} depends on the sector D_p of the configuration space since Kähler coupling strength depends on p-adic length scale in a logarithmic manner typically predicted by $U(1)$ gauge theories. This hypothesis allows to answer to the basic questions related to the definition of the Kähler function.

1. Why absolute minimization of Kähler action?

The first consequence of the hypothesis is that absolute minimization of the Kähler action maximizes some kind of information. This is achieved by generation of Kähler electric fields necessarily accompanied by mind-like space-time sheets, whose contribution to N_d compensates the negative Kähler action. Perhaps this could partially explain why electric fields, in particular those associated with the cell membranes, are so important in biosystems. The construction of conscious systems artificially perhaps possible some day could thus involve construction of Kähler electric fields.

2. Why quantum criticality?

This hypothesis throws also new light to the precise mechanism of the quantum criticality. At quantum criticality the degeneracy factor N_d in the functional integral over the configuration space compensates the exponent of the negative Kähler function even when its value is infinite! Below quantum criticality the probabilities for 3-surfaces having negative Kähler function suffer exponential cutoff so that only the 3-surfaces for which the value of Kähler function per volume vanishes, are important. The resulting universe is obviously much less interesting than quantum critical universe, which maximizes complexity. Also the maximum for the total information content of the quantum jump is always finite for subcritical universe unlike for quantum critical universe. Above quantum criticality the degeneracy dominates over vacuum functional and configuration space integral of the

vacuum functional diverges so that the theory becomes mathematically ill defined. Therefore quantum critical universe possesses maximal complexity and is as interesting and intelligent as universe can be! Note that quantum criticality was already earlier realized to be crucial for consciousness since it makes possible long range quantum correlations and hence arbitrarily large macroscopic quantum systems.

It deserves to be noticed that the proposed estimate for the value of the degeneracy factor N_d gives for the TGD inspired theory of consciousness a status of a quantitative theory. Once the value of the Kähler function is known, then also the representational (symbolic representations seem to be in question) capacities associated with the 3-surface are known. A reasonable guess is that this criterion makes sense also for finite space-time regions. The fact that $\alpha_K(p)$ decreases with p-adic length scale means that the degeneracy increases exponentially as the function of $1/\alpha_K(p)$. This is just what p-adic evolution suggests: the larger the value of p, the larger the typical space-time surface and the larger the degeneracy since new modes emerge, when p increases.

In [E5, E6] arguments leading to the determination of the precise value of the Kähler coupling strength was proposed. The argument reduced the problem to the guess about the general form of the partition function for an arithmetic quantum field theory: the bosonic part of the partition function was assumed to be expressible in terms of Euler Zeta function.

The interpretation of this partition function was as a fictitious partition function emerging in the calculation of the fermionic determinant associated with the functional integral defined by the induced spinor fields. It is however possible to interpret this partition function also as a real partition function providing a statistical description of the degrees of freedom related to symbolic representations provided by the mind-like space-time sheets. If this interpretation is correct, then the connection between infinite primes and symbolic representations provides support for the arithmetic quantum field theory based ansatz for the partition function. An open question is whether these two interpretations are actually mutually compatible.

10.3.4 The role of electric fields in living matter

Absolute minimization of Kähler action is achieved by generating strong Kähler electric fields, or essentially equivalently, strong electric or Z^0 electric fields. The generation of magnetic fields has opposite effect as is clear from B^2-E^2 decomposition of the Maxwell action. The proposed information theoretic interpretation of the Kähler function implies that the generation of the Kähler electric fields generates resources of symbolic information. An attractive, considerably stronger, hypothesis is that in a good approximation the negative of the total Kähler action in a given space-time volume of Minkowski space gives the symbolic information resources contained in this volume. Amazingly, strong electric fields are known to be vital for the functioning of the living systems. Needless to say, there is no obvious explanation for this in standard physics context.

1. Classical electric fields are in a fundamental role in biochemistry and living biosystems are typically electrets containing regions of spontaneous electric polarization. Fröhlich [36] proposed that oriented electric dipoles form macroscopic quantum systems with polarization density serving as a macroscopic order parameter. Several theories of consciousness share this hypothesis. Experimentally this hypothesis has not been verified. TGD suggests much more profound role for the unique di-electric properties of the biosystems: the presence of strong electric dipole fields is a necessary prequisite for cognition and life and could even force the emergence of life. Strong electric fields imply also the presence of the charged wormhole BE condensates: the surface density of the charged wormholes on the boundary is essentially equal to the normal component of the electric field so that wormholes are in some sense 'square root' of the dipole condensate of Fröhlich! Wormholes make also possible pure vacuum polarization type dipole fields: in this case the magnitudes of the em field at the two space-time sheets involved are same whereas the directions of the fields are opposite. It has been already suggested that the splitting of Z^0 wormhole contacts creates cognitive neutrino pairs. Also microtubules carry strong longitudinal electric fields.

2. One of the basic mysteries of cell biology is the rest potential of the living cell. Living cell membranes carry huge electric fields: something like 10^7 Volts per meter. The electric part of the Maxwell action gives a rough upper bound for the symbolic information resources of an axon:

$$-K \sim \frac{1}{16\pi \times \alpha_K} \times E_K^2 \times Vol \times T \ .$$

One obtains order of magnitude estimate for the Kähler electric field across membrane as $E_K \sim V/d$, where V membrane potential of order $V \sim .1$ Volts and $d \sim 10^{-8}$ meters is the thickness of the axonal membrane. $Vol = 2\pi \times R \times d \times L$ is the volume of the axonal portion of neuronal membrane. The radius and length of the axonal membrane can be taken to be $R \sim 10^{-6}$ meters and $L \sim 10^{-6}$ meters respectively. For definiteness one can take the lifetime of the cell membrane to be $T \sim 1$ year ($\alpha_K \sim 1/137$ denotes Kähler coupling strength) In this manner one finds an upper bound

$$-K \sim 10^{21} \ \text{bits}$$

for the symbolic information resources of the axonal membrane. This is huge amount of information. Of course, only a small fraction of it contributes to single conscious experience since the dispersion of the configuration space spinor field in the 'mindlike' degrees of freedom is never complete and single quantum jump reduces only a small amount of the total sensory degeneracy.

3. Also EEG oscillations, which have emerged at rather late stage of evolution, give a sizable contribution to Kähler action. The amplitude of EEG is roughly one per cent of the membrane potential so that the fractional change of sensory information resources is about 10^{-2} per cent. Since the value of the Kähler action per space-time volume is huge, this however means a huge increase of the symbolic information resources. The slower the EEG rhythm, the larger the amplitude of EEG, which suggests increased cognition. Meditative states of consciousness are indeed associated with slow EEG rhytms. Note that neural activity and hence presumably also neural contribution to consciousness, is small in meditative states.

4. Epileptic seizures involve anomalously large electric fields in some brain regions. Perhaps epilepsy is the price paid for anomalously high information content of sensory experience (recall the characters of Dostojevksi's novels having their epileptic attacks!). Epilepsy has always been the professional disease of prophets: perhaps precognition necessitates exceptionally strong electric fields!

10.3.5 Generation of artificial life by generating strong electric fields?

The observation that the generation of strong electric fields is necessarily accompanied by cognition might be the counterpart of the $E = mc^2$ formula in consciousness theories and make possible the construction of artificial life. Also the symbiosis of living systems with electronic systems containing strong electric fields could be considered. Nanotechonology could be perhaps used to build strong electric fields in short length scales. Of course, even ordinary computers might have some conscious intelligence, not for the reasons proposed by AI people, but because their circuits contain electric fields.

One could consider the possibility of testing TGD inspired theory of consciousness by studying whether the presence of strong electric fields could lead to any phenomena characteristic for life. The total Maxwell action for these systems gives a precise estimate for their representative resources. In [I5] an explanation of $1/f$ noise [24, 20, 28] based on quantum criticality and quantum control of the behaviour of material space-time sheets performed by mind-like space-time sheets, will be proposed. If this explanation is correct, $1/f$ noise serves as a signature for the presence of the mind-like space-time sheets. Electronic circuits are characterized by $1/f$ noise as a rule, which indeed suggests that some kind of primitive cognition is present. One testable prediction is that the generation of electric fields should increase the intensity of $1/f$ noise. The simplest, but not the only possible, explanation for the effect of anesthetics is that their presence reduces electric fields of, say, microtubules and cell membranes. One could also test the effect of anesthetics on $1/f$ noise appearing in biosystems.

10.4 Association sequences and selves

The concepts of association sequence and self are fundamental in TGD inspired physics based model for symbolic and cognitive consciousness and "ontogeny recapitulates phylogeny" metaphor relates them closely to each other.

10.4.1 Association sequences and classical non-determinism

Quite generally, the non-determinism of Kähler action corresponds to that of symbolic representations (say language) and p-adic non-determinism to that of intention, cognitive representations, and imagination. Imagination indeed involves maps of cognitive representations to symbolic representations provided by say nerve pulse patterns.

Association sequences are related to the classical non-determinism forcing the generalization of the concept of 3-surface by allowing sequences of 3-surfaces with time like separations. There is extremely tight correlation between the 3-surfaces of the sequence and typically only a finite number of new degrees of freedom labeled by a finite number of binary digits results in this manner. In case that non-determinism corresponds to N subsequent bifurcations in the time-development of the system, the number of the association sequences is 2^N.

Association sequences can be interpreted as symbolic simulations of classical time development and the associated conscious experiences correspond to multitime snapshots of time evolution, in which the individual snapshots are however experienced subjectively as simultaneous events. Mind-like space-time sheets, almost vacuum space-time surfaces with finite time duration, are especially promising candidates for association sequences since in this case the enormous vacuum degeneracy of the Kähler action suggests strongly classical non-determinism for the dynamics determined by the absolute minimization of Kähler action. But also material space-time sheets having infinite duration can behave non-deterministically and correspond thus to association sequences, which can consists of infinite number of 3-surfaces.

"Ontogeny recapitulates phylogeny" metaphor allows to identify association sequences associated with the mind-like space-time sheets as the geometric counterparts of selves. Whereas self can be regarded as a heap of moments of consciousness occurred after the wake-up, association sequence can be regarded as a sequence of snaphots about classical time evolution. Quantum non-determinism at the level of self corresponds to classical non-determinism at the level of the association sequence. Whereas selves give rise to subjective memory about previous moments of consciousness, association sequences give rise to geometric memory making possible simulations of the geometric past and future, which are reliable in the limit that the effect of quantum jumps is negligible.

10.4.2 Association sequences of association sequences and model for abstraction

Also association sequences of association sequences of ... can be formed. An attractive interpretation is as formation of abstractions and an entire hierarchy of abstractions is possible. At the level of selves this corresponds to the formation of selves from subselves and summation hypothesis states that the experience of self is sum over the abstracted experiences of its subselves. Association sequences of associations sequences of ... can be regarded as a geometric realization for the self hierarchy. This interpretetation is consistent with the identification of the reflective and proto levels of consciousness as contributions of self and its subselves to conscious experiences. The difficulty of consciously forming higher level abstractions such as experiencing what it is to have an experience of having experience of having experience of red can be understood if subselves are represented as abstractions providing average experiences about subselves of subselves. Effectively subsub...selves represent unconscious mind.

One could also consider the identification of the reflective level of the consciousness as represented by the fermionic Fock space whose state basis has interpretation as Boolean algebra. This interpretation is however not favoured by "onthogeny recapitulates phylogeny" metaphor: it seems that fermions provide only a representation for Boolean mind. Fermionic state basis can also be regarded as a finite field $G(2, N)$ having 2^N elements as also do have association sequences associated with N multi-furcations. In case of closed space-time surfaces one could perhaps even speak about super-

symmetry relating the Boolean algebra defined by cognitive fermion pairs and mindlike space-time sheets.

10.4.3 Products of association sequences

It is possible to form products of association sequences by combining association sequences associated with two weakly interacting subsystems. Association sequences of association sequences can be formed by taking association sequence at p-adic level p and by gluing to each 3-surface associated with this sequence a 3-surface at level $p_1 < p$. This operation gives rise to $N(p_1)^{N(p)}$ association sequences and could be interpreted as a geometric model for abstraction process. Obviously the process yields fractal like structure when repeated several times. An attractive possibility is that this kind of process gives rise to cognitive and sensory hierarchies and realization of the Slaving Hierachy of Haken at the level of conscious experience. This picture could also provide a geometric model for the formation of language such that phonemes, words, sentences, etc correspond to a hierarchy of mind-like space-time sheets with increasing value of p-adic prime.

At the level of selves product of association sequences corresponds to parallel selves belonging to the same level of hierarchy and having no direct access to each other's experiences. Right and left halves of brain of split brain patient are a possible example of this kind of situation. Formation of join along boundaries bonds between space-time surfaces defining two association sequences in the product makes possible generation of quantum entanglement between corresponding selves and formation of single self and disappearance of composite selves. Formation of wholes from parts at the level of mental images presumably corresponds to this process. Conscious association $A \leftrightarrow B$ might be formed when the entanglement between selves disappears in quantum jump.

10.4.4 Replication of association sequences

The replication of association sequences provides a possible manner for a quantum state to construct representations for some aspects of its time development via quantum jumps and hence to remember something about its previous quantum states by re-experiencing some aspects of previous quantum jumps. Replication provides also a manner to produce entangled association sequences just like the decay of a particle to two particles produces entangled particle pair. Replication could play same role in the cognitive and sensory evolution of individual as it plays in the ordinary evolution. The replication at the level of selves would correspond to replication of memes, ideas. Language is a mechanism of meme replication, which is much more advanced than mere copying. What happens is that standardized sound patters generate standardized self-organized self-cascades giving rise to generation of selves followed by the generation of subselves followed by.... Note that the decomposition of particles to... elementary particles at the level of matter corresponds to the decomposition of processes to.... elementary processes consisting of sequences of quantum jumps at the level of subjective existence. For instance, DNA molecules could represent elementary selves in biosystems.

10.4.5 What is the typical time span for association sequences?

One can wonder what is the typical time span of for the association sequences at level p. p-Adic length scale hypothesis suggests that the characteristic spatial length scale is just $L(p)$ and that the corresponding time scale is by dimensional analytic argument determined $T \sim L/v$, where v is the typical velocity of information transfer in the system. In elementary particle length scales v can be identified as light velocity whereas in many particle systems the most natural guess for v is as some typical signal velocity from the requirement that a connection with the classical picture of information processing and transfer must exist. For instance, in brain the velocity of nerve pulse progation about $v \sim 10^{-6}c$ would give that for p-adic length scale corresponding to the size of brain of order .1 meters, the duration of association sequences is of order 10^{-3} seconds so that the time non-locality of conscious experience would be rather short. Of course, also longer association sequences are possible since also the next level of the abstraction hierarchy is realized partially.

Taking "ontogeny recapitulates phylogeny" metaphor to its extreme one could argue that the duration of association sequences associated with our selves is same as that of subjective memory identifiable as short range memory and thus of order of few seconds. On the other hand, our ability to plan in time scale of order lifetime suggests that we have access to much longer association sequences:

this could be however due to a temporary entanglement with higher level selves having also much longer subjective memories. Even our body could give rise to a mind-like space-time sheet with a duration of order our lifetime.

10.4.6 Quantum entanglement and association sequences

The role of quantum entanglement is crucial for the TGD inspired theory of consciousness. Quantum entanglement, unless it is bound state entanglement, is reduced in quantum jumps in fermionic degrees of freedom and fiber degrees of freedom of the configuration space. The localization occurring in zero implies that bound state entanglement in zero modes is not possible. The fermionic oscillator operators for leptons and quark like spinors represent fermionic degrees of freedom (note that also elementary bosons can be regarded as fermion-antifermion composites in TGD). The simplest fiber degrees of freedom correspond to the rotational and color rotational degrees of freedom associated with the space-time sheets and also mind-like sheets have these degrees of freedom. In fact, it might be possible to identify the quantum correlates of the various qualia associated with vision in terms of cm degrees of freedom for mindlike space-time sheets.

Bound state quantum entanglement between association sequences might be an important mechanism of symbolic thought.

1. Quantum entanglement for the association sequences suggest a manner to realize associations $a \leftrightarrow b$. Association sequences a and b could correspond to single instances of a more general bundle of associations $A \leftrightarrow B$.

2. An interesting possibility is that this kind of entangled superpositions of associations could be regarded as theorems $A \rightarrow B$. At fermionic level quantum entanglement could give metalevel statements of type $P(a) \rightarrow P(b)$ stating that statement $P(a)$ implies statement $P(b)$. There is however a problem associated with the direction of the arrow of implication: does a imply b or vice versa? The fact that the logical implication seems to be very closely related to the arrow of time suggests that implication is realized by quantum entanglement in time direction between parts of the association sequence. Ordinary entanglement in spatial directions would give rise to ordinary non-directed associations. One could however argue that logical causation cannot be represented as association since geometric time does not possess inherent arrow. This does not exclude the possibility that various rules about behaviour of external world could not be coded into associations represented as quantum entanglement between association sequences associated with mind-like space-time sheets.

10.5 Logic and fermions

The state basis for the fermionic Fock space has a natural interpretation as a Boolean algebra (fermion number $=1/0\leftrightarrow$ yes/no). In this manner ordinary Boolean algebra is extended to vector space spanned by fermionic states. When cognitive fermion pairs are used instead of fermions, fermion number conservation does not pose any constraints and full linear superposition of the Boolean algebra elements is possible. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic.

The simplest TGD based model for thinking systems leads to the result that thoughts correspond to quantum states in discrete spaces. The reason is that slightly non-deterministic classical time evolution means a finite number of multi-furcations. These additional dynamical degrees of freedom correspond to N-element set labelling the different time evolutions associated with given initial values. This suggests that a suitably defined *binary* Hilbert space having Z_2 rather than complex numbers as a coefficient field could provide a simple quantum model for a thinking system. This raises the following question.

What would a quantum field theory in discrete space and with the field of complex numbers replaced with binary numbers Z_2 (0,1/Yes,No) look like?

The answer is following.

1. The state basis of the quantum field theory defined in N-element set is nothing but a Boolean algebra consisting of 2^N elements: all possible statements about the N elements interpreted as

propositions! Bosons and fermions are one and the same thing and behave like fermions since occupation number can have only the values 0 and 1.

2. The requirement that triangle equality for the inner product is satisfied, does not allow linear superposition and one must choose some orthogonal basis for the space. The absence of quantum superposition means that theory is completely classical. Thus it seems that Boolean QFT is completely classical and the transition from classical mechanics to quantum theory could be regarded as a transition from binary QFT to complex QFT or from a binary logic to complex logic.

3. Quantization means construction of statements about statements: the simplest model for an abstraction process one can imagine! One can of course continue this quantization: second, third, etc., quantization is possible and this corresponds to a construction of statements about statements about..... Hence a direct connection with the ideas about genetic code emerges.

4. Also the state basis in the Fock space of the ordinary fermions has interpretation as a Boolean algebra, all possible statements about some propositions (particle with a definite spin component is at point x).

10.5.1 The state basis of fermionic Fock space as Boolean algebra

The state basis of a fermionic Fock space can be interpreted as a basis of a Boolean algebra. In quantum TGD all elementary particles are constructed using fermionic oscillators operators. This suggests that entire quantum field theory is actually a representation of Boolean algebra and N-fermion states have interpretation as statements about basic propositions labelled by the indices labelling fermionic oscillator operators. In particular, configuration space spinor structure is constructed in terms of the fermionic oscillator operators for the second quantized spinor fields on space-time and this suggests a deep connection between spinor geometry and logic. Perhaps one could say that quantum logic is C-valued in the sense that all complex superpositions of a statement and its negation are possible.

In Boolean algebra one can select the maximum number of 2^{N-1} mutually consistent statements as axioms. An interesting possibility is that only these mutually consistent statements are physically realized so that the number of states is reduced by a factor of one half. Amusingly, in the ordinary fermionic field theory the states created by a finite number of oscillator operators are the counterparts of the mutually consistent statements, their negations would correspond to a vacuum state obtained as an infinite product of all creation operators annihilated by creation operators. The states created by annihilation operators from this states are not allowed in QFT since they would have infinite energy.

One can identify the complex valued linear space of fermions as a generalization of Boolean algebra to complex Hilbert space. Cognitive fermion pairs could provide realization for this space as pairs of fermion and antifermion belonging to different space-time sheets and representing logical statement and its negation: the automatic presence of negation is rather natural from the point of view of consciousness theory. The splitting of the wormhole contacts connecting the space-time sheets gives rise to annihilation process generating fermion and antifermion pair (fermionic quantum numbers reside on the boundary components of the split wormhole contact). In this manner one avoids problems related to fermion number conservation encountered otherwise in physical realization of the fermionic logic. Alternative possibility is to assume fixed number of fermions and associate truth values with the direction of spin.

10.5.2 Boolean algebra as Boolean QFT

Boolean algebra $B(N)$ is generated by all possible yes/no statements about N propositions. It consists of sequences of N binary digits of form $(...,1,0,0,..,1)$ having value of 0 or 1. Addition is with respect to Z_2 so that $1+1=0$. Boolean algebra is Z_2 linear space and the elementwise multiplication of the binary digits in the string makes it algebra. $(0,0,0,..)$ and $(1,1,....,)$ are zero and unit elements of the algebra.

Geometrically Boolean algebra $B(N)$ corresponds to all possible subsets of an N-element set. Sum corresponds to a symmetric difference (take the union of sets and throw away the common elements). Multiplication corresponds to the intersection of the sets. Entire set represents unit element and empty

set zero. Empty set is not physically realizable, or equivalently, the zero element of the Boolean algebra does not correspond to a physical state in the Z_2 Hilbert space defined by the Boolean algebra.

Quantum field theory in N-element set formed by the basic propositions (analogous to 3-space in QFT) means associating to each element of the N-element set creation and annihilation operators and postulating standard commutation relations with them:

$$[a^\dagger(i), a(j)] = 1 \quad .$$

One can also consider fermions that is anticommutation relations but since -1=1 in Boolean algebra, they are equivalent with the bosonic commutation relations so that Boolean bosons and fermions are one and the same thing in the Boolean QFT.

The states of this QFT are constructed in the usual manner. The only difference is the occupation numbers are Z_2 valued and are either one or zero just as in the case of fermions. Thus Boolean particles are fermions always. Since N creation operators are involved one obtains a space generated by 2^N states. The proposition and its negation correspond to the states created by, say I oscillator operators and the dual of this state created by the remaining $N-I$ oscillators operators. Statement corresponds to I particles and its negation to I holes in the dual ground state containing all N oscillator operators.

Thus the state basis is nothing but the Boolean algebra associated with the N element set! Thus the state basis of Z_2 valued quantum field theory in the set of N propositions is nothing but the formation of all possible statements about these statements: a model for abstraction process. One can apply this process to the $2^N - 1$ element set and by continuing this process get a sequence of second quantizations as a sequence of abstractions.

The assumption of unrestricted linear superposition in Z_2 Hilbert space leads to difficulties with Schwartz and triangle inequalities. The physical interpretation of the theory requires that inner product satisfies Schwartz inequality

$$|(x, y)| \leq |x||y| \quad .$$

Linear superposition allows states, say y, with zero norm since any superposition of even number of orthonormal states has zero norm in Z_2. The norm of the inner product of one of the basis states appearing in zero norm state, call it x, with the zero norm state y equals to one and is not smaller than the product of the norm of the basis state and state with vanishing norm: one obtains $1 < 0$, which does not make sense if inner product is interpreted as real number (as a Z_2 valued number one could perhaps say $1 = -1 < 0$). One ends up to difficulties also with the triangle inequality: $|x + y| \leq |x| + |y|$ if x and y are zero norm states with single common element of orthonormal basis so that one has $|x + y| = 1$.

The only possible manner to save Schwartz and triangle inequalities is to assume that linear superposition is not allowed for Z_2 Hilbert space. This in turn means that situation is completely classical! If the set generating Boolean algebra consists of entire 3-space, this means that every state is gauge equivalent with an N-particle state of completely localized particles. This in turn implies that Boolean QFT should be more or less equivalent with classical mechanics and one could understand the transition from classical physics to quantum physics as the replacement of Z_2 with complex numbers C as the coefficient field of the state space.

One can change state basis by unitary transformations. Unitary matrices are obtained from orthogonal Z_2 valued unit vectors possessing entries equal to 1 or 0. Any unitary matrix corresponds to a matrix representing the permutation of 2^N elements of the basis of the Boolean algebra. Time development operator in this quantum field theory is always defined for a *finite* time interval only (the length of the 'chronon' is fixed naturally in p-adic QFT) and represents a permutation of this basis. In particular, a nonlinear transformation of the oscillator operators in general occurs. All unitary transformations are permutations, which do *not* lead to state basis involving superpositions of the basic states. This is in accordance with the observation that Boolean QFT is completely classical.

10.5.3 Boolean mind and neutrinos

Very low energy neutrino physics a la TGD differs from that predicted by standard model dramatically because TGD predicts the presence of classical Z^0 fields coupling to neutrinos. Even more classical Z^0 fields become important above cell length scale since this length scale corresponds to the Compton length of neutrinos.

Ordinary fermions cannot reside on mindlike space-time sheets unless they are created as pairs with vanishing total quantum numbers (in particular energy!): this is possible only if the second spacetime sheet has negative time orientation. Exotic, possibly dark, neutrinos are however exceptional [M6, J7]. Exotic neutrinos are an ideal tool of cognition since they do not couple to electromagnetic interactions and, having couplings only to the classical weak fields. TGD based model of condensed matter predicts that the classical Z^0 binding energy of the exotic neutrino with condensed matter makes neutrino energy in condensed matter negative and large [F9, M6].

From this it is still a long way to precise models and one can make only educated guesses.

1. Cognitive neutrino pairs could reside in the defect regions of neutrino super conductor which is superconductor of type I having complicated stripe like defect regions near criticality. TGD based model for the interaction of neutrinos with condensed matter predicts that the thickness of the defect regions is of order 10^{-8} meters. Hence cell membranes are excellent candidates for the defect regions. One indeed ends up to a detailed quantitative model of cognition and memetic code by combining this idea with the observation about magnetic and Z^0 magnetic transitions as a fundamental element of our consciousness [M6].

2. Also chromosomes (having same thickness as cell membranes) could be identified as defect regions of neutrino super conductor. Very simple model for the abstraction process as a hierarchy of Boolean statements about Boolean statements about... starting from two basic statements explains the basic numbers of the genetic code [L1]. It is difficult to believe that this could be mere accident. Cognitive neutrino pairs indeed allow to construct a model of a many-sheeted DNA realizing gene level Boolean mind and possibly explaining the mystery of introns [34] and the role of cognitive neutrino pairs is very similar to that in cell membrane cognition. One possibility is that cell membrane cognition assigns quantitative measures and names to conscious experiences as the integers defined by the sequences of the cognitive neutrino pairs whereas DNA cognition represents conscious beliefs: thus DNA would store information about both material and cognitive basic structure [L1, M6, L2].

10.5.4 Combinatorial Hierarchy as a hierarchy of 'genetic codes'

The simplest model for abstraction process is based on the process in which one forms first all possible Boolean statements about N basic statements, 2^N alltogether. If one drops one of the statements one has $M_N = 2^N - 1$ statements: M_N is Mersenne number. The motivation for the dropping of one statement might be that in set theoretical realization one of the statements corresponds to empty set and is not realizable. Alternatively, in the realization based on many-fermion states, vacuum state could correspond to this kind of state. One can form also statements about statements: the first level of abstraction. This leads to $M_{M_N} = 2^{M_N} - 1$ many-fermion states. Construction is especially intersting if the numbers $M(M_N)$ are primes, so called Mersenne primes. Indeed, in some cases one obtains hierarchies of Mersenne primes by repeating the construction as long as it works.

The so called Combinatorial Hierarchy, shown already earlier to provide an explanation for the numbers of the Genetic Code, emerges as the most notable hierarchy. The Combinatorial Hierarchy [16] consists of the Mersenne numbers $2, M(1) = 3, 7$,$127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitely listed ones are known to be primes. Combinatorial Hierarchy emerges from a model of abstraction process as subsequent transitions from level to metalevel by forming Boolean statements about Boolean statements of level n and dropping one statement away and starting from $n = 2$ basic statements. Combinatorial Hierarchy results also by constructing the sets of all subsets with empty set excluded starting from two element set.

The set of statements at level n can be given a structure of Finite Field $G(M(n), 1)$ if $M(n)$ is prime. The multiplicative groups $Z_{M(n)-1}$ form a nested hierarchy and the coset spaces $Z_{k_n} \equiv Z_{M(n+1)-1}/Z_{M(n)-1}$ are cyclic groups. Combinatorial Hierarchy based model of Genetic Code explains the number of DNA:s and aminoacids and the representation of words of the GC as triplets of 4 different codons. Aminoacids correspond to $k_{n=3} = 21$ axioms of a formal system defined by $n = 3$ level of Combinatorial Hierarchy having a unique imbedding as the group $Z_{k_n} \subset Z_{M(n)-1} = Z_{126}$ and DNA:s correspond to the set $X_{N(DNA)} \subset Z_{M(n)-1}$ of $N(DNA) = (M(n) + 1)/2 = 64$ mutually consistent statements at level n regarded as special cases of general theorems. GC corresponds to the mapping $x \to x^{k_{n-1}} = x^6$ in $Z_{M(n)-1}$ mapping DNA type statements to aminoacid type statements. The numbers of DNA:s coding single aminoacid are reproduced in a symmetry breaking mechanism

involving the finite groups $Z_{p_{n-1}}$ and Z_{k_n} and symmetry breaking is in a well defined sense minimal. The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complicated lifeforms or forms of intelligence.

10.5.5 Boolean mind and memetic code

For quite a long time it has been clear that neutrino and antineutrinos might providea a realization of Boolean mind and the memetic code. There are actually several candidates for this kind of realizations.

1. The first model of memetic codon is based on *geometro-temporal* sequences of cognitive neutrino pairs having nearly vanishing energy. The classical non-determinism of Kähler action is absolutely essential prequisite. The intuitive idea is that cognition involves multi-locality with respect to the geometric time. Rigidity and robustness requires that identical memetic codons must form analog of magnetized phase and that conscious experience results in spin flips of cognitive antineutrino sequences so that all pairs of the final state point to the direction of the external Z^0 magnetic field. This model emerged long before the notion of self. The model requires that cognitive antineutrino pairs annhilate and are created regularly in time scale of millisecond and this assumption is obviously quite strong.

2. A more conventional model emerged after the notion of self and a general vision about cognitive/symbolic representations in terms of spin glass type phases with bits 1/0 represented as spin blocks with opposite directions of magnetizations. The phase transition reversing the direction of magnetization to that of an external magnetic field gives rise to a conscious experience about the second value of the bit. Only $2^N - 1$ bit sequences give rise to a conscious experience so that Mersenne primes emerge naturally. The model relies on *subjecto-temporal* sequences of Z^0 magnetization directions (true/false) of a block of antineutrinos at the cell membrane space-time sheet. In this model the approximate vanishing of net energy for neutrino-antineutrino pairs in biomatter only facilitates the generation of anti-neutrino phases. Also spatial sequences of Z^0 magnetized antineutrino blocks could define memetic codons.

The hypothesis that memetic code corresponds to the next level of the Combinatorial Hierarchy characterized by Mersenne prime M_{127}, when combined with p-adic length scale hypothesis, leads to a prediction of .1 seconds for the duration of the 'wake-up' period of subself corresponding to the codon of the memetic code. Bits are expressed as separate mental images if they correspond to sub-selves, otherwise they are experienced as a "clump" and presumably only the number of bits matters so that a reduction to something akin to 64 bit genetic code results at the level of conscious experience.

The memetic codon consists of 126 bits with two possible spin directions corresponding to the two values of Boolean statement. This implies that 1/1260 seconds should be the duration of single bit: this time scale is indeed fundamental for nerve pulse activity but nerve pulses tend to have somewhat longer duration: a more natural realization seems to be in terms of membrane oscillations. Both hearing and vision have .1 second time scale as fundamental time scale.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-,5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is .1 seconds. Thus there is some support for the realization of at least a degenerate version of the memetic code in terms of nerve pulse patterns but the realization using membrane oscillations seems to be a more plausible option and it is known that sounds are coded to electric oscillations in ear.

The simplest assumption is that memetic code is a newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. One can test the hypothesis about cognitive neutrino pairs: the presence of very intensive Z^0 magnetic fields could generate neutrino pairs and spontaneously magnetize cognitive antineutrinos and make conscious thought impossible. Rapid magnetic pulses could be accompanied by rapid Z^0 magnetic pulses. An interesting possibility is that the magnetic pulses associated with nerve pulses involve also Z^0 magnetic field with changes the direction of the spin of the cognitive neutrino pair. This mechanism would code

nerve pulse patterns to patterns of cognitive neutrino pairs such that nerve pulse would mean change of the direction of the spins in the temporal sequence of cognitive neutrino pairs.

10.5.6 How nerve pulse patterns and membrane oscillations could be coded to Boolean statements?

The representation of Boolean mind based on the identification of the antineutrino Z^0 magnetization direction with the value of the Boolean statement seems to be the most realistic one found hitherto. This option also allows to identify a mechanism coding membrane oscillations and perhaps even nerve pulse patterns to Boolean statements.

1. Antineutrinos reside in the strong Z^0 magnetic field associated with the cell membrane and having the direction of the axon. The presence/absence of nerve pulse corresponds to true/false statement in accordance with neuro science intuition. Nerve pulse flips the spins of antineutrinos in the block representing single bit of the codon and in this manner changes the direction of Z^0 magnetization. Nerve pulse must induce a magnetic pulse orthogonal to the original magnetic field inducing with a high probability a quantum jumps changing the direction of antineutrino spin.

2. Since the spin of the antineutrino signifies Boolean statement, the change of the spin direction of the cognitive neutrino pair should correspond to a transition between harmonic oscillator states (n, up) and $(n+1, down)$ of the cognitive antineutrino in the strong Z^0 magnetic field in the direction of axon. This transition should be induced by the generation of nerve pulse.

3. It seems that the transition must occur as a quantum jump induced by a harmonic perturbation of the Z^0 magnetic field changing the direction of spin. Harmonic perturbation causes transition only if its frequency is equal to the difference of energies for the initial and final states so that the angular frequency of the perturbation must be equal to the difference $\omega = E(n+1, down) - E(n+1, up)$ of the antineutrino energies so that resonant transition is in question. If the transition rate is sufficiently large the transition occurs with high enough probability. There are two options.

   i) The model of nerve pulse is based on Z^0 MEs propagating along axon with an effective phase velocity equal to the conduction velocity (see the [M2]). Z^0 MEs acting as the clock, whose "tick" corresponds to the duration of the bit of the memetic codon, could be also responsible for the well-known neuronal synchronization in the millisecond time scale. The magnetic field pulse carried by Z^0 ME could change the direction of the Z^0 magnetization of the antineutrinos of a single bit of the memetic codon since it causes a torque (classically the torque caused by the magnetic field on spin is proportional to the cross product $S \times B$) in a correct direction.

   ii) There is also another option. Rather remarkably, or one could say almost miraculously, for muonic and tau neutrinos the(n, up)-$(n+1, down)$ transition frequency corresponds to the duration defined by the duration of nerve pulse for a reasonable value of the axonal Z^0 magnetic field. Thus the Z^0 ionic currents associated with nerve pulse could generate Z^0 magnetic field having correspond basic frequency in its Fourier expansion [L1]. This perturbation would be induced by the Z^0 ionic currents associated accompanying nerve pulse (note that all nuclei are completely ionized Z^0 ions: this is essential also for the model of nerve pulse generation).

10.6 Quantum computationalism

TGD Universe can be formally regarded as infinite quantum computer like structure in the sense that each quantum jump involves the unitary process U analogous to a Schrödinger evolution lasting infinite time and is followed by state function reduction and state preparation process. Therefore TGD suggests what might be called quantum computationalism. Universe would be performing huge quantum computation and the computation like processes performed by us or by our brains would be only a ridiculously small portion of this computation. Of course, this must be taken as a rough metaphor, the quintessence of the conscious quantum computation like processes could be quite different from the essence of the ordinary quantum computation.

The average increment of the psychological time in quantum jump is rather small: the simplest guess suggest that the average quantum of psychological time is or order 'CP_2 time', about 10^4 Planck

times. This means that the relation of the information processing performed by biosystems to quantum jump would be the same as the relationship of macroscopic physics to physics in CP_2 scale about 10^4 Planck length scales. This would however mean an extremely short decoherence time in an obvious conflict with the experimental facts. Macrotemporal quantum coherence, which corresponds to the formation of bound states, however effectively fuses a sequence of quantum jumps to a single quantum jump so that the decoherence occurring otherwise in CP_2 time scale can be circumvented.

The notion of self is absolutely crucial for TGD approach to consciousness and makes possible to understand consciousness in macroscopic time scales. A very natural notion is that of cascades of selves within selves generated spontaneously or by quantum jumps. This implies a connection with the basic conceptual structure of computationalism. The cascades have natural modular structure, which is quintessential for the understanding of the symbol processing performed by brain. A very attractive hypothesis is that selves within selves are conscious counterparts of computational agents or more or less equivalently, of the subroutines of computer program. Selves can perform two kinds of quantum jumps and a natural identification of these modes is as computational and sensory (input) modes. Subjective memory takes automatically care of ouput in the sense that the subjective history of subself is experienced as an abstracted memory by self.

Communication between selves could occur as it does between human beings. Also 'mass media' at neuronal level seem to be possible and would make possible the concept of global workspace. Quantum jumps can be regarded hopping in the space of zero modes identifiable as fundamental order parameters and Haken's theory of feature recognition generalizes. Quantum entanglement in turn provides elegant realization of association concept so that the basic ideas of connectionism emerge naturally from quantum computationalism. There are also drastic differences with between TGD and computationalism, basically implied by the different concept of psychological time which implies that cognition has holistic aspect also with respect to time. Thoughts are definitely not deterministic computations and living systems are definitely not robots.

10.6.1 Computationalism and connectionism

Computational approach to cognition [50] is the dominating approach in cognititive and neuro sciences and has had undeniable successes. Computationalism is often identified as traditional AI based on the concept of truth preserving manipulation of symbols according to some fixed rules of the formal system. This approach indeed explains nicely computational aspects of mind. Combinatorial explosion is the basic failure of the approach at practical level. Connectionism relies on the concept of association and associative neural net provides a quantitative model for how brain learns. Connectionism is often regarded as a variant of the computationalism and it is believed that neural nets provide models for unconscious parallel information processing whereas conscious information processing is best modelled by hierarchical program like structures. The general philosophical shortcomings of these approaches are obvious: they cannot provide any insights to the problem how meaning, understanding, emotions and volition, which are factors crucially important for the functioning of conscious brain, arise. This has even led some advocates of this approach [50] to believe that human brain, being computer basically, is simply uncapable of understanding the problem of consciousness! This would probably be the case if human beings were robots: fortunately we are not!

Traditional AI approach

In the traditional AI approach brain is modelled as a complicated computer. Computation is realized using rigid algorithms, which are hierarchical structures consisting of subprograms. Using more abstract terminology, the basic concepts are symbols and agents, 'demons'. Symbols are inputs for 'demons', subroutines of program manipulating symbols and creating new outputs as symbols. One could however interpret also agents themselves as symbols. The concept of global work-space [44] realizes the intuition that short-term memory is available to many users. Also the concepts of belief and desire can be formulated without referring to consciousness. Beliefs are inscriptions about the world and desires are identified as goals. For instance, problem solving means simply making trials with the aim of minimizing the difference between goal and result of trial. The concept of representation is central. It is known that brain realizes several types of representations [50]. Visual mosaic like representations, phonological representations in short-term memory consisting of few phonemes (say remembering phone number for some time), grammatical language like representations with hi-

erarchical structures and 'mentalese', which is the most abstract representation type summarizing in very implicit manner the essentials of, say, mathematical model.

Computationalism explains nicely the general features of language by providing a representation for the hierarchical structure of language. One can also easily think brain as a population of (possibly) conscious demons. Some demons receive sensory input, some demons process it and the ouputs of some demons are realized as motor outputs. It seems that this approach models quite satisfactorily those aspects of cognition, which can be realized as purely mechanical truth preserving symbol manipulation modellable universally by Turing machine. The best proof for the claim that computers have catched something about the basic structure of cognition is that computers are already now able to beat chess champions. The weak point of the computationalism is its extreme rigidity: minor input error or programming error and program fails to work. Combinatorial explosion is second shortcoming. For instance, all possible melodies formed from finite number of musical notes with finite number of durations for each and lasting the typical length of musical piece is immense. In computer chess combinatorial explosion makes the simple-minded trial and error approach completely unpractical and the only possible manner to proceed is to teach the computer by mechanizing the human intuitions about good chess.

Connectionism and neural nets

Connectionism provides a modern version of associationism proposed by British philosophers Locke, Hume, Hartley, Berkeley and Mills. Behaviorism was the first purely mechanistic version of this approach but was quite too simplistic to work. Associationism consists of two laws. The first law states that the ideas which are often experienced together get associated: when one is activated also the other one gets activated. Second law states that similar ideas activate each other. Connectionism tries to realize these two aspects of associationism mathematically and construct practical realizations for associative thinking. Typical application would be feature recognition and machines learing automatically from their inputs some predetermined tasks.

Neural nets provide a mathematical model for the concept of association and associative learning. The simplest model for learning simply associates unique self-organized state of a dissipative neural net to the state of the external world represented as an external force driving the neural net. Dissipation realizes also the second law: if input is sufficiently similar to the standard input generating given standard output, the standard output is indeed generated. Also Haken's model for feature recognition realizes second law as a feature recognition based on nonequilibrium thermodynamics. Features correspond to equilibrium states of a nonlinear dissipative system (free energy minima for order parameters). If input creates initial output belonging to the attractor of the feature, dissipative dynamics takes care that the asymptotic output is feature.

Associative net can be regarded as a many-layered structure, in which the states of some nodes correlate strongly with the states of some other nodes. The state of node is characterized by a component of vector, whose components give the values of the amplitude in the nodes. For a given input the net rapidly achieves equilibrium in which the associations created by the input are determined by those nodes in which the amplitude is large. The equilibrium states of neural nets with coupling to external are identified as representations for stable mental states representing some states of the external world.

The flexibility of the neural nets is the strength of connectionism. Also combinatorial explosion can be avoided. Neural nets might indeed model lower level cognition which is mostly unconscious to us. The absence of the hierarchical structures means the loss of 'expressive power' essential for higher cognition and leads to the problems decribed in [50].

1. Connectionistic approach is not able to distinguish between individual and class: what is created from the inputs is some kind of average individual: neural network can learn to recognize human face but not a particular human face or to recognize particular human face but not to make abstraction about what human face looks like.

2. Second problem is so called compositionality: the ability of the representation to be build out of parts and represent the meaning of the whole deriving from the meanings of parts. A related problem are the difficulties in the identification of the meaning of linguistic expressions. For instance, the meanings of the expressions consisting of words 'the child', 'ate' and 'the slug' depend on the order in which the words are represented and connectionism is not able to

distinguish between 'the child ate the slug' and 'the slug ate the child'. The natural ordering of symbols provided by hierarchical tree solves this problem in AI approach. Simple neural network learns easily to recognize picture containing horse but if the picture contains two horses, network fails completely!

3. The third problem is a combination of these two. An example from [50] illustrates this. Network can learn to sum 1 and 3 to 4. When it learns to sum 2 and 2 to 4 it can lose the already learned ability. Second example: consider the exression 'Every forty five seconds some-one in the United States sustains a head injury'. Human brain can easily realize the meaning of this sentence which suggests that quantification occurs in brain and human brain transforms the sentence either to expression "Every forty-five seconds {there exists an X[who gets injured]}" instead of "There exists an X{who every forty-five seconds[gets injured]}"

4. What multiplies human thoughts is recursion. We can take proposition and give it a role in another prosition and so on. In this manner a combinatorial explosion of propositions is generated. To get propositions-inside-propositions network, one could add a new layer of connections but this solution is clumsy and non-economical. The addition of a new level of abstraction would mean a new network containing additional level. In computationalism the solution of the problem is much more elegant. Each proposition is represented in long term memory once. One can of course combine computationalism and connectivism and use simple neural networks as basic modules of computer program like modular structure.

5. Neural net models, which realize connectionistic philosophy in practice, have serious problems in modelling long term memory. If its is assumed that long term memories are coded into the matrices defining output of the node in terms of its inputs, which are modified during learning process, the unavoidable conclusion is that new memories destroy the old ones. Childhood memories seem however to be the most stable ones.

10.6.2 How connectionism emerges from TGD framework?

Brain as an associative net in TGD

TGD leads to a variant of connectionism which differs from the standard version in some crucial respects. Brain as a quantum self-organizing system moving in spin glass energy landscape generalizes the neural net realization of connectionism. The plasticity of the neural substrate corresponds directly to the spin glass property and the notion of frustration fundamental for spin glass type systems is guaranteed by the inhibitory/excitatory nature of nerve pulses. Neural net becomes dynamical rather than being a fixed structure. One can view brain as system moving in the space of neural nets and perceiving and affecting its own position in this abstract space.

Brain can be regarded as a conscious associative net developing by quantum self-organization to asymptotic self-organization patterns which correspond to recognized features, learned habits, skills $\cdots$: dissipation can be said to serve as fundamental Darwinian selector in this process. By music metaphor each neuron, when it fires, generates a characteristic neuronal experience possibly contributing to our conscious experience: only the intensity of this experience depends on the nerve pulse pattern. The firing of a neuron gives rise to a conscious neuronal association $A \rightarrow B$.

This would suggest that brain is like a conscious music instrument, or rather, entire orchestra, played by the nerve pulse patterns and our experiences corresponds to the sound patterns created by this orchestra. It has turned out that this view is probably quite not correct. Brain and body are much more. The music is at the level of sensory organs as sensory qualia, and neural activity cognizes, that is analyses the sensory music to notes and represents the notes. This view, which is certainly not possible in the standard neuroscience framework and surprisingly close to what a layman knowing nothing about neuroscience would think spontaneously, makes sense in TGD framework if one assumes that entanglement between brain and sensory organs binds sensory qualia with the cognitive associations generated by the sensory input. This view also allows to understand elegantly the differences between sensory experience, dreaming, hallucinations, and imagination. An essential element is the feedback from brain to sensory organs enabling "qualifacation" during dreaming and hallucinations. This feedback is also active during the ordinary wake-up consciousness.

Spin glass energy landscape is four-dimensional in a well defined sense and the identification of the long term memories as geometric memories solves the basic paradox of the neural net models of

memory. One can also understand how brain knows that the mental image represents memory and why repetition and reverberation of nerve pulse patterns in neural circuits leads to learning and why emotional experiences are easily remembered.

Feature recognition

The first law of associationism states that similar ideas tend to induce each other. For instance, a part of familiar face in the visual field induces a memory about the entire face. In computational approach feature recognitition is believed to involve unconscious low level parallel processing. Haken [25] has proposed an elegant model of feature recognition based on non-equilibrium thermodynamics. The features to be recognized represent the minima of the potential depending on order parameteres and the presence of dissipative terms implies that system ends up to potential minimum representing feature.

Haken's theory generalizes to TGD context almost as such. Dissipative time evolution is replaced with quantum self-organization by quantum jumps and in each step entire macroscopic space-time surface is replace by a new one. The zero mode degrees of freedom of the configuration space are identifiable as fundamental order parameters and each quantum jump involves complete localization in continuous zero modes. The localization in discrete zero modes characterizing cognitively degenerate space-time surfaces need not be complete: what is needed is localization to a subset of space-time sheets for which the eigenvalues of the p-adic density matrix are degenerate. This means that the time evolution by quantum jumps corresponds to hopping in the space of zero modes, which leads to that part of zero mode sector, where configuration space spinor field has largest value. The maxima of Kähler function are excellent candidates for the attractors of the quantum self-organization process.

A more concrete brain level model of feature detection based on the realization of the self-hierarchy as a hierarchy of Josephson currents frequency-modulating each other perhaps helps to clarify the abstract general ideas about conscious feature detection.

1. The feature to be detected is represented as a reference supra current flowing in a neural circuit and weakly coupled to a parallel neural circuit representing the input. When the supra currents are identical, constructive interference of the Josephson currents flowing between the two circuits occurs and induces large modulation of the rest potentials of neurons of the circuit and leads to a synchronous generation of nerve pulses. Synchronous neural firing can start under rather wide limits depending on the alertness of the neural circuit (how near to the threshold value resting potential is) controlled by the modulating Josephson currents also.

2. Synchronous neural firing wakes-up subself which starts to self-organize and develops into an asymptotic pattern representing a mental image about the detected feature. The final state depends only weakly on the initial state of the neural circuit representing self so that genuine feature detection is in question. For instance, some minimal number of neurons firing in the neural circuit leads to given final state pattern so that the constructive interference of the Josephson currents need not be maximal.

3. The self-organization parterns in neural circuits define a population of sub-selves defining cognitive mental images, features. These sub-selves wake-up and fall asleep (even periodically during their lifetime (after images)). Falling asleep occurs, when the sub-system generates a bound state entanglement with some other sub-system, and wake-up by a reduction of the bound state entanglement.

4. Self-organizating neural circuit starts to approach the maximum of 'subsystem' Kähler function (recall that approximate representability of Kähler function as a sum of subsystem Kähler functions is probably possible) is accompanied by the wake-up of subself. This corresponds to the motion of neural circuit in its spin glass energy landscape induced by various neural transmitters inducing short term or long term changes in the synaptic contacts. Thus self-organization induces also a generalized motor action shifting the position of the neural circuit in the spin glass energy landscape.

5. Feature detection involves kind of *Eureka!* experience. Perhaps the subself representing the mental image about recgonized object remains for some time irreducible and hence does not possess any subselves (and is in 'enlightened' state). This could be the situation for some time

until subselves are generated during self-organization and lead to the analysis of of the recognized feature.

It seems that the presence of an algebraic p-adic-real entanglement with a positive entanglement negentropy a is a physical correlate for the experience of understanding and Eureka experience. Real bound state entanglement can give rise to experiences like seeing beauty, feeling truth, and feeling love. Thus both p-adic and real physics, cognitive and symbolic representations, must be involved. Cognitive representations realized in terms of p-adic cognitive neutrinos are generated from the real physics based symbolic representations. The entanglement between cognitive and symbolic would give rise to the Eureka experience. The need to separate cognitive and symbolic representations from each other is highly non-trivial implication.

Learning of associations

The second law of associationism states that ideas experienced simultaneously tend to form associations. TGD suggests two mechanisms for realizing associative learning.

1. The purely quantal mechanism realizes associations in terms of quantum entanglement. This mechanism would be extremely elegant because super position principle allows huge capacity of forming associations. Quantum entanglement however seems to associate parts to form wholes with the ensuing loss of conscious information about parts rather than giving rise to conscious associations $A \to B$. One could say that the association in question is spatial rather than temporal. Note also that quantum entanglement lacks the directional character of association. It seems that this mechanism is essential for associating various cognitive features at the level of brain with sensory qualia at the level of sensory organs.

2. In second mechanism the classical neural net type realization is replaced by a process in which subself wakes up another sub-self. A process in which presynaptic neuron wakes up postsynaptic neuron and the mental images of these neurons form the association, could indeed serve as building blocks of our associations.

It has turned out that these mechanisms are actually not mutually exclusive, and that both are involved with the association mechanism. The TGD based notion of sub-system, relying on the topological non-triviality of the many-sheeted space-time, makes possible for separate selves (unentangled systems) to share mental images via the entanglement of their sub-selves. Topologically this corresponds to the following situation. Two selves (say sensory mental image and cognitive mental image) are realized as disjoint space-time sheets S_i, $i = 1, 2$ and their sub-selves as smaller space-time sheets S_{ij} glued by wormhole contacts to the space-time sheets S_i. When sub-self space-time sheets S_{1j} and S_{2k} are connected by join along boundaries bonds, the fusion and sharing of these mental images occurs.

The neural network model for the formation of associations relies on the idea that some states of the neural net are in a correspondence with the states of the external world. Also the states of different layers of neural net have natural mutual correspondence. Association basically creates one-one map. In neural net models the interaction with external world occurs via driving force and dissipation leads to asymptotic states, which can be interpreted as association of net-states with the states of the external world. The problem of the neural network models is how the learning process could be realized in living brain. In particular, how two simultaneous ideas represented by the substates of neural net get associated with each other. This seems to require that the presence of two active nodes present in the net tends to strengthen their mutual coupling. There is a lot of empirical supports for this and neural transmitter action is an essential element of this process. In TGD framework this process corresponds to the gradual movement of neurons and brain in their spin glass energy landscape induced by neural transmitter action.

In TGD framwork the formation of association $A \to B$ would mean that the stimulus A alone can generate B. This means that the subself representing mental image A tends to wake up the subself representing mental image B. At the neuronal level this simply means that the firing presynaptic neuron excites postsynaptic neuron so that it also fires: the long term changes of the synaptic connection promotes this ability. At the level of our mental images the waking up process must involve nerve pulse transmission from neural circuit representing subself A to the neural circuit representing subself

B. Josephson current model suggests that during learning period, when A and B are experienced simultaneously, they are mapped to reference currents in feature recognition network $A + B$. Later when only A serves as input, part A of the circuit $A + B$ begins to fire when it receives A as input. If the synaptic connections between circuits A and B have been strenghtened during learing period, the firing spreads out to B and also B wakes up. This in turn leads to the self-organization process generating experience $A + B$.

Many associations are bi-directional: for instance, symbols for real world objects are bi-directional associations. In TGD framework one can model the generation of the bi-directional associations in classical sense along following lines. Denote by A and B the symbols to be associated: A and B correspond to subselves of say self X. Neural net philosophy suggests that A and B should co-operate to keep each other in wake-up state (alive!): self-organization by quantum jumps could lead to this kind of co-operation. This is achieved if sensory experiences stimulate automatically co-operative self-populations, whose members tend to keep each other awake. This model is consistent with the fact that associations do not involve conscious thought. For instance, A could generate nerve pulse patterns waking up B and vice versa. Note that at the next level of the self hierarchy this could be regarded as a formation of self-association $X \to X$ possibly giving rise to a stable short term memory and also as survival of self X guaranteed by co-operation of subselves.

10.6.3 Computationalism and TGD

Computationalism in strong sense (brains as deterministic machines) does not emerge from TGD. The basic reason is that the time concept is totally different from that of computationalism. One can say that quantum jumps select between different time evolutions and the overall-important modular structures result from self cascades.

How computationalism and TGD approach differ?

A good example is provided by vision discussed in [50]. Vision builds representation or description of the world from sensory data. Since inverse optics is not possible, implicit assumptions about the structure of the external world are necessary. Typically illusions rely on the breaking of these implicit assumptions. Illusions are not always undesirable. Two-dimensional pictures are an example of an illusion making possible visual communication! Auto-stereograms [50] consisting of diffuse soup of points are a particularly striking example of illusion: looking the picture for a sufficient time, one can experience a dramatic reshapening of the experience: beautiful 3-dimensional picture emerges from the chaos. Auto-stereograms support the hypothesis that vision involves computational activities or quantum counterparts of them. This process can be seen as a school example about how brain adds to a pure sensory input symbolic and cognitive representations.

In TGD universe brain does not probably deduce the representation of the world from picture by a straightforward computation. Certainly the data and implicit or learned assumptions about the world appear as an input in some sense. Some kind of iterated guessing based on implicit assumptions seems to involved: guess is made and compared with the actual picture. Quantum self-organization indeed makes possible the iteration, being in itself an iterative process. Guesses are very probably based on the existing abstract data about possible configurations of the world. The paradigm of 4-dimensional brain allowing to realized long term memoryes as geometric memories could be crucial in this respect. One can wonder whether the implicit assumptions might also develop from temporal entanglements with larger selves (during sleep) giving rise to information about world in longer length and time scales.

Control of motion is second good example of what might happen. There is no deterministic program proceeding with respect to geometric time and selecting what happens next and creating the quantum history step by step. Rather, the entire pattern of motion is selected by the creation of the main program self by quantum jump. The subsequent quantum jumps occur in the cascade proceeding in top-to-bottom type manner to shorter spatial and temporal scales. Thus the main program corresponds to, say the pattern of large scale motion, and sub-programs correspond to the details of the motion. What is new as compared to computationalism is that the program is created while it runs.

At the level of CNS anatomy sensory perceptions and motor actions loook mirror images of each other. TGD suggests that they could be mirror images at much deeper level. Motor actions would

be time reversal of sensory perception in appropriate time scales for MEs (topological light rays, "massless extremals") and routinely involve breaking of the second law in this p-adic time scales. This assumption implies that motor action results like a painting starting from a rough sketch. Dissipation and its time reversal automatically perform Darwinian selection leading quantum jump by quantum jump to the final motor action. No detailed planning is needed. Motor imagination is motor action starting from some level above the muscles and motor skills can be learned by imagining them.

Real selves as symbols

The ability to think in terms of symbols is certainly one of the key features of intelligence. The hierarchical structure of selves within selves and the possibility of cascades creating selves within selves allows to interpret subselves of self as conscious representations for symbols, at least under certain additional conditions. The condition seems to be that symbol subself and the primary subself representing the real object must be able to wake-up each other bi-directionally. Symbol self and 'real self' could also belong to different levels of the hierarchy. For instance, single neuron could serve as a representative of neuron group in the sense that neuron and neuron group can wake-up each other. Perhaps Grandma neuron serves as a symbol for a complicated experience of entire neuron group. Linguistic associations would certainly be subselves representing this kind of representative function very effectively. This kind of symbol neurons would correspond to leaders at the level of human society. Indeed, words can generate actions and word selves are excellent candidates for the leaders of the neuronal society!

Selves allow also other interpretations. In very general sense they can be identified as agents or 'demons' in the sense of computationalism. Agents can be also regarded as counterparts of submodules of main program. The call of subroutine from main program could be regarded as a wake-up of subprogram self. The main program forms automatically abstraction of the entire subjective history of subprogram self. The input data of submodules realized as subselves is most naturally realized as sensory input. For instance, neurons are expected to have chemical senses making communication between neuronal selves possible [K3]. Nerve pulses provide obvious candidate for a communication mode.

The concept of global workspace [44] is one of the basic concepts used in the modelling of cognition and short term memory. The model visualizes short term memory as a global workspace, kind of common blackboard seen by various agents. The agents in turn can add write data to the global work space. Communication via global workspace is clearly analogous to mass media. Communication via global work space could be realized as chemical communication. Hormonal system could be an example of mass media operating at the level of our conscious experience. A surprisingly large volume of brain is free of neurons and glial cells and there is experimental evidence for chemical communication occurring via this free volume [27]. In TGD framework global work space could be also realized in terms of coherent photons if selves act as quantum antennas able to receive and send messages: this would be very much like mass media in neuronal and subneuronal length scales.

Wholes and parts, classes and individuals

Wholes contra parts and classes contra invividuals are basic concepts of computationalism and should allow representation as quantum level concepts. Also in TGD framework these concepts emerge naturally. The subselves X_i of self X are individuals and a natural hypothesis is that X experiences X_i as separate subselves. The self Y at the next level of hierarchy containing X in turn experiences the set $\{X_i\}$ of subselves of X as an average $\langle X_i \rangle$, typical representative of class X. For instance, if subselves of X represent different faces, then Y forms abstraction about the concept of face.

'Whole' is a concept different from class. A good example of 'whole' is letter F formed from smaller F:s. Whole is something more than a sum of invididuals and the problem is to understand how this whole is represented at quantum level. A very natural hypothesis is that the whole formed by subselves is formed by quantum entanglement between subselves leading to the disappearance of the invidual subselves. When entanglement is destroyed, subselves or some of them are experienced as separate: this mechanism could also be regarded as a quantum mechanism for the formation of associations. Sensory experiences would wake up sensory selves involving sensory organ and parts of brain giving rise to different representations of sensory data and the analysis of sensory experience would involve the decomposition of these selves to subselves.

Our body consciousness provides testing ground these ideas. Contrary to the basic dogma of neuroscience, in TGD framework the fundamental representation of the body is formed by the body itself as is clear also on basis of the concept of self. Of course, representations at the level of brain are also involved and make possible the analysis of the body experience. We do not however experience our bodies as a huge number of separate cells. The explanation is that our subselves correspond to structures that are much larger than cell. Various parts of our body could obviously correspond to the subselves of our self. The fact that we recognize all parts of our body as such suggests that our self is at least as large as our body or perhaps even larger. Interestingly, in some brain disorders patient does not admit that some part of body, say left side of the body, belongs to them. This would suggest that the self of these persons is reduced to the self of the other side of the body rather than that of entire body.

Predictions and memories

The paradigm of 4-dimensional brain (and of 4-dimensional body and even of 4-dimensional Universe!) differentiates between TGD based computationalism and classical computationalism. One of the most important predictions is the possibility of two kinds of memories: geometric 'memory' generating simulations of past and future and subjective memory making it possible to have genuine memories about previous moments of consciousness. The comparison of the predictions with what actually happened seems to be basic activity of conscious mind. The fundamental realizations of both subjective and geometric memory elegantly circumvent the memory storage problems encountered in the computationalistic approach and multiplied by the combinatorial explosion.

These basic memory types allow several realizations. The identification of immediate short term memories as subjective memories is very natural. Geometric memories seem to be the only reasonable candidate for long term memories. Procedural memories relying on association of say nerve pulse patterns with experiences are possible.

Self at a given level of hierarchy forms automatically abstractions about the wake-up periods of the lower level selves. This makes possible to form abstractions about the time development of subselves and to gain wisdom given by experience. Long term memories involve both the formation of abstractions as some kind of time averages and detailed information. This is difficult to realize in the neural network approach.

Boolean logic and logical deductions

One can easily invent models of logical reasoning but probably the most realistic model is based on representing the premises of the logical deduction using Boolean statements realized in terms of cognitive (that is p-adic) neutrinos. These cognitive representations are transformed by p-adic-to-real transition to symbolic ones, and generate a neural activity representing the logical deduction which is basically realized using learned associations. The outcome is represented again in terms of cognitive neutrinos. Thus only the inputs and outputs of the deduction process are represented in terms of cognitive neutrinos (this must be so since the experience of understanding requires p-adic-real entanglement with a positive entanglement negentropy). This model involves minimum amount of p-adic physics, is essentially isomorphic with the model of imagination, and is consistent with neuro-science facts.

An interesting possibility is that many particle states of cognitive neutrino pairs providing representation of logical thoughts could replicate. This might be possible. If the macroscopic phase determined by cognitive neutrino pairs is compeletely fixed by the structure of mindlike space-time sheets then the replication of the material space-time sheet and mind-like space-time sheet would lead to the replication of thought. DNA replication seems to occur in too short length length scale to be associated with this process. Cell replication could however quite well involve replication of thoughts. Cell replication does not seem to occur at the level of brain. Presumably nerve pulses generating standardized patters of cognitive neutrino pairs have replaced direct decay of cell as a more effective manner to replicate thoughts and eventually even communicate them.

Beliefs and desires

Computational approach does not have much to say about emotions. Beliefs and desires are however concepts allowing symbolic (one might say computational) representation: this of course does not

explain what gives for belief or desire its emotional content.

Beliefs could be very generally regarded as basic axioms of formal system from which various deductions by truth preserving symbol manipulations are obtained. The mathematical model behind numerical calculation is a nontrivial example of this kind of belief system. Desires can be realized in computational science in terms of goals assigned with the initial state. For instance, the desire of the problem solver is to solve the problem that is get from initial state to the desired final state by applying fixed rules. Initial state could correspond to the assumptions of a theorem and final state to the theorem itself. If it is possible to solve the problem at the level of symbolic representation, the solution of problem can be mapped to the real world. Beliefs and desires could easily be represented symbolically in terms of neural activity using associations. A Boolean representation of beliefs could be in terms of logical statements using cognitive neutrinos or real neutrinos.

It is not so easy to understand what gives rise to the conscious experience of belief or desire. The geometric time development can be regarded as a prediction of future (and past) whereas "reality" corresponds to the subjective time development. The belief about what happens in the future is a special belief and could be seen as 'memories' with respect to the geometric time: seeing to the future. Intention would be the p-adic counterpart of this kind of belief, seeing to the p-adic future. A wide class of emotions could result from the comparison of the predicted and real. That predicted and real coincide, could correspond to nearly identical sub-selves able to form a bound state accompanied by a a period of macrotemporal quantum coherence and a positive emotion like understanding.

The fundamental desire of the subself is to stay conscious, to survive. Cognitive, symbolic, and Boolean representations would give for the desire of the mental images of the conscious world model to survive an interpretation as a higher level desire. Also beliefs might be determined to a large extend by the desire of the sub-selves to survive: giving up a belief means death of the corresponding mental images and unpleasant mental images are a threat for mental images defining the self model. We tend to have beliefs which do not threat our ego.

Simple model for problem solving

Problem solving is certainly quite high level cognitive skill. A good test for the proposed scenario is how simple conscious problem solving could proceed. The basic desire of problem solver is to achieve the goal given the initial state. Problem solver makes trials and when goal and achieved state are sufficiently near to each other problem can be said to be solved. The model for this activity could be roughly like follows:

1. Goal is represented as a physical state of some subsystem and the basic problem is how problem solver can compare the result of trial with the goal. It seems that all conscious comparisons must reduce at fundamental level to the comparisons of geometric and subjective time developments of some subself. Thus it seems that problem solver self must directly experiences whether the goal was achieved by experiencing how much the hoped for geometric time development and subjective time development generated by the trial resembled each other.

2. This approach as such is not practical. Standard computationalism would the comparison of the result of a trial to the goal necessitates circuit which carries out comparisons. This kind of circuit is easy to realize. For intance, Josephson junctions could physically realize the difference between the result of trial and goal as the phase difference between weakly coupled superconductors. To know whether the trial was succesful, problem solver must compare the desire represented by a binary digit one in geometric memory with the result of comparison represented by a binary digit having one one or zero in subjective memory. For instance, limbic brain could be the seat of these binary digits and comparison could occur there.

3. Problem-solver subself generates solution trials. Most naturally this involves quantum jump leading to decomposition of problem solver self to two subsystems. This decomposition represents the trial. Good problem solver must be able to generate very many different trials: this means that entangelment entropy is almost constant function of subself generated in quantum jump.

4. Problem solver self performs the comparison. When output is 'No' problem-solver self generates a new trial. System must have a *Eeureka!* experience, when the problem is solved. This is achieved if 'problem solver' self is 'enlightened' when it receives ouput 'yes' from the comparison

circuit. This means that problem-solver selves begins to make quantum jumps reducing matter-mind entanglement and does not generate trials anymore. Note that the Eureka requires a generation of p-adic-real entanglement with positive entanglement negentropy.

5. The trials could be representable as p-adic space-time sheets defining the initial states of the symbolic representation defining the world model and realized as patterns of neural activity based on association mechanism. Their transformation to real ones would initiate the simulation. Also this process is very similar to that behing logical reasoning and imagination.

There is no need to add that in reality problem solving is much more complicated procedure! The above model could however provide insight about the conscious experiences related to the problem solving.

10.6.4 How brain builds the model of the external world?

What we experience is not completely determined by the sensory data: a lot of computation like processes at the level of cortex is involved. In TGD generation of symbolic representations would perhaps be more appropriate term. The phenomenon of illusions, most importantly, our ability to see planar pictures as 3-dimensional, shows that this computation involves a model of external world based on definite assumptions [50]. Stereo vision [50] is a good example of a sensory experience involving a lot of cognitive processing at the level of cortex. Depth cannot be experienced directly and the deduction of the actual positions for the points of the visual field must involve large amount of cognitive processing carried out in cortex. At the level of conscious experience the fusion of right and left visual fields to single visual field seems to be responsible for the emergence of the 3-D visual experience.

That complicated information processing is involved is demonstrated by autostereograms, in which a chaotic set of points experienced as a planar picture organizes to a beautiful 3-dimensional picture after intensive concentration (all subject persons are not able to see the 3-dimensional picture). It is known that stereo vision develops in age of few months at the same time when some cortical neurons specialize to receive input from only single eye instead of superposing the inputs from both eyes. Brain is also able to estimate the state of motion of objects of visual field from sensory data and this must involve a lot of computation. The fact that some people cannot experience motion in the visual field provides a support for the claim that this experience is a result of a complicated neuronal processing. At first, the computational aspects of the conscious experience would seem to be in conflict with the idea that sensory organs are the primary sensory experiencers. The situation is however not so simple as the closer examination of the computational aspects of the visual experience demonstrates. The basic point is that brain quantum entangles to the sensory representation various symbolic and cognitive representations giving meaning to what is sensed.

TGD based view about construction of sensory representations

The motion of eye or head does not induce the sensation that the world is moving although the sensory image moves around the cortex. Rather, brain acts like a (possibly moving) canvas at which the sensory input is projected and monitored by an external observer. This very simple observation is a strong objection against the idea that the ultimate sensory and cognitive representations reside inside brain, and leads to the view that the magnetic flux tube structures associated with the primary and secondary sensory organs define a hierarchy of sensory and symbolic representations outside brain. Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly from sensory organs and even neurons. MEs serve as projectors and place coding by magnetic transition frequency associated with ME wakes-up sensory subselves at various positions of magnetic flux tubes having varying thickness and associate thus various sensory qualia and even more complex attributes to the objects of the perceptive field. Thus the experiencer would the complex containing so called material body and hierarchy of field bodies.

EEG MEs correspond to our level in this hierarchy of projections. The simplest possibility is that the sizes of these sensory selves are of the order of EEG ME sizes ($L(EEG) = c/f(EEG)$) and thus can be of the order of Earth size! Thus the ultimate sensory representations are magnetic gigants in TGD and diametrical opposites of the neurophysiological dwarfs of standard neuroscience populating also TGD brain.

The known strange effects of large scale perturbations of Earth's magnetic field on consciousness (say, statistics about the effects of magnetic storms in mental state and tectonic activity inducing UFO experiences) provide a rich palette of anomalies supporting this view. The conservation of magnetic flux makes the magnetic flux tube structures of Earth size very stable: thus physical death presumably means only that our magnetic body redirects its attention to something more interesting. Near death experiences discussed in more detail in [I3] indeed support this view. Of course, this view about human consciousness is not new, it is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically.

It would seem that the generation of the visual experience involves some kind of iterative computational process laeding to an optimal conscious sensory representation of the external world. This process must involve a model of the external world, which is improved iteratively. Each computational step must provide an estimate for the various positional coordinates of the object and features associated with it and a subsequent comparison of the real sensory data with the virtual sensory data yielded by the model world. The virtual world sensory input yielded by this model is compared with the real world sensory input in comparison circuit and when virtual and real inputs are sufficiently near each other synchronous neural firing leading to a wake-up of sensory subself and conscious recognition of the object of the perceptive field occurs. This could also involve intermediate cognitive, symbolic, and sensory representations not conscious to us who see only the final product of this process. In case of vision the model suggests that both eyes yield actually stereovision separately in ordinary circumstances. This might be the case: one must hold second eye closed for sufficiently long time before the picture gradually flattens.

This quasi-computational process is cognitive process involving imagined sensory, motor and Boolean representations ('this is true' experiences) realized. If the primary qualia are at the level of sensory organs it is easy to understand why imagination lacks the sensory qualia. Only during dreams and hallucinations would the back-projection to the sensory organs occur and "qualiafy" the symbolic representations generated by imagination. Imagination involves p-adic-to-real phase transitions transforming p-adic space-time sheets to the initial value nerve pulse patterns serving as symbolic representations and initiating an associative simulation. The genuinely p-adic aspect of imagination would be thus analogous to the free choice of initial values in a computer simulation. If motor actions is a geometric time reversal of sensory perception in relevant p-adic time scales, motor actions are initiated at some level above muscles and proceed to higher levels so that there is no danger that real motor actions are generated. Dissipation and its time reversal implying a Darwinian selection of mental images are probably the basic tools of imagination and problem solving: second law becomes an ally rather than an enemy. Problem solving and motor actions quite generally start from a rough sketch and there is no need for rigid and bureucratic program structures as in case of AI. Program develops as it runs.

There are several information sources at use when cortex deduces the positional coordinates for the objects of the perceptive field. In case of vision the decomposition of the right and left visual fields to objects is an essential element of the approach. For instance, simple estimate for the distance of object results from the comparison of the positions of the images of object in the retina. If illumination is constant, the comparison of the intensities of the reflected light coming from various planar pieces of the surface representing object gives estimate for the normal direction of the planar piece. Also the fact, that some points of the object are not seen simultaneously by right and left eye can be used as a constraint. In case of autostereograms there is no decomposition into objects and the problem is to identify, which points of the right eye and left eye correspond to same point of the external world: the color of the points is obvious clue. Also long term memories about objects seen earlier are obviously involved.

In the simple situation that the visual world consists of simple objects, no comparison of the model world with the real world is needed provided that cortex is able to perform some simple arithmetics (which is not at all obvious!). In the general situation experience is yielded by the iterative computation like process (actually a rather long sequence of quantum computations if single quantum computation lasts about 10^4 Planck times).

A possible model for the computational aspects of sensory experience

The mind-like space-time sheets in the regions of cortex and various brain nuclei could see each other in the illumination provided by the Bose-Einstein condensed photons propagating along axonal

(possibly also microtubular) wave guides. This would make possible comparison circuits in which inputs from two different areas of brain to area of brain are compared. The comparison circuit based on Josephson currents is ideal for this purpose. In case that inputs are identical, synchronous neural activity results. The comparison of the images could be crucial in realizing the iterative evaluation of the computational aspects of sensory experience. This iterative comparison process need not be conscious to us.

From our point of view brain seems to generate only symbolic representations. Cortex might however also generate virtual world sensory experiences at lower levels of the self hierarchy and not conscious to us. These could be compared with the genuine sensory input in (say) thalamus and convergent iteration would lead to a resonant firing and conscious experience of recognition. This would explain the observed adaptive resonance phenomenon in which thalamo-cortical feedback loop directs conscious attention to those aspects of sensory percept which agree with the expectation. Direction of attention would mean generation of a sensory subself representing the recognized part of perceptive field. Novelty detection could occur at higher information processing level and could be based on inhibitory projections from feature detectors to the novelty detecting neural circuit.

Just to concretize the idea, one could imagine the following rough scenario for how the comparison involving neuronal sensory qualia (not ours) could proceed.

1. Neurons in some parts of brain, most naturally in the thalamus, have neural window to the primary sensory organ radiating coherent light propagating along microtubular waveguides to thalamus. Besides vision and perhaps even hearing, neurons would also have chemical senses and receptor-transmitter complexes would define different qualia. Different sensory modalities feed different regions of thalamus with difference wavelengths characterizing the sensory modality so that the neuronal window based on coherent light might be used by all sensory modalities to achieve this comparison. This is consistent with the fact that microtubuli are present in all axons. There is an intensive feedback from cortex to thalamus and this feedback could quite generally be related to the cognitive representations generated in cortex and communicated to thalamus for comparison. The results of the comparison are sent back to the cortex coded in nerve pulse patterns and change the properties of the model world to give a better fit.

2. The imagery model world consisting of neuronal mindlike space-time sheets in cortex represents the results of a cortical computation. Mind-like space-time sheets radiate coherent light with the intensity determined by the model of the external world specifying the intensity of the reflected light from a particular object. The simplest possibility is that the representation consists of mind-like space-time sheets whose size and shape are deduced from the size and shape of the objects and from the estimated values of the height function. Only the active cortical neurons send coherent light along microtubules to thalamus. The result of the comparison is coded to nerve pulse pattern and sent back to cortex to make possible next trial.

Connection with the observations of Barbara Shipman

There is also an interesting connection with the model the model of Barbra Shipman for the dance of honeybee [17, 18, 19].

1. The model relies on the puzzling observation that the manifold $F_3 = SU(3)/U(1) \times U(1)$ parametrizing different choices of color quantum numbers seems to be involved with the dance [K3]. In TGD framework color rotations do not leave classical Z^0 and em fields invariant although induced Kähler field is color invariant. For instance, in a color rotation a pure Z^0 ME is in general transformed to a ME carrying a lightlike vacuum em current generating a hologram possibly acting as a biological control command. This suggests an explanation for the observations of Shipman and also that the canonical coordinates (P_i, Q_i) for the 6-dimensional symplectic space F_3 play crucial role in the construction of sensory representation. In fact, in Shipman's model the Hamiltonians associated with color isospin and hypercharge take the role of planar coordinates for the dance floor at which the dance of honeybee takes place. More generally, it might be possible to represent the position of the object of a perceptive field using some coordinates of F_3. The optimal situation would be that both the velocity and position would be coded to a point of F_3 so that CP_2 orientation of space-time sheet would represent position for an object of a perceptive field.

2. If this view is correct, the values of the positional coordinates and the velocity of the object of the perceptive field should correlate with the CP_2 orientation of the active neuron and/or ME(s) associated with it. First of all, the level of hologrammic activity for ME measured by the strength of the lightlike em current depends on its CP_2 orientation. Secondly, different CP_2 orientations correspond to slightly different values of the membrane potential and could be directly mapped to the degree of alertness of neuron. For instance, if a moving object of the perceptive field is in nearby space and moves towards the perceiver, the (P_i, Q_i) values could be such that the resting potential is lowered and nearer to the critical value for firing. Also the lightlike em currents associated with MEs would be stronger in this kind of situation.

10.7 Holographic brain and quantum TGD

Brain as a hologram paradigm states that one cannot locate the information in brain in any specific region. There is indeed considerable empirical support for this hypothesis [46, 51, 48].

10.7.1 Evidence for holographic brain

The first empirical motivations for holographic brain came from the experiments of Lashley [46] with rats. Psychologist Karl Lashley started 1920 lifelong study of the effect of brain vaults in memory. Lashley studied the behaviour of rats in mazes and found that the reduction of the brain tissue did not destroy the visual memory of rats totally, only the intensity of the memory was weakened. This led to the introduction of the terms mass action and equipotentiality. Mass action says that the intensity of the memory depends on the amount of the brain tissue present and equipotentiality says that each neuron carries the memory traces. The experiments of Lashley lead to the idea that the memory storage mechanism in brain is nonlocal and hologram like.

In 1948 physicists Dennis Gabor discovered the idea of optical hologram and within twenty years the same principles had been applied to brain. What hologram stores is the information about both amplitude and phase of incoming light wave, quantum mechanically identifiable as the order parameter characterizing coherent light. What makes holographic information storage so attractive is its extreme robustness and flexibility: a small piece of hologram carries same information as entire hologram, albeit in blurred form. Philip Westlake [56] was one of the first mathematicians to argue that hologram priciple matches with what brain does with the information. Karl Pribram [51] and colleagues have done a lot of experimental work with monkeys using the holographic theory to see in detail how the theory makes it possible for brains to remember. The book 'Shuffle brain' [Pietch] popularizes in an enjoyable manner the idea of holographic brain and the work Pietch with salamanders. The experimental work of Pietch provides rather convincing experimental support for the idea of holographic data storage [48]. The experiments of Pietch with salamanders involved the cutting the brain of the salamander to pieces, shuffling the pieces randomly and putting them back together: no detectable changes in the behaviour of salamander occurred as a result of this operation! It is hard to imagine a computer which would function after this kind of treatment.

Holographic data storage is extremely flexible and stable. Since brains have developed in jungle rather than in safe computer laboratory, these properties make the idea of holographic brain much more attractive than the paradigm of computer brain. Also transformations between sensory modalities are easily realized. For instance, acoustic holograms can be transformed to optic holograms. One can however also invent objections against holographic data and memory storage.

1. The creation of hologram is based on the interference of a reference beam of light with the beam of light reflected from the object. The reading of the hologram is done by using reference beam to regenerate the original picture. It is however not clear whether this kind of mechanism is possible to realize at the level of brain. Furthermore, in reality it is the real beam which stimulates memory recall rather than the hypothetical refence beam! It seems that comparison of reference pattern representing the expected experience with input is what happens in brain rather than illumination of holograms.

2. In order to have holographic memory, it should be possible to code very many holograms simultaneously to single hologram. Multiple holograms are indeed possible [48]. One must however admit that the idea about storing large number of temporal events to same multiple hologram

does not look very attractive. The identification of the long term memory as geometric memory solves these problems in TGD framwork so that hologram idea could survive as a a restricted principle determining how the experience is generated.

3. The structure of the human brain suggests that data representation is not completely hologram like. For instance, the various phonemes are recognized by well defined regions located in linguistic areas of the brain like potatoes in the field. The differences between right and left brain are a challenge for the hologram idea in its simplest form. One must however notice that it is brain functions that are localized whereas data storage could quite well be hologram like. Of course, it could quite well be that brain decomposes into regions in which data represented as a hologram is different: for instance, different sensory modalities seem to use different regions of brain. In particular, the existence of various sensory homunculi in brain is consistent with the holographic data representation.

10.7.2 Three explanations for the hologram like properties of brain

The fact is that brain seems to be extremely flexible and this does not fit nicely with the idea that brain is some kind of extremely complicated electronic circuit. Hologram like data storage in which each neuron is like a part of hologram provides only one explanation for the empirical data. The common feature of TGD based explanations is that conscious experience is not so strongly dependent on the neurophysiogical state of the neural substrate as the vision about brain as a computer would suggest.

1. Quantum self-organization implies that systems self-organize to dynamical patterns which do not depend very much on the initial state. For sufficiently simple brains, whose presence is not absolutely crucial for the 'household' activities of the organism, this could be all that is needed. For instance, the ability of a lizard to generate a new head supports this view. Salamanders are simple creatures and the mere quantum self-organization without recourse to hologram memory could explain the results of the experiments of Pietch.

2. TGD based model of conscious brain relies on self hierarchy realized in terms of various Josephson currents forming a master-slave hierarchy. Josephson currents do not depend very strongly on the material substrate of brain. Josephson currents and associated supra currents allow also basic wave like phenomena like interference crucial for hologram model. Comparison circuits formed by weakly coupled super conductors and constructive interference of Josephson currents provide a quantum model of brain which resembles hologram model but also differs from it in certain crucial aspects. In particular, reference ray is replaced by reference current representing expected experience. Also comparison circuits in which parallel supra currents of same intensity flow in coupled superconductors, are possible. In this case large Josephson net current is generated by constructive interference of Josephson currents when the phases of supra currents differ by a constant phase.

3. It might be that brain is indeed hologram like in some sense although reference rays are probably not involved. In TGD framework it seems to be possible to abstract from the hologram idea its essentials, namely the fact that a piece of hologram is like a small window. This makes it possible to circumvent the most obvious objections against the idea.

   i) The essential feature of the hologram is that a small piece of a hologram acts like a window. The visual experience is not changed much even when one perceives through a small window. Hence one could give up the assumption that brain prepares holograms. Rather, one could consider the possibility that neurons see part of the same sensory scene through neuronal windows. Seing would be made possible by some field like quantity whose values would be determined by its sources in the same nonlocal manner as electromagnetic field is determined by its sources. Sources could be either objects of the external world or of model world generated by sensory experience, constisting perhaps of mind-like space-time sheets. Massless fields are especially attractive alternative since the form of the wave is preserved during propagation. Hence coherent photons generated by so called massless extremals [J4] assumed to be associated with the linear structures like microtubules contained inside every axon, are especially promising as a tool of neuronal vision.

ii) TGD framework provides extremely general mechanisms of subjective and geometric memory corresponding to actual memories and expectations for what will happen and possibly happened. In principle it is possible to avoid memory storage completely. The experiments of Lashley could be understood by assuming only that the sensory data are experienced through neuronal windows. Thus there is no need to store memories in multiple holograms and even holograms are un-necessary. All boils down to the idea of neural window and TGD based quantum model of memory.

iii) The existence of sensory homunculi is not in conflict with the holographic data representation. What happens is that single neuron sees part of the perceptive landscape through a window. Each neuron could be specialized to particular task, such as recognizing whether particular feature is present in the the sensory landscape. This would involve simple comparison circuit making possible feature recognition perhaps involving neuronal wake-up. Feature recognition could rely basically on the generalization of Haken's theory [I1].

10.7.3 From holographic brain to neuronal window?

The notion of neural window

All sensory experiences should reduce to representations generated by zero modes, in particular zero modes characterizing classical Kähler field, which can reduce to pure electromagnetic (vision?) or Z^0 field (auditory experience?). If the primary or secondary stimuli generate Kähler electric fields proportional to the gradient of the intensity one can understand the generation of the objects of the perceptive field. If the gradient is strong, as it is on the boundary of the image of the object, the conservation of the Kähler electric flux forces the generation of mind-like space-time sheet at which part of the flux goes. Thus secondary sensory organ would automatically create representation for the objects of the perceptive field as mindlike space-time sheets, which in turn could give rise to selves representing objects of the perceptive field as mental images.

The idea that parts of brain automatically form a model for the objects of the external world as mind-like space-time sheets suggests an interesting connection with the holographic model of brain [48] and with micro-tubules as quantum antenna hypothesis [J4].

1. If mind-like space-time sheets are massless extremals, they act as quantum antennae and generate coherent photons. Axons contain microtubules and this leads to ask whether these axons could serve as wave guides for the coherent light generated by the mind-like space-time sheets representing the objects of the external world. Also the vacuum currents associated with these microtubular massless extremals could code the intensity of the coherent light emitted by the mind-like space-time sheets. If either of these guesses is correct, axons provide neurons with a direct sensory window to the representation of the external world formed by the mind-like space-time sheets residing at sensory organs. Coherent photons would also give rise to neuronal lingua franca realized as a direct neuronal/microtubular vision.

2. Sensory window would be in question in a rather literal sense. The fact that a piece of hologram provides the representation given by the entire hologram, albeit in a somewhat blurred form, is essentially equivalent with the possibility to see through a small window. Therefore the idea about neuronal window is in accord with the holographic model of brain [51, 48], which is based on the idea that all neurons receive more or less the same sensory input, analogous to the visual experience generated by a piece of hologram. Clearly, coherent photons would serve as kind of mass media at the level of brain.

3. What is interesting is that the decomposition of the neuronal vision to a large number of different views represented by small groups of light sensitive neurons could even help to build monocular stereoscopic vision since much more information would be used about the visual field.

4. Music metaphor provides a considerable restriction to the neuronal window idea. The Bose-Einstein condensed photons should correspond to single frequency equal to some cyclotron frequency. Thus it would seem that the sensory input of single neutron is yes/no type. The neuronal window however makes however still sense for neuronal groups: in this case the input would be determined by light and dark pixels. Various nuclei or brain could thus have neuronal windows to cortex and other nuclei of brain.

Neural window and imagery

Mental imagery is something which is difficult to understand in the framework of the standard neuro science. There are empirical results suggesting that mental images correspond to patterns of activity inside cortex, which are three-dimensional and continuous so that neural activation provides a concrete recognizable image about object [50]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [50]. It is also known that imagery uses same regions of cortex as real sensory experience and the problem is to understand why there is genuine sensory experience involved with imagery.

In the framework of the standard neuroscience the obvious question is why the pattern of the imagery activity is not accompanied by a direct sensory experience. Also the boundary between direct sensory experience and imagination is sometimes problematic: for instance, in the state between sleep and awake, sensory images often enter into mind. During dreams one can have sensory images and eidetic memory is essentially sensory memory. I have a personal experience about extended state of consciousness, or rather whole-body consciousness (this experience actually made me consciousness theoretician!). During this state I could see my thoughts as vivid visual images and had also peculiar odour and taste experiences also reported to occur during mystic experiences. Could the correct interpretation be that thalamus, cortex and sensory organs temporarily formed a larger self during this experience?

If one accepts that sensory qualia are at the level of sensory organs and neural activity only builds symbolic and cognitive representations, it is easy to understand the difference between imagination and sensory perception. Sensory imagination is sensory perception without sensory qualia. Quantum entanglement between sensory organs and cortex and TGD based view about long term memory resolves the obvious objections against this view.

This does not exlude the possibility that neurons have chemical senses and even see and hear. Neurons would not only contribute to our experience. Neurons able to perceive sensorily would be probably much more effective information processors than neurons which are blind and deaf. Therefore the notion of neuronal window could be useful metaphor in the modelling the neuronal basis of the mental imagery. For instance, the understanding of processes like rotation of an imagined object of visual field provides an exciting challenge. The rotation of mind-like space-time sheet should induce the rotation of the region containing nerve pulse activity. Neuronal window idea suggest that the imagined rotation of the object involves virtual sensory experience generated in the somatosensory-auditory-visual association region of the neocortex (note that only humans have these associatin regions). This region would be able to form representations of the basic objects of the perceptive field and manipulate them. The imagined rotation of the object could occur here and would be observed by the primary sensory regions.

Sensory perceptions involve a lot of computation like processing at the level of cortex (consider stereo vision as an example), which can be naturally identified as imagination yielding successive models for the external world as consisting of familiar objects. Both the imagined world represented by the mind-like space-time sheets inside cortex and the mindlike space-time sheets in the sensory organ could be seen by the secondary sensory organs in thalamus and compared to see whether the imagined world yields the same sensory input as the real world. The result of the comparison would be fed back to cortex as a nerve pulse pattern serving as a feedback modifying the model.

Neuronal window and blind sight

The phenomenon of blind sight [54] suggests that there is kind of a Zombi within us [47], which can see but that this vision does not give rise to a conscious vision. Typically persons who have blind sight can grasp the object of the visual field once they have been told that it contains the object. The Zombi within us seems to be much more rapid and reliable than the conscious 'I' in its responses but it seems to be much less flexible. It also seems that Zombi within us cannot be cheated by illusions unlike conscious 'I', which suggests that much less theorizing and pattern recognition is involved. Rapid responses of Zombies within us are certainly consistent with the fact that cortical processing is not involved. Nonflexibility would be the price paid for the reliability and absence of higher level cognitive processing.

One can imagine many models for Zombi within us and probably there are many of them (and they are actually not Zombies at all!).

1. Thalamus projects sensory data to amygdala which is often called brain inside brain, or emotional brain. Amygdala would thus have neuronal window to to thalamus and could give rise to unconscious-to-us mental activity responsible also for the blind sight. Also the sensory perception at the level of retinae might be enough if one assumes that primary sensory qualia are at the level of sensory organs.

2. Formation of the symbolic representations for the objects of the perceptive field could occur also in the thalamic nuclei.

3. The decomposition of the perceptive field to objects could occur for the first time already at the level of retina and the coherent light from the mind-like space-time sheets provides a representation of the visual field seen by neurons of thalamus, whose regions serve as secondary secondary organs identifiable Zombies within us (Zombies only from our view point!).

10.7.4 Possible evidence for the neuronal window idea

To find whether the neuronal window based on coherent light hypothesis could make sense, it would be important to eliminate the effects of the higher level information processing. This requires the study of simple organisms having primitive sense of vision. There is indeed experimental support for identifying the coherent states of photons as associated with vision. It is known that some monocellulars possess elementary vision based on the microtubules [33]. The emergence of the multicellulars during the Cambrian explosion was preceded by the appearance of the microtubules. If the emergence of the microtubules meant the emergence of the visual consciousness in the length scale of the cell, then the formation of the multicellulars as cell societies can be understood as a natural consequence.

The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. The coherent light in question could be identifiable as bio-photons of Popp [37]. The architecture of retina is 'wrong' from the engineering point of view. The ganglial axons feeding sensory input to brain are in front of the retina. This is in accordance with the TGD based model of vision in which the photons of incoming light Bose-Einstein condense on the ganglial axons and amplify the signal to the thalamus.

A further piece of evidence comes from the work of Callahan about the sense of smell of insects [27]. Many insects, such as moths and ants, are known to be attracted by light, say candles and electric lamps and Callahan took as his challenge to understand what is involved. Callahan discovered that insect's olfaction is not based on chemistry (alone) but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other biomolecules. Insects see rather than smell the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify the incoming infrared radiation. Callahan also observed that the oscillation of insect antennae induce maser like emission from scent/etc. molecules by creating an oscillating emf. Thus sensory experiencing seems to involve active participation from the part of insect. In any case, the results of Callahan suggest that coherent light could be important also in our neuronal sensory experiencing.

The infrared light emissions from pheromones mediate sexual messages in case of insects. Quite remarkably, pheromones are known to mediate sexual and social signals also in case of many mammals. For instance, certain chemical messages from a female mouse can make male mouse to mate immediately while certain chemical messages from other males make him agrresive. Many mammals, for instance rodents, are known to possess vomeronasal organs, small cigar like sacks containing neurons and having length of order few millimeters [19], giving rise to an accessory olfactory system, which is known to have much more primitive structure and to work in different way than the ordinary olfactory system. It is also known that this systems bypasses cerebral cortex in rodents. There is evidence that even humans have the ability to sniff certain chemicals mediating social and sexual signals without being aware of it and there is already now an entire perfurme industry based on this evidence. The chemicals giving rise to sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in case of both insects and mammals, is hardly an accident and suggests that the sensory mechanism must be the same and be based on the infrared emissions by phreromones. If the response is at neuronal level and if the cortex is not involved, one could understand why these messages are not experienced consciously. One could test this hypothesis by finding whether coherent infared radiation at frequencies emitted by pheromones can affect the behaviour of higher mammals including humans.

There is a further peculiar co-incidence: the cascade of transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odours whereas the receptor cells that respond to sound use a very different system [19]. Could this mean that also the experience of odour primarily involves the detection of (also) infrared light so that humans would not basically differ from insects or that olfactory system has evolved from the receptor neurons originally sensing infrared light? This would conform with the idea that the Kähler field generated in ear corresponds to classical Z^0 field, which does not generate coherent photons but couples with neutrinos. One must however notice that the resemblances between visual and linguistic imagery suggest that some part of ear generates cognitive representation based on coherent light and experienced by the secondary sensory organs in the thalamus.

10.7.5 Massless extremals as quantum holograms

It took long time to really understand what MEs really and along with this understanding came the vision about precisely how MEs could act as holograms and what biological functions these holograms could correspond to. It indeed seems that massless extremals (MEs) are perhaps the most fundamental solutions of the field equations as far as TGD inspired theory of consciousness is considered. What is important is that MEs play both the roles of quantum gravitational holograms [26] and dynamical holograms [29].

The hologram principle of quantum gravitational theories roughly states that the quantum theory in space-time with boundary reduces to a conformal quantum field theory at the boundary. If Kähler action were deterministic, precisely this would happen. The construction of the configuration space geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action do not radically modify the picture resulting assuming complete determinism.

It has indeed turned out that the basic construction in which everything to the lightlike boundary of M^4_+ (moment of big bang) acting as a hologram in quantum gravitational sense and defining conformal quantum theory, generalizes. The basic construction survives as a template of a more general construction in which also the lightlike boundaries of MEs having always lightlike M^4_+ projection are taken into account besides δM^4_+ as surfaces at which initial values can be prescribed arbitrarily. This brings in also time effectively absent in a strictly deterministic theory. The quantum gravitational hologram defined by δM^4_+ is replaced by a fractal structure formed by δM^4_+ and Russian doll hierarchy of the lightlike boundaries of MEs inside MEs. The supercanonical and superconformal invariances of the lightlike boundaries generalize in an elegant manner on basis of the basic properties of MEs.

There are good reasons to expect that the lightlike selves defined by the boundaries of MEs are fundamental in TGD inspired theory of consciousness. The supercanonical quantum states associated with the lightlike boundaries are genuine quantum gravitational states defined by configuration space spinor fields, whose dependence on configuration space fiber degrees of freedom does not reduce to mere vacuum functional, and therefore do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds, so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems.

MEs carry lightlike vacuum currents. In passive state these currents are Z^0 currents whereas in active state, obtained by a color $SU(3)$ rotation, the current is electromagnetic and generates coherent state of photons. One can say that the lightlike current provides a dynamical variant of the diffraction grating defined by the ordinary static hologram. This leads to a model of living matter in which the coherent states of ordinary photons and colored configuration space photons act as control commands. Their phase conjugates (time reversals) in turn correspond to the time reversed commands. What is especially beautiful is that simple reference wave can activate arbitrarily complex hologram acting as a control command. This provides new visions about healing by time reversed reference waves forcing the biological program responsible for an illness like cancer to run backwards in time. One can also construct a general theory of sensory representations based on MEs [H4]. To sum up, it seems that the hologram principle is they key element of brain and biological functioning but in a sense somewhat different from what it was believed to be by the pioneers.

10.7.6 The notion of conscious hologram

The notion of conscious hologram is the last step in the development of ideas related to biohologrames. The basic challenge is to generalize the notion of the ordinary hologram to that of a *conscious* hologram,

about which bio-holograms would be examples. The notion of quantum gravitational hologram is defined at the level of geometric, purely physical existence whereas conscious holograms exist at the level of subjective existence defined by the sequence of quantum jumps and giving rise to the self hierarchy. Of course, these two notions of hologram must be closely related.

The notion of conscious hologram combines the saint and sinner aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand.

In nutshell, the notion of conscious hologram follows from the topological field quantization. Classical fields and matter form a Feynmann diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules,...), and virtual bosons are replaced by topological light rays ("mass-less extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to 'real photons' are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by 'virtual photon' MEs also analogous to laser beams. Hence also 'self-holograms' with no laser beam from external world are possible (brain without sensory input).

The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as mass-less particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length. The particle like high frequency MEs induce 'bridges' between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. Under certain conditions the leakage followed by dropping back to the larger space-time sheet can also give rise to a many-sheeted laser. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competion.

The 3-D vision associated with ordinary holograms generalizes to stereo consciousness resulting in the fusion of mental images associated with the points of conscious hologram [K4].

10.8 Four-dimensional fractal brain as an associative net

The identification of brain as 4-dimensional fractal associative net seems to provide a promising paradigm for the understanding of brain functioning. The associative net structure and mere real physics considerations are certainly not all that is needed. p-Adic physics as physics of cognition means that fundamental cognitive representations correspond to p-adic space-time regions, and, needless to say, in this respect huge amount of work remains to be done in order to build connections between theory and observations. In the following only the real physics aspects of brain as an associative net are considered.

10.8.1 Brain as an associative net

The notion of associative net suggests a general paradigm making it possible to understand brain functioning. The subjective time development of an associative net consists of experiences representing associations $A \to B$. In case of brain associative net is a network of neurons. "A$\to$ B" association is made possible because the emission of synaptic vesicles implies that postsynaptic and presynaptic neuronal space-time sheets form a connected space-time sheet. A is represented by the various presynaptic inputs and B corresponds to the output of the postsynaptic neuron. A and B can correspond to various sensory qualia or Boolean statements represented in terms of memes which in turn decompose into sequences of codons consisting of 126 binary digits and represented in terms of cognitive neutrino-antineutrino sequences. Memetic codons could also have interpretation as binary representations of

integers providing quantitative measures for qualities. In Boolean case associations are experienced as logical implications "If A then B" is true. A and B can represented arbitrarily complicated statements composed of elementary statements. Neuron receives the conclusions of postsynaptic neuron as premises and feeds its own conclusion as premises to its own postsynaptic neuron.

Self-organization by quantum jumps selects gradually the allowed "A $\rightarrow$ B" correspondences as asymptotic self- organization patterns. Quantum self-organization and quantum statistical determinism suggest a natural Darwinian selection of the memes caused by the dissipation inside self and completely analogous to protein folding. The correspondences $A \rightarrow B$ would be determined by chemical macro variables characterizing the state of the neuron and chemical transmitters would play a crucial part in the learning of the responses. Syncronization is necessary for the function of the network. Emotional control can modify the associations "A$\rightarrow$ B" in long time scale (conditioning and desensitization): for instance, some conditions belonging to premises A of Boolean association drop away or B can change.

10.8.2 4-dimensional fractal brain

One needs two additional principles in order to have vision about brain a la TGD.

1. Brain is 4-dimensional in well-defined and very restricted sense. This follows from the classical non-determinism of Kähler action. Self-organization by quantum jumps replaces the classical space-time surface repeatedly with a new one and the final result represents classically the activity as it would be detected by a compeletely mechanical instrument. One can say that the classical time development describing say sensory experience, long term memory, motor activity or logical thought is gradually refined by starting from a rough sketch and making successively finer corrections iteratively. The process is like making a painting stating from a rough scetch. The four-dimensionality of the brain and difference between subjective and geometric time is absolutely essential element.

2. Fractality is second element. The successive refinement process proceeds from long to short time and spatial lenght scales. Thus large and slow neural circuits correspond to rough sketches and small and rapid circuits to small details. Small circuits are simultaneously active (in sense of subjective time) in the entire space-time region defining the duration of the activity. Thus again the 4-dimensionality of brain is crucial.

The notion of associative net suggests a very general view about how brain functions and gives rise to conscious experiences. Brain itself is a huge associative circuit but decomposes into more or less autonomous subcircuits.

10.8.3 Sensory experiences, logical thinking, associations and simulations

The notion of associative net allows readily to understand what happens in sensory experiencing, logical thinking, formation of associations and imagination

1. Sensory representations are formed by an iterative process involving comparison which takes also care about the computation of unknown data such as distances of the objects of the perceptive field. For instance, various cortico-thalamic loops could be related this process. The updating of the zero modes of the sensory inputs from sensory organs is performed in the thalamic neurons receiving real sensory input from the sensory organ and expected sensory input from cortex. An automatic comparison process possibly realized at quantum level in terms of two weakly coupled super conductors is in question [I4, I5]. This process involves also the concentration of attention to specific features of the sensory experience.

2. Neuronal input represents in general case several sensory modalities and conscious output single sensory modality or 'Boolean quale' represented by memetic codon. Thus associative circuits can represent the formation of associations in associative regions of brain. Note however that pre- and postsynaptic neurons in principle represent always an association at the neural level and neuronal associations are basic building blocks of 'our' associations involving entire groups of neurons and entire neural circuits. Also the formation of associations is very probably an iterative process.

3. The circuits of the associative net provide an ideal realization for predictive simulations of type $A \to B \to ....$ in terms of various kinds of sensory qualia. This makes possible imagination. The difference with respect to the standard neural net is that conscious neuron represents some sensory modality or Boolean modality: this makes the simulation "real" and assigns meaning to nerve pulse patterns: note that the generation of meaning is basic problem of the neural net models of consciousness. This kind of simulation circuits are expected to be related with frontal lobes and to be crucial for the planning of the future activities. Motor circuit involving basal ganglia, thalamus and prefrontal cortex is also a possible example of this kind of circuit. Again iteration bringing in more and more details to the motor plan is involved.

4. Logical deductions do not differ from simultation in an essential manner: the only difference is the replacement of the temporal causation by logical causations. In case of logical deductions premises and conclusions are coded to memetic codons represented by cognitive neutrino pairs. Much of our logical thinking might be actually habitual and almost deterministic deduction sequences associated with circular loops and unconscious to us. Logical consistency is thus not guaranteed and, unless the brain of a ideal mathematician is not in question, and results only from the logical consistency of the external world.

10.8.4 Formation of long term memories

Associative circuit give rise to learning of long term memories. Short term memories correspond to reverberating nerve pulse patterns in closed circuits giving rise to a repetition of the same component of experience again and again. In Boolean case periodic association sequences represented by closed loops $A \to B \to ...A$ correspond to tautologies. Reverberating memories are remembered with high probability if long term memories are realized as geometric memories. The reason is that there is high probability for a randomly generated cognitive space-time sheet in geometric past to reside on the region occupied by a reverbarating loop. Repetition is the manner to learn. It is rather plausible that Nature has discovered effective learning in this manner and there are indeed circuits associated with long term learning.

A quite recent finding in neuroscience is that during the learning of spatial tasks hippocampus and some other parts of brain generate long spike sequences. Typical interval between spikes varies between 1-2 milliseconds. This would mean that a sequence of 126 spikes would correspond to .1-.25 seconds which is of the same order of magnitude as the duration of our self identified as the duration of immediate sensory memory. Also long term memories are constructed as kind of artworks or charicatures.

10.8.5 Planning and realization of motor programs

Associative circuits are associated with planning and realization of the motor programs.

1. Motor activity is the reverse of sensory experiencing in a well-defined sense. The imagined motion of the object in the working memory representing perceptive field is transformed to the motion of the real world counterpart of the object so that motor organs are like puppets bound to axonal strings and moved by the little man in the brain. The perceptive field, where imagined motion occurs is located in the frontal cortex with primary motor cortex excluded. Several copies of the perceptive field providing different representation of the perceptive field are probably involved as 'working memories'. These working memories are formed by topographical maps between different parts of brain.

2. Planning of the motor action is almost motor action: the only difference is that the last stage when nerve pulse patterns characterizing the motion are fed to motor organs is not performed. Plan is essentially four-dimensional pattern of nerve pulse activity.

3. The ability to realize plan seems to require that it is memorized: this would require that the performance of the motor activity is repeatedly imagined and finally allowed to occur. Thus the nerve pulse activity representing plan becomes a periodical nerve pulse pattern and the actual motion starts when the coupling to primary organs is turned on. As a matter fact, 4-dimensional brain allows to give up the assumption about reverberation. Also the activation

of a motor plan in the geometric past could be possible! This would be consistent with the results of the experiments of Libet about active aspects of consciousness: what was observed that neural activity started before the conscious decision to raise index finger. The relevant time scale would be of the order of second. Of course, an interesting question is whether adult person could initiate in the geometric childhood a motor action affecting dramatically the geometric present, say leading to traffic accident! This possibility would seem to lead to paradoxal looking consequences.

4. Learning of a motor skill presumably means that motor plans very rapidly self-organize to their final shapes. Learned skills correspond to motor plans which are winners in the Darwinian selection associated with self-organization.

5. The realization of the motor plan requires initial value sensitivity and muscles indeed provide an excellent example of an initial value sensitive system in which single nerve pulse generates macroscopic motion.

Motor action is planned and performed as a four-dimensional pattern. Construction of the motor plan means that *four-dimensinal* virtual perceptive landscape is gradually deformed into the desired shape. Motor activity can be seen as a fractal top-down process analogous to the construction of a space-time fractal: fractal classical determinism of Kähler action is absolutely crucial for this and $1/f$ noise [I5] is one of the consequences of the fractality. The non-determinism of the p-adic differential equations is very probably a direct correlate of the classical non-determinism of the Kähler action.

Macroscopic motor activity starts from a rough 4-dimensional sketch of motion which is gradually refined to the final artwork and possibly memorized to represent a reverbarating structure. The sketch and its various refinements are represented at the virtual perceptive landscape of the premotor cortex. More concretely:

1. First a large quantum jump realizing in rough sense the motor action occurs (for instance, hand grasps the object): this corresponds to certain classical time development starting in geometric past on new space-time surface. This stage corresponds to the activation of slow and large neural circuits with time scale characterizing the entire motion. This is like construction of the first sketch of a 4-dimensional fractal representing motor plan.

2. After this a cascade of smaller scale quantum jumps adding details to the motor plan occur: this is like adding further details to a four-dimensional fractal. The neural circuits involved are smaller and faster. Addition of details takes places in the entire time interval T of the geometric time associated with the full motion. This involves multitime moments of consciousness so that also neural circuits are active in the geometric interval defined by T.

10.8.6 Language

Memetic codons represented as temporal sequences of 126 binary digits should be the basic building blocks of the linguistic consciousness. The value of single binary digit is represented at the neural level by the presence/absence of nerve pulse and at the level of cognitive consciousness by the direction of the spin of the cognitive antineutrino. Boolean interpretation is not necessary: the interpretation of the sequences of 126 bit as integers providing quantitative measures for, say the intensities of the sensory experiences, is also possible. The proposed quantum models for the quantum correlate of hearing and for Boolean mind [K3, L1, H8] suggest that sound frequencies are mapped to Z^0 magnetic cyclotron frequencies of ions whereas thinking corresponds to Z^0 magnetic cyclotron frequency which is above the range of the audible sound frequencies. This supports the idea that memetic codons are as such experienced as some kind of internal speech and also that only certain brain regions allow Boolean mind: the generation of cognitive neutrino pairs indeed requires strong axonal Z^0 magnetic fields which could be present only in the postsynaptic axons of the associative regions of cortex.

The differences between right and left brain suggest that the output axons in the associative regions of left brain represent information using cognitive neutrino pairs whereas the corresponding axons in the right brain hemisphere could represent information in terms of Z^0 cyclotron frequency varying above the audible frequency range (left brain talks and right brain sings!). If audible frequencies are involved, Josephson frequencies must be sufficiently far from cyclotron frequencies so that right brain

imagines of hearing the thoughts rather than actually hears them. Unless higher harmonics of the cyclotron frequency are used (which is quite possible!), this requires parallel mode of representation since music metaphor suggests that the Z^0 cyclotron frequency of the axon is not variable.

Language circuits would be involved with the translation of the Boolean statements to linguistic expressions coded eventually to motor activities yielding speech. This process is only special case of a motor activity and thought as an internal speech is like a motor plan. Language represents one possible realization of the memetic code analogous to the translation of DNA sequences to proteins. It is instructive to look what contraints the memetic code poses on the general structure of language. The first empirical fact is that the meaning of the linguistic experience is insensitive to the local variations in the speed of speech. In particular, the repetion of a phoneme is usually interpreted as providing no additional purely linquistic information. On the other hand, the linguistic meaning of speech is determined by its purely local structure.

These facts are consistent with the hypothesis that phonemes are the basic codons of speech having fixed duration and that a repeated phoneme has the same linguistic meaning as single phoneme. This supports the identification of the phonemes as representations of the memetic codons: phoneme would thus represent single linguistic subself. By the previous estimate the duration of the memetic codon should have duration in the range $.1 - .25$ seconds. A more precise estimate comes from the detailed model for the physical realization of the memetic code and from the model of nerve pulse [L1, M2]: the resulting estimate for the duration of the memetic codon is about .14 seconds. The facts that a frequency $f \sim 10$ Hz represents the fundamental frequency associated with speech organs and that 20 Hz frequency represents the lower limit for the audible frequencies are consistent with the identification of the phonemes as linguistic images of the memetic codons.

Note that cognitive neutrino pairs of duration of order one millisecond are not experienced as separate components of conscious experience if time averaging is involved with temporal binding. This is consistent with the fact that language does not contain any smaller consciously experienced constituents than phonemes. Not that speech represents (very-!) many-to one expression of the menetic code (faithful coding would require language with 2^{126} different phonemes: this gives good idea about the present evolutional level of human culture!). Genetic code is not unique and some cell organelles, such as mitochondria, possess their own genetic code. Various languages could correspond to different translations of the memetic code to nerve pulse patterns in turn coded to motor activities representing expressions of language. The Mersenne prime $2^{127} - 1$ could be clearly re-christened to be the number of Babel!

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Gap junctions between the nerve cells are not common but are encountered in the large coherently firing groups of nerve cells in the brain, in the sensory organs and other organs such as heart. The value of the parameter K is only slightly larger than the critical value $K = 1$ for EEG since the period of EEG oscillations is typically by a factor of order 10^8 longer than the period of small oscillations. The problem disappears when higher levels of dark matter hierarchy are allowed. Of course, if the potential difference in question corresponds to the membrane potential, one must have $K \gg 1$. One can wonder whether the criticality might have some deeper significance: perhaps phase transitions between EEG:s corresponding to rotating and oscillating gravitational penduli are possible.

Do the frequency scales of right and left brain EEGs differ by a factor 1/2?

The model for fractal hierarchy of EEGs [M3] suggests a deep difference between right and left brain hemispheres. Since the model makes the considerations in sequel more comprehensible it deserves to be reviewed.

1. The basic prediction is that quantum control from $k_{em} = 4$ magnetic body is carried out by using cyclotron radiation travelling along magnetic flux sheets traversing through DNA and containing genes very much like pages of book contain written text. Single text line contains genes from very many cells and even cells from different organisms.

2. Most biologically important bosonic ions have cyclotron frequencies f_c in alpha band of the strength of the endogenous magnetic field at flux sheets is $B = 2B_E/5$, $B_E = .5$ Gauss. Sensory input to magnetic body comes from neuronal membrane at frequencies $nf_c \pm f_J$, $f_J = 5$ Hz. This means that theta and beta bands can be assigned to sensory input and can be regarded as satellites of alpha band representing the sensory response of cell membrane to the cyclotron radiation from magnetic body. $f_J = 5$ Hz for $Z = 2$ correspond to a fundamental "drum beat". Note that for $Z = 1$ (assignable to say exotic bosonic ions of type $I^{++,-}$, $I = Ca, Mg, Mn, ...$) one has $f_J = 2.5$ Hz.

3. The model explains the band structure of EEG and predicts correctly the narrow resonances at $3, 5, 7$ Hz and $13, 15, 17$ Hz [**?**]. Also the basic correlations between EEG and the state of consciousness can be understood, in particular why the chaotic character of beta band correlates with a state of strong concentration and high activity can be understood directly from the general expression of the Josephson current.

4. The difference between EEGs during wake-up and sleep can be understood if there are two classes of neurons such that the magnetic flux quantization condition $Ze \int BdS = n\hbar(k_{em})$ corresponds to $Z = 1$ for type I neurons $Z = 2$ for type II neurons so that the magnetic field strength assignable to flux sheets traversing DNA is B_E for type I and $B_E/2$ for type II. The key implication is that the cyclotron frequency scales differ by a factor $1/2$ so that the alpha bands would be around 10 Hz *resp.* 5 Hz for these two types of neurons. The first guess is that $Z = 1$ *resp.* $Z = 2$ correspond to neurons of right *resp.* left hemisphere. Left and right hemispheres could actually correspond to separate magnetic bodies with different field strengths.

   Also the value of $\hbar$ could be by a factor 2 larger for the right magnetic body so that also f_J would scale down by factor $1/2$. If also magnetic field for right magnetic body is weaker by a factor $1/2$, the area of of its flux quanta would is a factor 4 larger than for left magnetic body.

If the portions of brain corresponding to type I neurons falls first in sleep the control signals in alpha band and sensory input in beta and theta bands to the (corresponding) magnetic body disappear and only their scaled down variants remain. This explains why only theta and delta bands are present during sleep. Sleeping spindles can be understood as occasional wake-ups of type I regions. In the deepest stage of sleep only the cyclotron delta bands around 1 Hz and .5 Hz assignable to DNA cyclotron frequencies for type I and II neurons and having interpretation in terms of quantum control applied to DNA remain.

That at $k_{em} = 3$ level of hierarchy .5 Hz corresponds to kHz frequency of neuronal synchrony suggests that $k_{em} = 3$ magnetic bodies are in deep sleep during neuronal synchrony. In a similar manner deep sleep at our level would correspond to the analog of neuronal synchrony at higher level corresponding perhaps to the analogs of nerve pulse patterns assignable to double neuron layers and characterized by a time scale of 2 seconds instead of millisecond. The analog of type I (II) alpha band would correspond to a time scale of 200 (400) seconds and might define a detectable biorhythm.

Left/right $\leftrightarrow$ space-like/time like?

It has been already proposed that space-like/time-like dichotomy most naturally corresponds to axon-neuron body dichotomy. One can however consider also alternative possibilities. The difference of EEG frequency scales (if assignable to left-right dichotomy) need not be the only difference between the EEGs of right and left hemispheres. If there is a correlation between the character of EEG waves and that of solitons sequences at $k_{em} = 4$ level of dark hierarchy, the difference between left and right

brain could indeed reflect the differences between space-like propagating space-like soliton sequences and non-propagating time like soliton sequences. Only dominance would be in question, both modes would appear certain fraction of time in both brain hemispheres (recall that millisecond is the natural unit of time and 10^{39} quantum jumps occurs during one second). Propagating soliton sequences could give rise to a relatively large number of sub-selves (mental images) corresponding geometrically to linear brain circuits and representing linear and temporal aspects of cognition (speech and thought). 'Boolean' mind represented by sequences of cognitive neutrino pairs might be possible only in this mode[1]. Time like soliton sequences would be associated with relatively few and large spatial regions representing selves. This would give rise to a parallel processing of information.

An interesting question is whether epileptic seizures could involve non-propagating EEG of anomalously high amplitude. Also meditative states and 'whole-body consciousness' might involve non-propagating EEG: the basic procedure for achieving meditative states is emptying of mind from all possible mental images which means formation of large sub-selves represented by brain regions with time like EEG. The identification of the dominance of standing EEG waves with this kind of mental states is consistent with the absence of sensory consciousness. The low level of motor activity suggests that the standing EEG waves produced by time like soliton sequences are not responsible for motor control.

10.8.7 Quantum tools for bio-control and -coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps corresponds to quantum control. More precisely, the non-dissipative Josephson currents associated with weakly coupled super conductors would be the key element in coordination whereas resonant dissipative currents between weakly coupled super conductors would make possible quantum control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [32]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with a well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in the case of the vertebrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

Homeostasis as many-sheeted ionic flow equilibrium

The experimental work of Ling, Sachs and Qin [42, 41] and other pioneers [40, 39] challenges the notions of ionic channels and pumps central to the standard cell biology. Ling has demonstrated that the ionic concentrations of a metabolically deprived cell are not changed at all: this challenges the notion of cell membrane ionic pumps. The work of Sachs and Qin and others based on patch-clamp technique shows that the quantal ionic currents through cell membrane remain essentially as such when the membrane is replaced by a silicon rubber membrane or by a cell membrane purified from channel proteins! this challenges the notion of cell membrane ionic channels. A further puzzling observation is much more mundane: ordinary hamburger contains roughly 80 per cent of water and is thus like a wet sponge: why it is so difficult to get the water out of it?

These puzzling observations can be understood if the homeostasis of cell and its exterior is regarded as an ionic flow equilibrium in the many-sheeted space-time. Ionic super currents from super-conducting controlling space-time sheets flow to controlled atomic space-time sheets and back. Currents are of course ohmic at the atomic space-time sheets. One can understand how extremely small ionic densities and super currents at cellular space-time sheets can control ionic currents and much higher ionic densities at atomic space-time sheets. Immense savings in metabolic energy are achieved if the ohmic currents at the atomic space-time sheets flow through the cell membrane region containing the strong electric field along super-conducting cell membrane space-time sheet (rather than atomic

[1] See the chapter "Genes and memes".

space-time sheets) as a non-dissipative supra current. This clever energy saving trick makes also the notion of ionic channels obsolete for weak ionic currents at least.

Super-conducting space-time sheets contain a plan of the bio-system coded to ion densities and magnetic quantum numbers characterizing the super currents. Bio-control by em fields affects these super currents and one can understand the effects of ELF em fields on bio-system in this framework. The model relies crucially on the liquid crystal property of bio-matter (hamburger mystery!) making possible ohmic current circuitry at the atomic space-time sheets as a part of the many-sheeted control circuitry. There is a considerable evidence for this current circuitry, Becker is one of the pioneers in the field [43]: among other things the circuitry could explain how acupuncture works.

Quantum model for pattern recognition

Time translation invariant pattern recognition circuit can be realized by using two coupled super-conductors. The first super-conductor contains the reference supra current and second super-conductor contains the supra current determined by the sensory input. Supra currents are assumed to have same spatially and temporally constant intensity. If the supra currents have spatially constant phase difference, also Josephson currents are in the same phase and sum up to a large current facilitating synchronous firing. The temporal phase difference of supra currents does not matter since it affects only the overall phase of the Josephson current. Therefore patterns differing by time translations are treated as equivalent. Quite generally, the requirement of time translational invariance, favors the coding of the sensory qualia to transition frequencies.

The destructive interference of supra currents provides an tool of pattern cognition in situations when the precise timing is important. The pattern to be recognized can be represented as a reference current pattern in some neuronal circuit. Input pattern determined by sensory input in turn is represented by supra current interfering with the reference current. If interference is destructive, synchronous generation of nerve pulses in the circuit occurs and leads to a conscious pattern recognition. Obviously the loss of time translation invariance makes this mechanism undesirable in the situations in which the precise timing of the sensory input does not matter. One can however imagine situations when timing is important: for instance, the deduction of the direction of the object of the auditory field from the phase difference associated with signals entering into right and left ears could correspond to this kind of situation.

In both cases one can worry about the regeneration of reference currents. The paradigm of four-dimensional quantum brain suggests that sensory input leads by self-organization to a stationary spatial patterns of supra-currents and this process depends only very mildly on initial values. Thus self-organization would generate automatically pattern recognizers.

General mechanism making possible biological clocks and alarm clocks, comparison circuits and novelty detectors

Weakly coupled super conductors and auantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two super-conductors provides a manner to realize a biological clock. Josephson current can be written in the form [30]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{10.8.1}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of super-conductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the super conductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [30]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s \Delta}{d} \ . \tag{10.8.2}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the super conductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two super conductors. By the previous arguments the density of the Cooper pairs is an ideal tool of bio-control and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{10.8.3}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both super conductors carry parallel supra currents or whether only second super conductor carries supra current.

1. If both super conductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second super conductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector 'wakes-up' into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second super conductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the un-stability of the structure. When the supra current in the circuit dissipates below a critical value, un-stability emerges. This provides a general mechanism of biological alarm clock.

   Assume that the second super conductor carriers a supra current. As the time passes the reference current dissipates by phase slippages[31, 30]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to a un-stability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The un-stability itself can regenerate the reference current to the clock. If the alarm clock actually 'wakes-up' the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second super conductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

How MEs could generate soliton sequences?

MEs could as bio-controllers using the same general mechanism which underlies remote mental interactions and this aspect of bio-control could be seen as endogenous remote mental interactions between cells and other parts of organism. Pairs of low and high frequency MEs are involved. Low frequency MEs, say EEG MEs, serve as correlates for quantum entanglement between body parts: already this is enough for remote viewing regarded as sharing of mental images by fusion of mental images. The psychokinesis aspect is possible by high frequency MEs propagating like massless particles inside low frequency MEs. These MEs induce bridges and thus leakage of ions between various space-time sheets at the receiving end. This means self-organization by dissipation.

MEs can also act as Josephson junctions connecting super-conducting space-time sheet characterized by p-adic primes which can be different. This kind of Josephson junction contains the em field associated with ME as an external field and the mathematical description of this coupling follows from the model for the coupling of electromagnetic field to super conducting order parameters. In Minkowski coordinates the modification of the Sine-Gordon equation is simple:

$$\partial^\mu \left[\partial_\mu \Phi - Ze\Delta A_\mu\right] \quad = \quad m_{12}^2 sin(\Phi) \ . \tag{10.8.4}$$

Here Φ denotes the phase difference over the Josephson junction, which is idealized with a continuous Josephson junction, and actually is a continuous Josephson junction in the case of ME. ΔA_μ denotes the difference of the vector potential over the junction.

The coupling to the vector potential can in the lowest order described by the condition

$$\partial_\mu \Phi_0 = Ze\Delta A_\mu$$

assumed to hold for a maximal number of components of vector potential. Here of course integrability conditions pose restrictions. One can develop perturbation series for Φ by substituting Φ_0 to the right hand side and calculating Φ_1 using the right hand side as a source term, and so on.

If the transversal em field associated with ME contains time independent radial electric field this gives rise to a constant potential term giving rise to a generation of soliton sequences. The period Ω of rotation for the soliton satisfies $\Omega = eV$, where eV corresponds to the potential difference defined by the constant part of the electric field of ME. It can also happen that ME contains only the oscillatory electromagnetic field: if the frequency is same as the frequency associated with small oscillations of the Sine-Gordon pendulum a resonant coupling is expected to result. In this case the frequency is in radio frequency range.

Also noise is present and it is quite possible that the noise provides the energy needed to amplify the weak periodic signal provided by ME to a soliton sequence by stochastic resonance. The mechanism is discussed in detail in the chapter "Quantum model for EEG and nerve pulse". This suggests that MEs could basically control small very fast oscillations of the membrane potential.

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Chapter 11

p-Adic Physics as Physics of Cognition and Intention

11.1 Introduction

TGD as a generalized number theory vision stimulates the hypothesis about p-adic physics as the physics of intention, cognition and imagination. This interpretation has far reaching implications for both TGD inspired theory of consciousness and for the general world view provided by TGD. Intentionality and cognition is predicted to be present in all length scales and the success of the p-adic physics in elementary particle length scales forces to conclude that intentionality, cognition are present even at this level. In this chapter these implications are studied from the point of view of cognitive consciousness.

11.1.1 The three non-determinisms

TGD Universe is characterized by a 'holy trinity' of non-determinisms. The first non-determinism is associated with quantum jumps between quantum histories and is what makes possible subjective existence and consciousness. Second non-determinism is classical non-determinism of Kähler action and is to symbolic representations and perhaps also with macroscopic volition. The third non-determinism is inherent to all p-adic field equations and corresponds to the non-determinism of imagination and thus makes possible cognition and intentionality. There is no conscious experience associated with classical nor with p-adic non-determinism as dualist might think. These three non-determinisms have turned out to be basic building bricks of TGD inspired theory of consciousness.

Mind like space-time sheets are the geometric correlates of selves in the TGD framework. In the real case mind like space-time sheets have a finite temporal duration. In the p-adic context this restriction is in principle un-necessary. Classical and p-adic non-determinisms make it natural to introduce the notion of association sequence defined as a sequence of space like 3-surfaces with time like separations determining uniquely the absolute minimum space-time surface going through these 3-surfaces. In case of CP_2 type extremals discrete association sequences become in principle continuous sequences of 3-surfaces.

11.1.2 Classical non-determinism and symbolic representations

In case that classical non-determinism gives rise to macroscopic multifurcations of the time development of 3-surface, it is tempting to identify the branches of the multifurcations as alternative choices involved with volitional acts. Contrary to the long held believes, it however seems that classical non-determinism is most naturally associated with symbolic representations understood in a very general sense (one could even understand classical space-time surfaces as symbolic representations of quantum dynamics). The assignment of sensory experiences with real mind like space-time sheets explains why the contents of sensory experiences are localized with respect to geometric time.

The book "Gödel, Escher, Bach" by Douglas Hofstadter about self-reference has been perhaps the most fascinating of my intellectual arm chair adventures and it stimulated the dream about the

identification of the physical counterpart of self-reference. The physics as a generalized number theory vision finally stimulated concrete ideas about how this self-reference might ber realized. Classical non-determinism, besides being crucial for the construction of S-matrix in the approximation that particles correspond to CP_2 type extremals, indeed seems to make possible self-referential Universe already at elementary particle level.

By crossing symmetry, one can interpret S-matrix elements as transition amplitudes between two vacua differing only by the presence of mind like space-time sheet containing zero energy state with incoming and outgoing particles having positive and negative energies respectively. These zero energy states thus provide physical representation for particle reactions and in fact also for sequences of particle reactions. Thus the classical non-determinism and the possibility of negative energies make possible for the Universe according to TGD to represent the laws of physics in the structure of zero energy physical states. That all possible vacua provide representation for physics is very much akin to the ideas of Eastern philosophies, and is bound to have deep implications from the point of view of TGD inspired theory of consciousness. In this chapter the main emphasis is however on the implications of the p-adic non-determinism.

11.1.3 p-Adic non-determinism and cognition

p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff.

Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. Thus p-adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious interpretation for the solutions of the p-adic field equations would be as geometric correlates of intentionality. Plans, intentions, expectations, dreams, and cognition in general are expected to have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general. One must be very cautious in order to not misinterpret the role of p-adic physics. Imagination and cognition, as they are defined in the neuro-science, have also definite neural correlates at the level of real physics so that obviously both p-adic and real physics are involved. It would seem that p-adic space-time sheets define the initial values for the neural processes responsible for imagination and cognition in the standard sense.

1. Standard view about cognition and imagination would support the interpretation of p-adic physics as physics of intentionality and nothing else.

2. The following argument shows that this interpretation is incorrect in TGD Universe. p-Adic-real entanglement is possible in fermionic degrees of freedom if one assumes that the entanglement coefficients are algebraic numbers. The number theoretical entanglement entropy can be also negative so that the information content can be positive. In this case entanglement is stable against self measurements and macro-temporal quantum coherence results. The natural guess is that this kind of entanglement is a correlate for the experience of understanding. This would strongly encourage the interpretation as a cognitive entanglement so that the corresponding self measurement could be called cognitive measurement. Thus the core element of cognition and imagination would be the p-adic space-time sheet representing the initial values of the neural process, which in turn could be seen as a symbolic representation of cognition or imagination. Therefore cognition/imagination in the usual sense of the word decomposes in TGD Universe to the genuine cognition/imagination which is p-adic plus the real symbolic representation generated by it. In this conceptual framework cognitive representations are p-adic and symbolic representations real and brain mostly builds symbolic representations from the sensory input and from cognitive representations.

Before proceeding it is useful to summarize the basic view about qualia [K3].

1. Geometric qualia correspond to the increments of configuration space zero modes in quantum jump and are cognitive qualia. Shape, size,length duration, ... etc. are good examples of geometric qualia. Real geometric qualia could be also called symbolic qualia. The universe of symbolic representations is completely classical since a complete localization in the zero modes occurs in each quantum jump as it occurs also in p-adic configuration space degrees of freedom so that also cognition at configuration space degrees of freedom is completely classical.

2. Sensory qualia correspond to the increments of quantum numbers related to the quantum fluctuating degrees of freedom, non-zero modes. They are genuine multi-verse qualia since the final states of quantum jumps are superpositions of space-time surfaces with varying values of non-zero modes. One cannot understand color red in terms of space-time geometry.

3. The trinity sensory-symbolic-cognitive is central for understanding consciousness in TGD framework. Also the division to fermionic (configuration space spinor) and configuration space degrees of freedom at the level of qualia is important. Fermionic qualia correspond to Boolean qualia (both p-adic and real and associated with conformal and quaternion conformal fermionic degrees of freedom). Configuration space qualia correspond to geometric and sensory qualia in the real case and only geometric qualia in the p-adic case (cognition has no colors).

p-Adic–real phase transitions and matter-mind interaction

If one accepts the idea that real and p-adic space-time regions are correlates for matter and intentionality, one encounters the question how matter and mind interact. A good candidate for this interaction is the phase transition leading to a transformation of the real space-time regions to p-adic ones and vice versa. These transformations can take place in quantum jumps. p-Adic-to-real phase transition would have interpretation as a transformation of thought into a sensory experience (dream or hallucination) or intention to an action. The reverse phase transition might relate to the transformation of the sensory experience to cognition. Sensory representations could be also transformed to cognitive representations by initial values realized as common rational points of a real space-time sheet representing sensory input and a p-adic space-time sheet representing the cognitive output. In this case the cognitive mental image is unique only in case that p-adic pseudo constants are ordinary constants.

p-Adic teleportation

Massless extremals (MEs) are an excellent candidate for a hierarchy of life forms repr esenting MEs. MEs represent classical gauge fields propagating with a light velocity such that the shape of the wave form is preserved. They allow the coding of any pulse shape to the shape of the classical gauge field and are thus optimal for representing information classically. This is why MEs are in a key role in TGD based theory of consciousness including the model of EEG [M3, M4, M5].

For the p-adic MEs conservation laws allow reflection in a spatial or temporal direction, and one can consider gluing of pieces of ME to get zigzag curves with reflections in spatial or time direction. In the reflection to the direction of geometric past a time reversed copy of the cognitive representation is formed, in the next reflection a copy of the original is formed, etc... This mechanism makes possible both the meme replication and their transmission with a super-luminal velocity. Even transfer of memes to the geometric past becomes possible. Time reversed cognition is the basic prediction very much analogous to the prediction of the antimatter in Dirac's theory of electron. Obviously p-adic teleportation and real–p-adic phase transition provide also general mechanisms for a large variety of paranormal effects.

Cognitive degeneracy and the survival of the fittest

The construction of quantum TGD suggests strongly that p-adic space-time regions do not contribute to configuration space geometry and thus to physics in the conventional sense. This has nontrivial implications. First of all, all space-time surfaces which differ only cognitively are physically equivalent and one can speak about cognitive degeneracy. This means that physical system with a large cognitive degeneracy is analogous to a system with a large state degeneracy. If the final states of quantum jumps

have roughly the same probabilities, this means that quantum jumps lead with highest probability to those states for which cognitive degeneracy is highest. The mere ability to imagine would mean winning in the fight for survival. The possible weak point of this hypothesis is the assumption that probabilities for various final states are roughly the same. Indeed, if the cognitive degeneracy is roughly equal to the negative exponent of the Kähler function, as proposed earlier [H7], the two exponents cancel in the total probability for quantum jump to given physical state, and the argument fails.

An alternative, and perhaps a more realistic, manner to see the situation is that a physical system with high cognitive degeneracy has large repertoare of transformations of cognitive space-time sheets to real space-time sheets and is thus highly adaptive and survives for this reason.

11.1.4 How to test p-adic physics?

The obvious question is how to test p-adic physics empirically. Since the times of Newton physicists have modelled the world using solely real numbers. Hence a careful reconsideration of the relationship between physical theories and experimental physics is needed before one can answer this question.

The basic heuristic guideline is that thinking is essentially p-adic sensory experiencing. Hence the reduction of the Cartesian theories–experimental science dichotomy to p-adic–real dichotomy seems natural. Just as experimental science is an extension of the everyday real sensory experience, theories would represent an extension of the everyday p-adic sensory experience (common sense thinking). Thus the basic test is how well p-adic physics based theories describe cognition.

Also indirect experimental testing is possible. The p-adic models for physical systems are models for cognitive models of real physics. The successes of these highly predictive models of models support the paradigm of p-adic cognition. A representative example is provided by the elementary particle mass calculations [F2, F3, F4, F5] based on p-adic thermodynamics and characteristically involving only very few integer valued parameters and exponentially sensitive dependence of the masses on single integer parameter. Therefore either the success of the model is extremely improbable statistical miracle or the model indeed describes physical reality. A second example is the consistency of the very strong predictions of p-adic length scale hypothesis with empirical facts. It is also evident that, in TGD framework at least, the physics of matter must be based on real numbers. For instance, p-adic non-determinism would mean that basic conservation laws would not hold true expect in piecewise manner: at the level of imagination this cannot be allowed but not in the laboratory.

p-Adic–real phase transitions transform thought to action and sensory input to thought. The theories of brain functioning should at the fundamental level involve modelling of these transitions and the success or failure of these models serves as a further test for p-adic physics as physics of cognition.

11.2 p-Adic physics and intentionality

The basic vision is that volitional acts are realized as phase transitions of a p-adic space-time region to a real space-time region. These phase transitions are 4-dimensional and induces in quantum jumps.

11.2.1 Materialization of intentions

Em fields, in particular ELF em fields, are crucial for TGD inspired model of brain and a natural assumption is that p-adic–real phase transitions occur also for massless extremals (MEs). Energy is conserved if MEs are created in pairs having opposite signs of energies. Generation of pairs of MEs have been suggested as a mechanism of coherent locomotion made possible by the maximally coherent momentum carried by ME and resulting as a recoil momentum of material system absorbing second ME. In fact, the mechanism is optimal since the momentum of ME is completely coherent. Thus a possible interpretation is as a transformation of intention to real motion. Of course, it is difficult to say whether this mechanism occurs in cellular or micro-tubular length scales or perhaps even in macroscopic lengths scales. And there are certainly also other mechanisms.

A more refined picture about the materialization of intentions emerges, when one asks how a precisely targeted intention could be realized at the atomic or molecular level. Molecules can only intend to make a quantum transitions. If the transition occurs to a lower energy state it can occur spontaneously whereas the transitions to a higher energy states do not. Only the latter transitions

allow precisely target intention. What would happen is that first a p-adic ME representing the intention to perform the transition is generated. Then the transition occurs and conservation laws require that the p-adic ME is transformed to a negative energy ME in the transition. Physical intuition suggests that the p-adic ME and the corresponding real ME resemble each other in the sense that they go through the same rational points in some p-adic resolution. Quite generally, it seems that intention can be realized in a precisely targeted manner only for the transitions which cannot occur spontaneously, and thus involve the emission of negative energy MEs. The generation of negative energy MEs utilizes thus the buy now-let others pay mechanism of metabolism, which implies extreme flexibility. Of course, there must exist a unselfish self, which is able to pay and this puts severe constraints on the mechanism. This leads to the view that sensory, cognitive and memory representations are realized in terms of positive energy MEs spontaneously whereas intentionality and motor actions are much like time reversed sensory representations and realized in terms of negative energy MEs.

11.2.2 Psychological time as front of volition identified as p-adic-to-real phase transition

A natural resolution of the problems related to the preferred role of single moment of time for conscious experience is based on the idea that biological growth and self-organization is a 4-dimensional phase transition like process proceeding also in the direction of the geometric future quantum jump by quantum jump. And, in particular, that the dominating contribution to the conscious experience comes from the front of the phase transition where the volition is. The phase transition in question is nothing but transformation of intentions to action and thus p-adic-to-real phase transition proceeding quantum jump by quantum jump towards geometric future.

More concretely:

1. There is electromagnetic body serving as a template around which ordinary matter self-organizes by phase transition and at the same time modifies this template. The phase transition front proceeds from the moment of birth to the geometric future in a manner analogous to the polymerization process or to the gradual build-up of a protein in mRNA-protein translation. Electromagnetic body could correspond to the electromagnetic part of the genetic information hypothesized to be coded by transversal magnetic mirror structures (massless extremals parallel to magnetic flux tubes) [K5]. The motivation for this hypothesis comes from the TGD based quantum models for bio-control and sensory representations, from the data about homeopathy and the puzzles related to genome (in particular intron mystery), from the mysteries of the bio-chemical self-organization, and from the experimental work related to phenomena like remote vision and healing. Among other things this model explains processes like molecular recognition which remain mysterious in standard framework of biochemistry.

2. Each choice made during life cycle is analogous to an addition of a new protein in mRNA-protein translation process. There is a lot of freedom of choice associated with the addition of the new building blocks to a growing protein. The freedom to modify the already existing structure is however relatively restricted. The already existing part of protein can adopt a highly restricted repertoare of conformations but the ordering of the component amino-acids remains essentially fixed as also the chemical structure of the individual amino-acids. Translating this to the level of evolution of individual: presumably only the non-determinism associated with various sensory and cognitive representations is present whereas the non-determinism associated with say macroscopic motor actions and decisions affecting dramatically future is absent in our geometric past. Thus the classical (and also quantum) non-determinism is concentrated at the phase transition front propagating towards the geometric future quantum jump by quantum jump. As a consequence, also the contents of conscious experience are concentrated around the value of the geometric time characterizing the location of this front.

3. Quantum criticality of TGD universe suggests that also the reverse phase transitions can occur and could proceed most naturally towards geometric past like the depolymerization of a protein (later a more convincing support for this hypothesis will be discussed). Fractality of the TGD universe in turn suggests that these phase transitions and their reversals occur in all length and time scales.

4. The idea that 4-D body is kind of a 4-D sculpture constructed gradually by trial and error process suggests that the 4-D growth process proceeds by trial and error and when dead end appears the reverse of the phase transition corresponding to a polymerization occurs and proceeds backwards in the geometric time to the moment when the wrong choice was made. Thus our life would not end at the physical death but would be an iterative process starting again and again from the moment when things went wrong.

5. Physical death means that the 4-D body becomes mature and could survive at least for some time in a state in which conscious experience does not contain the dominating input from the phase transition zone. Some kind of a timeless form of consciousness should be in question. This vision conforms with the idea that physical life is only one stage in much longer lasting process of conscious evolution.

6. What is this fundamental phase transition giving rise to what we call life? We know that the front of phase transition corresponds to volitional consciousness. We also know that volition as a transformation of intention to action in TGD universe corresponds to the p-adic-to-real phase transitions of space-time space-time sheets taking place in quantum jumps. Thus the natural conclusion is that p-adic-to-real phase transition is the fundamental phase transition inducing the biological self-organization. This phase transition could occur for massless extremals (MEs) and perhaps also for the flux tubes of wormhole magnetic fields representing the plan for the evolution of the biological system.

7. The simplest view assumes that the front of volition does not propagate after the physical death. One could however consider the possibility that the front of volition continues to propagate by transforming p-adic magnetic mirror structures to real ones: volitional life would continue in electromagnetic form. This would make possible the communications of the deceased with living since the resulting magnetic mirrors could connect the deceased with the living. Since magnetic mirror structures are fundamental for the field realization of the genetic code, one can quite well consider the possibility that this process induces also the self-organization of the ordinary living matter around the magnetic mirror structures. This would have interpretation as a reincarnation. Buddhas able to resist the temptation to reincarnate would continue their life at the field level. Interestingly, the development of physics from Newtonian physics of the material bodies to Maxwellian physics of fields would mirror the evolution of consciousness from concrete biological life to life at the field level. If this view is correct then deceased build magnetic mirror bridges with the living and thus interact and communicate with them. This leads to rather concrete views about claimed communications between dead and alive.

11.2.3 Entire society/biosphere as a phase transition front proceeding towards geometric future?

The only possibility to avoid paradoxes is that we are parts of a phase transition front of a larger organism and possess more or less the same psychological time. Entire biosphere would thus have common psychological time. This assumption is motivated by the success of the the standard identification of the subjective time with geometric time.

1. Unless the value of the psychological time is common, we would experience all fellow human beings whose psychological now is in our future as very passive beings. In fact, most organisms around us would look more or less like dead. One could argue that the free will exercised in the self-organization front induces changes in the geometric past and creates the illusion of genuine volition occurring behind the wave front but this explanation does not sound convincing.

2. Suppose that some fellow human being dies physically. How it is possible that my fellow human beings whose subjective now is in the geometric future participate the funerals and even arrange it if they effectively live in future and experience the funeral attended also by me as a memory?

The only conclusion seems to be that at least the selves at the same level of self hierarchy possess same value of psychological time. It might even be that the entire living biosphere could be seen as a phase transition front proceeding to the direction of the geometric future. This conclusion is of utmost importance since it leaves no other possibility that to accept that even biosphere defines conscious

self and we correspond to only single level in the self hierarchy. In particular, the notion of collective consciousness is more or less 'a must' in this framework.

The fractality of TGD Universe suggests that there are phase transition fronts inside phase transition fronts each with their characteristic span with respect to the geometric time and age with respect to subjective time suffering the 4-dimensional analogs of cell decay and regeneration. One can imagine a fractal hierarchy of phase transition fronts in which sub-selves experience a common psychological time and experience the systems, whose psychological time is in the geometric future, more or less as dead because the degree of non-determinism in the geometric past of the four-dimensional body is low. Perhaps what we call non-living matter corresponds to life for which self-organization front is in the distant geometric future. Also the idea about gradual build-up of four-dimensional sculptures by 4-D phase transitions and their reversals at all levels of the self hierarchy looks attractive.

11.2.4 p-Adic physics, life, and paranormal phenomena

The key question related to the attempts to understand paranormal phenomena like remote vision and healing, claimed materialization events, psychokinesis and communications with deceased, to mention some examples is how intention is transformed to real action. p-Adic physics as physics of intention suggests the answer: basic mechanism is the transformation of p-adic space-time sheets to real ones, which according to usual believes would occur only within the boundaries of our physical body.

The crucial role of magnetic mirrors (or rather, mirror pairs) consisting of magnetic flux tubes and MEs parallel to them in TGD based model of living matter suggests that the p-adic-to-real phase transitions of these structures are fundamental process in living matter and life could be regarded as phase transition process for these structures in turn inducing self-organization of ordinary matter around the resulting field templates. Magnetic mirrors serve as electromagnetic bridges between biomolecules and make them able to recognize each other so that miracles like translation of mRNA to protein can occur. Magnetic mirrors connect also different organisms and make possible remote healing, telepathy and similar phenomena. Magnetic mirrors can connect also organisms and electronic systems and could make possible phenomena like instrumental transcommunication. Magnetic mirrors make also possible long term memories and communication between living and deceases the only difference being that memories are now not from own 4-dimensional body but that of deceased.

11.2.5 The emergence of symbols

p-Adic non-determinism gives rise to cognitive representations whereas the non-determinism of the real Kähler action gives rise to symbolic representations in terms of association sequences consisting of space like 3-surfaces with time like separations: the individual space like 3-surfaces play the role of words of sentence.

Conscious activities are indeed highly symbolic: a push of button can initiate a nuclear war. The reduction of the p-adic-to-real phase transitions to some fundamental level, perhaps to the level of nerve pulse transmission, indeed makes possible a build-up of very complex actions by using a repertoare of very simple basic actions serving p-adic memes translatable to symbols in case that system is initial value sensitive. p-Adic MEs provide an excellent candidate for the cognitive representations and would initiate neural processes defining symbolic representations. Also memetic code and cognitive neutrinos would be involved.

The idea that motor actions are time reversed perceptions allows a simple view about imagined motor activities. Imagined motor actions are initiated by a transformation of p-adic MEs to real negative energy MEs at some level above muscles and proceed to the cortex as time reversed activities as far as the MEs controlling these activities are considered. Negative energies make possible precisely targeted intention. There is no need to stop the imagined motor action so that it is not a safety risk. It is possible to learn motor actions by initiating them from a level above the muscles. Time reversal means negative energies for MEs and buy now-let others pay mechanism implies extreme flexibility. Time reversed dissipation can be interpreted as a healing mechanism since entropy decreases in the standard direction of the geometric time. Thus the motor action can be thought of as a carving of a four-dimensional statue by a gradual refinement and error corrections using dissipation as a Darwinian selector. No detailed planning is needed: only a rough sketch is enough in the time scale of the motor action and Nature takes care of the rest.

p-Adic fractality suggests that cognitive representations are present at all length scales: in particular, p-adic MEs are excellent candidates for cognitive representations. Symbolic representations are obtained from these by p-adic-to-real phase transitions. Nothing however forbids a repertoare of simple MEs serving as symbols, typically frequencies or field patterns, and generating neural activities in turn amplitied to macroscopic actions.

11.3 How cognitive representations develop?

11.3.1 Questions about cognitive representations

One can ask a myriads of questions about cognitive representations. Here are only some of the most obvious questions.

1. What are the basic types of cognitive representations? There are two basic correspondences between reals and p-adics induced by common rationals and canonical identification or some map akin to it. This suggest that self-representations are induced by common rationals whereas representations of the external world are induced by canonical identification or an analogous map. In both cases there is some pinary cutoff determining the goodness of the representation.

2. How cognitive representations evolve? p-Adic field equations are same as real field equations so that one can say that Nature determines the p-adic cognitive representation once the p-adic integration constants, which are pseudoconstants, are given. p-Adic pseudoconstants are the basic input of the cognitive representation determined more or less completely by the sensory input coded into nerve pulse patterns and EEG waves.

3. What is the mechanism of the reality testing? There must be somekind of reality testing for cognitive representations allowing to gradually tune up the values of the p-adic integration constants. p-Adic-to-real phase transitions in principle make possible this kind of testing. For instance, cognitive representation can be transformed to real (symbolic) one and compared with the sensory input represented by nerve pulse and propagating in a closed loop in neural circuits. An iterative procedure converging rapidly to a fixed point representation could be involved. At least in some case ideal representation is the one for which p-adic pseudo constants reduce to genuine constants. This kind of iterated comparison process could be also seen as a self-organization process leading to standardized final state patterns.

4. What is the relationship to the memetics of Susan Blacmore [38]? p-Adic cognitive representations are excellent candidates for the physical realization of memes . Susan Blackmore sees memes as independent objects using brain as a tool of replication. One can wonder whether p-adic cognitive representations could also have equally independent existence and use brain as at tool for the materialization and replcation, and whether there are p-adic memes floating all around and waiting for a materialization. TGD based interpretation of DNA as a material realization of association sequences suggests also that DNA should could have a p-adic counterpart possibly able to replicate. A further interesting question is is the role of the p-adic ghostly DNA double helix as as a template in the replication of the physical DNA.

11.3.2 Two kinds of cognitive representations

At the level of the space-time surfaces and imbedding space the construction of cognitive map boils down to the task of finding a map mapping real space-time region to a p-adic space-time region. These regions correspond to definite regions of the rational imbedding space so that the map has a clear geometric interpretation at the level of rational physics.

The basic constraint on the map is that both real and p-adic space-time regions satisfy field equations: p-adic field equations make sense even if the integral defining the Kähler action does not exist p-adically. p-Adic non-determinism makes possible this map when one allows finite pinary cutoff characterizing the resolution of the cognitive representation. The fact that field equations are satisfied implies that physics laws are automatically build into the cognitive representation.

There are two basic types of cognitive representations which might be called self-representations and representations of the external world and the map mediating p-adicization is different for these two maps.

1. The correspondence induced by the common rational points respects algebraic structures and defines self-representation. Real and p-adic space-time surfaces have a subset of rational points (defined by the resolution of the cognitive map) as common. The quality of the representation is defined by the resolution of the map and pinary cutoff for the rationals in pinary expansion is a natural measure for the resolution just as decimal cutoff is a natural measure for the resolution of a numerical model.

   The characteristic feature of the identification by the common rationals are long range correlations and microscopic chaos with respect to real distance measure. Long range correlations result from the fact that poits differing by large power of p are p-adically near to each other so that also the values of p-adically continuous functions are same for points different by large power of p. We indeed experience our life as narrative and as having a purpose despite the fact that there is micro-temporal chaos. If p-adic cognitive model with its long range correlations reflects the properties of real world, our life is indeed more like a fractal 4-dimensional sculpture than random Brownian motion.

2. Canonical identification maps rationals to rationals since the periodic pinary expansion of a rational is mapped to a periodic expansion in the canonical identification. The rationals $q = m/n$ for which n is not divisible by p are mapped to rationals with p-adic norm not larger than unity. Canonical identification respects continuity. Real numbers with real norm larger than p are mapped to real numbers with norm smaller than one in the canonical identification whereas reals with real norm in the interval $[1, p)$ are mapped to p-adics with p-adic norm equal to one: in this case one might speak about self map. Obviously the generalization of the canonical identification can map the world external to a given space-time region into the interior of this region and provides an example of an abstract cognitive representation of the external world. Also now pinary cutoff serves as a natural measure for the quality of the cognitive map. For this map the inversion of the pinary digits means there is short range order and long range chaos: this is consistent with the fact that sensory input gives information only about the nearby regions of the system.

A fascinating possibility is that cognitive self-maps and maps of the external world at the level of human brain are basically realized by using these two basic types of mappings. Obviously canonical identification performed separately for all coordinates is the only possibility if this map is required to be maximally continuous. An interesting possibility is that not only exterior-to-interior, but also interior-to-exterior map is involved. The latter map would give rise to bird's eye of view cognitive representation about organism and genuinely extrasensory component of consciousness becoming conscious in OBE and NDE experiences. Perhaps also self-model involves interior-to-exterior mapping and is thus non-sensory.

It is important to notice that these maps are four-dimensional. This means that long periods of life cycle are mapped to short temporal intervals giving summary of life cycle. Future plans are also included to this map. Interior to exterior mapping could also gives bird's eye of view about entire life perhaps becoming conscious in NDE experiences. An interesting basic feature of p-adics is that p-adics axis is analogous to non-negative real axis. One can wonder whether this might have something to do with the asymmetry of the future and past with respect to geometric memories. The fact that the evolution of the notion of negative number has required quite a long time might correlate with the fact that the notion of negative p-adic number is not well-defined: if so, the limitations of our instinctive mathematical thinking would directly reflect the properties of the p-adic numbers. The ability to imagine spaces of arbitrary high dimension mathematically might correlate with the fact that p-adic space-time regions can arbitrarily high algebraic dimension (as opposed to physical dimension) as algebraic extensions of the p-adic numbers.

p-Adic cognitive representations should be extremely detailed (but faithful only above some length scale) and contain immense amounts of unconscious-to-us information. Brain research has indeed demonstrated that only part of sensory information is conscious-to-us.

11.3.3 The notion of pinary cutoff

The notion of pinary cutoff is central for p-adic TGD and it should have some natural definition and interpretation in the new approach. The presence of p-adic pseudoconstants implies that there

is large number of cognitive representations with varying degrees of faithfulness. Pinary cutoff must serve as a measure for how faithful the p-adic cognitive representation is. Since the cognitive maps are not unique, one cannot even require any universal criterion for the faithfullness of the cognitive map. One can indeed imagine two basic criteria corresponding to self-reprsentations and representations for external world.

The subset of rationals common to the real and p-adic space-time surface could define the resolution. In this case, the average distance between common rational points of these two surfaces would serve as a measure for the resolution. Pinary cutoff could be defined as the smallest number of pinary digits in expansions of functions involved above which the resolution does not improve. Physically the optimal resolution would mean that p-adic space-time surface, 'cognitive space-time sheet', has a maximal number of intersections with the real space-time surface for which it provides a self-representation. This purely algebraic notion of faithfullness does not respect continuity: two rational points very near in real sense could be arbitrary far from each other with respect to the p-adic norm.

One could base the notion of faithfulness on the idea that p-adic space-time sheet provides almost continuous map of the real space-time sheet belonging to the external world by the basic properties of the canonical identification. The real canonical image of the p-adic space-time sheet and real space-time sheet could be compared and some geometric measure for the nearness of these surfaces could define the resolution of the cognitive map and pinary cutoff could be defined in the same manner as above.

The concept of pinary cutoff is crucial for the p-adic counterpart of the Negentropy Maximization Principle [H2]. p-Adic negentropy vanishes identically when all entanglement probabilities are rational numbers with a p-adic norm equal to one. The intuitive view is that if the p-adic norm is smaller than one for all p-adic probabilities, then p-adic negentropy must also vanish. This suggests that p-adic negentropy should be defined using $O(p^k) = 0$ for $k > 0$ pinary cutoff. This definition would fix uniquely the notion of subcritical entanglement in the p-adic context.

11.4 Cognition and intention at elementary particle length scales

The success of p-adic mass calculations [F3, F4, F5] does not leave much room for the interpretations if one identifies p-adic physics as a physics of cognition: cognitive representations must be present already at elementary particle level. One possibility is that cognitive representations are provided by the region exterior to the elementary particle by a map analogous to the canonical identification. An alternative possibility is that p-adic–real phase transitions occur and transform virtual p-adic particle pairs to real particle pairs of zero energy.

This hypothesis allows to understand p-adic length scale hypothesis as resulting from evolution at elementary particle length scales. p-Adic primes near power of prime powers of 2 ($p \simeq 2^k$, k power of prime) would correspond to space-time sheets with especially high cognitive degeracy. If elementary particle horizon has a radius given by the p-adic length scale associated with k, this is indeed the case since the cognitive representations associated with both k and p become possible [E5].

The classical non-determinism of CP_2 type extremals is a second characteristic feature of TGD and essential for the possibility to understand Feynmann diagrammatics topologically. As already noticed, classical non-determinism makes possible also self-referential physics in which physical laws are represented by zero energy states. If one assumes that classical non-determinism gives rise to sensory experiences and perhaps even volition even at the level of elementary particle physics, the only conclusion is that that TGD Universe is conscious and cognitive already at elementary particle level and the success of quantum field theories can be seen is direct signature of this feature.

It must be emphasized that also real space-time sheets are labelled by p-adic primes and the value of prime probably relates to the character of classical nondeterminism associated with the space-time sheet. One natural looking possibility is that the number N of deterministic pieces of the space-time sheet contains the p-adic prime p as a factor.

11.4.1 What about intention at elementary particle level?

TGD predicts also space-time sheets with negative energies. Thus it becomes possible to generate pairs of positive and negative energy particles by p-adic-to-real phase transition. It is also possible to imagine photon emission by p-adic-real-phase transition in which p-adic boson representing line of Feynmann diagram starting from real particle transforms to real one and gives the recoil momentum to the real particle. Thus it would seem that intention could be or have been at work even at elementary particle level. If so the picture of Eastern religions about universe as a product of intentional process might be basically correct and that the anecdotes about yogis able to conjure material objects from vacuum might have some seed of truth in them.

A more conservative vision is that p-adic-to-real phase transitions have already occurred in large time scales at this level so that ordinary matter is relatively stable against intentional action and that topological field quanta of em fields at much longer length scales are subject to p-adic-to-real transformations. Cognitive neutrinos might however form exception in this respect. One must however emphasize that this is mere guess: fractality suggests that the process is occurring still but the effects of intentionality are not visible above time scale determined by elementary particle Compton length scale. What elementary particle physicists are doing would be realization of intentions at much longer time and length scales inducing visible effects at elementary particle length scales (consider only creation of antimatter in macroscopic amounts).

11.4.2 p-Adic-to-real transitions for cognitive neutrino pairs

Cognitive neutrino pairs play a key role in the original model of the memetic code [L1]. Cognitive neutrino pairs are real. The terminology is here not logical: the reason is that the notion of cognitive neutrino pair was introduced long before the idea about p-adic physics as physics of cognition and intention. The members of cognitive neutrino pairs are at different space-time sheets and the one at the cellular space-time sheet has negative energy due to the large interaction energy with the classical Z^0 Coulomb field generated by nuclear Z^0 charges. Cognitive neutrino pairs should form lattice like structures in the direction of geometric time with each pair having a finite lifetime of order millisecond. This is in principle possible by the classical non-determinism of the Kähler action but certainly not in the standard physics framework. Robustness requires a large number of identical temporal sequences of cognitive neutrino pairs forming the analog of a spontaneously magnetized phase.

It has become clear that the model of the memetic code can be realized under much less restrictive assumptions since the notion allows to integrate sequences of quantum jumps to single experience. There is no absolute need for the temporal sequences of cognitive neutrino pairs and the neutrinos could be ordinary neutrinos. The direction of the Z^0 magnetization for cognitive antineutrinos at the cell membrane space-time sheet codes for Boolean truth values and memetic codon corresponds to a temporal sequence of varying directions of Z^0 magnetization, 127 bits altogether. Each bit in the sequence defines a sub-self (mental image). If the bits do not define separate sub-selves, the experience involves averaging over the bits and only the number of bits would presumably matter so that a reduction to a 7-bit code or even 6-bit genetic code would occur. The replacement of the spin direction with magnetization direction guarantees robustness. In this framework speech recognition involves a generation of Z^0 MEs inducing membrane oscillations inside ear and generating memetic codewords. The origin of the internal speech can be also understood if one accepts that motor actions are time reversals of sensory perceptions in an appropriate time scale for MEs. Internal speech would be speech which does not start from speech organs but from some higher level and proceeds to the cortex in a time reversed direction.

Of course, the generation of cognitive neutrino pairs would still be an important control mechanism.

1. The splitting of Z^0 wormhole contacts feeding Z^0 gauge flux between $k = 151$ cell membrane space-time sheet and $k = 169$ cell space-time sheet could generate cognitive neutrino pairs.

2. Z^0 MEs carrying transversal electric and magnetic fields have the sources of the fields near the boundaries of ME, and neutrinos and antineutrinos are one possible realization of the sources besides vacuum currents and wormhole contacts. When the Z^0 ME forms a bridge between $k = 151$ and $k = 169$ space-time sheets, neutrinos of Z^0 ME can flow to $k = 169$ and antineutrinos to $k = 151$ space-time sheet. In the case of nerve pulse generation this bridge formation is

assumed to lower the effective phase velocity of Z^0 ME to that of the nerve pulse. Also Ca^{++} waves and membrane oscillations can be induced by the same mechanism.

It is of some interest to study what one might say about the splitting of the wormhole contacts as a source of cognitive neutrino pairs. Besides the conservation of quantum numbers, the splitting of wormhole contacts is limited by the requirement that space-time surface correspond to the maximum of the Kähler function defined as an absolute minimum of the Kähler action. The creation of a real cognitive neutrino pair generates negative Kähler action associated with the CP_2 type extremals associated with the neutrinos. This action should be somehow compensated. Compensation could be achieved by a transformation in which also p-adic magnetic or Z^0 magnetic field is transformed to a real one. The positive Kähler action associated with magnetic flux tube would give rise to a compensating action.

A quantitative grasp to the situation is obtained by requiring that the magnetic action density per volume is same as the average amount of Kähler action per volume associated with the CP_2 type extremals created in the real-p-adic phase transition. The action is a small fraction of Kähler action associated with full CP_2 type extremal associated with gravitons. In this case simple and very rough estimate shows that if the magnetic field as has strength of order Earth's magnetic field, then the space-time density of CP_2 type extremals is roughly

$$\frac{e^2B^2}{8\pi\alpha} \times V_3cT \sim \epsilon\frac{\pi}{8\alpha_K} \quad , \quad \epsilon = \frac{V}{V(CP_2)} \quad .$$

Here T is the average duration and V_3 is the average 3-volume taken by CP_2 type extremal, $V/V(CP_2)$ is the fraction of the volume of the neutrino CP_2 type extremal from that for a full CP_2 type extremal, which is rather small for all elementary particles. This gives

$$B^2 \sim \frac{\epsilon\pi}{\alpha_K VcT} \quad .$$

If one assumes that there is one cognitive neutrino pair of duration about 10^{-3} seconds per volume defined by the cell membrane p-adic length scale $L(151) \simeq 10^{-8}$ meters, the resulting estimate for the magnetic field strength is roughly $\sqrt{\epsilon}10^{-6}$ Tesla so that Earth's magnetic flux tubes (B is roughly 10^{-4} Tesla in this case) more than compensates the increment of Kähler action. Note that also the generation of gravitons might be possible by the same mechanism. If the volume taken by the cognitive neutrino pair is of order atomic volume as in case of pairs possibly associated with the DNA, the required field strength is roughly $\sqrt{\epsilon}$ Tesla. The transformation of real MEs to the p-adic MEs is constrainted only by energy conservation since the Kähler action vanishes for MEs.

11.4.3 Tests for p-adic physics at elementary particle level

A basic test for the p-adic physics is materialization of intention by p-adic-to-real phase transition. If cognitive neutrinos are indeed responsible for the memetic code, this transformation should be possible even at elementary particle level. In principle (and probably only in principle) one cannot exclude the science-fictive possibility that these transformations could be possible for other elementary particles too. The fact that the effective coupling constants of the fundamental interactions are not genuine constants in TGD framework, suggests also the science-fictive possibility that human consciousness could affect elementary particle properties. A possible effect might be the creation of particle pairs by p-adic-to-real phase transition. Crossing symmetry implies the possibility of real zero energy states such that the particles with negative/positive energies represent outgoing/incoming particles of the particle reaction. One might wonder whether the p-adic variants of these states could be transformed to their real counterparts in a suitable quantum jump. If so, universe could study elementary particle physics using symbolic representations.

11.5 Various aspects of cognition

11.5.1 p-Adic physics and imagination

p-Adic non-determinism makes it natural to interpret p-adic space-time sheets as geometric correlates of intentions and perhaps. The wildest vision generalizing the memetics of Susan Blackmore [38] is

that the world is full so p-adic space-time sheets serving as geometric correlates for plans, expectations, intentions,etc.. and waiting for their materialization to real space-time sheets. It would be natural to guess that p-adic physics is also physics of imagination but one must very carefully define what this means.

It seems that the transformation of the p-adic Z^0 MEs to real ones sets only the initial values of the neural activity leading to a generation of an imagined sensory experience or motor action. If sensory organs are the seats of the primary sensory qualia, one can understand imagined sensory experience as a perception, which does not start from the level of sensory organs but some higher level and gives rise only to cognitive representations. Dreaming and hallucinations would involve a feedback to the primary sensory organs "qualiafying" the cognitive representations. If motor action is essentially a time reversal of the sensory perception in a relevant time scale for MEs then imagine motor actions would differ from real ones only in that they would be initiated from some higher level than muscles.

11.5.2 How dreams and hallucinations relate to sensory experiences?

Dreams could be seen as processes in with cognition is transformed into sensory experience. This would mean that the transformation of p-adic space-time sheets to real mind like real space-time sheets initiates a process leading to imagination or dream depending on the situation. Clearly, the generation of dream would be a process reverse to the generation of cognition from sensory experience [H4]. If primary sensory qualia are realized at the level of sensory organs, then the reversal process continues down to the level of the primary sensory organs and "qualiafies" the cognitive mental images. Rapid eye movements and otoacoustic sounds would be a signature of this qualiafication. Spontaneous movements during dreaming would in turn be the signature of "qualiafication" of the imagined motor activities. This view about dreams as a de-abstraction process have been represented already earlier and explains nicely the observations of Claude Rifat about lucid dreaming [59]. The strange piecewise logical consistency of dreams is indeed consistent with the p-adic non-determinism. De-abstraction process could be initiated from some higher level of self hierarchy so that dreams could really be messages from higher level selves.

This view about dreaming is in accordance with the recent observations (reviewed in [23]) that dreaming is not produced by random inputs from brain stem to cortex but is cognitive skill learned gradually during infancy. The most primitive dreams represent static pictures, then these pictures become dynamical, and at the age of about eight the dreamer becomes a participant of the dream. In lucid dreaming the dreamer has taken active role in transforming cognitive representations to sensory experiences.

One must actually distinguish between two kinds of "hallucinations": a genuine sharing of sensory mental images involving no "qualiafication" and interpretable as telepathy, and the receival of cognitive information, which is then qualiafied by the receiver like during dreaming. The presence/absence of a feedback to the sensory organs allows to discriminate between these options. The semitrance model for the bicameral mind is based on the idea that these experiences are communicated by higher levels of the self hierarchy during semitrance. This communciation could be purely telepathic.

11.5.3 Are cognitive representations generated from sensory input?

Brain certainly generates symbolic representations from the real sensory input and from p-adic cognitive representations. Essentially a transformation of action to intention and of a real symbolic representation to a p-adic cognitive representation would be in question. The first question to be answered is whether this transformation is needed.

1. The transformation of action to intention could be seen as (subjective) time reversed volition. This kind of process could serve as a healing and error correction mechanism.

2. The experience of understanding accompanies naturally p-adic-real bound state entanglement. The transformation of symbolic representations to cognitive ones might be needed for the purpose of understanding. More generally, meaning might result only via the symbolic to cognitive transformation.

3. Symbolic representations could be enough to decompose the world to objects and actions. Objects and actions would naturally correspond to real space-time sheets serving as correlates for

mental images (sub-selves). On the other hand, one might argue that the ultrametricity of the p-adic topology making p-adic world 'granular' might be essential for this decomposition into objects. A possible fundamental definition for an spatiotemporal object could be as a region of p-adic space-time for which integration constants of field equations are genuine constants.

One can consider two kinds of mechanisms leading to the generation of cognitive representations from symbolic representations/intentions from actions.

1. The first mechanism correspond to a phase transition changing real mind like space-time sheet representing the sensory input to a p-adic cognitive space-time sheet. The transformation of a real ME coding a nerve pulse pattern to a p-adic ME is a possible candidate for this kind of transformation. Conservation laws require that this process necessary involves a transition of a real system. For instance, a positive/negative energy ME could be transformed to a p-adic ME. These two options would correspond to a transformation of a sensory input to cognition and undoing what was already done.

2. Second mechanism is based on the idea that real and p-adic space-time sheets have a common boundary region which is 3-dimensional and consists of common rational points. If classical field equations where completely deterministic the initial values on the boundary region would determine the behaviour in the interior more or less uniquely. Now the situation is slightly different since it is a subset of rational points of the imbedding space which are common to real and p-adic region, because there is pinary cutoff involved, and because p-adic non-determinism is also present. The idea that the generation of a sensory representation via 'common rationals on boundary' mechanism has gradually evolved to the nervous system is attractive because sensory representations are basically generated by the input coming from the outer boundary of organismm.

11.5.4 Cognition, sensory experience, and Boolean mind

Thoughts have not color and pure thoughts seem to be free of emotions, with aesthetic experiences induced by abstract ideas being perhaps an exception. Pure thoughts involve often the experience that something is true or false but not beautiful or ugly or right or wrong. These simple observations provide tests for the identification of the p-adic physics as physics of cognition and for the model of sensory qualia, Boolean qualia, and emotions. These observations also lead to a concrete identification of the physical realizations for the Boolean algebras of ethics, aesthetics, and logics.

Cognition has no colors

Sensory qualia have been identified as averages of quantum number increments associated with the quantum jump sequence defining the subself representing sensory mental image. Quantum number increments relate to the quantum fluctuating configuration space degrees of freedom. Since complete localization occurs in all p-adic configuration space degrees of freedom in each quantum jump, these degrees of freedom are purely classical and one cannot even speak of quantum number increments. There are thus no p-adic sensory qualia and cognition is colorless. This means that all p-adic configuration space degrees of freedom can be regarded as geometric degrees of freedom in the classical sense of the word.

Does cognition involve emotions?

Emotions have been identified as characterizing the rates of change for the entropies associated with various quantum number increments in quantum jump sequence determining self. Since there are no quantum number increments in p-adic configuration space degrees of freedom, corresponding emotional component is absent from cognition.

In p-adic quaternion conformal fermionic degrees of freedom the situation might be different. If one regards p-adic entropy as the fundamental quantity, the notion of sign of the entropy gradient does not make sense. In fact, the entropy gradient vanishes since p-adic piecewise constant functions have vanishing derivative. In the case that the p-adic entropy can be identified as an algebraic number (rational entanglement coefficients), one could argue that it is the real counterpart of the p-adic

entropy that matters. If so, cognition is accompanied by emotions. What makes this interesting is that positive entanglement negentropy is possible in the p-adic context and could indeed increase or decrease during the sequence of quantum jumps. The real counterpart of the p-adic entanglement entropy can both grow and decrease and could give a significant contribution to the emotion. The experience of understanding/confusion would correspond to positive/negative entanglement negentropy and the growth/decrease of this negentropy would give rise to a positive/negative emotion.

It might be possible to assign some kind of emotions to the real entropy gradient associated with the increments of the p-adic configuration space coordinates (all of which are zero modes and effectively classical degrees of freedom). For instance, the aesthetic experience accompanying imagining an abstract geometric shape might represent this kind of emotion but one can always argue that it results from the association with genuine sensory experiences. The objection to this kind of assignment is that in the p-adic case even the notion of entropy gradient is questionable since the p-adic norm of entropy is discrete and need not change at all. Furthermore, p-adic numbers are not well ordered so that one cannot assign a definite sign to the gradient of the entropy determining in the real context whether emotion has positive or negative tone. Pain and pleasure are absent from the p-adic world of cognition.

Logic, aesthetic, ethics and configuration space spinors

The first guess is that Boolean qualia correspond to fermion number and that true/false (or more generally, right/wrong or beautiful/ungly) corresponds to fermion number one/zero for a given mode of fermion. Fermion number conservation however requires that fermionic and antifermionic Boolean algebras appear as pairs so that the net change of fermion number is always zero. 8-dimensional chiral invariance in turn implies that lepton and baryon numbers are separately conserved. Thus the state created by the unitary operator U is a superposition of states obtained by acting on the initial state by configuration space sigma matrices which are bilinears in fermionic and antifermionic oscillator operators having vanishing lepton and baryon numbers. It is however quite possible that the members of the fermion pair created or annihilated in quantum jump belong to space-time sheet representing different selves so that Boolean qualia indeed correspond to fermion number 1/0.

In any case, Boolean qualia must relate to the changes of the spin quantum numbers of the configuration space spinors and always have interpretation as pair of Boolean qualia associated with fermion and antifermion. If this is the case, Boolean qualia correspond to various spin quantum numbers for configuration space spinors. This is indeed the assumption made in the model of cognitive neutrinos [M6]. Somewhat confusingly, I have called real neutrinos cognitive neutrinos in earlier work.

Spin quantum numbers associated with the quaternion conformal symmetry are non-trivial also in the p-adic degrees of freedom. These degrees of freedom are zero modes associated with the elementary particle horizons rather than with the purely geometric degrees of freedom contributing to the configuration space metric. Kac-Moody algebras associated with Poincare, electroweak and color symmetries are in question. Thus p-adic cognition has thus Boolean element which should correspond to completely un-emotional 'true/false', or even more neutrally, to '1/0'.

Also aesthetic 'beautiful/ugly' and ethic 'right/wrong' statements have Boolean algebra structure and can be seen as true/false type statements accompanied by emotional color. Aesthetic 'beautiful/ungly' statements naturally correspond to sensory experience and thus to the spin degrees of freedom associated with the configuration space metric and are absent from cognitive sector: hard science does not make any aesthetic statements. Moral 'right/wrong' statements would in turn correspond to real quaternion conformal spin degrees of freedom and reduce to '1/0' statements in p-adic degrees of freedom.

11.5.5 p-Adic teleportation, replication of memes, and morphic fields

The notion of quantum teleportation is one of the ideas accompanying the development of the theory of quantum computation. The notion of p-adic teleportation suggests itself very naturally as a more flexible mechanism of teleportation. p-Adic teleportation in fact provides a model for the replication of memes and Sheldrake's morphic fields can be seen as a generalization of memetics in this framework.

p-Adic teleportation

The idea is to teleport only the p-adic cognitive model of the object rather than the object itself.

1. The description of object is p-adic space-time sheet representing the cognitive model of the real object. Object is thus basically 4-dimensional. This cognitive model could be constructed most naturally by p-adic-to-real phase transition. This phase transition could be followed by a replication which is in the p-adic case possible by zigzag type motion with temporal reflection at each temporal turning point of the path. In this manner one obtains time-reversed and ordinary copies of the object.

2. The zigzag curve makes it possible to transfer the object effectively instantaneously over arbitrarily long distances so that one can speak of p-adic telepathy. At the receiving end the p-adic cognitive representation must be transformed back to a real representation. This requires that the receiver and sender are sufficiently similar so that this transformation process is possible.

3. An objection against the time reflection is that there should be some control mechanism forcing it to occur in a predictable manner. If cognitive space-time sheets is topologically condensed on larger mind like space-time sheet with some finite temporal duration, the reflection could occur automatically on the temporal boundaries of the larger space-time sheet.

p-Adic teleportation between different brains could give rise to rather dramatic effects. I could admire the beautiful landscapes in a distant corner of globe where my friend is visiting or share even his/her feelings and emotions. Again one must ask, whether this actually occurs to some extent: we certainly have the ability to feel empathy. Perhaps I could also teach some practical motor activity (one of those very few I handle) by hand to my friend by teleporting the imagined motion.

One could quite well argue that p-adic teleportation is precisely what we are at some basic level doing all the time when we communicate plans and intentions to our fellow human beings using written and spoken language. Typically, the drawings of a building could be seen as this kind of communication involving several symbolic real–p-adic steps and the realization would involve a lot of creative imagination.

Replication of p-adic cognitive representations by p-adic teleportation

Memes are in central role in the theory of Susan Blackmore [38] and p-adic space-time sheets are excellent candidates for memes understood in a more general sense. Contrary to the vision of Susan Blackmore, memes would be conscious selves rather than unconscious deterministically behaving objects, and brain would not be an un-conscious machine used by memes but serving as conscious transformation vehicle materializing cognitive representations to real action and vice versa.

Although the notions of the meme and meme replication are very attractive, the mechanism of imitation is only partially known. The so called mirror neutrons are certainly an important of it. In the p-adic context learning by imitation could be understood as a two-step process. First of all, a high-level p-adic cognitive representation is formed as in sensory perception. Secondly, this representation is transformed back to motor action to yield an imitation. Thus it could be that the enhanced ability to generate p-adic-to-real transformations in prima vista manner distinguishes between humans and animals.

1. p-Adic teleportation as means of meme replication and transport

p-Adic teleportation could make possible a replication mechanism of memes at microscopic level. A p-adic space-time sheet, say a p-adic massless extremal, can define zigzag type piecevice continuous path in the space-time: first travelling into the direction of the future, reflecting then to the direction of the past, then again to the direction of the future,... This motion would yield copies of the meme and if some copy is transformed to a real action, an imitation results. One could imagine that sensory input creates first a real symbolic representation which is then transformed to a p-adic cognitive representation which then replicates and is transformed back to symbolic representation. Also symbolic representations can replicate and this might be more reliable manner to replicate since p-adic non-determinism is eliminated now. Inhibition and double inhibition can make possible replication of the symbolic representations. For instance, the replica could be associated with the mirror neutrons.

2. Time reversed cognition

p-Adic teleportation predicts that time reflection yields time reversed cognitive representations. Also spatially reflected cognitive representations could result in spatial reflections. Sama applies to

symbolic representations. The observation of these representations could serve as a test of the theory. There is indeed some evidence for this rather weird looking time and spatially reversed cognition.

1. I have a personal experience supporting the idea about time reversed cognition. During the last psychotic episodes of my 'great experience' I was fighting to establish the normal direction of the experienced time flow.

2. The occurrence of mirror writing is well known phemonenon [48]. Spatial reflections of MEs are also possible and might be involved with mirror writing.

3. Reverse speech would be also a possible form of reversed cognition. Time reversed speech has the same power spectrum as ordinary speech and the fact that it sounds usually gibberish means that phase information is crucial for storing the meaning of speech. Therefore the hypothesis is testable.

3. Reverse speech

Interestingly, the Australian David Oates claims that so called reverse speech is a real phenomenon [53], and he has developed entire technology and therapy (and business) around this phenomenon. What is frustrating that it seems impossible to find comments of professional linguistics or neuroscientits about the claims of Oates. I managed only to find comments by a person calling himself a skeptic believer but it became clear that the comments of this highly rhetoric and highly arrogant commentator did not contain any information. This skeptic even taught poor Mr. Oates in an aggressive tone that serious scientists are not so naive that they would even consider the possibility of taking seriously what some Mr. Oates is saying. The development of science can often depend on ridiculously little things: in this case one should find a shielded place (no ridiculing skeptics around) to wind tape recorder backwards and spend few weeks or months to learn to recognize reverse speech if it really is there! Also computerized pattern recognition could be used to make speech recognition attempts objective since it is a well-known fact that brain does feature recognition by completing the data into something which is familiar.

The basic claims of Oates are following.

1. Reverse speech contains temporal mirror images of ordinary words and even metaphoral statements, that these words can be also identified from Fourier spectrum, that brain responds in unconscious manner to these words and that this response can be detected in EEG. Oates classifies these worlds to several categories. These claims could be tested and pity that no professional linguist nor neuroscientist (as suggested by web search) has not seen the trouble of finding whether the basic claims of Oates are correct or not.

2. Reverse speech is complementary communication mode to ordinary speech and gives rise to a unconscious (to us) communication mechanism making lying very difficult. If person consciously lies, the honest alter ego can tell the truth to a subself understanding the reverse speech. Reverse speech relies on metaphors and Oates claims that there is general vocabulary. Could this taken to suggest that reverse speech is communication of right brain whereas left brain uses ordinary speech? The notion of semitrance used to model bicameral mind suggests that reverse speech could be communication of higher levels of self hierarchy dispersed inside the ordinary speech. There are also other claims relating the therapy using reverse speech, which sound rather farfetched but one should not confuse these claims to those which are directly testable.

Physically reverse speech corresponds to phase conjugate sound waves which together with their electromagnetic counterparts can be produced in laboratory [20, 21]. Phase conjugate waves have rather weird properties due the fact that second law applies in a reversed direction of geometric time. For this reason phase conjugate waves are applied in error correction. TGD based description of both electromagnetic and sound wave phase conjugation is based on negative energy space-time sheets representing classically electromagnetic fields and Z^0 fields [G3]. In fact, the existence of phase conjugate sound forces the conclusion that Z^0 MEs are space-time counterparts of sound waves and that the strength Z^0 electric field determines the amplitude of sound wave. Hence the notion of classical Z^0 force finds a completely operational meaning. Negative energy topological light rays are in a fundamental role in the TGD based model for living matter and brain, and the basic mechanism of

intentional action relies on time mirror mechanism utilizing the TGD counterparts of phase conjugate waves. In particular, Z^0 MEs generate nerve pulse patterns so that their negative energy counterparts could generate the time reversed nerve pulse patterns. Thus it would not be surprising if time reversed variants of nerve pulse patterns generating ordinary speech could be produced by brain. These would in turn induce phase conjugates of the sound wave patterns associated with the ordinary speech.

A connection with the ideas of Sheldrake

In [I1] I have discussed a possible TGD based justification of Sheldrake's ideas about learning at the level of species. The discussion can be easily rephrased in terms of p-adic cognition and p-adic teleportation and leads to a more detailed variant of the original model.

If one assumes that memes correspond to p-adic cognitive representations, that the replication of memes by zigzag mechanism is possible, and that MEs involved can have even sizes of order Earth size, it is not too difficult to imagine how species memory could be realized. p-Adic space-time sheets take the role of the morphic fields in TGD framework and represent habits, skills, ideas,... Susan Blackmore would call these morphic fields memes but basically only a naming convention and generalization is in question (amusingly, skeptics honourize Sheldrake as a pseudoscientist but Blackmore as a serious scientist, perhaps because she has empasized her skepticism in the publicity!).

The meme associated with the development of a particular skill could be realized in a particular brain and replicate itself. When the replicas would encounter other brains of the same species by p-adic teleportation, the skill could be manifested as a real action and lead to learning without direct the mediation of a direct sensory communication. Sheldrake's theory thus generalizes memetics and thus make Sheldrake pseudo scientist. That a given meme could be realized only in brains of the same species might be understood in this framework by using resonance argument: morphic resonance is the notion used by Sheldrake. It is also possible that stochastic resonance [17] to be discussed later in more detail could be involved with the morphic resonance. The individuals that learned the habit first, need not even live anymore since p-adic memes remain and replicate by zigzag mechanism even when the physical body dies. Amusingly, TGD predicts that the memes could travel also in the direction of geometric past so that also the geometric past could learn the skill! Creativity would obviously correspond to the p-adic non-determinism. Memes are continually changing and those which are transformable to real action are realized and correspond to discoveries.

11.5.6 Learning

There are many forms of learning. Although the learning by associations is perhaps the simplest form of learning, even logical reasoning might be basically rely on sequences of associations. Learning by trial and error is second mode of learning. Imitation in in turn a higher, essentially social, form of learning. Susan Blackmore believes that imitation is a characteristically human form of learning and sees imitation as a replication of memes. There is however evidence that also animals are able to imitate although imitation is certainly not the dominating form of learning. p-Adic teleportation already discussed could be fundamental mechanism in this kind of learning. Learning as construction of cognitive models is basic view of Piaget and of constructivists and fits nicely with the idea about p-adic physics as physics of cognition.

Associative learning

It is not clear whether there is any need to assign any cognition to these associations when they occur completely automatically. The p-adic representations, if needed at all, for these associations $A \to B \to ...$ could be regarded as a space-time sheet consisting of deterministic pieces representing A, B,... Perhaps the learning of rules $A \to B$ about the behaviour of the external world might correspond to establishment of this kind of p-adic cognitive representations. The generation of a model of the external would could also correspond to a formation of much more detailed p-adic space-time sheets for which p-adic pseudoconstants are gradually transformed to genuine constants. Only very limited amount of information about this p-adic world model need become conscious.

Trial and error

At least higher level learning involves an evolution of a cognitive model. Learning by trial and error is a good example of this. The naive expectation is that p-adic cognitive representation can be transformed to real action if p-adic pseudoconstants are actual constants. If this is true, then the learning of a skill by trial and error can be understood as a gradual development of a p-adic cognitive representations such that p-adic pseudo constants become genuine constants. This is in accordance with the fact that if skill is well-learned, a 'flow-state' in which performance is almost unconscious and occurs 'naturally' results. The testing of the learned skill serves obviously as a feedback loop modifying the cognitive representation. This means changing the values of the pseudo constants of the imagined p-adic action.

Constructivism

The basic vision of constructivism is that higher level learning means gradual construction of cognitive representations, maps or schemes. This means that the world is seen as consisting of objects and events classified into categories having mutual relations. Also a dynamical model of world involving rules for the behaviour of the world develops. The ultrametricity of the p-adic topology was proposed already by Parisi [19] to make possible classification of objects into categories. p-Adic pseudoconstants define a natural division of p-adic space-time sheets into four-dimensional objects (events). The emergence of the causal models is automatic and due to the fact that p-adic physics obeys the same field equations as the real physics.

Piaget entered by empirical means to his model of learning which is rougly the following.

1. The first two life years correspond to a sensorimotor period during which childs builds a set of concepts about world and a model for how it works. During this period sensory world and real world are identified (child believes that the object does not exist if it is not in the visual field). This period could be identified as period for the formation of symbolic p-adic cognitive representations coding layman physics in terms of p-adic physics for cognitive images of real world objects.

2. During pre-operational stage (2-7 years), child is not yet able to conceptualize abstractly and needs concrete situations.

3. During the period of concrete operations (7-11 years) the child starts to conceptualize, creating models that explain her physical experiences. Abstract problem solving becomes possible: for instance, mathematical equations can be solved with numbers, not just by using concrete objects (say counting by fingers).

4. During the period of formal operations (11-..) the cognitive abilities of child are like those of adult. For instance, abstract reasoning and formal problem solving of mathematical equations using abstract variables rather than only numerical values becomes possible.

Various stages in the development could be seen as gradual establishment of p-adic cognitive representations based on reality testing leading gradually to relatively stable and realistic cognitive representations.

Social aspects of learning

The social aspects of learning are certainly of utmost importance and higher level learning can be also seen as a fundamentally social phenomenon. The notion of self-hierarchy suggests that learning process occurs at several levels of self hierarchy simultaneously and involves communications between various levels. For instance, the learning of social behaviour and development of a model of self as seen by others might involve this kind of interactions in an essential manner. Imitation can be seen as an important mechanism of social learning: Susan Blackmore raises meme replication as the fundamental process instead of learning. Sheldrake's morphic fields would make possible even more general form of learning. As far as p-adic cognition is considered, the same mechanisms are at work at each level and p-adic teleportation makes in principle possible both meme replication and the learning at the level of species.

11.5.7 Some special aspects of cognition from p-adic point of view

In the following some basic aspects of cognition like the formation of concepts and classification into categories, long term memories, logical reasoning, and problem solving are discussed.

Formation of concepts

The most natural model for the formation of concepts is as temporal ensembles of sufficiently similar mind like space-time sheets (real or p-adic) defining an ensemble of sub-sub-selves experienced as average subself (mental image). The idea about concept as average is is accordance with the fact that conceptual thinking emerges gradually when child gathers experiences.

The observations of Claude Rifat [59] about lucid dreaming suggest that lucid dreaming is a de-abstraction process in which lucid dreamer goes one level lower in self hierarchy and experiences the instances giving rise to a particular concept as separate mental images. For instance, the experience of this kind could consist of a set of clocks seen by the subject person during some period of his lifetime. This transformation would involve also p-adic-to-real phase transition transforming cognitive representation to sensory image.

The basic question is whether conceptualization in the sense of classification and averaging can occur both at real and p-adic level. If one assumes that the world of pure sensory experience does not consist of objects, then concepts emerge at cognitive level only and are averages over p-adic sub-selves forming of p-adic subself. The averaging of purely sensory experiences represented by real mind like space-time sheets would not give rise to anything useful in this picture. A more general view is objects correspond to sub-selves of subself, and that concepts make sense at both cognitive and sensory level. At sensory level emotions could be the counterparts of concepts and emotional intellect would correspond to emotional conceptualization. Emotions indeed represent in a well-defined sense the average color of a pixel in a picture containing large number of pixels. Thus cognition-emotions dichotomy would correspond to the p-adics-reals dichotomy.

How cognitive are long term memories?

It is known that purely visual memories have a very short duration whereas conceptualize visual scene consisting of objects can be remembered for much longer time. This suggests that long term memories are realized as p-adic space-time sheets rather than real sensory space-time sheets. This would also explain why our sensory experience is located around a definite value of geometric time whereas as conceptual memories are scattered around entire life cycle. There are however also episodic, almost relived long term memories and these memories could be perhaps regarded as genuine multitime sensory experiences perhaps resulting in p-adic-to-real transformations of cognitive space-time sheets responsible for conceptual memories.

Of course, p-adic cognitive representations in principle make possible to scale down of the conceptual representation of the entire life cycle in a fraction of second and it is an open question whether conceptual memories result as averages of the p-adic sub-sub-selves over life cycle or whether temporal p-adic scaling contracting the lifehistory to a pocket size could be involved. p-Adic fractality suggests the possibility of this kind of hologram like representation.

Reasoning based on temporal logic

p-Adic space-time surfaces allow representations of the temporal logic as rules of type $A \to B$. Various instances A could be represented symbolically as standard irreducible pieces of the p-adic space-time surface characterized by genuine integration constants. Logical reasoning could be based on the generation of this kind of surfaces. Reliability could be achieved by using ensembles of this kind of surfaces representing causation sequences $A \to B \to ....$ [H7]. Replication of cognitive representation by the zigzag mechanism could generate ensembles of memes. These sequences are by no means stable and can change in quantum jumps. Thus some kind of stabilizing mechanism is required. Perhaps some kind of reality testing mechanism based on sensory input is at work. Logical consistency is a higher level test of this kind.

Problem solving

p-Adic cognition suggest a formal definition for the problem solving as a process in which one tries to find a p-adic space-time surface connecting initial p-adic space-time surface with the final one. This surface is constructed using some rules. In case of a learned skill this space-time surface corresponds to p-adic constants which are genuine constants and thus realizable as real space-time surface by phase transition. In case of a mathematical proof the p-adic space-time surface would perhaps be constructed from standard pieces (symbols) with genuine integration constants representing symbolically the steps of the deduction sequence and using the rules $A \to B$ of the cognitive model of the mathematical system. A mouse in a maze might construct and memorize by trial and error a p-adic cognitive representation of the maze with rules stating which branchings lead to a dead end.

11.6 Empirical evidence for p-adic cognition?

If p-adic physics is physics of cognition and if also real space-time sheets are characterized by p-adic prime (p-adic length scale hypothesis), p-adic physics should have clear experimental signatures. In particular, if cognition is present already in elementary particle length scales, it should not be too difficult to identify the finger prints of p-adic physics. In the sequel some possible candidates for these finger prints are discussed.

11.6.1 Quantization phenomena in psychophysics

p-Adicity might provide understanding of some phenomena of psychophysics related to the discrimination between different intensities of stimuli and to threshold phenomena of sensory perception. I am grateful to Robert Gazerro for telling me about these strange effects.

1. When over-learning occurs in tasks involving temporal discrimination, the memory images about the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [34] such that the plateaus where response remains constant are octaves of each other. This suggests that the memory image about the sensation depends only on the 2-adic norm of the 2-adic image of the ratio I/I_0 of the intensity of the stimulus to the threshold stimulus under canonical identification.

   This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jumpwise replacement of the n:th harmonic by n+1:th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of overlearning or neurons involved act unisono and the underlying 2-adicity is not masked anymore. At the level of ELF selves this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier.

   There is a an analogous quantization effect related to the discrimination of brightness about which I learned from Robert Gazerro. If one compares brightnesses of object at two subsequent values of time, one can distinguish the brightness difference if the ratio of brightnesses is above 2. If one compares two objects simultaneously, one can distinguish between brightnesses whose ratio even when it is below 2. This would suggest that cognitive memory about brightness is coded by the 2-adic norm of 2-adic counterpart of brightness whereas experience about brightness corresponds to a real number. Note that in case of discrimination of a pitch of a sound situation is different although also now two subsequent frequencies can be discriminated only if they differ by some minimum amount.

2. According to Robert Gazerro, the resolution of the sensory experience seems to be of order $\Delta I/I \sim 1/100$, where I is the intensity of the stimulus. When the signal-to-noise ratio is below roughly 100 visual picture is regarded as having poor quality. The natural order of magnitude estimate for the relative accuracy of p-adic cognition is $\Delta I/I = 1/p$. This number provides also

an estimate for the relative accuracy of perception involving real space-time sheets characterized by p-adic prime p. Since $p = 127$ can be interpreted as p-adic prime associated naturally with genetic code, one might think that $p = 127$ is fundamental p-adic prime in living matter. Thus a possible explanation of magic number $\Delta I/I \sim 1/100$ is in terms of 127-adicity.

11.6.2 Metrology and 2-adicity

Usually theoretical physicists would regard metrology as a practical science of unit conversions and as something rather un-interesting both from the view of mathematics and physics. The discussions with Robert Gazerro however taught me that some intriguing phenomena of metrology challenge the standard intuitions and suggest that 2-adic cognition might directly manifest itself in computerized metrology. Unfortunately, this phenomenon represents common implicit metrological wisdom and I cannot represent formal references to this phenomenon. Of course, the reader can take the following considerations as a model for how 2-adic cognition might reveal itself in a rather dramatic manner in the science of metrology. Also the reader is allowed the liberty to ponder whether I am cheating or not!

In practical metrology a complex system of references (essentially natural units for the measured signals) is necessary to convert the directly measured signal to a value of the observable that one is interested in. This involves a set of conversion factors translating different units to each other. The simplest example of a reference is standard meter. The values of these references are not constant but drift all the time and must be updated continually. The reader can take what follows as an excerpt from some science fiction if he/she wishes.

The puzzling observation is following.
If one makes a sloppy experiment using un-updated conversion factors, one tends to obtain a result which on the average is related by a factor of $X = 2$ or $X = 1/2$ to the result obtained by a measurement using updated conversion factors. There are two strange aspects involved.

1. The unreasonably high value of X. This is so because the values of the references are rather stable by definition and therefore the net variation in the measurement accuracy should be determined by the sum of the variations of the references if the measurement of the conversion factor can be regarded as a classical measurement and provided that one can neglect the human factor.

2. The quantization of X, which brings in mind the difficulty of distinguishing between different octaves of musical note, suggests that 2-adic cognition might be involved.

Somehow it seems that some of the conversion factors involved becomes too large by a factor 2 or too small by a factor 1/2: as if the most significant bit in the binary representation of the conversion factor in the computer memory would come out wrongly in the sloppy measurement. If this indeed occurs, it can be only due only to some external agent interfering with the data storage of the conversion factor.

In the sequel a simple (and highly idealized) model explaining the large value of X and its quantization is discussed. This model is based solely on the properties of the 2-adic canonical identification interpreted as cognitive map. The model is just for definiteness model and allows modifications.

Cognitive interference as a mechanism giving rise to very large errors in conversion factors

The model for the mystery of the large errors in the determination of the conversion factor is based on the following assumptions.

1. Every measurement is quantum measurement. In particular, the determination of a conversion factor between two references is quantum measurement. In the ideal situation this means that the systems R_1 and R_2 representing the two references are entangled before the measurement, and that this entanglement is reduced when the value of the conversion factor is determined. The conversion factor is represented as a bit sequence in the computer memory and also the construction of this representation can be regarded as a quantum measurement assigning to the physical quantity expressing the conversion factor a bit sequence in the computer memory, call

it C. The drifting of the references and conversion factors follows from the fact that in each quantum jump these systems entangle during the unitary process U and disentangle during the state function reduction phase of the quantum jump. The system in question is thus $R_1 \otimes R_2 \otimes C$ and in an entangled state before the measurement of the conversion factor and in a disentangled state after the measurement. It would however seem that this drifting cannnot cause large measurement errors.

2. The representation of the measurement result in the computer memory is as a bit sequence. In particular, the average value $\langle X \rangle$ of the conversion factor X is used as a unit for the conversion factor:

$$Y = \frac{X}{\langle X \rangle} \ ,$$

so that the number stored in the computer memory is near unity and fluctuates around it. This assumption is rather strong and could perhaps be weakened.

3. The measurement error is basically due to the interference of some conscious 2-adic cognitive system C_2 with the ideal measurement. That 2-adic cognitive system is in question is natural if this system is associated with the computer using binary representation for numbers. This system could represent kind of a primitive cognitive model of the computer about its own state. If the computer uses prime p as a base then the cognitive system in question would be naturally p-adic.

   The interference of the cognitive system C_2 means that there is cognitive entanglement between the system $R_1 \otimes R_2$ formed by the references and C_2 and between C_2 and computer C so that one has the entangled sequence

$$R_1 \otimes R_2 \otimes C_2 \otimes C$$

   instead of the sequence $R_1 \otimes R_2 \otimes C$ obtained in the ideal case. Thus the large and quantized measurement error would be due to the 2-adic cognitive consciousness of the computer and serve as a direct signature of it. C_2 could represent some other cognitive system, may be some part of the experimenter's brain.

4. $(R_1 \otimes R_2) \otimes C_2$ entanglement mediates a mapping of the quantum state representing the conversion factor to its p-adic counterpart. In the same manner $C_2 \otimes C$ entanglement maps the cognitive image of the conversion factor to a bit sequence in the computer memory. These maps must be such that the presence of the cognitive entity C_2 perturbs minimally the original system and at the limit of ideal cognition does not affect at all the measurement result.

5. Canonical identification I is defined as

$$I : x_p = \sum x_n p^{-n} \to \sum x_n p^n \equiv x_R$$

   The inverse I^{-1} of the canonical identification has precisely the same form. Canonical identification is in a fundamental role in p-adic mass calculations and forces to conclude that cognition is present already at elementary particle level. This suggestw the interpretation of canonical identification as a cognitive mapping mapping p-adic observables to real ones and vice versa.

The requirement that ideal cognitive interference does not affect the computer representation of the conversion factor is satisfied if the map defined by the entanglement corresponds to the inverse I^{-1} of the canonical identification as the map mediating cognitive entanglement in the case of $(R_1 \otimes R_2) \otimes C_2$ and to the canonical identification I in the case of $C_2 \otimes C$. Also more general cognitive maps $g \circ I \circ f$, where f resp. g is an analytic mapping of p-adic resp. real numbers satisfying $f(1) = 1$ resp. $g(1) = 1$ yield essentially the same result at the limit of a maximally sloppy measurement.

If C_2 is always involved in the measurement, the notion of a sloppy measurement might be translated to a cognitive representation with a minimal precision. C_2 could correspond to a cognitive subself of the experimenter or self (in the sloppy case only marginally) interested in performing the

experiment. C_2 could also represent the intention to perform the measurement and would be transformed to a real space-time sheet when the measurement is performed. In a sloppy experiment C_2 has minimal cognitive resolution.

If the resolution of the cognitive mapping is ideal, there is no pinary cutoff. This means that the values $1-\epsilon$ and $1+\epsilon$ of the conversion factor are mapped to bit sequences representing very nearly the same real numbers. Cognition has however a finite precision which means that the map $x_R \to x_p$ involves a pinary cutoff. This finite precision explain the mysteriously large value of the ratio $X(sloppy)/X(precise)$.

Explanation for the mysterious factor two

The solution of the $X = X(sloppy)/X(precise)$ mystery relies on the fact that canonical identification $R \to R_p$ is discontinuous at $x_R = p^n$ and the ratio of the p-adic norms for $x_p(x_R = p^n_-)$ and $x_p(x_R = p^n_+)$ ($p^n_\pm$ means $lim_{\epsilon>0\to 0} p^n \pm \epsilon$) is

$$\frac{x_p(x_R = p^n_-)}{x_p(x_R = p^n_+)} = 1/p \ .$$

In 2-adic case this ratio is 1/2. In the presence of C_2 characterized by a cognitive binary cutoff this discontinuity indeed induces large measurement error. The worst situation is encountered when only the lowest pinary digit is included in the cognitive representation provided by C_2. In this case the numbers $1-\epsilon$ and $1+\epsilon$ are mapped to 1/2 and 1 respectively.

This allows to understand why the ratio $X = \frac{X(sloppy)}{X(precise)}$ tends to be $X = 2$ or $X = 1/2$. In a sloppy experiment without the calibration of the references just before the experiment, it may happen that the value of the reference has drifted from its value of say $1+\epsilon$ to $1-\epsilon$ (or vice versa) after the last calibration. If the cognitive accuracy is smallest possible in the sloppy measurement, one indeed obtains $X = 1/2$ ($X = 2$). In a precise measurement following immediately after calibration the situation is different and one obtains much better accuracy since the difference $Y - 1$ has not yet had time to change its sign so that large error is not induced.

Summary and tests

The mysteriously large and quantized valuue for the ratio of the results of the sloppy and precise measurements provides support for several basic assumptions of TGD inspired theory of consciousness and cognition.

1. The assumption of the macroscopic quantum coherence implying that all measurements are quantum measurements, in particular the determination of the conversion factor between two references and the translation of the measured value of the conversion factor to a bit sequence in the computer memory.

2. The presence of 2-adic cognition in the computer system, in brain, or some other system entangling with the computer. C_2 could be interpreted as an intention to perform the measurement.

3. Canonical identification map as the fundamental cognitive map and is characterized by a pinary cutoff giving rise to a finite cognitive resolution.

The proposed model is the simplest one that can imagine several variants and alternative interpretations. The model makes the following easily testable predictions.

1. If one uses some other unit than the average value of the conversion factor, which is not related to the average value by scaling by a power of 2, the effect should be reduced dramatically since the binary representation of the conversion factor is not so unstable anymore. For instance, if one uses $(2/3)\langle X\rangle$ as a unit, the value of Y is around 3/2 and the variation is much smaller in a sloppy experiment.

2. If one represents the conversion factor in the computer using base p, the maximal ratio Y equals to $Y = p$ or $Y = 1/p$. For instance, for $p = 3$ one has $Y = 1/3$. Thus one can test the role of the computer and base for the number system.

11.7 How p-adic cognition is realized at brain level?

Symbolic (cognitive in neuroscience context) functions like perception, memory and language are based on parallel and highly distributed information processing. One of the major unresolved questions of brain science is how the information can be integrated and how coherent representational states can be established. Temporal binding has been suggested as a mechanism making this possible. The synchronized neuronal firing has been proposed as an underlying mechanism of temporal binding inside and between various cortical areas. The assemblies of neurons firing synchronously could even define neuronal correlates for objects of perceptive field. Synchrony mechanism would apply also to motor actions and allow selection of perceptually and behaviourally relevant information. Temporal binding has been proposed by Crick and Koch as a necessary and sufficient condition for the generation of conscious percepts.

In TGD framework the synchronously firing neuronal assemblies are excellent candidates for sub...selves. Synchrony should result from the presence of a TGD counterpart of a computer clock ticking with a frequency of order kHz associated with the memetic code. What came as a surprise was that the question about the origin of this clock relates so closely to two fundamental open questions in TGD inspired theory of consciousness, namely:

1. What is the fundamental role of Z^0 force and Z^0 MEs at brain level?

2. How are p-adic cognitive representations generated from real sensory input and how p-adic intentions are transformed as real actions at the level of brain? Shortly: ho

w is the interaction between p-adic and real physics realized?

The most plausible explanation for the synchrony is as resulting from the presence of Z^0 MEs. Neurally passive (p-adic) Z^0 MEs represent thoughts/plans/ intentions whereas neuronally active (real) act as selective switches forcing synchronous firing and bring thus order into neuronal chaos so that self-organization patterns begin to develop. Obviously, by criteria based on the coherency of the theoretical framework this explanation deserves to be taken seriously and developed further.

11.7.1 Temporal binding by synchronization

The article of Engel *et al* [35] provides an excellent representation about the development, motivations and the recent empirical status of temporal binding by neuronal synchrony. The article contains also references to the original work and the references to the results represented below can be found from this article and are not separately mentioned.

There are many reasons why for binding by synchronization.

1. Synchrony provides the counterpart of computer clock making possible a precise presynaptic summation of the neural inputs in turn implying fast and precise and fast neural processing. Synchrony makes also possible coordinated changes of the synaptic efficacies: this is of obvious importance for the associative learning at synaptic level. Also the robustness of neural processing is implied: army does not need single man.

2. Synchronized neuronal assemblies define natural candidates for the neural correlates of conscious percepts and synchronization might be a basic mechanism of attention.

3. Sensory (or rather, symbolic if sensory qualia are at the level of sensory organs), cognitive, and motor processing in brain is known to be highly parallel and distributed: for instance, there are about 30 distinct visual areas in monkey brain. Synchronization between various sensory, motor and associative areas has been proposed as a candidate for the mechanism generating coherent gestalts.

4. Synchronization has been proposed as key element for functions like learning and short term memory. Quite generally, it seems that non-synchronized brain regions are analogous to a computer without a global computer clock and thus seats of neural chaos.

5. Synchronization has been also suggested by Crick and Koch to be a necessary and sufficient condition for conscious experience to occur. From the TGD point of view and on general

philosophical grounds this hypothesis seems to be too far-fetched. Rather, synchronization seems to provide the counterpart of computer clock in TGD framework feeding order in neuronal chaos. Synchronized regions define however natural correlates for sub...selves.

11.7.2 Empirical evidence for synchronization

Neuronal synchronization is by now a well established phenomenon (see [35] and references therein).

1. Synchronization inside and between sensory, motor and associative areas has been established. Synchronization has been observed also inside subcortical structures such as lateral geniculate nucleus, superior colliculus and brain stem and even in retina [35]. Synchronization has also found even between areas belonging to different hemispheres.

2. Synchronization in visual system predicts synchronization inside visual areas and betwees areas across large cortical distances. These predictions have been verified. For instance, two neurons fire synchronically only if they respond to the same visual object but not otherwise. It has been found that the basic criteria for the gestalt formation (such as continuity and coherent motion), shown to support by perceptual grouping, are also important for the formation of a synchrony between the neurons of the visual cortical. Synchronization has been studied also in non-visual modalities: synchronization in the olfactory systems of various vertebrate and invertebrate species has been found and both auditory and somatosensory cortex has been demonstrated to show precise synchronization. Synchronization has been observed also in hippocampus and frontal cortex.

3. Synchronization has been observed in motor areas and between areas of sensory and motor system. For instance, the study of cats performing visuomotor tasks has shown that the synchronization between visual and parietal as well as visual and motor areas occurs in those task epochs where the animal processes attentively information to direct the required motor response.

4. Synchronization seems to serve as a neural correlate for conscious percepts [35]. For instance, in binocular rivalry, the neuronal activity in V1 does not change when the consciously perceived stimulus changes. However, highly synchronous firing is what distinguishes the perceived stimulus from the non-perceived one.

11.7.3 Does neuronal synchronization with millisecond precision require Z^0 MEs?

The time precision for the synchronization is in the millisecond range. This amazing precision for synchrony is something which I personally find difficult to understand in terms of neural circuits. Computer metaphor suggests strongly the presence of a counterpart of a computer clock producing a kHz rhytm. Neither 40 Hz frequency or any frequency in EEG range is enough to achieve this. Indeed, in [35] gamma activity between 20-70 Hz is carefully distinguished from synchronization. The fact that kHz corresponds to the duration of single bit for the memetic code suggests that synchronization is closely related to the realization of the memetic code whose presence is one of the basic predictions of TGD based approach to conscious brain. Gamma band synchrony would be a consequence rather than the reason in this framework and associated with EEG patterns represented by MEs providing compressed mesoscopic representations of information at neuronal level and thus representing what might be called features.

Thus kHz rhytm suggests strongly itself as a fundamental rhytm defining the counterpart of a computer clock in brain and the basic question relates to the origin of this rhytm. Concerning the physical realization of synchronization there are two possibilities in TGD framework: millisecond rhytm is either in EEG or ZEG.

1. Millisecond rhytm is present in EEG

Electromagnetic MEs oscillating with kHz frequency are the first candidates for the synchronizing agents: they would induce oscillations of membrane potential leading to the synchronization of the neuronal firing. Thalamocortical synchrony could be realized if a bundle of radial em MEs emerging from the thalamus takes care of the synchronization of neural firing (much like march song serves as

a pacemaker). The dynamical selection of the objects of the perceptive field as synchronized regions could be realized by transitions transforming em MEs to Z^0 MEs and vice versa by color rotations.

There is an objection against this option: this kind of synchronous oscillation of membrane potentials should have been already observed at the level of EEG and MEG. EEG and MEG studies demonstrate that high frequency components of sensory evoked potentials exhibit precise neuronal synchrony in the awake state but disappear in deep anaesthesia [35]. Also gamma synchronization is enhanced during arousal and focused attention as well as during a conscious perception of distinct auditory events and of coherent visual stimuli during attentive visual search. All these findings are however related to the part of EEG which reflects reactions to the stimuli and therefore they do not provide support for the presence of background kHz rhytm in EEG.

2. Millisecond rhytm is present in ZEG

In TGD framework one must consider seriously the possibility that Z^0 force could have a crucial role in brain functioning: in particular Z^0 MEs could act as synchronizers of the neuronal activity. The lack of appropriate measurement techniques for ZEG explains why the memetic rhythm has not observed directly yet. The mechanism predicts that the evoked responses in EEG and MEG should reveal synchrony and this is what has been found.

The rough formulation of the model goes as follows.

1. Classical Z^0 force emerges at cellular length scale but is assumed to be present also in cell membrane space-time sheets in the model for the realization of the memetic code [M6] What is of crucial importance is that Z^0 interactions become very strong at cell length scales since Z^0 charge densities can be very high. Z^0 interactions of cells could be possible even over astrophysical distances which inspires rather science fictive possibility of bio-control over astrophysical distances. What makes this more than mere weird speculation is the abundance of various anomalies finding explanation in terms of the classical Z^0 force: in particular, the correlation of radioactive decay rates and chemical reaction rates with astrophysical periods has been reported [71].

2. The join along boundaries contacts of Z^0 MEs with cellular and cell membrane space-time sheets would induce naturally synchronization since atomic nuclei are Z^0 ions and have thus a strong coupling to the classical Z^0 fields.

3. The proposed realization of the memetic code in terms of cognitive neutrinos requires an oscillatory Z^0 field with a frequency defined by the duration of the bit of the memetic code and thus of order kHz (1260 Hz is the precise value implied by the p-adic length scale hypothesis).

4. Also for this option a radial bundle of MEs emerging from thalamus provides a simple model for the synchronization. The only natural candidate for the passive state of Z^0 ME is its p-adic variant providing a cognitive representation for thought or intention (not necessarily ours!). p-Adic–real phase transition would transform intention to a real action or sensory input to a a thought. The role of the p-adic-to-real transition could be minimal: it could only selectively switch on standard processes and allow the composites of them to lead to self-organization patterns without further interference.

5. The simplest mechanism allowing p-adic–real transitions is based on pairs of Z^0 MEs with positive and negative time orientations (and thus energies). Since the net energy is vanishing, energy conservation allows p-adic–real transitions to occur without energy transfer to or from surroundings. Similar pairs make also possible very effective mechanisms of locomotion by recoil since MEs posssess maximal possible coherent momentum. Thus it seems that the admittedly very science fictive looking ideas about cognition and locomotion in living matter might have been realized.

6. One can consider also the possibility that Z^0 MEs transform to em MEs. A signature for this is the occurrence of rhytmic millisecond oscillations in EEG. Empirical findings do not support this process. One can also wonder whether the sensory MEs be just Z^0 MEs emanating from the thalamus transforming to real MEs when the sensory representation at the magnetic canvas is generated. This is probably not the case: by the scaling law to be discussed later these sensory representations, if present, could most probably correspond to neuronal sensory representations with characteristic millisecond time scale instead of .1 second time scale.

11.7.4 What is the dynamics of volition and thought?

The proposed simplified view leaves open some fundamental questions which basically relate to how the geometric correlate of matter-mind interaction as p-adic–real transformations for space-time regions takes place at brain level. The are two basic questions.

1) How the dynamics of thought generation is realized?

The understanding of the feedback from the sensory (real) level to the cognitive (p-adic) level is required. More precisely, how sensory (real physics) input is transformed to cognition involving generation of p-adic Z^0 MEs? There are also questions related to the role of neutrinos. What is the role of the spin flips of Z^0 magnetized blocks of cognitive antineutrinos representing memetic codewords in this process? Are also cognitive many-particle states of neutrino pairs needed besides Z^0 MEs. Do p-adic–real transitions occur for neutrinos?

2) How the dynamics of volition is realized?

Typically, the transformation of p-adic Z^0 MEs in some part of the cortex induces synchronous neural firing excitating or inhibiting some other regions. In excitatory case this should somehow lead to a cascade in which p-adic Z^0 MEs of excited regions are transformed to real ones. For inhibited regions already existing real Z^0 MEs might be transformed back to p-adic ones or disappear. The basic question is what mechanism induces the transformation of the p-adic Z^0 MEs to real ones and how a precisely targeted intention is achieved.

p-Adic length scale hypothesis suggests that some kind of a resonance dynamics possible at kHz resonant frequency and involving a feedback between p-adic and real physics is involved. Also a symmetry between the dynamics of volition and the dynamics of generation of thoughts looks plausible. This leads to the following view about what is involved.

1) Dynamics of volition

I If negative energy Z^0 MEs are involved and accompy a transition which does not occur spontaneously, conservation laws force a targeted intention. p-Adic-to-real transformation of Z^0 ME could occur with a high probability when p-adic Z^0 ME oscillates with a frequency which corresponds to the duration of the bit of the memetic code word which is related to an appropriate p-adic length scale in a simple manner. When out of tune, p-adic Z^0 ME would transform to a real ME with a low probability. This option would suggest the realization of volition by frequency tuning. Volition is involved also with the selection between percepts (not by us however) in situations like binocular rivalry. The difference of an imagined almost real motor action and actual motor action might be that the frequency for the motor area responsible for the switching-on of the real motor action is out of resonance.

2) Dynamics of thought generation

p-Adic Z^0 MEs could be created with a high probability in real space-time regions where there is an approximate neuronal synchronization. The approximate synchronization could be induced by the neural input from an already synchronized region. This mechanism would lead to a generation of p-adic MEs. p-adic length scale hypothesis favours preferred synchronization frequencies correspond to p-adic length scales. Thus, if the sensory input contains resonance frequency as a seed, p-adic ME is generated and in turn transforms to a real ME in turn re-inforcing the synchronization and leading to phase transition like generation of a synchronized region.

11.7.5 A general view about the role of synchrony

The hypothesis that synchronization is due to the presence of p-adic and real Z^0 MEs suggests the following general view about how conscious brain functions.

1. The basic states for the various areas of brain could represent more or less chaotic neuronal activity without synchrony. During sleep primordial neuronal chaos could be realized in the scale of the entire cortex. Real version of Z^0 ME would select from this sea of chaos islands of order and generate objects of perceptive field nor behaviour (by sensory-motor analogy one might perhaps speak of 'behavioural field') realized as sub-selves. Sensory input or spontaneous neuronal activity could serve as a seed generating p-adic Z^0 MEs at kHz resonant frequency and these would transform to real ones. Real Z^0 MEs would feed negentropy to the neuronal primordial chaos and generate sharp sub-selves lasting for a sufficiently long time to contribute significantly to the contents of consciousness and behaviour (note the analogy with a social group: very shortlived member does not contribute significantly to the development of the social group).

2. The question whether there exist non-neuronal correlates for consciousness s definitely settled in this framework: they do exist and correspond to both p-adic and real Z^0 MEs besides em MEs and the synchronous firing of neurons provides a direct experimental evidence for these correlates visible already at the primary sensory areas.

3. The mesoscopic feature level visible in EEG and reflecting the synchrony of Z^0 MEs represents higher abstraction level in which memetic code at Z^0 ms level is compressed to the genetic code: many-sheeted space-time allows to understand the emergence of this level naturally.

Summarizing, this view combined with the general vision about the realization of the sensory representations represents the first coherent view about the functioning of conscious brain combining all TGD inspired ideas about conscious brain.

11.8 Frontal lobes and p-adic physics

p-Adic quantum entanglement with a positive entanglement negentropy is possible and is stable against self measurement if NMP holds true. This very encouraging finding suggests that cognition is necessarily p-adic. For instance, it becomes possible to understand what it is to understand! To have an experience of understanding is to have a p-adic subself (cognitive mental image) with a positive entanglement negentropy.

Frontal lobes are regarded as seats of the highest mental functions such as cognition, intention, volition, attention, evaluation of actions, self model, and perception of and reaction to social situations. Long term memory and language are largely independent of frontal lobes whereas working memory can be located to the dorsolateral parts of prefrontal lobes. Thus the concrete model both p-adic physics of intention and cognition might boil down to a model of frontal lobe function: presumably also the notion of field body and magnetic cognitive canvas are needed to understand the highest levels of the control. In particular, social control could be performed basically by the multibrained collective selves by activation of social habit routines as suggested by the fact that the persons who have lost these routines are able to deduce the correct social behaviour.

11.8.1 Basic functional anatomy of frontal lobes

Frontal lobes involve the most complex association networks of brain. In fact so complex, that the diagostics based on simple reflex schema and the idea about exact locations of mental functions applied to subjects having serious frontal lobe damage suggested that frontal lobes have no function at all! Only a view in which brain is regarded as self-regulating and self-organizing system allowed to develop diagnostic tools revealing the effects of frontal lobe damage.

Dorsolateral frontal lobes seem to be specialized with various aspects of cognition such as problem solving, judgement, reasoning, and discrimination. In particular, what is identified usually as working memory is located here. These areas are also involved with imagination and corresponding loops extend to sensory areas. In TGD framework dreams can be seen as a particular kind of imagination in which imagined sensory features are mapped to the magnetic sensory canvas.

The medial and ventral frontal lobes are involved with intention, planning, volition, and attention. These regions are also crucial for the routine perception of and reaction to social situations. Affect and motivation are crucial concepts here and the complex circuits connnecting frontal lobes, amygdala/brain stem and cortex are essential for planning and decision making. Salience detection or rather, selective amplification of those aspects of percepts which are significant seems to be basic function of these loops. The lesion for these loops implies effective loss of volition as well as emotional flatness.

Phineas P. Gage is a classic example of a person with serious damage for the circuits. He did not lose either his intellectual abilities nor memory but lost the ability of planning and the access the previously acquired social conventions and rules, and became childish and irresponsible. Gage was also well aware that he did was not anymore able to react emotionally. Gage was also able to use to theoretically deduce what would be the appropriate behaviour in social situations but in everyday life this was impossible.

These findings suggest that frontal lobes perform high level control and habit routines are the basic tools of cognition and planning, and that frontal lobes both active, generate, modify and replace these

habit routines by new ones. Using brain as computer metaphor one might say that working memory provides the initial values of the parameters of the habit routines.

11.8.2 Some neurophysiological findings related to the functioning of frontal lobes

The notion of cortical tone characterizes the state of cortex and is maintained by CNS. In so called inhibitory phase state the tone is low and brain responds with similar response to both strong and weak stimuli. This phase is also called equalization phase. In paradoxal phase weak stimuli can give rise to strong responses and vice versa. In this state no organized thought appeares and selective associations are replaced by non-selective and more or less random associations. REM sleep is regarded as an example of paradoxal phase. The interaction between medial frontal lobes, reticular activating system and cortex controls the cortical tone.

Gray Walter found that any expectation elicits characteristic slow waves emanating from frontal lobes and spreading to other regions. Expectancy wave diminishes if the the probability of expected signal diminishes. When the instruction that elicited the expectation states is negated, the wave ceases. Similar wave phenomenon is detected during concentration, say during an attempt to solve a complex mathematical problem. The interpretation as a correlate for binding by quantum entanglement suggests itself.

Orienting reaction is a vegetative and electrophysiological reaction to stimulus. Constriction of the vascular system to the arms, dilation of the vascular system to the head, galvanic skin changes and alpha wave amplitude reduction are involved. Habituation to the simulus reduces orienting reaction. Orienting reaction can be however increased and stabilized by verbal instruction that links meaning to the stimulus. If frontal lobe lesion affects attention, the orienting reaction fails to be stabilized by this mechanism. The interpretation is that for polar, medial and mediobasal section of the frontal lobe, the physiological tools for the regulation of attention are deranged.

11.8.3 TGD based view about frontal lobes

The TGD based model for how frontal lobes cognize forces some new interpretations of classic experiments. Also a new view about working memory is unavoidable.

Paper, pencil, and eraser metaphor

The unability to modify existing routines or replace them with new ones rather than loss of these routines seems to accompany the lesions of ventromedial frontal lobes. Or more precisely, new routines can be acquired but instantaneus replacement of active routines with new ones is not possible. In a classic experiment already performed by Pavlovian school a person having a frontal lobe lesion in the ventromedial area started to plane an plank and continued until there was no plank anymore and continued ot plane the bench. In the so called Wisconsin card sorting test the subject is presented with a series of stimulus cards and a deck of response cards. The cards bear coloured geometric patterns and can be matched by categories such as colour, form or number. The experimenter selects category but does not inform subject person who guesses rapidly the category by trial and error. After ten cards experimenter changes the category without informing the subject person about the change. Patient is not able to revise his strategy and continues to make wrong guesses.

These persons can adopt strategy but cannot change it. This is something very essential. The proposed interpretation is however that these persons do not have motor imagination and therefore cannot construct new habit routine. This seems to be wrong since in the beginning card experiment the subject was able to achieve this. Something more delicate is involved: patient is not able to replace an activated strategy with a new one instantaneousy The activated strategy however becomes deactivated spontaneously sooner or later.

This leads to pencil, paper, and eraser metaphor as a model for what frontal lobes are doing. Creation of habit routines is creation of symbolic representations and frontal lobes both create and erase habit routines just as we do when we do our calculations or type text to computer file. The patient with dorsolateral frontal lobe lesion must wait until the erasure happens spontaneously to establish a new habit routine. Of course, stucking into habit routines seems to a part of human condition, in particular at the old age.

Interestingly, during psychedelic experiences frontal lobes are very active. Habit routines are what one gets rid in these experiences and also during meditation. The interpretation would thus be that a very intense erasure of old and generation of new habit routines is going on.

Working memory quantum mechanically

The notion of working memory does not seem to be an appropriate concept in TGD framework. The proper interpretation seems to be as erasure and replacement mechanism for habit routines. Short term geometric and subjective memories are automatic side products. Mirror mechanism is also now the natural mechanism for geometric memories but one cannot exclude the interpretation of working memory as subjective memory. Note that it does not make sense to construct long term memory representations of all intermediate stages of habit routine construction (just as it does not make sense to publish all intermediate and often erratic stages of a long mathetical calculation).

Erasure and replacement mechanism corresponds in spin glass metaphor to the kicking of the system out from the bottom of a potential well. In quantum framework this means a formation of a delocalized state in zero modes followed by a localization to the bottom of some other potential well representing the new habit routine. Delocalized states in zero modes are however not possible. Rather, a generation of a bound state implying a temporary transformation of the zero modes in question to quantum fluctuating macroscopic quantum degrees of freedom is required. This is the TGD counterpart of Penrose-Hameroff mechanism. State of oneness, quantum computing macrotemporally qcoherent system, moment of consciousness effectively lasting very many quantum jumps: all these characterizations apply to the resulting state.

The creation of new habit routine might even mean the changing synaptic connections. This would mean a multiverse state of multineuron system with different synaptic strengths such that one of these states is selected when the bound state decays. Interestingly, it is known that the synaptic connections related to the somatosensory representations of rat's whiskers change in an incredibly short millisecond time scale. The explanation as a macroscopic quantum effect strongly suggests itself.

Also quantum superposition of entangled axons with varying membrane potentials near axonal hillock and thus with a varying firing probability could be considered. Also the ends of axons might be in entangled quantum superposition: Ca^{++} waves and sol-gel transition might be involved.

Where and how p-adic physics enters the picture?

p-Adic physics should represent the genuine intention and cognition whereas neuronal activity would provide a symbolic representation for cognition just like spoken and written language represent our thoughts. p-Adic-to-real transition is needed to transform cognitive to symbolic and intention to action. Working memory would the system responsible for this p-adic-to-real transformation.

p-Adic memetic codons (cognitive representations) could transform to real ones (symbolic representations of thoughts) with two possible directions of antineutrino Z^0 magnetization representing binary digits. A possible realization of the cognitive memetic codons is as p-adic Z^0 MEs which, when transformed to real ones, would induce a a temporal sequence of antineutrino Z^0 magnetization directions representing the cognitive memetic codon symbolically in terms of Boolean qualia.

Consider now how the cognitive entanglement between p-adic and real memetic codons could be realized.

1. The assumption about the complete classicality of the p-adic configuration space degrees of freedom implies that cognitive entanglement must involve both p-adic and real fermions. In this case the entanglement is necessary algebraic so that the number theoretic definition of entanglement entropy certainly applies. Thus a negentropic entanglement stable against self measurements is possible, and the cognitive mental image would carry a genuine cognitive information (or dis-information) and the outcome would be an experience of understanding (or confusion).

2. A p-adic Z^0 ME with the topology of a hollow cyclinder anti-neutrinos/neutrinos at its inner/outer boundaries glued along its boundaries to the cell membrane space-time sheet and to the cell exterior space-time sheet would be naturally the basic structure since it is involved with the generation of cell membrane oscillations and nerve pulse patterns [M2].

3. Both the p-adic and real many-particle states would be spin glass type Z^0 magnetized states with the minimum length of a Z^0 magnetized portion of ME determined by the effective phase

velocity of Z^0 ME and by the duration of single qubit of the memetic codon of 1/1270 seconds. This length is for the alpha wave phase velocity $v = 10\ m/s$ of order of one centimeter. The entire axon would have the same direction of Z^0 magnetization and one have a pair of real and p-adic qubits. It is natural to assume that memetic codeword is basic computational unit also along axon. For $v = 1\ \mu m/s$ (typical velocity for Ca_{++} waves) the length of a single qubit would be one nm so that the axon length 10^{-4} meters would be able to represent $\sim 10^5$ qubits and $\sim 10^3$ mememetic codewords.

4. p-adic neutrino qubit and real antineutrino qubit must entangle with each other. Also the entanglement between p-adic neutrino and anti-neutrino qubits is possible but not necessary for the minimal realization of quantum computation like operations made possible by the macro-temporal quantum coherence. The duration of $T_2(127) = .1$ seconds of the temporal memetic codon would define the minimum duration of macro-temporal quantum coherence and the unitary quantum evolution with this duration would define a superposition of memetic codewords with the same first qubit as is clear from the path integral formulation of the discretized unitary time evolution.

5. p-Adic-to-real phase transition would transform the entanglement to a real entanglement and a symbolic representation for the cognitive entanglement would result. The transition would not require much energy and might occur even spontaneously. The reason is that the energies of antineutrino at $k = 151$ space-time sheet and neutrino at $k = 169$ space-time sheet would approximately cancel each other (the Coulombic interaction with nuclear Z^0 charges makes neutrino energy negative at $k = 169$ space-time sheet).

Cognitive quantum computation like processes at neurolevel

If one assumes that an eigenstate of the density matrix or of the negentropy operator results in self measurement, the system must end up to an entangled state corresponding to some eigenspace of the density matrix. The requirement that the increase of entanglement negentropy is maximal, fixes this eigenspace uniquely. For the resulting state density matrix is proportional to unit matrix and entanglement negentropy is maximal $N_R = Nlog(p)$, when the number of states is $n = p^N n_0$, n_0 not divisible by p, $N > 0$: otherwise it vanishes. Quantum computers indeed operate with systems for which entanglement probabilities are identical. A very strong prediction is that the dimension of the state space should be divisible by p^N.

A possible neurolevel realization of a cognitive quantum computation is following.

1. Information is represented as a sequence of p-adic and real memetic qupits along axon. If the effective phase velocity of Z^0 ME is sufficiently low quite high number of qupits can be realized as already found. Incoming p-adic and real memetic codewords can be taken to be identical un-entangled sequences of p-adic and real memetic codewords. The unitary time development is discrete with a time step of 1/1270 seconds and lasts an integer multiple of $T_2(127) = .1$ seconds (127 steps). Thus the minimal quantum computation involves $2^{127} - 1$ quantum jumps effectively glued to a single quantum jump by macro-temporal quantum coherence. The outcome of the cognitive self-measurement is a pair of memetic codewords representing the initial memetic codeword and the result of the cognitive quantum computation.

2. A conscious experience results, when the spin directions of the real oddball qubits flip to the direction of the external Z^0 magnetic field at the cell membrane space-time sheet. The spatial sequences of qubits in the direction of the Z^0 magnetic field are excluded because these states do not give rise to any spin flips. In this manner a quantum computer with $p = 2^{127} - 1$ results. The spin flips of the real qubits induce Z^0 MEs which in turn induce membrane oscillations and perhaps even nerve pulses.

11.8.4 Goal structures and emotions

Daniel Pouzzner has proposed quite an interesting theory of emotions relating most emotions to cognitive models and goal structures [36]. Goal structures are also cognitive models assumed to have correlates at the level of neurophysiology.

Quite many emotions originate basically from comparisons of expectations or goals with reality and Pouzzner's model of emotions relates emotions to the dynamics of the goal structure. The failure to reach a goal or giving up a goal is accompanied by a disappointment or sadness; realization of a goal is accompanied by a feeling of success; fear or rage is experienced when the achievement of a goal is threatened. The failure of a model is accompanied by a surprise; the success of a model which has been questioned by experience involves a feeling of relief; etc..

There are of course exceptions: for instance, physical pain and pleasure, excitement, love and perhaps also pure rage without any object. The basic question is whether the comparison type emotion accompanies inherently comparison or whether emotions as such have nothing to do with comparisons and brain has only evolved to associated emotions to comparison results to guide the behaviour. In the model of Pouzzner the latter view is adopted and various neurotransmitters are identified as correlates of emotions. The problem is to understand how cognitive models and goals could be represented in real physics.

In TGD framework negative emotions relate to the increase of the entropies associated with various quantum number and zero mode increments defining qualia and are automatically generated by quantum decoherence. There are no emotions associated with cognitive (p-adic) degrees of freedom unless one counts the experiences of understanding and lack of it as emotions. Positive emotions relate to the decrease of these entropies. The formation of bound states generating sub-selves in a state of oneness which do not quantum decohere are obviously excellent candidates for quantum correlates of positive emotions. The challenge is two-fold.

1. Construct a concrete model for intentions and goal structures analogous to the model of long term memories.

2. Develop a model for the comparison process explaining why a quantum coherent subself results if the mental images about the predicted and actual states of the world are nearly identical and decohering subself results if these mental images are too different.

p-Adic model of goal structures

The models for geometric memories and intentions should be very symmetrical the basic difference being that real numbers are replaced by p-adics and geometric past with the geometric future in the model for intentions. This has nontrivial implications.

1. Intentions and goals should correspond to time like p-adic entanglement of the brain of the geometric now with the brain of the geometric future.

2. It should be possible to speak about intention fields characterizing various brain cells according to how long is the temporal distance T to the event of the geometric future representing the intention. The cells corresponding to the highest values of T should be found in frontal lobes.

3. p-Adic counterparts of the gravitational MEs (equivalent with Z^0 MEs) should be the entanglers unless one allows bound state entanglement between real and p-adic systems. Perhaps the transformation of real gravitational MEs emitted by systems with spin glass degeneracy to p-adic ones can occur routinely.

In TGD cognitions and intentions should appear also at brain level and have definite correlates. A good first guess is that cognitive representations are realized using memetic code in terms of Z^0 MEs (of course, also em MEs might be involved). The construction of the symbolic representations means the transformation of the p-adic Z^0 MEs to real ones. The real Z^0 MEs in turn induce further symbolic representations in terms of time varying antineutrino Z^0 magnetization and cell membrane oscillations or nerve pulse patterns.

How comparison type emotions could result?

The challenge is to understand how comparison type emotions could result from the comparison of a p-adic cognitive model with the reality. What is needed is a concrete model for the comparison process.

1. The information about real world state is provided by sensory input represented as real sub-selves whereas the prediction of the cognitive model is represented by a p-adic subself. Therefore the real subself representing the relevant data must be transformed to a p-adic subself. Or alternatively, cognitive subself must be transformed to a symbolic subself. Both transformations presumably occur and correspond to different comparison processes with different outcomes at the level of conscious experience. The fact that p-adic physics should not give rise to emotions plus the assumption that brain performs the comparison more or less automatically, favours the comparison of the real mental images realized in terms of nerve pulse patterns. It allows also to understand why emotions have definite neurophysiological correlates.

2. The comparison of symbolic (real) sub-selves generates an emotion: if two sub-selves are identical, the emotion is positive. If they are too different, the emotion tends to be negative. In the comparison process the nearly identical real sub-selves representing the mental images to be comapred should be able to form a a bound state with a high probability and this would give rise to a quantum coherent state accompanied by the experience of 'oneness' and positive emotion. Too different sub-selves should not form a bound state at all or the bound state should be very short lived. The increase of the various entropies of the unbound mental images quantum jump by quantum jump should give rise to an unpleasant emotion.

3. In p-adic context the formation of a state with positive negentropy should give rise to an experience of understanding rather than positive emotion. The experience of understanding or lack of it would result in a comparison process in which a real mental image representing real world is transformed to a cognitive one and compared with a p-adic mental image representing a prediction of a cognitive model. The formation of p-adic bound states should be highly probable for nearly identical p-adic mental images.

4. Nearly identical real systems are indeed able to form bound states. Nearly identical systems have same transition frequencies and negative energy massless extremals (MEs) representing these transitions give rise to a strong resonant interaction. Negative energy MEs would define the join along boundaries bonds connecting these systems to form a bound state. This is not the only possibility as will be found: also the TGD counterparts of the non-Hertzian scalar waves of Tesla can play the role of negative energy MEs.

Comparison process at neuronal level

The fundamental comparison giving rise to comparison type emotions should be between nerve pulse patterns representing symbolically the mental images. Nerve pulse patterns define association sequences, that is temporal sequences of space like 3-surfaces with time like separations analogous to the words in a sentence. There should be some kind of resonant interaction between two nearly identical nerve pulse patterns giving rise to bound states.

One can imagine two mechanisms.

1. Transversal negative energy MEs created during the generation of the nerve pulse might give rise to a bound state interaction between nerve pulse patterns propagating in parallel axons.

2. The second candidate for the resonant interaction relies on the TGD counterparts of non-Hertzian scalar waves.

Both mechanisms could generate metabolic energy by buy now-pay later mechanism and the observed anomalously low oxidative metabolism during syncrhonous firing could be due to this mechanism.

The non-Hertzian option deserves a more detailed discussion.

1. TGD predicts a huge family of electret type solutions dual to magnetic flux tubes characterized by a constant density of Kähler action. Living matter is indeed full of liquid crystal electrets, cell membrane being the basic example.

2. The solution family contains also counterparts of the non-Hertzian scalar waves of Tesla. These solutions represent a pulse of electric field having a finite duration and spatial extent and resemble MEs in the sense that they correspond to a finite space-time sheet moving with light velocity. Electric field is in the direction of propagation and almost constant.

3. Non-Hertzian scalar waves are believed to be generated by short but very strong pulses of electric field. Nerve pulses certainly satisfy these criteria and could thus create scalar waves propagating in directions orthogonal to axons and inducing a resonant interaction between two nerve pulse patterns in parallel axons. This suggests that the comparison of two sub-selves could involve join along boundaries bonds defined by negative energy scalar wave space-time sheets between parallel bundles of nerve fibers. Topologically this mechanism would not differ from that based on negative energy MEs. If the nerve pulse patterns are identical, the scalar waves give rise to a maximum number of join along boundaries bonds responsible for the resonant interaction and representing the bound state energy. Neural synchrony in millisecond time scale plus millisecond duration for the nerve pulses might be enough to guarantee that this interaction mechanism works.

4. The energies involved would correspond to kHz scale and correspond to gravitational binding energies for cell sizes structures: note that non-Hertzian scalar are accompanied by anomalously strong classical gravitational fields due to the facts that classical gravitational field couples to classical field energy 10^8 times stronger than to ordinary matter and that scalar wave space-time sheets carry very strong classical gravitational field at their boundaries.

11.8.5 Experimental support for binocular rivalry as a quantum phenomenon

For years ago I constructed a quantum model for binocular rivalry and generalized it to a general model of volitional act as a quantum jump selecting not only between alternative motor actions but also between percepts. In this model different alternatives were represented as superpositions of neural firing patterns. The model allows to see sensory perception as an active volitional process (at some level of hierarchy of selves) and explains sensory rivalry as a quantum phenomenon.

The work of Efstratios Manaosakis

I learned from New Scientist [38] that physicist Efstratios Manousakis has now published an interesting work [39] about binocular rivalry providing experimental support for this model.

Recall that the classical demonstration of binocular rivalry [37] is a pattern experienced either as a vase or two opposite faces. The two percepts alternate with some frequency and it is not possible to consciously experience both patterns simultaneously. This has led Manousakis to consider the idea that binocular rivalry could provide direct evidence for the notion of quantum consciousness. The obvious idea is that either of the percepts results by a state function reduction from the superposition of both percepts.

The model predicts that the flip rate correlates with neuronal firing rate. The prediction is confirmed by using as subjects persons who have a reduced firing rate due to the use of LSD. The work of Manousakis might turn out to be an important step of progress in the development of theories of quantum consciousness and might help also main stream physicists to get rid of their atavistic fears relating quantum consciousness.

Justification for the model in TGD framework

The finding conforms with TGD view about quantum jump in which U process creates a quantum superposition and state function reduction selects either of the percepts. TGD however brings in new elements.

1. In the conceptual framework of the standard quantum mechanics there is no known mechanism making possible macroscopic quantum coherence in the time scales involved. If dark matter with large $\hbar$ is involved with the formation of conscious percept there is no problem in understanding the time scales in question. Actually a hierarchy of rivalries of various kinds in various time scales is predicted corresponding to the p-adic time scale hierarchy and hierarchy of Planck constants.

2. Another ingredient which is new from the point of view of standard quantum mechanics is that the hierarchy of Planck constants implies self hierarchy actually identifiable actually as a hierarchy of quantum jumps having quantum jumps within quantum jumps ..... The fractal

structure of state function reduction process means that it is possible have macroscopic quantum behavior in given time scale but dissipative self-organization in shorter time scales.

This is actually not new: in hadron physics hadrons are described as quantum systems whereas parton dynamics in the shorter time scales is assumed to be dissipative. In the recent case this means the possibility of quantum superposition of dissipative self-organization processes involved with the formation of neuronal correlates of percepts and proceeding in time scales of order milliseconds considerably shorter than the time scale of binocular rivalry.

TGD based model for rivalry and its generalization

The TGD based quantum model for binocular rivalry relies on the idea that the formation of quantum superposition of competing percepts is somewhat analogous to quantum computing in which large number of quantum parallel computations are carried out and one computation is selected as the computation halts.

In TGD framework one does not assign a conscious experience to the mere state function reduction part of quantum jump and the question arises whether the transitions periods are experienced consciously as a kind of inability to disentangle what is there and if so what is the subjective time duration of these periods and is it very short in absence of some other periodic sensory input defining a clock. The TGD prediction would be that the mental image defined by the percept is absent but consciousness is not lost.

The formation of quantum superposition of right and left percepts has evolutionary advantages which suggest also a generalization to a model of volitional action as a selection between neural firing patterns leading to alternative motor actions.

1. The formation of superposition would be metabolically advantageous. In the classical world one should form both right and left percept simultaneously. The associated self-organization process requires a metabolic energy feed. When only single brain hemisphere forms the percept and one has quantum superposition of right and left percepts metabolic energy feed is reduced by factor 1/2. A highly synchronous neural firing distinguishes the perceived stimulus from non-perceived so that a quantum superposition of patterns of two neural firing patterns would be in question.

2. This picture leads naturally to a proposal that one function of sleep is to make possible quantum superposition of large number of neural firing patterns via quantum entanglement with external systems (perhaps other sleeping brains) so that sleep would be a process analogous to quantum computation.

3. The formation of alternative percepts would have an obvious evolutionary advantage in a situation in which several percepts are consistent with the sensory input. For instance, bipolar mood disorders seem to involve sticking of consciousness to either hemisphere. This generalizes also to cognition: of course, percepts actually consist of sensory input plus cognition.

4. This framework is behind TGD based model of volitional action applying to both motor actions and selection of sensory percepts. For a brain living in jungle it would be highly advantageous to develop in a difficult situation a quantum superposition of alternative motor actions and select the proper one only at the eleventh moment.

5. Sensory rivalry is analogous to an ability to move fluently between - say - skeptic and new age views about world. There is also a parallel at the level of society and in TGD framework the rivalry of various views (religions, political parties, competing scientific theories,...) might perhaps be seen as counterpart of binocular rivalry at the level of collective consciousness. The complete dominance of only single view - be it religious or materialistic world view, market economy or communism, or super-string model or loop quantum gravity - would be something comparable to a bimodal mood disorder.

11.9 p-Adic cognition at the level of DNA and proteins

I learned from Tidjani Negadi about some new ideas related to the attempt to understand the basic numbers of the genetic code [24]. Some of these ideas stimulated some speculations about genetic code

and its relationship to cognition and led to a discovery of two number theoretical miracles related to the realization of cognition at DNA and protein level.

11.9.1 Symmetry breaking generates conscious information

What is very attractive in Negadi's approach is the interpretation of the reduction of the entropy in the symmetry breaking as information [25]. This kind of a philosophy fits nicely with the general TGD based view about the generation of the macro-temporal quantum coherence.

1. Macro-temporal quantum coherence corresponds to a formation of bound states and is accompanied by a dramatic reduction of entanglement entropy since bound state entanglement is not entropic.

2. The generation of macro-temporal quantum coherence involves a breaking of symmetry in the zero mode sector transforming some zero modes to quantum fluctuating zero modes. On the other hand, state function reduction (localization in zero modes) and self measurements giving rise to state preparation do not occur in bound state. The localization in zero modes is counterpart of Higgs mechanism and its absence can be seen as the absence of symmetry breaking induced by quantum jump. Hence the loss of symmetry at the level of configuration space is accompanied by a gain in symmetry at the level of conscious experience and vice versa.

3. In the p-adic context bound state entanglement is negentropic [H2]. This suggests that the information resulting in the symmetry breaking involved with the establishment of the genetic code could be realized as a conscious cognitive information associated with the p-adic bound state entanglement.

11.9.2 Cognitive codes as a realization of the information generated by DNA-protein symmetry breaking?

Before the establishment of the genetic code the assignments of DNA triplets to amino-acids are random. This means that the symmetry group is a direct product of the permutation groups permuting 64 DNA triplets and 20 amino-acids. The symmetry entropy is logarithm about the number of elements of the symmetry group

$$S_{max} = log(w) \quad , \quad w = 64! \times 20! \quad . \tag{11.9.1}$$

One obtains $S_{max} \simeq 4 \times 61.8789$.

The work of Negadi inspired the question about whether one could interpret protein-DNA symmetry breaking as a process in which the information $I = S_{max} - S$ is generated and represented in a concrete manner as an additional conscious cognitive information associated with DNA and protein sequences. In case of DNA sequences the symmetry breaking is maximal so that one has $I = S_{max}$. In case of protein sequences symmetry breaking is partial and $I = S_{max} - S$, where S corresponds to the entropy due to the fact that DNA triplets coding for the same amino-acid are equivalent from the viewpoint of protein. This means that DNA sequences carry more cognitive information than protein sequences.

p-Adic physics as physics of cognition predicting that cognition is present already in elementary particle length scales provides clues about how this additional information could be represented.

1. p-Adic bound states for which kp^N states entangle with similar states are automatically quantum computer type states with identical entanglement probabilities (this guarantees stability against self measurements [H2]. Most importantly, they carry positive entanglement entropy and genuine information. In the real context entanglement negentropy is always non-positive and is assumed to vanish for bound state entanglement (of course, one could criticize this assumption).

2. If p is Mersenne prime: $p = M_k = 2^k - 1$, temporal sequences of k Z^0 magnetization directions for neutrino blocks provide a concrete mechanism of quantum computation (for $k = 127$ associated with the memetic code at least. This suggests that DNA triplets or amino-acids could be accompanied by $p = M_k$-fold degeneracy resulting from the assignment of a sequence of k blocks of Z^0 magnetized neutrino blocks to each DNA triplet and/or amino-acid.

3. This representation of information should relate somehow to the realization of the memetic code in terms of DNA and amino-acid sequences. In the model of the memetic code sequences of 21 DNAs are a natural candidate for the realization of the memetic code words since the number of different sequences is $64^{21} = 2^{126}$, which is the number of the memetic code words representing maximal number of mutually consistent statements in the Boolean algebra represented by sequences of 127 bits. The sequences of 21 proteins are a natural candidate for defining the memetic counterpart of the DNA-protein translation if one assumes that the translation of genetic code induces directly the translation of the memetic code to proteins. A test is to find whether sequences of 21 DNAs/proteins might appear in the tertiary structure of DNAs/proteins.

4. The argument above suggests that one should try to find a representation of the cognitive information by assigning a temporal sequence of $p = M_k$ neutrino Z^0 magnetization directions to each DNA/protein in the the sequence of 21 DNAs/proteins. This representation makes sense if the condition

$$I = 21 \times log(M_k) \simeq 21 \times k \times log(2) \quad (11.9.2)$$

giving

$$k = \frac{I}{21 \times log(2)} , \quad (11.9.3)$$

is satisfied for k Mersenne prime. The condition is obviously extremely restrictive and a number theoretical miracle is required since k has exponential sensitivity to the value of I. Even more, this miracle is required to occur twice: for both DNA and proteins!

11.9.3 M_7^2 and M_{17} codes

It turns out that the number theoretical miracle indeed occurs twice. The complete symmetry breaking occurring at the level of DNA corresponds to the Mersenne prime M_{17} whereas the partial symmetry breaking occurring at the protein level corresponds to the square of Mersenne prime M_7 defining genetic code.

Is M_{17} code realized for DNA sequences?

In case of DNA sequences the symmetry breaking is complete so that one has $I = S_{max}$. For k one obtains

$$k = 17.0043 \simeq 17 . \quad (11.9.4)$$

$k = 17$ holds true with a relative accuracy of 2.5×10^{-4}! Both S_{max} and I correspond to 357 bits of information. What is fascinating is that M_{17} is indeed a Mersenne prime, even a very special one, since $k = 17$ is the largest Fermat prime $F_4 = 2^4 + 1 = 17$. Thus one has $M_{17} = M_{F_4}$, somewhat analogously with the basic definition of Combinatorial Hierarchy: $M(n+1) = M_{M(n)}$.

Is M_7^2 code realized in case of proteins?

The DNA triplets coding for the same protein are equivalent from the point of view of proteins. Therefore symmetry breaking reduces the symmetry group to the subgroup $S_1^2 \times S_2^9 \times S_3^2 \times S_4^5 \times S_6^3$ of S_{64}. Here the subindex n of S_n denotes the number of DNA triplets coding a given amino-acid and the exponent m in S_n^m denotes the number the proteins with degeneracy n. The symmetry entropy is in this case

$$S = log(2!^9 \times 3!^2 \times 4!^5 \times 6!^3) = 4 * 11.0584 . \quad (11.9.5)$$

Information gain in the symmetry breaking is $I = S_{max} - S = 4 \times 50.8205$. The value of k for proteinic cognitive representations becomes

$$k \;=\; 13.9654 \simeq 14 = 2 \times 7 \ . \tag{11.9.6}$$

$k = 2 \times 7$ holds true with the relative accuracy of 8.5×10^{-4}. $k = 14$ equals twice the Mersenne prime 7 defining Mersenne prime $M_7 = 2^7 - 1 = 127$ defining the genetic code! A p-adic representation containing p^2 states with $k = 7$ and $p = M_7 = 127$ could be thus considered as a realization of this code. There is internal consistency in the sense that the time scale .1 seconds associated with the memetic code corresponds to a secondary rather than primary p-adic time scale associated with M_{127}.

M_{17} and M_7^2 codes as degenerate forms of the memetic code?

The natural guess is that M_{17} and M_7^2 codes represent degenerate forms of 127-bit memetic code to 17- resp. 14-bit code, some kind of a predecessors of the memetic code. If so, then the duration of the M_{17} and M_7^2 codewords is (roughly) the duration .1 seconds of the memetic codeword.

1. Internal consistency requires that the p-adic time scales in question can be regarded as n-ary p-adic time scales for M_7 and M_{17} for some value of n. For M_7 one has $M_7^{36} \simeq M_{127}^2$ in the approximation $M_n \simeq 2^n$ so that .1 seconds corresponds to 36-ary M_7 time scale. For M_{17} one has $M_{17}^{15} \simeq 2M_{127}^2$ in the same approximation so that M_{17} corresponds to the $15-ary$ M_{17} time scale equal to $\sqrt{2} \times .1 \simeq .14$ seconds. The corresponding frequencies are 10 Hz (mean alpha frequency) for M_7 and 7.07 Hz for M_{17}, which is just below the alpha band and Schumann frequency 7.8 Hz and cyclotron frequencies 7.5 Hz for K^+ in magnetic field .2 Gauss. This value of magnetic field is suggested by the observations that ELF fields have effects on vertebrate brain at harmonics of Ca^{++} cyclotron frequency of 15 Hz. Note that Earth's magnetic field has nominal value of .5 Gauss so that the magnetic field assignable to the magnetic body would be slightly below the minimal value of Earth's magnetic field about .3 Gauss.

2. Single bit of M_{17} code would last $\tau = .14/17 \simeq 8.3$ milliseconds. For M_7 code the duration of bit is $\tau = 14.3$ milliseconds. It would be interesting to look whether electromagnetic oscillations with roughly 121 Hz resp. 70 Hz frequency are involved with DNA resp. protein dynamics and perhaps also with neuronal firing.

3. If one assumes that the duration .1 seconds is the precise duration of the memetic codeword, the duration of a single bit is about $100/127 = .79$ milliseconds. This would require that the temporal distance between the nerve pulses realizing memetic codeword at neural level is .79 milliseconds. It might be that brain is too slow to achieve this in its recent developmental stage: M_7^2- and M_{17} codes are however not problematic in this respect. The representative capacity of the full memetic code is enormous: consider only the fact that all files in the computer systems of world are planned to be named by 128-bit sequences giving them kind of fingerprints! Thus it might be that 17-bit or even 14-bit code is quite enough: for instance, the number of phonemes of the spoken language is ridiculously small as compared to the number of memetic codewords.

Interpretation of the memetic code word

The memetic codeword consisting of 127 bits allows elegant interpretation as an intention to promote or inhibit the expression of DNA sequence of 21 DNAs coded by 126 bits. The last bit tells whether the expression is promoted or inhibited. Memetic code codes same things as cognitive code for proteins but in a different manner making it possible to activate genetic expressions directly without the mediation of the information-molecule-receptor complex.

The model of the millisecond neuronal synchrony based on classical Z^0 MEs suggests that memetic code is not realized as nerve pulse patterns nor as miniature potentials but as oscillations of Z^0 potential at the cell membrane. The model of nerve pulse and EEG leads to this same picture. One should also notice that the duration of nerve pulses is somewhat longer than 1/1270 seconds so that memetic code cannot be realized in terms of nerve pulses if the duration of codon is .1 seconds. This oscillation could be transferred to nuclear membrane along micro-tubuli and induce in turn the activation of genes coding promoters and inhibitors of the expression of some genes. The realization of the memetic code in terms of nerve pulses would be degenerate. Frequency coding suggests that only the number of nerve pulses per codon matters. If the average duration of nerve pulse is about

2 milliseconds, the number of pulses is at most 64 and one would have genetic code. Genetic code realized in this manner might well be enough to code the phonemes of the language. There is also a second kind of frequency coding. If nerve pulses occur with a constant interval between them (this could be induced by stochastic resonance, the degenerate memetic codons would correspond to different nerve pulse frequencies and also now a 6-bit code would result.

11.9.4 Cognitive codes and bio-systems as molecular societies

The presence of cognition at DNA and protein level gives additional support for the vision about bio-systems as a molecular society. In the following only the term cognitive code is used although one should in principle speak about cognitive and symbolic codes.

Is p-adic cognitive information static or dynamical?

The general question is whether p-adic cognition degenerates to a representation of a static information analogous to genetic information or does it represent a dynamic information. There are several arguments supporting that the information in question is dynamical and that this is what makes the soup of bio-molcules a molecular society.

1. The basic character of the p-adic physics is non-determinism and it is difficult to imagine that cognitive representations could be static DNA like representations.

2. The cognitive information at DNA and protein level is essentially like the cognitive information at brain level and should be therefore highly dynamical.

3. The fractality of consciousness suggest that one should look the situation at higher level. In human society books represent static information analogous to that coded by DNA whereas conscious brains carry dynamical information which is not a faithful copy of what one can find in books.

This view allows to answer to several related questions.

1. M_{17} codeword would be a temporal sequence of 17 cognitive neutrino pairs. Note that M_{17} code would define 16-bit sequences as maximal set of mutually consistent Boolean statements. M_7^2 codewords could be represented as a pair of temporal sequences of 7 Z^0 magnetization directions for neutrinos. The maximal number of the statements consistent with given atomic statement would be 64 so that a cognitive version of the genetic code would be realized at the level of proteins. Might it be useful for a protein to remember the DNA sequence which coded it? This kind of information has no obvious relevance and conflicts with the dynamical character of p-adic cognition.

2. Is there a translation of M_{17} code to M_7^2 code analogous to DNA-protein translation in which some information is lost and proteins carry part of the cognitive information carried by DNAs? The ratio of cognitive information contents for protein and DNA sequences is

$$\frac{I(DNA)}{I(protein)} = \frac{log(M_{17})}{2 * log(M_7)} \simeq .822 \tag{11.9.7}$$

whereas for DNA-protein translation it is $log(21)/(6log(2)) \simeq .7321$. That proteins would not carry independent cognitive information, would be in conflict with the dynamical character of p-adic cognition. The only possible conclusion seems to be that one cannot reduce biological information to the information represented at DNA level so that the central dogma fails even in its generalized form.

Cell membrane as a cognizing structure?

The physical realization of the proposed cognitive codes deserves some comments.

1. M_{17} resp. M_7^2 cognition would add an enormous amout of conscious information to genes resp. protein sequences. DNA triplet resp. amino-acid would contain 17 resp. 2×7 additional bits of cognitive information dominating over the chemically coded information. This additional information might allow to understand the paradoxical finding that humans and wheat have roughly the same amount of DNA if the number of DNA sequences longer than 21 DNA triplets is higher in the human genome.

2. Real cognitive neutrino pairs should have nearly vanishing net energy in order that p-adic-to-real transition occurs with high probability [M6]. This is possible to achieve only for p-adic length scales not shorter than cell membrane thickness ($L(151) = 10$ nm).

3. The minimal length of 21 amino-acids corresponds to a minimal length of 21 nm for the information molecule. Neurotransmitters and -modulators have lengths much shorter than 21 amino-acids. The molecular weights of hormones (in particular peptides) are measured typically using 10^4 proton masses as unit and this means that the number of amino-acids is larger than 21. Thus it would seem that very many peptides, regarded often as 'information molecules' and 'molecules of emotion', could be regarded as intelligent messengers. Various receptors of the information molecules associated with cell membranes have typically sizes larger than the lower limit 21 nm and could thus behave as cognizing entities making cell membrane an intelligent and cognizing structure. The number of receptors in the cell membrane would serve as a kind of an intelligence quotient of the cell membrane.

11.9.5 Peptides as molecules of emotion and code of intentionality

The view about peptides and proteins as cognizing and intentional entities allows to translate to TGD language often used expressions like 'emotions are expressed', 'blocked emotions are released', 'emotions are stored to the body as traumatic body memories', 'peptides are molecules of emotion and information molecules'. Most importantly, a concrete code for intentionality emerges in which elementary intention represents inhibition or facilitation of gene expression.

Unasked questions

The interactions of the information molecules involve the formation of receptor-information molecule complex either at cell surface or in the cell plasma inside cell. Receptor-information molecule complex inside cell can move to genome and induce gene transcription. In case that the complex is formed at the surface of cell, second messenger action is involved. One can also speak about N:th messenger action. There are many poorly understood aspects related to the mechanisms of information molecule action [26].

1. There are only few second messenger pathways and relatively few receptors but large number of different functions. This phenomenon is known as pleiotropy or multi-functionality. For instance, given second messenger causes different effects depending on the hormone that activated it (the phenomenon is somewhat analogous to the phenomenon in which message can be understood in several manners depending on the state of receiver).

   At purely chemical level the problem is how second messenger knows what hormone activated it? In steroid action the complex formed by information molecule and receptor in turn activates some gene. Now the question is: How the activated RNA polymerase knows which gene has to be activated? Pleiotropy appears also at level of hormones. Same hormone can have multiple effects and the border between hormone, neuropeptide or even neurotransmitter is unclear. For instance, a hormone which by definition transmits long distance communications, can have effects in nearby cells and thus acts like a neuropeptide. How hormone knows what function it must perform? Also drugs and treatments can have different effects and side effects.

2. There is also functional redundancy: the same function is performed by several second messenger molecules. For instance, glucagon, growth hormone, adrenaline and corticosteroids elevate

glucose levels. This suggests that there is deeper level of communication involved and that second messenger molecules are more like computer passwords than subprogram calls. Now the question is: What these subprogram calls do correspond physically?

3. Biological functions can be initiated also in nonchemical manner. The phenomena of healing by touch and the effects of meditation and biofeedback are examples of biological self-organization processes are initiated in nonchemical manner. Even other treatments like massage, acupuncture or meditation can decrease or inhibit pain. These observations suggest that chemical level is not the deepest level involved with biological functions and the question is: What is this deeper control level?

Simple lock and key mechanism cannot provide answer to the questions raised above. If information molecules carry p-adic intentions about say gene level expression of emotions, situation changes since additional information transfer is involved.

The code of intentionality

The expressions of emotions are usually symbolic. Emotions involve often intentions (not always benevolent!. This intention could be represented by p-adic Z^0 MEs and translated to a symbolic and cognitive representation in terms of real and p-adic antineutrinos (bit being represented by the direction of Z^0 magnetization). For instance, when the opinion of a quantum consciousness theorist about reductionism and materialism cannot be expressed, the p-adic intention does not transform to real ones and does not generate the nerve pulse patterns or other activity responsible for the symbolic expression.

What it means that peptides are responsible for the expression of emotions? Perhaps information molecules transfer the intentions to express emotions at molecular level between body parts. It is indeed known that nervous system, immune system, and endocrine system are in an intense information exchange using information molecules. Information molecule would literally act as a postman transferring intentions to the proteins of the body which are also carriers of p-adic cognition.

Emotions are eventually expressed at the gene level. M_7^2 code consists of sequences of 7-bits and 7 bits is enough to tell both the name of the gene and whether the expression of this gene is to be facilitated or inhibited. Certainly the simplest possible biologically relevant intention is the intention to facilitate or inhibit the expression of some gene! The doubling of the intention to translate DNA sequence to protein brings strongly in mind the double strand structure of DNA. There might be good reasons for the doubling to occur also at the level of intentions and 7-bit sequences would represent DNA and its conjugate. Doubling might allow error correction as in the case of double DNA strand.

If information molecules carry more or less standardized intentions, the intentions carried by the information molecules cannot be directly transformed to actions. Rather, a process similar to the translation of DNA to protein would occur. A copy of the second intention is formed (generation of mRNA) and transferred near the nucleus where it is tranformed to action (translation of DNA to protein). Of course, p-adic physics at protein level has also other aspects. Doubling would make possible p-adic quantum computations at the protein level since 7-bit sequences could entangle to form p-adic bound states. At DNA level p-adic quantum computations would be made possible by the bound-state entanglement of the 17-bit sequences associated with the two DNA strands: this would also partially explain why two strands are needed.

A model for what happens information-molecule receptor complex

There is evidence for M_7^2 code. It is known that membrane proteins are in a helical conformation (so that the pair of p-adic intentions forms a helical structure just like DNA double strand!) such that the number of proteins in the portion connecting the cell exterior and interior is 20 [27]. This is not quite 21. It could be that the cell membrane space-time sheet is 5 percent thicker than the join along boundaries condensate of the atomic space-time sheets so that 21 proteins are actually involved. A more plausible explanation is based on the observation that the sequences of $10 \times n$ DNA triplets are very special in that the net helical rotation along the sequence is a multiple of 2π. Perhaps the sequences of 20 DNA and thus also of 20 amino-acids carry the relevant genetic information. 21^{st} amino-acid would contains a control intention which, when realized, attaches the information molecule

or receptor to the cell membrane such that the follower of the control amino-acid is the first one inside the cell membrane.

The interpretation would be that the portions of proteins inside cell membrane contain cognitive antineutrinos. This interpretation conforms with the model of the memetic code based on the assumption of almost zero energy neutrino pairs are assumed to have neutrino at $k = 169$ space-time sheet and antineutrino at $k = 151$ space-time sheet. There should be a $k = 151$ space-time sheet associated also with the information molecule making possible the realization of memetic codewords. This is important constraint and could mean that the transversal size of the information molecule is of order $L(151) = 10$ nm. Alternatively, the molecule to which information molecule is bound during its travel to the target molecule could provide the $k = 151$ space-time sheet.

These findings allow to make guesses and questions about what might happen in the information molecule-receptor complex.

1. Cell membrane-information molecule-receptor complex

The cognitively active parts of the receptors corresponds to the parts of these proteins traversing the cell membrane. Often the receptors are proteins which traverse the cell membrane many times and the interpretation would be that each portion of 20 amino-acids defines one elementary intention defining a portion of DNA sequence to be translated and initiating a process leading to an expression of some gene(s). 7-bit code suggests that the codeword activates control genes which promote or disfavor the expression of some gene(s). An interesting question is whether DNA sequences consisting of 21 DNA triplets have some very special role in the control part of the genome.

2. What are the contributions of the receptor and information molecules to the intention?

Does receptor molecule form only a copy about the intention of the information molecule to the segments of the receptor going through the cell membrane or do both the receptor and information molecule contribute to the intention? Could it be that the static quasi-static part of the intention is coded by the receptor and the varying part is coded by the information molecule? Selection among not too different intentions would give flexibility without a loss of safety. Quasi-static part would bring in some context dependence. This would allow also to understand what happens in synaptic contacts: in the case of standard neurotransmitters, which cannot be intelligent messengers because of their small size, there would be only a quasi-static receptor contribution to the intention determined by the postsynaptic neuron.

3. How the intention to express the gene is realized?

Generalizing the ideas about the realization of the memetic code one ends up with the following picture. The contribution of the information molecule to the intention is possibly copied in the interaction with the receptor to the receptor molecule or transformed directly to action. After the p-adic system is transformed to a real one and this process automatically generates a sequence of electric signals when the spins of real antineutrinos flip to the direction of the Z^0 magnetic field associated with the cell membrane space-time sheet. This does not yield nerve pulses but weaker signals, presumably completely analogous to miniature potentials generated in the receptors of the postsynaptic neurons, and these potentials code for the gene expression. In principle there would be no difference to what happens in the postsynaptic neuron.

Micro-tubular cytoskeleton which is piezoelectric structure claimed to allow 64 bit code [28, 40] could mediate the electric electric signal to the nucleus and activate the desired genes. Massless extremals and TGD counterparts of scalar waves of Tesla could be involved. Recall that scalar waves correspond to electric pulses propagating with light velocity with electric field in direction of propagation: now these pulses would propagate to the interior of the cell and generate miniature potentials in the membrane potential of nucleus. The generation of the second messenger would represent a standardized part (there are relatively few second messenger pathways) of the process of realizing gene expression no responsible for the transfer of the intention.

Failure to express emotions

It seems that the expression of emotions can fail at several levels. If the intention to express emotion at brain level fails to be realized, information molecules are not generated and transferred around the body. The un-expressed emotion would be stored in the brain of the past. The second possibility is

that the intention to express emotion is transformed to action and the peptides flow around entire body but for some reason the intentions carried by the information molecules are not expressed. For instance, the information molecules could fail to bind to their receptors for some reason or the transfer of information inside thre receiving cell would fail for some reason. In this case the unexpressed emotion would be stored to the body. In both cases the 4-D body changes gradually more and more p-adic, and becomes full of unrealized intentions and the carving of 4-D body, self-realization, is inhibited.

An important function of sleep and dreams might be the expression of the un-expressed emotions of the geometric past. Also meditation and various therapies might have the same effect. Neuropharmacological approach, as long as it tries to affect only the geometric now, cannot change the geometric past and would not seem therefore very useful healing method for emotional traumas. My own rather traumatic academic past provides a good testing ground for this hypothesis. As a scientific heretic I lost my academic human rights for long time ago. It became clear that if I react to this, I will be labelled as an asocial paranoid. Apart from few exceptions, when the psychic pain was simply too intolerable, I managed to avoid this. This left a lot of unexpressed emotion to my geometric past and the reward for a civilized behavior was a label of a stupid sissy. Gradually it became also clear that there is no hope: the academic decision makers have unlimited power. It is hard to imagine a more effective mechanism for generating deep frustration and long term depression! Gradually I however realized that the coin had also the other side: the role of an academic zombie gave me an unlimited intellectual freedom which those professors did not possess and I had actually ideal circumstances for carrying out my mission optimally. Besides the incredible stupidity of the academic power holders I have been wondering second strange phenomenon during these years. Why do I spend practically all my dream time in my past? Could a partial answer be that I have been busily trying to express these un-expressed emotions: during sleep it is easier to break the academic etiquette.

11.9.6 Questions relating to the M_{17} code

There are many questions related to the interpretation of the M_{17} code.

1. What seems clear is that DNA double strands cognize and p-adically quantum compute by bound state-entangling the neutrino sequences of the two strands: the nucleus is the cognitive brain of the cell. 17 bits means much more information than two 7 bit sequences. This suggests that DNA has emerged in the evolution after proteins, and also after cell membrane, which results from self-organization and needs no coding. Also membrane proteins can quantum compute when they are not making sex with the information molecules. Cell is full of membranes and this maximizes the cognitive and intentional activities in the protein sector.

2. The realization of the DNA neutrino sequences requires the presence of $k = 151$ space-time sheets. Cromosomes are indeed rather thick and there are helices inside helices indicative of a hierarchy of space-time sheets. All the four space-time sheets characterized by Gaussian Mersennes ($k = 151, 157, 163, 167$), could be carriers of cognitive antineutrinos whereas neutrinos would reside at the $k = 169$ space-time sheet. Thus a four-levelled hierarchy of cognition is in principle possible and perhaps partially realized by a hierarchy of helices inside helices. The hierarchy of DNA helical structures could contain $k = 151$ and $k = 157$.

3. The outcomes of DNA quantum computations can be interpreted as intentions which, when realized, represent the result of the computation symbolically as the activity of the organism and/or as a conscious experience at some level. There is no reason to assume that these intentions would be realized only inside genome. Rather, they could be represented by electromagnetic and Z^0 MEs which are already earlier assumed to give an additional contribution to the genetic information. Also the TGD counterparts of scalar waves of Tesla suggest themselves and could transform this information to nerve pulse patterns by generating miniature potentials first. If the duration of the DNA cognitive codon is .14 seconds it is not clear whether these intentions could relate to the 'features', which have duration between .8-.12 seconds. The corresponding frequency is about 7.1 Hz and slightly smaller than the nominal value of Schumann frequency. This information projected by MEs could be unconscious-to-us and realized as magnetospheric sensory representations contributing to the conscious experience of the multi-brained higher level selves. An interesting question relates to the interpretation of the 17 bits of the cognitive

codeword. It would be interesting to try to find evidence for features lasting about .14 seconds and modulated by sequences of 17 yes/no pulses.

11.10 What might be the basic principles behind molecular cognitive and sensory representations?

The challenge of understanding how intentions and cognitions are realized at the molecular level is a fascinating and potentially very rewarding challenge. The work with genetic and memetic codes based on the notion of Combinatorial Hierarchy [L1, L2, M6] represents first steps in this direction but does not yet involve p-adic aspects. The ideas of preceding section provide a lot of additional insight but do not provide any general theory. This section is devoted to an attempt to develop a general theory of cognitive and symbolic representations at the molecular level assuming that even molecular structures have intentions and cognition and are able to transform intentions to actions.

The basic hypothesis is that molecules provide both static and dynamic symbolic representations for cognitive codes. Cognitive codes are characterized by the symmetry groups of finite geometries and their projective counterparts. The requirement that cognitive quantum computation is possible raises the primes defining Mersenne primes to a preferred position. The symmetry groups of finite geometries are assumed to act as the symmetries of the molecular structures responsible for the symbolic representations. This leads to strong predictions as some examples treated below demonstrate and one might even speak about Golden Road to the understanding of cognition and intentionality at molecular level.

11.10.1 Number theoretical ideas

The predictive power of the model to be proposed derives basically from number theoretical constraints. Mersenne primes are in a unique position as far as p-adic quantum computation is considered. One can imagine a good reason for why Gaussian Mersennes should have a unique role. Fibonacci numbers characterize often the structure of biological systems, and there are reasons to believe that they might relate very intimately also to the evolution of cognitive representations.

Mersenne primes an cognitive hierarchies

The findings about new cognitive codes initiated by the idea of symmetry entropy of DNA-protein system can be compressed to a generalized notion of abstraction hierarchy, which was introduced years earlier. Any Mersenne prime M_p, p prime defines an abstraction hierarchy containing at most two levels. The $2^p - 1$ elements of the finite field $G(M_p, 1)$ represent all possible statements about p basic statements except the one which is not representable for some physical reason. Hierachies start from some prime which is $2, 5, 13, 17, 19, 31, 89, 107$ in the range of p-adic time scales of interest and can have several levels.

1. Combinatorial hierarchy $p = 2, 3, 7$ (single base pair), 127 (genetic code), M_{127} (memetic code whose mutually consistent statements are realized also as sequences of 21 DNAs) is the longest hierarchy. It is not known whether $M_{M_{127}}$ is prime: Hilbert conjecture states the entire infinite hierarchy consists of Mersenne primes. This would mean that universe possesses infinite ability of cognitive abstraction.

2. The next hierachy starts from prime 5 and contains three levels $p = 5$, M_5=31, and $M_{31} = 2^{31} - 1 \simeq 2 \times 10^9$.

3. The remaining known to me hierarchies are two-step hierarchies and any Mersenne prime defines such a hierarchy. The largest Mersenne prime hierarchy of this kind relevant for human consciousness is M_{127} which is the p-adic prime characterizing electron and memetic code. M_{521} is the next Mersenne prime and corresponds to a completely super-astrophysical time scale.
   i) The first abstraction pair (p, M_p) corresponds to $p = 13$. Micro-tubuli are excellent candidates for the realization of M_{13}^{13} representations with $13^2 = 169$ bits of information (recall that $k = 169$ characterizes the p-adic length scale associated with neutrinos!).
   ii) Next Mersenne M_p prime corresponds to $p = 17$ and was deduced by the argument relating

to the information gain in complete symmetry breaking of the DNA-protein system.
iii) Also the Mersenne primes M_p associated with $p = 19, 31, 61, 89, 107$ should be there.

The beauty of Mersenne representations is that one can construct from them product representations containing M_p^k cognitive states and bits replaced by pinary digits M_p. Furthermore, by fractality any time scale $2^{pm/2}T_{M_p}$ is possible for sufficiently small primes p so that these representation can be present in and a wide spectrum of time scales ranging from the time scales relevant for the conformational dynamics of molecules to the time scales relevant for neural activity and EEG and even time scales measured in years.

What about Gaussian Mersennes?

The Gaussian Mersennes $G_n = (1+i)^n - 1$, n some prime, are expected to be also of fundamental importance and one expects that they give rise to complex cognitive representations. The Gaussian Mersennes possibly relevant to life correspond to primes $n = 2, 3, 5, 7, 11,\ 19, 29, 47, 73, 79, 113,\ 151, 157, 163, 167,\ 239, 241, 283$. The length scale range between cell membrane thickness and size of small bacterium contains only Gaussian Mersennes: they are $n = 151, 157,\ 163, 167$. The norm squared of the Gaussian Mersenne $G_{n=2k+1}$ is $p_n = 2^{21+1} + 2^{k+2} + 1$ and larger than 2^n.

One might guess that the number of Gaussian integers with norm smaller than the norm squared of Gaussian prime G_n defines the number of states in this kind of representation and that this number must be prime. Some very beautiful cognitive structures might be involved with Gaussian Mersennes and it remains to be found what this structure is. Obviously the idea that one could use sequences of n bits to realize $p_n = 2^n - 1$ points as phase transitions by spontaneous magnetization to an analogous representation of $p_{n=2k+1} = 2^{2k+1} + 2^{k+1} + 1$ points. One can write p_n in a form which gives hints about what kind of physics this representation might require:

$$p_{n=2k+1} \equiv N_1 + N_2 + N_3 \ ,$$

$$N_1 = 2^{2k+1} - 1 \ , \qquad N_2 = 2 \times 2^k - 1 \ , \quad N_3 = 2 \times 2 - 1 \ .$$

p_n is sum over numbers of magnetization phase transitions for three phases of the fermion system. N_1 corresponds to a system of $2k+1$ fermions. N_2 corresponds to a system consisting of one fermion plus k Cooper pairs: by the indistinguishability of fermions the combinatorial factor k is absent from N_2. N_3 corresponds to a system consisting of one fermion and a Bose-Einstein condensate of all k Cooper pairs behaving like a single particle. Neutrinos at $k = 169$ space-time sheet suggest themselves strongly as a realization of this phase.

Fibonacci numbers and the evolution of cognition

Fibonacci numbers proliferate living matter (logarithmic spirals) and emerge in the simplest models of growth: living matter is full of logarithmic spirals and also micro-tubular structure involves the sequence $3, 5, 8, 13$ of Fibonacci numbers. The natural guess is that Fibonacci numbers are also involved with cognitive growth and evolution: especially so if this biological growth is basically intentional and involves growth of plans from rough sketches to more detailed ones and if this development is seen in the structure of intention. In particular, 21 DNA/protein codeword could decompose to ordered hierarchy of subsequences of $1, 2, 3, 5, 8, 13, 21$ DNAs and these sequences with increasing length gradually give better and better representation of codeword. The development of the full cognitive code word or intention, would be like an interactive growth of a population of 21 cognitive organisms, primitive intentions associated with single DNA. Older unit intentions react to the presence of new ones by generating new unit of intention each. When, say, a generation consisting of 5=2+3 unit has been established, 3 units of previous generation generate new units (5+3=8) as a response to the presence of new 2 units.

For intance, single micro-tubule would represent only the 13 first DNAs and would not give faithful coding of the codeword. The wall of a double micro-tubule with 21 tubulin strands at its wall would do it. Interestingly, triple micro-tubules seem to contain the total of 33 or 34 micro-tubules, whether the number is 34=21+13, the next Fibonacci in the micro-tubular series, is not clear on basis of material that I have seen. Because of its Fibonacci structure of micro-tubule could automatically represent 5, 8 and 13 DNA approximations to the full intention represented by a sequence of 21 DNAs.

11.10.2 Representations

Representations are fundamental notions in geometry and physics and, as it seems, also sensory, symbolic, and cognitive representations make sense. The basic idea is that Nature codes its mathematical cognition to various kinds of symbolic representations. The fascinating possibility is that practically every bio-structure which results in genetic expression represents some cognitive/intentional structure somehow. We have been used to think that our theories represent those structures we see: it might be fruitful to see the situation as just the opposite! DNA and proteins would be only particular hardware realization of finite geometries associated with cognition. This view might be general enough and certainly practical: one can deduce the symmetry groups associated with various structures and look whether one can assign them to finite geometries or their projective counterparts and thus to p-adic cognition.

Various types of representations

One can distinguish between several kinds of representations.

1. There are cognitive representations in terms of temporal sequences of p-adic neutrinos. Sequences of 21 DNA triplets could realize any representation defined by Mersenne prime since the temporal character of the sequences means that the density of neutrinos needed does not depend on the Mersenne prime. Thus there is no really deep reason for making too restrictive assumptions at this stage.

2. There are symbolic representations resulting when p-adic many neutrino states associated with p-adic Z^0 MEs transform to real ones. This transformation means transformation of intention to action or cognitive representation to a symbolic representation. The realization of this representation has been already discussed.

3. The symbolic representations can transform further to dynamical representations as either nerve pulses or oscillations of membrane em or Z^0 membrane potential. This representation generalizes: what is needed are two-state systems in an external field which forces a process analogous to spontaneous magnetization.

4. One can also consider the possibility of static geometric representations in terms of molecular geometry. These kind of representations could be realized for any prime p and in case that M_p is Mersenne prime, the structure characterized by p parts related by a cyclic symmetry Z_p could serve as a template for dynamical representations obtained by attaching a two-state system at every unit of the system. For instance, DNA triplets realize statically the mutually consistent statements of $M_7 = 127$ cognitive representation and single DNA triplet could realize $M_3 = 7$ representation if each basepair can be in two states. Clathrin molecule gives 12-fold product of $p = 5$ representation in terms of 12 disjoint pentagon faces whose vertices carry a two-state system (the polarization of the triskelion protein could define the two states).

The basic principle for realizing dynamical representations

According to TGD inspired theory qualia, primitive qualia correspond to spin flips, and more generally, to phase transitions changing the direction of spin or some other quantity characterizing the state of the two-state system. In case of neutrino representations the essential elements are the presence of Z^0 magnetic field, the fact that the neutrino is a two-state system which flips in the direction of external Z^0 magnetic field, and the fact that the number of representable states is $M_n = 2^n - 1$ rather than 2^n states since the state in which all spins are parallel does not give rise to spontaneous magnetization and conscious experience.

Any two state system can replace neutrino and Z^0 magnetic field can be replaced with an electric or magnetic field. The replacement of single particle states with say spontaneously magnetized states guarantees rigidity and robustness. Spin glass type phase is optimal for the representative purposes and TGD universe is indeed a quantum spin glass. Dynamic representations can be realized in terms of molecular conformations instead of using fields. Micro-tubule representations provide a fundamental example but there are a lot of others. If magnetic flux tubes and electrets are indeed fundamental building blocks of living systems (they represent fundamental solutions of field equations of TGD),

living system should be a huge fractal collection of these representations. Also cell membrane is expected to carry representations of this kind.

What this means is that the projective finite geometry with $M_n + 1 = 2^n$ points is represented dynamically by n two state systems such that the point at infinity is not realizable as spin flip pattern since it corresponds to the spontaneous magnetization or electret state in which all n two-state systems have spin /polarization/... direction parallel to external field and nothing happens. This is indeed what is required by the realization of qualia as quantum number increments. At the level of set theoretical Boolean algebra representation the point at infinity corresponds to the empty set.

If the strength of the background field can be controlled, the representation could be generated by weakening the field temporarily so that there results either a spin glass phase at criticality optimal for the storage of bits or a phase above criticality optimal for signal propagation. The transformation inducing 'spontaneous magnetization' responsible for the conscious experience could be generated by increasing the strength of the magnetic or Z^0 magnetic/electric field to its original value. For instance, in case of micro-tubular conformational representations reading would result by introducing strong electric field forcing the conformations to ground state conformations.

Magnetic flux tubes and their electric duals provide these background fields. In case of magnetic flux tubes cyclotron transitions are these transitions and spins of Cooper pairs define the bits. This allows a deeper understanding of also sensory representations.

Fractal hierarchy of time scales

The beauty of the realization of cognitive representation in terms of Mersenne primes is that all fractal powers $T(p,n) = p^{(n-1)/2}T_p$ of p-adic time scale T_p are a priori possible and correspond in good approximation to the square roots of the octaves of the fundamental time scale. The first implication is that the entire span of biologically relevant time scales can be realized using relatively few fundamental time scales defined by small Mersenne primes. This means also that for large Mersenne primes corresponding to relatively long time scales there can be several small Mersenne representations with essentially the same time scale. The signatures for these time scales are resonance frequencies corresponding to the time scales defining the duration of the codeword and also the duration of single bit. How much the duration of the codeword can vary around the p-adic time scale is still an open and important question: the width of alpha band suggests that the variation is about $\pm$ 20 per cent.

11.10.3 Finite geometries and cognition

Finite geometries defined by Galois fields $G(p,n)$ with p^n elements and identifiable as integers in an algebraic extension of p-adic numbers modulo p and corresponding projective geometries are the natural mathematical framework for simplest cognition. The primes p defining Mersenne primes $M_=2^p - 1$ and Gaussian Mersennes and these primes themselves are preferred primes for the reasons already explained.

1. The evolution of mathematics represents the evolution of cognition since ontogeny recapitulates phylogeny also at the level of cognition. This means that ancient mathematicians constructed also models for the basic structures of cognition. The Platonic solids could represent basic cognitive structures rather than only vice versa as it is usually thought.

2. Symmetry group characterizes a given geometry. This group is cyclic group Z_p for the simplest finite geometries defined by finite fields $G(p,1)$, p prime, and finite projective group for for their projective counterparts obtained by adding the point at infinity.

3. One can interpret spatial and temporal sequences of antineutrino Z^0 magnetization directions as representing points of finite geometries or their projective counterparts defined by Mersenne primes. The point at infinity corresponds to all spins in the direction of Z^0 magnetic field so that no membrane oscillation is generated: infinity is un-reachable. Operational infinity is something which one is not able to achieve or perceive. This finding generalizes to a more general representational principle using two-state systems in an external field which forces the two-state systems to the same state. The cognitive state is coded to a conscious experience resulting in the phase transition to the ground state. If there are p two-state systems such that M_p is Fermat prime this system codes the points of the finite geometry M_p to conscious experiences.

If this view is correct, the mathematicians were studying their own cognitive consciousness when they were proving theorems about Platonic and Archimedean solids or doing ruler and compass constructions. In fact, I realized for years ago that Pythagorean triangles which pop up naturally in p-adic context, represent the very early view about world as mere rational numbers. The simplest mathematical cognition relies on finger counting: amusingly, decimal code pops up already at the level of DNA: 10 DNA triplets correspond to a helical twist which is minimal multiple of 2π.

Finite geometries

Ordinary finite geometry understood as having a structure of number field involves only a set of p (prime) ordered points defining the finite field $G(p,1)$ and subsets of points of this geometry. The projective counterpart involves also the point at infinity and contains thus $p+1$ points. Also the algebraic extensions $G(p,n)$ of $G(p,1)$ containing p^n points are possible but not discussed here. The symmetry group of the finite geometry $G(p,1)$ is cyclic group Z_p and the sequences of Z^0 magnetization directions of p cognitive neutrino blocks represent the subsets of $G(p,1)$ as ordered sets. In case of projective finite geometry containing also the point infinity projective transformations induced by 2×2 unimodular matrices

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \tag{11.10.1}$$

induce projective transformations via the formula

$$x \to \frac{ax+b}{cx+d} \ . \tag{11.10.2}$$

By studying the unimodularity condition $ad-bc=1$ in finite field one easily finds that the number of elements in the projective group is

$$N \ = \ (p-1)\times[(p-1)\times(p-2)+4\times(p-1)+2]/2 \ . \tag{11.10.3}$$

For $p=5$ one obtains $N=60$ corresponding to the number of vertices in truncated icosahedron representing thus the symmetry group of 6-point projective finite geometry consisting of the group A_5 of even permutations of five objects. For $p=3$ the number of elements is $N=224$ and corresponds to the group S_4 of permutations of four objects whereas for $p=2$ the number of elements is $N=6$ and corresponds to the group S_3 of the permutations of three objects.

The projective transformations of finite projective geometries are counterparts of Lorentz transformations. One can assign to finite geometries also a spinor structure. Spinors have two-components and the action of the projective transformation on the spinor is by matrix multiplication. It was actually this finding which led to the realization that there might be a deep connection between cognitive representations by cognitive neutrino representations and finite (projective) geometries.

Representations of finite geometries

An interesting question is what finite geometries can be realized as polygons in plane or as Platonic or Archimedean solids. This requires that the symmetry group of the finite geometry or of its projective counterpart acts as a subgroup of the rotation group $O(3)$. For finite geometries having Z_p as a symmetry group regular polygons of plane with p vertices and edges provide this realization. At molecular level a realization by helical twisting is natural. If the number of units corresponding to a full helical twist of multiple of 2π is p or power of p one has a geometric realization of a finite geometry.

1. Polygons obtainable by ruler and compass construction

Of special interest are the polygons which can be constructed using only ruler and compass: for these structures lengths of various edges are either integers or involve iterated square roots of integers. The well-known theorem of Euler states that the only structures of this kind correspond to regular polygons with n vertices and sides of identical length having vertices at circle. The allowed values of n are given by

$$n = 2^k \prod_k F_k \ ,$$

where k is any non-negative integer and F_k is Fermat prime

$$F_k = 2^{2^k} + 1 \quad , \quad k = 1, 2, 3, 4 \quad .$$

The list of Fermat primes is $3, 5, 17, 287, 2^{16} + 1$. Interestingly, the lowest three Fermat primes define Mersenne primes M_{F_k} so that they are expected to be of special interest from the point of view of cognition. These structures are not finite geometries but could be regarded as Cartesian products of finite geometries $G(2, k)$ and $G(F_i, 1)$. These structures can be seen as Cartesian products of finite geometries.

A possible geometric representation of these structures is based on many-sheeted space-time so that various factors in the decomposition correspond to different space-time sheets characterized by appropriate p-adic topology (also real space-time sheets are characterized by p-adic prime). The hierarchical helical structures containing helices inside helices correspond to many-sheeted space-time structures and the numbers of basic units corresponding to single period at various levels could correspond to the prime factors appearing in the decomposition.

Bio-systems are full of helical structures. Five finger code and decimal code are included as almost simplest codes. 10 DNA molecules define a structures for which the total helical winding is multiple of 2π. Perhaps here is linear realization of the decimal code: that twist is multiple of 2π indeed says that one can form from DNA a loop where that cyclic group of 10 elements acts. One should look systematically through all helical structures and find the number of units which correspond to a minimal multiple of 2π rotation to see whether ruler and compass codes are realized.

2. Quantized Planck constant, dark matter, and Fermat polygons

One ends up with Fermat polygons from the quantization of Planck constant as $\hbar = \lambda\hbar_0$. Number theoretical arguments suggest a general formula for the allowed values of λ [C9] as $\lambda = n$ where the integer n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [C7]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17, F_3 = 257, F_4 = 2^{16} + 1$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales.

The p-adic vision about cognition suggests that algebraic extensions of p-adic numbers define a cognitive hierarchy and the lowest levels of this hierarchy correspond to algebraic extensions of p-adic numbers involving only iterated square root operation. These should emerge first in the evolution and therefore dark matter systems assignable to Fermat polygons should be the most abundant ones.

There is a lot of evidence for the presence of integers characterizing Fermat integers in living systems. For instance, the so called scaling law of homeopathy [K5] states that radiation with frequency f_l is accompanied by a radiation with frequency $f_h \simeq 2 \times 10^{11} f_l$. The scaling factor 2×10^{11} corresponds with 1.5 per cent accuracy to the integer $n_F = 2^{36} \times 3 \simeq 2.03 \times 10^{11}$ defining a Fermat polygon. This suggests an interpretation in terms of a decay of dark photon with a given wave-length to a bundle of n_F ordinary photons with the same wavelength. The energy of the dark photon would be by a factor n_F higher. This process could serve as an effective tool of bio-control. Dark photon could also transform to an ordinary photon with wavelength shorter by factor $1/n_F$. There is a lot of evidence that the powers of $n = 2^{11}$ define preferred scalings of $\hbar$: n_F corresponds to $n_F = 2^{3\times 11} \times 24$ which suggests that also the scale factors $n_F = 2^{k\times 11} \times 24$ could be favored. Quite generally, integers n_F defining Fermat polygons are a reasonable guess for the generalization of the scaling law of homeopathy and the search for these scaling factors could provide an experimental means of identifying the values of Planck constant relevant for living matter.

Even the time units of everyday life could reflect the properties of the dark matter hierarchy responsible for the control of living matter, in particular those of the sub-hierarchy defined by Fermat polygons. Indeed, one year corresponds to $n_F = 4 \times 3$ months, one month to $n_F = 2 \times 3 \times 5$ days, one day to $n_F = 8 \times 3$ hours, one hour to $n_F = 60 = 4 \times 3 \times 5$ minutes, and one minute to $n_F = 60$ seconds.

3. Chromosomes and neutrinos

Helices within helices could give rise to hierarchies of cognitive representations. Magnetic flux tubes can have complex helices inside helices hierarchies and in this case the number of units basically

consisting of super-conducting ions or of their Cooper pairs per single period at given level of hierarchy should be prime for a given loop.

Chromosomes are characterized by this kind of hierarchy of coiling and looping which helps to pack chromosome DNA (about 2 meters in humans) in a small volume. This hierarchy could give also make possible a hierarchy of cognitive codes corresponding to the space-time sheets defining the hierarchy. What makes this hierarchy so interesting is that the p-adic length scales in question correspond to the miracle length scales defined by Gaussian Mersennes corresponding to $k = 151, 157, 163$ and 167. The diameter of the largest structure involved with chromosomes is about .7 micrometers whereas the smallest structure has diameter of 11 nanometers. Thus all three primary p-adic length scales $k = 151, 157, 163$ could be realized and three levelled hierarchy is possible. n-Ary p-adic length scales could increase the number of possible levels. A test for this idea is whether the numbers of the basic units per period of helix at various levels are given by primes. The realization in terms of cognitive neutrinos involves only temporal sequences of n (M_n is Mersenne prime) Z^0 magnetized neutrino blocks so that the density of cognitive neutrinos is same for all realizations and at least one neutrino per DNA triplet. Robustness suggests Z^0 magnetized many-neutrino phase per DNA triplet (having length about one nanometer). This might well be possible since the density of condensed matter neutrinos is same as the density of neutrons and several per atomic volume.

The first possibility coming into mind is that the number of Z^0 magnetized units is determined by the space-time sheet involved and thus equal to $k = 151, 157, 163$. The corresponding primary time scales are rather short and below 10^{-14} seconds so that these intentions would be realized in a very short time scale. Thus fantastic amounts of cognitive processing would occur in time scales usually considered to not involve any kind of conscious intelligence. The spin flip could occur for the neutrinos at $k = 169$ space-time sheet or for the antineutrinos at $k < 169$ space-time sheet. Suppose that the space-time sheet labelled by k carries a Z^0 magnetic field with intensity roughly equal to $g_Z B_Z = 1/L(k)^2$ from the quantization of the Z^0 magnetic flux. Suppose further that the neutrino has mass of order $1/L(k)$. With these assumptions the order of magnitude for the rate of cyclotron transitions is about $g_Z B_Z(k)/m_\nu(k) \simeq c/L(k)$ and thus fast enough. Even neutrino spin flip at $k = 169$ space-time sheet might occur fast enough.

There are three different neutrinos corresponding to electron, muon, and τ lepton. The empirical data about neutrino masses forces the masses of neutrinos to be nearly identical and $k = 169$ is the stable level of topological condensation whereas the space-time sheets labelled by Gaussian Mersennes would allow meta-stable condensation of antineutrinos (this means a new kind of matter-antimatter asymmetry). The presence of three neutrino generations means three-fold increase of the cognitive capacity so that the strange looking degeneracy of the neutrino masses is taylor-made from the point of view of -cognition in TGD Universe. An interesting question is whether the different neutrino generations are specialized to different types of cognition and what these types of cognition are.

Realization of finite projective geometries using Platonic and Archimedean solids

For projective geometries the realization as Platonic solids in the sense that the projective symmetry group acts as group of symmetries of the Platonic solid are possible only for $p = 2, 3, 5$ cases. The 5 Platonic solids are tedrahedron, cube and octhedron, and icosahedron and dodecahedron. The basic transformation is duality changing faces and vertices. Tedrahedron (4 vertices and 4 faces) is self dual whereas cube (8 vertices and 6 faces) and octahedron (6 vertices and 8 faces) are duals of each other, as are also icosadedron (12 vertices and 20 faces) and dodecahedron (20 vertices and 12 faces). The number of edges is fixed by the Euler characteristic of sphere (solids are topologically spheres) given in terms of the numbers of vertices, edges, and faces by $V - E + F = 2$ and one has $E = V + F - 2$ giving for the number of edges $E = 6, 12, 30$ in the three cases respectively. Archimedean solids allow different types of faces and hexagons, octagons and decagons are possible (note that the number of vertices for faces is not prime anymore). Archimedean solids have same symmetry groups as Platonic solids from which they are obtained by 'truncations'.

It is interesting to look how the symmetry groups of finite geometries can be realized as symmetries of Platonic and some Archimedean solids.

1. For $p = 2$ the group of projective symmetries corresponds to the 6-element group S_3 of permutations of three objects acting on triangle and being generated by 2- and 3-fold symmetries. The 3 vertices represent the 3 points of the projective geometry and the generator of Z_2 acts

as a reflection permuting any pair of these points with the third point representing the point at infinity. The three faces of tedrahedron give rise to a representation of $p = 2$ finite geometry too. By assigning to each of these vertices a two-state system one obtains a representation for M_2. Tedrahedron allows M_2^2 representation with information content of 4 bits.

2. $p = 3$ projective geometry has four points and has the permutation group S_4 of four objects as a symmetry group. This group is the symmetry group of tedrahedron and the vertices of any face realize the finite geometry with three points with the fourth vertex taking the role of the point at infinity. Also octahedron and cube having symmetry group generated by 2-, 3- and 4-fold symmetries allow realization of the $p = 3$ finite geometry but not an isometric realization of the projective geometry since the tedrahedron defined by the 3 vertices nearest to a given vertex is not regular. 3-fold symmetries are rotations along diagonals. M_3 cognitive representation results by assigning to the 3 vertices of triangle, tehdahedron or cube two-state systems.

3. The symmetry group of $p = 5$ finite projective geometry and thus also the geometry are represented by dodecahedron and icosahedron which are dual to each other by vertex-face transformation, as well as by a truncated icosahedron, 'bucky ball', having 60 vertices and directly representing the projective group associated with the corresponding finite geometry [19]. This group is isomorphic with the group A_5 of even permutations of 5 objects and contains 2-,3-, and five-fold elements. The coset space of $A_5/Z_2 \times Z_5$ represents the projective space and consists of 6 pairs of opposite and disjoint pentagons representing the points of the finite projective geometry.

The points of the finite geometry are represented by a single pentagon as is clear from the fact that the cyclic group Z_5 acts on these pentagons) M_5 representation results by assigning to the vertices of any pentagon a two-state system. System allows actually much more: there are 12 disjoint pentagons so that M_5^{12} code can be realized with information content of 60 bits! Thus truncated icosahedron has an exceptional capacity for coding intentions and this might be the reason for why it is the geometry of the clathrin molecules which take care of logistics in cellular systems.

Platonic solids allow also lattice structures. Therefore cognitive structures allowing symbolic representations in terms of molecular and lattice structures based on Platonic solids are expected to be of fundamental importance. These correspond to correspond to 2,3, and 5 bit codes and Mersennes M_2, M_3, M_5. M_2 corresponds to geometry of a line interval/triangle, M_3 to triangle/tedrahedron, and M_5 to pentagon/icosahedron, dodecahedron or truncated icosahedron depending on whether one requires projective extension or not. The codes would be represented by assigning to the substructures representing the finite geometry a two-state system. For instance, electric polarization of the protein structure in electric field at larger space-time sheet could define the spinlike variable. By using lattice like structure formed by basic units one obtains products of representations of type M_n^k.

11.10.4 Application of ideas to micro-tubuli and clathrin molecules

The proposed general principle allow to develop detailed views about what kind of cognitive representations that various molecular structure can accommodate. There is a considerable freedom concerning the choice of the representative system and spin flips or analogous transitions can be amplified to magnetization type quantum phase transitions at higher levels of the self hierarchy.

Micro-tubular representations

Micro-tubuli [40, 41] are formed as hexagonal lattices of tubulin dimers on cylinder. The two conformations of a tubulin dimer define the two states of the micro-tubular representations. In an external electric field along micro-tubule at the larger space-time sheet the second tubulin conformation is unstable and the codeword is realized as a phase transition leading to the ground state. Spontaneous electric polarization of all tubulins in the same direction forced by an electric field in the direction of the micro-tubule defines the ground state. The ground state itself cannot give rise to conformational flips and thus cannot define a codeword and one obtains M_{13} rather than 2^{13} codewords realizable as a signal resulting in the flip to the ground state.

1. *Basic picture* Micro-tubuli have helical structure: there are two helical strands with 13-micro-

tubule periodicity. A full 2π twist for a tubulin dimer strand corresponds to 13 dimers and corresponds to vertical distance of 8 resp. 5 micro-tubules for the two arrays involved. Thus a full 2π twist defines naturally the codeword and corresponds to 13-bit M_{13} codeword. Each tubulin dimer strand defines a codeword: M_{13}^{13} representations with an information content of $13^2 = 169$ bits associated with single 13-plet of codewords results.

Rather remarkably, and hardly not accidentally, the p-adic length scale $L(k)$, $k = 13^2$, characterizes the space-time sheet at which the cognitive neutrino resides whereas antineutrino could reside at a space-time sheet labelled by $k = 151, 157, 163, 167$.

The small value of $p = 13$ means an extreme flexibility concerning the duration of the cognitive code word. All $2^{13k/2} \sim 90.51^k$ multiples of T_{13} are possible. An interesting working hypothesis is that the number N of the tubulin strands contributing to the codeword defined by single connected structure defines the duration of the codeword as $T(N) = 2^{N\times 13/2}T_{13}$.

1. If the $k = 21$ micro-tubules at the wall of micro-tubule doublet contribute give rise to the DNA representation, this rule would predict the duration of the code word to be $T = 2^{(21-13)\times 13/2}T(169) \simeq 67.7$ seconds with the duration of bit about 5.6 seconds, which is somewhat longer than the mysterious time scale of 5 seconds associated with the Comorosan effect [J5]. $k = 20$ would give a codeword with a duration of .8 seconds and with the duration of bit about 62 milliseconds. DNA should control the behavior of micro-tubules in a rather long time scale (translation of single amino-acid takes 1/20 seconds) and these timescales sound rather reasonable.

2. For triplets of micro-tubuli the number of tubuli in the wall is something like 29 and the rule would predict completely unrealistic duration of the codeword about 10^7 years. It seems that the time scale should be same as for doublet: note that only pairs of tubuli have direct contact in the triplet.

3. Micro-tubular representation would correspond to the duration $T(13^2) = T(169)$ the cognitive codeword which is about 1.7×10^{-14} seconds, which is much shorter than the time scale of conformational dynamics and corresponds to the time scale of infrared transitions. This time scale is considerably shorter than the time scale $\sim .1$ nanoseconds associated with the protein conformational dynamics so that some other spin or rpolarization type variable should define the representation if it is realized at all. Neutrino spin is an excellent candidate in this respect. By increasing $k = 13$ to $k = 15$ gives time scale of order .1 nanoseconds. It seems that the working hypothesis could give rough ideas about orders of magnitude but cannot be taken literally.

2. Cilia and centriole

Centriole resp. cilia are arrangements of micro-tubules containing 9 bundles of 3 resp. 2 micro-tubules at the boundary of cylinder like structure and possibly also a doublet of micro-tubuli in the center [41].

Micro-tubule doublets are associated with cilia crucial for the movement of monocellulars. Cilia consists of nine micro-tubule doublets at the surface of cylinder and one doublet in the center: also two separate micro-tubules are possible in the center. Some tubulin strands (usually three) are lacking from the second fused micro-tubule. According to some sources, the total number of tubulin dimer strands in doublet is 24 and 21 at the outer surface of doublet. 21 is Fibonacci number associated with the micro-tubular sequence of Fibonacci numbers and also the number of DNA triplets in cognitive codes. The complex of 21 tubulin dimer strands would be ideal for coding of M_{13}-bit sequences possibly associated with DNA or amino-acid sequences of 21 units and containing $21 \times 13 = 273$ bits of information. The code words associated with the wall of the cilium define $M_{13}^{9\times 21}$ representation with $13 \times 9 \times 21 = 2457$ bits.

Centriole are crucial for the control of the movement of the cell and are present only in motile cells (not in plants). If nucleus controls the movement of cell, centrioles and cilia should communicate with DNA in both directions in the act of transforming intentions to actions. T shaped centriole form an ideal antenna structure and could communicate both classically and quantally in terms of MEs. Centriole have 9 micro-tubule triplets at the boundary of a cylinder. Various sources give different values for the total number of strands but it seems that the total number of tubulin strands is about 33-34 and outer wall contains about 4 strands. Perhaps it deserves to be noticed that the total number of strands is near to Fibonacci number 34 associated with the micro-tubular sequence

of Fibonacci numbers. In case of centriole the 9 fused triplets of micro-tubules at the boundary each triplet containing about 33 tubulin dimer strands should give rise to a representation $M_{13}^{9\times 33}$ with $13 \times 9 \times 33 = 3861$ bits. Huge amounts of information are involved.

3. Neuronal micro-tubuli

Neurons, which are not motile cells, do not have the usual T shaped centriole structure. Micro-tubuli are however there and start from the region near nucleus and connect this region to the dendrites and to the end of the axon. The micro-tubuli associated with the axons can be very long, up to millimeters and are connected together by MAPs, micro-tubule associated proteins. This strongly suggests that micro-tubuli participate in an essential manner to neuronal communications or to short term information storage. For instance, the propagation of the nerve pulse could alter the electric field of the micro-tubule space-time sheet temporarily and give rise to spin glass state and thus induce representations of cognitive states in terms of tubulin conformations. The return of the membrane potential to the normal value would induce the conscious reading of the resulting representations. The minimal reason for this would be that axonal micro-tubules are responsible for the transfer of neurotransmitters to the axonal end and they must be cognizant about the overall nerve pulse activity.

Against the impressive representational capacity of micro-tubules the idea that nerve pulse involves the transfer of only single bit of information seems weird. Rather, the picture about micro-tubules would suggest that nerve pulse propagation are accompanied by a propagation of conformational spin glass state in the depolarized portion of the axon carrying information, and that one important function of the nerve pulse is to allow the propagation of the conformational wave carrying the information. Of course, also cell membrane could carry informational wave by same mechanism and one could see the events in the axonal membrane also as a realization of p-adic intentions basically. An objection against this view is related to the problem how the micro-tubular signal is transferred between micro-tubuli at MAPs. This is obviously needed if information from micro-tubuli is transferred to postsynaptic neuron. One must seriously consider the possibility is that the information is received only by micro-tubuli and their form an essential part of the conscious sensory pathway. This would explain why the lengths of micro-tubuli associated with sensory pathways are maximized (the information from given side of the body goes to the opposite brain hemisphere).

Clathrin molecule and cognition

Clathrin molecule [41] is involved with the transfer of various kinds of cargo through the cell membrane and also through intracellular membranes. Even viruses use clathrin molecule coating. Clathrin molecule induces a pit in the cell membrane and membrane pinches so that clathrin molecule providing coating for a piece of cell membrane and containing the cargo ends up to the cell interior. An area of cell membrane of football plane corresponding to that contained by entire brain is generated during one hour when clathrins coat cell membrane containing receptors and take it inside the cell. The generation of new cell membrane with this gigantic rate should involve huge dissipative losses unless macro-temporal quantum coherence is involved in the process.

Perhaps this argument alone convinces one day anyone about the presence of macro-temporal quantum coherence in brain. Clathrin molecule has the geometry of a truncated icosahedron, also the geometry of the soccer ball and fullerene or buckyball molecule C_{60} containing 60 carbon atoms arranged to the vertices of the truncated icosahedron. In clathrin molecule carbon atoms are replaced by three-legged triskelion molecules consisting of proteins. It is interesting to take a more careful look on the geometry of truncated icosahedron defining the geometry of the clathrin molecule, if not anything else, the for the purpose to get a glimpse about the amazing number theoretical regularities of this structure. Truncated icosahedron has 60=59+1 vertices, 90=89+1 lines, and 12=11+1 pentagonal and 20=19+1 hexagonal faces. Pentagonal faces are disjoint. 6 pentagonal face pairs can be naturally interpreted as points of a finite projective geometry associated with finite field $G(5,1)$.

What it is interesting is that all these numbers are of form $p+1$, p prime. With one exception (59) these primes also define Mersennes of Gaussian Mersennes. As a matter fact, the number of faces, edges, and vertices are of this form for all Platonic solids and also for several Archimedean solids. The interpretation in terms of a finite projective geometries suggests itself but the requirement that the symmetries of finite geometry are realizable as rotations excludes this interpretation since these substructures are not representations of the corresponding projective group realized in terms of rotations. Of course, one must keep mind open for the possibility that the imbedding of the symmetry

group to rotation group is not necessary.

Clathrin molecule is an excellent candidate for a very effective realization of molecular cognition and intention. If the triskelion proteins at the vertices of disjoint pentagons are electrically polarizable, a dynamical M_5^{12} representation with information content of 60 bits becomes possible by controlling the electric field at the space-time sheet at which the triskelions are condensed at. This information could relate to the basic function of clathrin molecules but also the idea that clathrin molecules transfer also information besides matter must be considered. For instance, this representation could be involved with the transfer of not only the neurotransmitters but also of (micro-tubular?) information from post- to pre-synaptic neurons.

What about cell membrane?

Cell membrane electric field makes it ideal for the realization of cognitive representations. Lipid molecules and membrane proteins are natural good candidates for representing the bit sequences represented as two different electric polarizations of proteins. The propagation of nerve pulse could generate a representation during depolarization phase which would be read when membrane potential has returned to its original value. The function of the nerve pulse would be thus to inform entire axon consciously.

11.11 Intentionality, cognition, and number theory

The identification of p-adic physics as physics of cognition and intention suggests strongly connections between cognition, intentionality, and number theory. The new idea is that also real transcendental numbers can appear in the extensions of p-adic numbers which must be assumed to be finite-dimensional at least in the case of human cognition. This idea, when combined with a more precise model for how intentions are transformed to actions, leads to a series of number theoretical conjectures. Also new insights about the number theoretical origin of the universal dynamics of conformally invariant critical systems emerge. The earlier approaches to the proof of Riemann hypothesis can be understood in a unified manner and the assumption that Riemann Zeta exists in all number fields when finite extensions are allowed for p-adic numbers leads to the view that that the zeros of Riemann Zeta correspond to the universal number theoretically quantized spectrum of scaling momenta associated with critical conformally invariant systems.

The first proposal to realize this idea was based on the hypothesis that numbers like e/π, $log(p)/\pi$, and $log(\Phi)/\pi$ could be rational numbers. This idea does not work as since π cannot belong to a finite-dimensional extension of p-adic numbers as will be demonstrated below. One can however develop a more general approach giving good hopes about p-adicization of TGD by algebraic continuation from rationals to reals and p-adic number field.

11.11.1 Should one allow also transcendentals in the extensions of p-adic numbers?

TGD inspired theory of consciousness leads to the identification of p-adic physics as physics of cognition and intention. This identification leads to a rather fascinating new ideas concerning the characterization of intentional systems.

The basic ingredient is the new view about numbers: real and p-adic number fields are glued together like pages of a book along common rationals representing the rim of the book. This generalizes to the extensions of p-adic number fields and the outcome is a complex fractal book like structure containing books within books. This holds true also for manifolds and one ends up to the view about many-sheeted space-time realized as 4-surface in 8-D generalized imbedding space and containing both real and p-adic space-time sheets. The transformation of intention to action corresponds to a quantum jump in which p-adic space-time sheet is replaced with a real one.

One implication is that the rationals having short distance p-adically are very far away in real sense. This implies that p-adically short temporal and spatial distances correspond to long real distances and that the evolution of cognition proceeds from long to short temporal and spatial scales whereas material evolution proceeds from short to long scales. Together with p-adic non-determinism due the fact that the integration constants of p-adic differential equations are piecewise constant functions this

explains the long range temporal correlations and apparent local randomness of intentional behavior. The failure of the real statistics and its replacement by p-adic fractal statistics for time series defined by varying number N of measurements performed during a fixed time interval T allows very general tests for whether the system is intentional and what is the p-adic prime p characterizing the "intelligence quotient" of the system. The replacement of $log(p_n)$ in the formula $S = -\sum_n p_n log(p_n)$ of Shannon entropy with the logarithm of the p-adic norm $|p_n|_p$ of the rational valued probability allows to define a hierarchy of number theoretic information measures which can have both negative and positive values.

Since p-adic numbers represent a highly number theoretical concept one might expect that there are deep connections between number theory and intentionality and cognition. The discussions with Uwe Kämpf in CASYS'2003 conference in Liege indeed stimulated a bundle of ideas allowing to develop a more detailed view about intention-to-action transformation and to disentangle these connections. These discussions made me aware of the fact that my recent views about the role of extensions of p-adic numbers are perhaps too limited. To see this consider the following arguments.

1. Pure p-adic numbers predict only p-adic length scales proportional to $p^{n/2}l$, l CP_2 length scale about 10^4 Planck lengths, $p \simeq 2^k$, k prime or power of prime. As a matter fact, all positive integer values of k are possible. This is however not enough to explain all known scale hierarchies. Fibonacci numbers $F_n : F_n + 1 = F_n + F_{n-1}$ behave asymptotically like $F_n = kF_{n-1}$, k solution of the equation $k^2 = k+1$ given by $k = \Phi = (1+\sqrt{5})/2 \simeq 1.6$. Living systems and self-organizing systems represent a lot of examples about scale hierarchies coming in powers of the Golden Mean $\Phi = (1 + \sqrt{5})/2$. According to Selvam [42] also meteorological phenomena involve spiral waves characterized by Golden Mean.

   By allowing the extensions of p-adics by algebraic numbers one ends up to the idea that also the length scales coming as powers of x, where x is a unit of algebraic extension analogous to imaginary unit, are possible. One would however expect that the generalization of the p-adic length scale hypothesis alone would predict only the powers $\sqrt{x}p^{n/2}$ rather than $x^k p^{n/2}$, $k = 1, 2, ...$ Perhaps the purely kinematical explanation of these scales is not possible and genuine dynamics is needed. For sinusoidal logarithmic plane waves the harmonics correspond to the scalings of the argument by powers of some scaling factor x. Thus the powers of Golden Mean might be associated with logarithmic sinusoidal plane waves.

2. Physicist Hartmuth Mueller has developed what he calls Global Scaling Theory [43] based on the observation that powers of e (Neper number) define preferred length scales. These powers associate naturally with the nodes of logarithmic sinusoidal plane waves and correspond to various harmonics (matter tends to concentrate on the nodes of waves since force vanishes at the nodes). Mueller talks about physics of number line and there is great temptation to assume that deep number theory is indeed involved. What is troubling from TGD point of view that Neper number e is not algebraic. Perhaps a more general approach allowing also transcendentals must be adopted. Indeed, since e^p is ordinary p-adic number in R_p, a finite-dimension transcendental extension containing e exists.

3. Classical mathematics, such as the theory of elementary functions, involves few crucially important transcendentals such as e and π. This might reflect the evolution of cognition: these numbers should be cognitively and number theoretically very special. The numbers e and π appear also repeatedly in the basic formulas of physics. They however look p-adically very troublesome since it has been very difficult to imagine a physically acceptable generalization of such simple concepts as exponent function, trigonometric functions, and logarithm resembling its real counterpart by allowing only the extensions of p-adic numbers based on algebraic numbers.

4. Number theoretic entropies measured in bits are proportional to $log(p)/log(2)$. The idea that these entropies are rational fractions of bit is attractive and implies that $log(p)$ for all primes is proportional to the same transcendental number. This would mean that logarithm of the rational number field would be a transcendental multiple of rationals.

These considerations stimulate the question whether, besides the extensions of p-adics by algebraic numbers, also the extensions of p-adic numbers involving e, and perhaps even π and and other transcendentals might be needed. The intuitive expectation motivated by the finiteness of human

intelligence is that these extensions might have finite algebraic dimensions. On the other hand, if one is only interested in quantities derived from phases $exp(i2\pi/n)$, a finite-dimensional algebraic extension is enough. π is needed only if one wants to deal with say length of circle's circumference in the p-adic context, and one could argue that p-adic Riemann geometry is local and only about angles and infinitesimal distances.

Second question is whether there might be some dynamical mechanism allowing to understand the hierarchy of scalings coming in powers of some preferred transcendentals and algebraic numbers like Golden Mean. Conformal invariance implying that the system is characterized by a universal spectrum of scaling momenta for the logarithmic counterparts of plane waves seems to provide this mechanism. This spectrum is determined by the requirement that it exists for both reals and all p-adic number fields assuming that finite-dimensional extensions are allowed in the latter case. The spectrum corresponds to the zeros of the Riemann Zeta if Zeta is required to exist for all number fields in the proposed sense, and a lot of new understanding related to Riemann hypothesis emerges and allows to develop further the previous TGD inspired ideas about how to prove Riemann hypothesis [16, 17].

11.11.2 General number theoretical ideas inspired by the number theoretic vision about cognition and intentionality

The following two ideas serve as guide lines in the attempt to relate cognition, intentionality and number theory to each other so that number theory would allow to construct a more detailed view about the realization of intentionality and cognition. As a matter fact, the general ideas about intention and cognition in turn generate very general number theoretical conjectures.

1. Real and p-adic number fields form a book like structure with pages represented by number fields glued together along rationals forming the rim of the book. For the extensions of p-adic numbers further common points result and the book becomes fractal if all possible extensions are allowed. This picture generalizes to the level of the imbedding space and allows to see space-time surfaces as consisting of real and p-adic space-time sheets belonging to various extensions of these numbers. This generalized view about numbers gives hopes about an unambigious definition of what some number, say e, appearing in an extension of p-adic numbers really means.

2. The first new idea is roughly that the discovery of notion of any algebraic or transcendental number x (such as Φ or e) involves a quantum jump in which there is generated a p-adic space-time sheet for which the existing finite-dimensional extension of p-adic numbers is replaced by a finite-dimensional extension involving also x. Also some higher powers of the number are involved. For instance, for e $p-1$ powers are necessarily needed (e^p exists p-adically).

3. The p-adic-to-real transition serving as a correlate for the transformation of intention to action is most probable if the number of common rational valued points for the p-adic and real space-time sheet is high. The requirement of real and p-adic continuity and even smoothness however forces upper and lower p-adic length scale cutoffs so that common points are in certain length scale range.

4. The points of M^4_+ with integer valued Minkowski coordinates using CP_2 length related fundamental length scale as a basic unit is a good guess for the subset of M^4_+ defining the rational points of the M^4_+ involved. CP_2 coordinates as functions of M^4_+ coordinates should be rational or belong to some finite-dimensional extension of p-adics. Of course, also rational points of M^4_+ are possible, and the evolution of cognition should correspond to the increase of the algebraic dimension of the extension.

5. A very powerful hypothesis is that the p-adic and real functions have the same analytic form besides coinciding at the chosen rational points defining the p-adic pseudo constant involved. Since the pseudo constant defines the corresponding real function in rational points, there are indeed good hopes that the transformation of p-adic intention to real action is possible. This assumption favors functions which allow at some point (most naturally origin) a Taylor series with rational valued Taylor coefficients.

Is e an exceptional transcendental?

Neper number is obviously the simplest one and only the powers e^k, $k = 1, ..., p-1$ of e are needed to define p-adic counterpart of e^x for $x = n$. In case of trigonometric functions deriving from e^{ix}, also e^i and its $p-1$ powers must belong to the extension.

An interesting question is whether e is a number theoretically exceptional transcendental or whether it could be easy to find also other transcendentals defining finite-dimensional extensions of p-adic numbers.

1. Consider functions $f(x)$, which are analytic functions with rational Taylor coefficients, when expanded around origin for $x > 0$. The values of $f(n)$, $n = 1, ..., p-1$ should belong to an extension, which should be finite-dimensional.

2. The expansion of these functions to Taylor series generalizes to the p-adic context if also the higher derivatives of f at $x = n$ belong to the extension. This is achieved if the higher derivatives are expressible in terms of the lower derivatives using rational coefficients and rational functions or functions, which are defined at integer points (such as exponential and logarithm) by construction. A differential equation of some finite order involving only rational functions with rational coefficients must therefore be satisfied (e^x satisfying the differential equation $df/dx = f$ is the optimal case in this sense). The higher derivatives could also reduce to rational functions at some step ($log(x)$ satisfying the differential equation $df/dx = 1/x$).

3. The differential equation allows to develop $f(x)$ in power series, say in origin

$$f(x) = \sum f_n \frac{x^n}{n!}$$

   such that f_{n+m} is expressible as a rational function of the m lower derivatives and is therefore a rational number.

   The series converges when the p-adic norm of x satisfies $|x|_p \leq p^k$ for some k. For definiteness one can assume $k = 1$. For $x = 1, ..., p-1$ the series does not converge in this case, and one can introduce and extension containing the values $f(k)$ and hope that a finite-dimensional extension results.

Finite-dimensionality requires that the values are related to each other algebraically although they need not be algebraic numbers. This means symmetry. In the case of exponent function this relationship is exceptionally simple. The algebraic relationship reflects the fact that exponential map represents translation and exponent function is an eigen function of a translation operator. The necessary presence of symmetry might mean that the situation reduces always to either exponential action. Also the phase factors $exp(iq\pi)$ could be interpreted in terms of exponential symmetry. Hence the reason for the exceptional role of exponent function reduces to group theory.

Also other extensions than those defined by roots of e are possible. Any polynomial has n roots and for transcendental coefficients the roots define a finite-dimensional extension of rationals. It would seem that one could allow the coefficients of the polynomial to be functions in an extension of rationals by powers of a root of e and algebraic numbers so that one would obtain infinite hierarchy of transcendental extensions.

Some no-go theorems

Elementary functions like exp(x), log(1+x), cos(x), sin(x), are obviously favored by the previous considerations, in particular by the requirement of the form invariance of the function in p-adic-to-real transition. They indeed have p-adic Taylor expansion which converges for $|x|_p < 1$. The definition at integer valued points for which $x \; mod \; p = n$, $n = 0, 1, ..., p-1$, requires the introduction of an extension of p-adic numbers. The natural first guess is that this extension is finite-dimensional. Of course, this is just a hypothesis to be discussed and motivated by the idea that p-adic extensions reflect our own finite intelligence.

1. *Can powers of $log(p)$ define a finite-dimensional extension of p-adics?*

The number theoretical entropy associated with any p-adic prime for which the ordinary logarithm $log(p_n)$ is replaced by the logarithm of the p-adic norm of p_n, is proportional to a $log(p)$-factor. As already noticed, if bit is used as unit, then only the rationality of $log(p)/log(2)$ is needed and $log(p)$ need not correspond to a finite-dimensional extension of p-adics.

The first observation is that $log(1+x)$, $x = O(p)$ exists as an ordinary p-adic number and the logarithm of $log(m)$, $m < p$ such that the powers of m span the numbers $1, ..., p-1$ besides $log(p)$ need be introduced to the extension in order that logarithm of any integer and in fact of any rational number exists p-adically. The problem is however that the powers of $log(m)$ and $log(p)$ might generate an infinite-dimensional extension of p-adic numbers.

First some no-go theorems inspired by wishful conjectures (professional number theorists must regard me as an idiot!).

1. $log(p) = q/t$, where t is a transcendental number, say π, cannot hold true. The reason is that the rationality of $log(p_1)/log(p_2) = q_1/q_2 = r/s$ implies that $p_1^s = p_2^r$ in contradiction with the prime number property of p_1 and p_2.

2. $log(q)$, q prime, cannot correspond to a finite dimensional extension of R_p in the sense that a finite power of $log(q)$ would be a rational number. Assume that this is the case, i.e. $(log(q))^{m_{p,q}} = x_{p,q}$, where $x_{p,q}$ is an ordinary p-adic number in R_p, and assume that e belongs to extension. For definiteness let us assume $|x_{p,q}| < 1$ and write

$$q = exp(log(q)) = \sum_n log(q)^n/n! = \sum_{k=0}^{m-1} c_k log(q)^k \quad , \quad c_k = \sum_n \frac{x_{p,q}^n}{(k+nm_{p,q})!} \quad .$$

   The righthand side gives m terms corresponding to the m powers of $log(q)$ and only the lowest term can be non-vanishing and equals to q. The convergence of series requires that $x_{p,q}$ has p-adic norm smaller than one. This however implies that lowest order term has p-adic norm equal to one. For $q = p$ this leads to contradiction since one would have $p = 1 + O(p)$. For $|x_{p,q}|_p \geq 1$ the argument fails since the expansion does not make sense. For $q = exp(p^k log(q))$, k sufficiently large, the expansion exists and in this case one as $q^{p^k} = 1 + O(p)$, which for $q = p$ gives a contradiction.

3. One might hope that $log(p)$ belongs to an extension containing e or its root, or in the most general case root of a polynomial with coefficients which belongs to an extension of rationals by e and algebraic numbers. For instance, the ansatz $log(p) = e^{q_1(p)} q_2(p)$ with $q_2(p_1) \neq q_2(p_2)$ for all pairs of primes, would guarantee that logarithms belong to a finite-dimensional extension. There are no problems with the prime property as is clear from the expression

$$p_1 = p_2^{[exp(q_1(p_1)-q_1(p_2)]\times \frac{q_2(p_1)}{q_2(p_2)}} \quad .$$

   From the assumption it follows that the exponent cannot reduce to a rational number.

   Unfortunately the ansatz does not work! One can write

$$p_1 = exp\left(e^{q_1(p_1)} q_2(p_1)\right)$$

   and for those primes p_2 whose positive power divides $q_2(p_1)$, one can expand the exponential in a converging power series in powers of a root of e, and one obtains that ordinary p-adic number is expressible as a non-trivial combination of powers of a root of e.

4. Obviously one must give up hopes for obtaining a finite-dimensional extension for the logaritms. One might however hope that $log(p)/log(2)$ is always rational in order that p-adic entropy would be always rational multiple of bit. This is achieved if one has

$$log(p) \quad = \quad e^{q_1(p)} q_2(p) \times t \quad , \quad q_2(p_1) \neq q_2(p_2) \quad \text{for} \quad p_1 \neq p_2 \tag{11.11.1}$$

such that t is a transcendental number not belonging to an extension defined by e so that one does not get contradiction by exponentiating both sides of the above equation. This ansatz does not lead to any obvious contradictions. For instance, power of π is a reasonable candidate and for physical reasons $t = 1/\pi$ is a favored value of t.

3. π cannot belong to a finite-dimensional extension of p-adic numbers

A simple argument excludes the possibility that π could belong to some finite-dimensional extension $\pi = \sum c_n e_n$. If this is the case one can write $exp(ip^k\pi) = -1$ as a converging Taylor expansion in powers of p for high enough value of k, and the coefficients of all e_n expect $e_0 = 1$ must vanish. Since the terms in this series come in powers of p it is highly implausible that they could sum up to zero. In fact, even the coefficient of $e_0 = 1$ has wrong sign. By considering more general numbers $exp(iq\pi)$ one obtains that the expansion in terms of e_i equals to the expression of phase in infinite number of different algebraic extensions. Thus it seems obvious that π cannot belong to a finite extension.

Does the integration of complex rational functions lead to rationals extended by a root of e and powers of π?

These cold showers suggest that the best one might hope is that the numbers like $log(p)$ and $log(\Phi)$ could be proportional to some power π with a coefficient which belongs to a finite extension of p-adic numbers containing e. This might make it possible to continue the theory to p-adic context and also make very strong predictions.

The elementary differential and integral calculus provides important hints for as how to proceed. Derivation takes rational functions to rational functions unlike integration since the integrals of $1/x$ and and $1/(1+x^2)$ give $log(x)$ and $arctan(x)$ leading outside the realm of rational numbers. One can go to complex plane and consider the integrals of complex rational functions with complex rational coefficients and here one encounters integrals over closed curves and between two points. The rational approach is to consider rational complex plane, and first restrict to Gaussian integers which allow primes.

i) The first observation is that residy calculus for rational functions gives always integrals which are of form $2\pi iq$, q a rational number.

ii) The integral $I = \int_a^b dz/z$, $a = m_1 + in_1$, $b = m_2 + in_2$ in turn gives

$$I = log(a/b) = \tfrac{1}{2}\left(log(m_2^2 + n_2^2) - log(m_1^2 + n_1^2)\right)$$

$$+i(arctan(n_2/m_2) - arctan(n_1/m_1)) \quad .$$

1. The strongest hypothesis would be that logarithm and arctan are also rationally proportional to π so that all integrals of this kind lead to an infinite-dimensional transcendental extension of p-adic numbers containing π. The strong hypothesis cannot be correct. Consider arcus tangent as an example. $arctan(m/n) = r\pi/s$ would imply $tan(r\pi/s) = m/n$, and this cannot hold true since it would imply that s:th powers of Gaussian integer $n+im$ would give an ordinary integer. This would be also true for Gaussian primes and the decomposition of Gaussian integers as products of Gaussian primes would become non-unique. There is this kind of uniqueness but this is due the units $exp(i\pi/4)$ and its powers. Indeed, $arctan(1) = \pi/4$ and proportional to π.

2. One can overcome this difficulty by replacing the ansatz with

$$arctan(q) = e^{q_1(q)} q_2 \pi$$

such that $q_1(q)$ is non-vanishing for $q \neq \pm 1 \pm i$ corresponding to the units of Gaussian primes. This ansatz is completely analogous to the ansatz for $log(p)$. The beauty of this ansatz would be that the imaginary parts for the integral of $1/(z - z_0)$ between complex rational points would be proportional to π irrespective of whether the integration is over a closed or open curve. The real parts of complex integrals in turn would be proportional to $1/\pi$ of $log(p) \propto 1/\pi$ ansatz holds true.

The requirement that complex integrals are powers of π could also mean quantization of topology in TGD framework. For instance, the conformal equivalence classes of Riemann surfaces of genus g are represented by period integrals of 1-forms defining elements of cohomology group H^1 over the circles representing the elements of homology group H_1. Restricting the cohomology to a rational cohomology, the periods with standard normalization would be quantized to complex rationals multiplied by a power of π. For surfaces characterized by a given power of π one might perhaps perform the p-adicization finite-dimensionally by suitable normalizations by powers of π.

Why should one have $log(p) = q_1 exp(q_2)/\pi$?

There are good physical arguments suggesting that $log(p)$ should be proportional to $1/\pi$.

1. π appears naturally in the plane wave solutions of field equations $exp(in\pi u)$, $u = x/L$). These phases are well defined in a finite-dimensional algebraic extension if x/L is rational. One can however consider also logarithmic plane waves

$$exp(iku), \quad u = log(x/L) \quad ,$$

   and ask under what conditions they are well defined and in particular, under what conditions the real/imaginary parts of these plane waves can have zeros at $u = e^n$ required by Mueller's hypothesis [43]. Mueller's hypothesis implies that $exp(ikn)$ has zeros so that $k = q\pi$ must hold true. Thus one obtains essentially ordinary plane waves.

   If one has $u = q_1 e^n$, q_1 rational, one obtains also the exponential $exp(iq\pi log(q_1))$. From the point of view of p-adicization program it would be very nice if also this exponent would exist p-adically. This is guaranteed if one has

$$log(p) = \frac{q_1(p) exp\,[q_2(p)]}{\pi}$$

   for every prime p. One can write

$$exp(iq\pi u) = exp\,[iqq_1(p) exp(q_2(p))] \quad .$$

   The exponential exists for those primes p_1 for which the exponent is divisible by a positive power of p_1. This means quantization conditions favoring selected primes p_1 or alternatively scaling momenta q. An easy manner to satisfy these conditions is to assume that q is a multiple of a power of p.

2. Besides Mueller's hierarchy in powers of e there are also p-adic hierarchies and the hierarchies associated with Golden Mean and one can look whether these hierarchies are obtained for suitable logarithmic waves. For $u = x/L = mp^n$ the scaling wave reads

$$exp(iku) = exp\,[iknlog(p)]\, exp\,[iklog(m)] \quad .$$

   For $log(p) = q_1(p) exp\,[q_2(p)]\,/\pi$ the existence of nodes for the the first factor requires $k = q\pi^2 exp\,[-q_2(p)]$. The second factor exists only for $m = 1$ so that nodes are possible only at $u = p^n$.

Note that $k = q\pi$ for e so that these length scale hierarchies are distinguishable number theoretically. This assumption implies that also the second exponential of product can exist in a finite-dimensional algebraic extension and can have even nodes. For the hierarchy defined by powers of Golden Mean the assumption $log(\Phi) = q_1 q exp(q_2)/\pi$ would lead to similar conclusions. Again one must leave door open for more general power of π.

p-Adicization of vacuum functional of TGD and infinite primes

A further input comes from TGD. The basic challenge is to continue the exponent $exp(K)$ of the Kähler function to p-adic number fields. K can be expressed as

$$K = \frac{S_K}{16\pi\alpha_K} \ ,$$

where α_K is so called Kähler coupling strength and $S_K = \int J_{\mu\nu}J^{\mu\nu}\sqrt{g}d^4x$ is Kähler action, which is essentially the Maxwell action for the induced Kähler form. The dream is that an algebraic continuation from the extensions of rational numbers defining finite extensions of p-adic numbers allows to define the theory in various number fields. The fulfillment of this dream requires that physically important quantities such as the exponent of Kähler function for CP_2 extremal and other fundamental extremals exist in a finite-dimensional extension of p-adic numbers.

1. What is the value of Kähler coupling strength?

The value of Kähler coupling strength is analogous to a critical temperature and can have only discrete values.

1. The discrete p-adic evolution of the Kähler coupling strength follows from the requirement that gravitational coupling constant is renormalization group invariant [E6]. When combined with the requirement that the exponent of CP_2 action is a power of prime, the argument would give

$$\frac{1}{\alpha_K(p)} = \frac{4}{\pi}log(K^2) \ , \ K^2 = \prod_{q=2,3,...23} q \times p$$

with $\alpha_K(p = M_{127}) \simeq 136.5585$ and $\alpha/\alpha_K \simeq .9965$. Note that M_{127} corresponds to electron length scale. If the action is a rational fraction of CP_2 action, and the extension of p-adic numbers is by an appropriate root of p is enough to guarantee the existence of the Kähler function.

2. One can consider also an alternative ansatz based on the requirement that Kähler function is a rational number rather than a logarithm of a power of integer K^2. This requires an extension of p-adic numbers involving some root of e and a finite number of its powers. S_R must be rational valued using Kähler action $S_K(CP_2) = 2\pi^2$ of CP_2 type extremal as a basic unit. In fact, not only rational values of Kähler function but all values which differ from a rational value by a perturbation with a p-adic norm smaller than one and rationally proportional to a power of e or even its root exist p-adically in this case if they have small enough p-adic norm. The most general perturbation of the action is in the field defined by the extension of rationals defined by the root of e and algebraic numbers.

Since CP_2 action is rationally proportional to π^2, the exponent is rational if $4\pi\alpha_K$ satisfies the same condition. If the conjecture $log(p) = q_1(p)exp\left[q(p_2)\right]/\pi$ holds , then the earlier ansatz $1/\alpha_K(p) = (4/\pi)log(K^2)$ does not guarantee this, and $4/\pi$ must be replaced with a rational number $Q \simeq 4/\pi$. The presence of $log(K^2)$, K^2 product of primes, is well motivated also in this case because it gives the desired $1/\pi$ factor.

This gives for the Kähler function the expression

$$K \ = \ Q\left[q_1(p)exp\left[q_2(p)\right] + \sum_i q_1(q_i)exp\left[q_2(q_i)\right]\right]\frac{S}{S_{CP_2}} \ . \qquad (11.11.2)$$

$exp(K)$ exists p-adically only provided that K has p-adic norm smaller than one. For given p this poses strong conditions unless one assumes that the condition $S/S_{CP_2} = p^n r$, r rational. In the case of many-particle state of CP_2 extremals this would mean that particle number is divisible by a power of p.

For single CP_2 extremal, the fact that p cannot divide $q_1(p)$ means that either Q contains a power of p or the sum of terms is proportional to a power of p. Obviously this condition is extremely strong and allows only very few primes. One might wander whether this could provide the first principle

explanation for p-adic length scale hypothesis selecting primes $p \simeq 2^k$, k integer, and with prime power powers being preferred.

Since $k = 137$ (atomic length scale) and $k = 107$ (hadronic length scale) are the most important nearest p-adic neighbors of electron, one could make a free fall into number mysticism and try the replacement $4/\pi \to 137/107$. This would give $\alpha_K = 137.3237$ to be compared with $\alpha = 137.0360$: the deviation from α is .2 per cent (of course, α_K need not equal to α and the evolutions of these couplings are quite different). Thus it seems that $log(p) = q_1 exp(q_2)/\pi$ hypothesis is supported also by the properties of Kähler action and might lead to an improved understanding of the origin of the mystery prime $k = 137$. Of course, one must be extremely cautious with the numerics. For instance, one could replace 137/107 with the ratio of $137/log(M_{107}$ and in this case the M_{107} would become an "easy" prime.

2. Could infinite primes appear in the p-adicization of the exponent of Kähler action?

The difficulties related to the p-adic continuation of Kähler function to an arbitrary p-adic number field and the fact that infinities are every day life in quantum field theory bring in mind infinite primes discussed in [E3].

Infinite primes are not divisible by any finite prime. The simplest infinite prime is of form $\Pi = 1+X$, $X = \prod_i p_i$, where product is over all finite primes. The factor $Y = X/(1+X)$ is in the real sense equivalent with 1. In p-adic sense it has norm $1/p$ for every prime. Thus one could multiply Kähler function by Y or its positive power in order to guarantee that the continuation to p-adic number fields exists for all primes. Of course, these states might differ physically in p-adic sense from the states having $Y = 1$. Thus it would seem that the physics of cognition could differentiate between states which are in real sense equivalent.

More general infinite primes are of form $\Pi = nX/m+n$, such that $m = \prod_i q_i$ and $n = \prod_i p_i^{n_i}$ have no common factors. The interpretation could be as a counterpart for a state of a super-symmetric theory containing fermion in each mode labelled by q_i and n_i bosons labelled in modes labelled by p_i. Also positive powers of the ratio $Y = X/\Pi$, Π some infinite prime, are possible as a multiplier of the Kähler function. In the real sense this ratio would correspond to the ratio m/n.

If this picture is correct, infinite primes would emerge naturally in the p-adicization of the theory. Since octonionic infinite primes could correspond to the states of a super-symmetric quantum field theory more or less equivalent with TGD, the presence of infinite primes could make it possible to code the quantum physical state to the vacuum functional via coupling constant renormalization.

One could also consider the possibility of defining functions like $exp(x)$ and $log(1 + x)$ p-adically by replacing x with Yx without introducing the algebraic extension. The series would converge for all values of x also p-adically and would be in real sense equivalent with the function. This trick would apply to a very general class of Taylor series having rational coefficients. One could also say that p-adic physics allowing infinite primes would be very similar to real physics.

The fascination of infinite primes is that the ratios of infinite primes which are ordinary rational numbers in the real sense could code the particle number content of a super-symmetric arithmetic quantum field theory. For the octonic version of the theory natural in the TGD framework these states could represent the states of a real Universe. Universe would be an algebraic hologram in the sense that space-time points, something devoid of any structure in the standard view, could code for the quantum states of possible Universes!

The simplest manner to realize this scenario is to consider an extension of rational rational numbers by the multiplicative group of real units obtained from infinite primes and powers of X. Real number 1 would code everything in its structure! This group is generated as products of powers of $Y(m/n) = (m/n) \times [X/\Pi(m/n)]$ which is a unit in the real sense. Each $Y(m/n)$ would define a subgroup of units and the power of $Y(m/n)$ would code for the number of factors of a given integer with unit counted as a factor. This would give a hierarchy of integers with their p-adic norms coming as powers of p with the prime factors of m and n forming an exception and being reflected in p-adic physics of cognition, Universe would "feel" its real or imagined state with its every point, be it a point of space-time surface, of imbedding space, or of configuration space.

In fact, one can any pair of infinite primes having finite ratio given by rational number can be divided by the prime in question to give a unit in real sense. These units are not units in the p-adic sense and have a finite p-adic norm which can be differ from one. Infinite primes form an infinite hierarchy so that the points of space-time and imbedding space can be seen as infinitely structured and able to represent all imaginable algebraic structures. Certainly counter-intuitively, single space-time

point is even capable of representing the quantum state of entire physical Universe in its structure. For instance, in real sense surfaces in the space of units correspond to the same real number 1, and single point, which is structure-less in the real sense could represent arbitrarily high-dimensional spaces as unions of real units. For real physics this structure is completely invisible and is relevant only for the physics of mathematical cognition. One can say that Universe is an algebraic hologram, and there is an obvious connection both with Brahman=Atman identity of Eastern philosophies and Leibniz's notion of monad.

11.11.3 A connection with Riemann hypothesis

The considerations of the preceding subsection led to the requirement that the logarithmic waves $e^{iKlog(u)}$ exist in all number fields for $u = n$ (and thus for any rational value of u) implying number theoretical quantization of the scaling momenta K. Since the logarithmic waves appear also in Riemann Zeta as the basic building blocks, there is an interesting connection with Riemann hypothesis, which states that all non-trivial zeros of $\zeta(z) = \sum_n 1/n^z$ lie at the line $Re(z) = 1/2$.

I have applied two basic strategies in my attempts to understand Riemann hypothesis. These approaches are summarized in the chapter "Number Theory and TGD: Riemann hypothesis" of [E8]. Both approaches rely heavily on conformal invariance but being realized in a different manner. The universality of the scaling momentum spectrum implied by the number theoretical quantization allows to understand the relationship between these approaches.

1. First approach

In this approach (see the preprint in [16] in Los Alamos archives and the article published in Acta Mathematica Universitatis Comeniae [17]) one constructs a simple conformally invariant dynamical system for which the vanishing of Riemann Zeta at the critical line states that the coherent quantum states, which are eigen states of a generalized annihilation operator, are orthogonal to a vacuum state possessing a negative norm. This condition implies that the eigenvalues are given by the nontrivial zeros of ζ. Riemann hypothesis reduces to conformal invariance and the outcome is an analytic reductio ad absurdum argument proving Riemann hypothesis with the standards of rigor applied in theoretical physics.

2. Second approach

The basic idea is that Riemann Zeta is in some sense defined for all number fields. The basic question is what "some" could mean. Since Riemann Zeta decomposes into a product of harmonic oscillator partition functions $Z_p(z) = 1/(1 - p^z)$ associated with primes p the natural guess is that $p^{1/2+iy}$ exists p-adically for the zeros of Zeta. The first guess was that for every prime p (and hence every integer n) and every zero of Zeta p^{iy} might define complex rational number (Pythagorean phase) or perhaps a complex algebraic number.

The transcendental considerations that one should try to generalize this idea: for every p and y appearing in the zero of Zeta the number p^{iy} belongs to a finite-dimensional extension of rationals involving also rational roots of e. This would imply that also the quantities n^{iy} make sense for all number fields and one can develop Zeta into a p-adic power series. Riemann Zeta would be defined for any number field in the set linearly spanned by the integer multiples of the zeros y of Zeta and it is easy to get convinced that this set is dense at the Y-axis. Zeta would therefore be defined at least in the set $X \times Y$ where X is some subset of real axis depending on the extension used.

If $log(p) = q_1 exp(q_2)/\pi$ holds true, then $y = q(y)\pi$ should hold true for the zeros of ζ. In this case one would have

$$p^{iy} = exp\left[iq(y)q_1(p)exp\left(q_2(p)\right)\right] \quad .$$

This quantity exists p-adically if the exponent has p-adic norm smaller than one. $q_1(p)$ is divisible by finite number of primes p_1 so that p^{iy} does not exist in a finite-dimensional extension of R_{p_1} unless $q(y)$ is proportional to a positive power of p_1. Also in this case the multiplication of y by a positive power of the ratio $Y = X/(1 + X)$, where $X = \prod p_i$ is the product of all primes, would save the day and would be completely invisible operation in real context.

The phase factors p^{iy} could be also products of Pythagorean phases which are complex rationals and roots of unity so that they would exist in a finite-dimensional extension of complex rationals. This

option is strongly favored by the work in basic quantum TGD. The conformal weights labelling the generators of super-canonical algebra acting as infinitesimal isometries of the configuration space of 3-surfaces are expressible in terms of zeros of Riemann Zeta. This hypothesis leads to several number theoretic conjectures deriving from the crucial assumption that the phases p^{iy} for any prime and zero of Zeta are analogous to multiplicative primes, or equivalently that the zeros y are for addition what ordinary primes are for multiplication.

3. Logarithmic plane waves and Hilbert-Polya conjecture

Logarithmic plane waves allow also a fresh insight on how to physically understand Riemann hypothesis and the Hilbert-Polya conjecture stating that the imaginary parts of the zeros of Riemann Zeta correspond to the eigenvalues of some Hamiltonian in some Hilbert space.

1. At the critical line $Re(z) = 1/2$ (z=x+iy) the numbers $n^{-z} = n^{-1/2-iy}$ appearing in the definition of the Riemann Zeta allow an interpretation as logarithmic plane waves $\Psi_y(v) = e^{iylog(v)}v^{-1/2}$ with the scaling momentum $K = 1/2 - iy$ estimated at integer valued points $v = n$. Riemann hypothesis would follow from two facts. First, logarithmic plane waves form a complete basis equivalent with the ordinary plane wave basis from which sub-basis is selected by number theoretical quantization. Secondly, for all other powers v^k other than $v^{-1/2}$ in the denominator the norm diverges due to the contributions coming from either short ($k < -1/2$) or long distances ($k > -1/2$).

2. Obviously the logarithmic plane waves provide a concrete blood and flesh realization for the conjecture of Hilbert and Polya and the eigenvalues of the Hamiltonian correspond to the universal scaling momenta. Note that Hilbert-Polya realization is based on mutually orthogonal plane waves whereas the Approach 1 relies on coherent states orthogonal to the negative norm vacuum state. That eigenvalue spectra coincide follows from the universality of the number theoretical quantization conditions. The universality of the number theoretical quantization predicts that the zeros should appear in the scaling eigenvalue spectrum of any physical system obeying conformal invariance. Also the Hamiltonian generating by definition an infinitesimal time translation could act as an infinitesimal scaling.

3. The vanishing of the Riemann Zeta could code the conditions stating that the extensions involved are finite-dimensional: it would be interesting to understand this aspect more clearly. The already mentioned hypothesis that phases p^{iy} are products of roots of unity and Pythagorean phases realizes this assumption in the simplest manner.

11.12 The relationship between p-adic and real physics and realization of intentions as p-adic-to-real transitions

This section provides the recent view about transformation of intentions to actions and the presence of this a motivation for its presence of p-adic cognitive neutrino pair. The interpretation of the p-adic as physics of cognition and the vision about reduction of physics to rational physics continuable algebraically to various extensions of rationals and p-adic number fields is an attractive general framework allowing to understand how p-adic fractality could emerge in real physics. In this section it will be found that this vision provides a concrete tool in principle allowing to construct global solutions of field equations by reducing long length scale real physics to short length scale p-adic physics. Also p-adic length scale hypothesis can be understood and the notion of multi-p p-fractality can be formulated in precise sense in this framework. This vision leads also to a concrete quantum model for how intentions are transformed to actions and the S-matrix for the process has the same general form as the ordinary S-matrix.

11.12.1 p-Adic physics and the construction of solutions of field equations

The number theoretic vision about physics relies on the idea that physics or, rather what we can know about it, is basically rational number based. One interpretation would be that space-time surfaces, the induced spinors at space-time surfaces, configuration space spinor fields, S-matrix, etc..., can be obtained by algebraically continuing their values in a discrete subset of rational variant of the

geometric structure considered to appropriate completion of rationals (real or p-adic). The existence of the algebraic continuation poses very strong additional constraints on physics but has not provided any practical means to solve quantum TGD.

In the following it is however demonstrated that this view leads to a very powerful iterative method of constructing global solutions of classical field equations from local data and at the same time gives justification for the notion of p-adic fractality, which has provided very successful approach not only to elementary particle physics but also physics at longer scales. The basic idea is that mere p-adic continuity and smoothness imply fractal long range correlations between rational points which are very close p-adically but far from each other in the real sense and vice versa.

The emergence of a rational cutoff

For a given p-adic continuation only a subset of rational points is acceptable since the simultaneous requirements of real and p-adic continuity can be satisfied only if one introduces ultraviolet cutoff length scale. This means that the distances between subset of rational points fixing the dynamics of the quantities involved are above some cutoff length scale, which is expected to depend on the p-adic number field R_p as well as a particular solution of field equations. The continued quantities coincide only in this subset of rationals but not in shorter length scales.

The presence of the rational cutoff implies that the dynamics at short scales becomes effectively discrete. Reality is however not discrete: discreteness and rationality only characterize the inherent limitations of our knowledge about reality. This conforms with the fact that our numerical calculations are always discrete and involve finite set of points.

The intersection points of various p-adic continuations with real space-time surface should code for all actual information that a particular p-adic physics can give about real physics in classical sense. There are reasons to believe that real space-time sheets are in the general case characterized by integers n decomposing into products of powers of primes p_i. One can expect that for p_i-adic continuations the sets of intersection points are especially large and that these p-adic space-time surfaces can be said to provide a good discrete cognitive mimicry of the real space-time surface.

Adelic formula represents real number as product of inverse of its p-adic norms. This raises the hope that taken together these intersections could allow to determine the real surface and thus classical physics to a high degree. This idea generalizes to quantum context too.

The actual construction of the algebraic continuation from a subset of rational points is of course something which cannot be done in practice and this is not even necessary since much more elegant approach is possible.

Hierarchy of algebraic physics

One of the basic hypothesis of quantum TGD is that it is possible to define exponent of Kähler action in terms of fermionic determinants associated with the modified Dirac operator derivable from a Dirac action related super-symmetrically to the Kähler action.

If this is true, a very elegant manner to define hierarchy of physics in various algebraic extensions of rational numbers and p-adic numbers becomes possible. The observation is that the continuation to various p-adic numbers fields and their extensions for the fermionic determinant can be simply done by allowing only the eigenvalues which belong to the extension of rationals involved and solve field equations for the resulting Kähler function. Hence a hierarchy of fermionic determinants results. The value of the dynamical Planck constant characterizes in this approach the scale factor of the M^4 metric in various number theoretical variants of the imbedding space $H = M^4 \times CP_2$ glued together along subsets of rational points of H. The values of $\hbar$ are determined from the requirement of quantum criticality [C7] meaning that Kähler coupling strength is analogous to critical temperature.

In this approach there is no need to restrict the imbedding space points to the algebraic extension of rationals and to try to formulate the counterparts of field equations in these discrete imbedding spaces.

p-Adic short range physics codes for long range real physics and vice versa

One should be able to construct global solutions of field equations numerically or by engineering them from the large repertoire of known exact solutions [D1]. This challenge looks formidable since the field equations are extremely non-linear and the failure of the strict non-determinism seems to make

even in principle the construction of global solutions impossible as a boundary value problem or initial value problem.

The hope is that short distance physics might somehow code for long distance physics. If this kind of coding is possible at all, p-adicity should be crucial for achieving it. This suggests that one must articulate the question more precisely by characterizing what we mean with the phrases "short distance" and "long distance". The notion of short distance in p-adic physics is completely different from that in real physics, where rationals very close to each other can be arbitrary far away in the real sense, and vice versa. Could it be that in the statement "Short length scale physics codes for long length scale physics" the attribute "short"/"long" could refer to p-adic/real norm, real/p-adic norm, or both depending on the situation?

The point is that rational imbedding space points very near to each other in the real sense are in general at arbitrarily large distances in p-adic sense and vice versa. This observation leads to an elegant method of constructing solutions of field equations.

1. Select a rational point of the imbedding space and solve field equations in the real sense in an arbitrary small neighborhood U of this point. This can be done with an arbitrary accuracy by choosing U to be sufficiently small. It is possible to solve the linearized field equations or use a piece of an exact solution going through the point in question.

2. Select a subset of rational points in U and interpret them as points of p-adic imbedding space and space-time surface. In the p-adic sense these points are in general at arbitrary large distances from each and real continuity and smoothness alone imply p-adic long range correlations. Solve now p-adic field equations in p-adically small neighborhoods of these points. Again the accuracy can be arbitrarily high if the neighborhoods are choose small enough. The use of exact solutions of course allows to overcome the numerical restrictions.

3. Restrict the solutions in these small p-adic neighborhoods to rational points and interpret these points as real points having arbitrarily large distances. p-Adic smoothness and continuity alone imply fractal long range correlations between rational points which are arbitrary distant in the real sense. Return to 1) and continue the loop indefinitely.

In this manner one obtains even in numerical approach more and more small neighborhoods representing almost exact p-adic and real solutions and the process can be continued indefinitely.

Some comments about the construction are in order.

1. Essentially two different field equations are in question: real field equations fix the local behavior of the real solutions and p-adic field equations fix the long range behavior of real solutions. Real/p-adic global behavior is transformed to local p-adic/real behavior. This might be the deepest reason why for the hierarchy of p-adic physics.

2. The failure of the strict determinism for the dynamics dictated by Kähler action and p-adic non-determinism due to the existence of p-adic pseudo constants give good hopes that the construction indeed makes it possible to glue together the (not necessarily) small pieces of space-time surfaces inside which solutions are very precise or exact.

3. Although the full solution might be impossible to achieve, the predicted long range correlations implied by the p-adic fractality at the real space-time surface are a testable prediction for which p-adic mass calculations and applications of TGD to biology provide support.

4. It is also possible to generalize the procedure by changing the value of p at some rational points and in this manner construct real space-time sheets characterized by different p-adic primes.

5. One can consider also the possibility that several p-adic solutions are constructed at given rational point and the rational points associated with p-adic space-time sheets labelled by $p_1, ..., p_n$ belong to the real surface. This would mean that real surface would be multi-p p-adic fractal.

I have earlier suggested that even elementary particles are indeed characterized by integers and that only particles for which the integers have common prime factors interact by exchanging particles characterized by common prime factors. In particular, the primes $p = 2, 3, ..., 23$ would be common to

the known elementary particles and appear in the expression of the gravitational constant. Multi-p p-fractality leads also to an explanation for the weakness of the gravitational constant. The construction recipe for the solutions would give a concrete meaning for these heuristic proposals.

This approach is not restricted to space-time dynamics but is expected to apply also at the level of say S-matrix and all mathematical object having physical relevance. For instance, p-adic four-momenta appear as parameters of S-matrix elements. p-Adic four-momenta very near to each other p-adically restricted to rational momenta define real momenta which are not close to each other and the mere p-adic continuity and smoothness imply fractal long range correlations in the real momentum space and vice versa.

p-Adic length scale hypothesis

Approximate p_1-adicity implies also approximate p_2-adicity of the space-time surface for primes $p \simeq p_1^k$. p-Adic length scale hypothesis indeed states that primes $p \simeq 2^k$ are favored and this might be due to simultaneous $p \simeq 2^k$- and 2-adicity. The long range fractal correlations in real space-time implied by 2-adicity would indeed resemble those implied by $p \simeq 2^k$ and both $p \simeq 2^k$-adic and 2-adic space-time sheets have larger number of common points with the real space-time sheet.

If the scaling factor λ of $\hbar$ appearing in the dark matter hierarchy is in good approximation $\lambda = 2^{11}$ also dark matter hierarchy comes into play in a resonant manner and dark space-time sheets at various levels of the hierarchy tend to have many intersection points with each other.

There is however a problem involved with the understanding of the origin of the p-adic length scale hypothesis if the correspondence via common rationals is assumed.

1. The mass calculations based on p-adic thermodynamics for Virasoro generator L_0 predict that mass squared is proportional to $1/p$ and Uncertainty Principle implies that L_p is proportional to $\sqrt{p}$ rather than p, which looks more natural if common rationals define the correspondence between real and p-adic physics.

2. It would seem that length $d_p \simeq pR$, R or order CP_2 length, in the induced space-time metric must correspond to a length $L_p \simeq \sqrt{p}R$ in M^4. This could be understood if space-like geodesic lines at real space-time sheet obeying effective p-adic topology are like orbits of a particle performing Brownian motion so that the space-like geodesic connecting points with M^4 distance r_{M^4} has a length $r_{X^4} \propto r_{M^4}^2$. Geodesic random walk with randomness associated with the motion in CP_2 degrees of freedom could be in question. The effective p-adic topology indeed induces a strong local wiggling in CP_2 degrees of freedom so that r_{X^4} increases and can depend non-linearly on r_{M^4}.

3. If the size of the space-time sheet associated with the particle has size $d_p \sim pR$ in the induced metric, the corresponding M^4 size would be about $L_p \propto \sqrt{p}R$ and p-adic length scale hypothesis results.

4. The strongly non-perturbative and chaotic behavior $r_{X^4} \propto r_{M^4}^2$ is assumed to continue only up to L_p. At longer length scales the space-time distance d_p associated with L_p becomes the unit of space-time distance and geodesic distance r_{X^4} is in a good approximation given by

$$r_{X^4} = \frac{r_{M^4}}{L_p} d_p \propto \sqrt{p} \times r_{M^4} \quad , \tag{11.12.1}$$

and is thus linear in M^4 distance r_{M^4}.

Does cognition automatically solve real field equations in long length scales?

In TGD inspired theory of consciousness p-adic space-time sheets are identified as space-time correlates of cognition. Therefore our thoughts would have literally infinite size in the real topology if p-adics and reals correspond to each other via common rationals (also other correspondence based on the separate canonical identification of integers m and n in $q = m/n$ with p-adic numbers).

The cognitive solution of field equations in very small p-adic region would solve field equations in real sense in a discrete point set in very long real length scales. This would allow to understand why the notions of Universe and infinity are a natural part of our conscious experience although our sensory input is about an infinitesimally small region in the scale of universe.

The idea about Universe performing mimicry at all possible levels is one of the basic ideas of TGD inspired theory of consciousness. Universe could indeed understand and represent the long length scale real dynamics using local p-adic physics. The challenge would be to make quantum jumps generating p-adic surfaces having large number of common points with the real space-time surface. We are used to call this activity theorizing and the progress of science towards smaller real length scales means progress towards longer length scales in p-adic sense. Also real physics can represent p-adic physics: written language and computer represent examples of this mimicry.

11.12.2 A more detailed view about how local p-adic physics codes for p-adic fractal long range correlations of the real physics

The vision just described gives only a rough heuristic view about how the local p-adic physics could code for the p-adic fractality of long range real physics. There are highly non-trivial details related to the treatment of M^4 and CP_2 coordinates and to the mapping of p-adic H-coordinates to their real counterparts and vice versa.

How real and p-adic space-time regions are glued together?

The first task is to visualize how real and p-adic space-time regions relate to each other. It is convenient to start with the extension of real axis to contain also p-adic points. For finite rationals $q = m/n$, m and n have finite power expansions in powers of p and one can always write $q = p^k \times r/s$ such that r and s are not divisible by p and thus have pinary expansion of in powers of p as $x = x_0 + \sum_1^N x_n p^n$, $x_i \in \{0, p\}$, $x_0 \neq 0$.

One can always express p-adic number as $x = p^n y$ where y has p-adic norm 1 and has expansion in non-negative powers of p. When x is rational but not integer the expansion contains infinite number of terms but is periodic. If the expansion is infinite and non-periodic, one can speak about *strictly p-adic* number having infinite value as a real number.

In the same manner real number x can be written as $x = p^n y$, where y is either rational or has infinite non-periodic expansion $y = r_0 + \sum_{n>0} r_n p^{-n}$ in negative powers of p. As a p-adic number y is infinite. In this case one can speak about strictly real numbers.

This gives a visual idea about what the solution of field equations locally in various number fields could mean and how these solutions are glued together along common rationals. In the following I shall be somewhat sloppy and treat the rational points of the imbedding space as if they were points of real axis in order to avoid clumsy formulas.

1. The p-adic variants of field equations can be solved in the strictly p-adic realm and by p-adic smoothness these solutions are well defined also in as subset of rational points. The strictly p-adic points in a neighborhood of a given rational point correspond as real points to infinitely distant points of M^4. The possibility of p-adic pseudo constants means that for rational points of M^4 having sufficiently large p-adic norm, the values of CP_2 coordinates or induced spinor fields can be chosen more or less freely.

2. One can solve the p-adic field equations in any p-adic neighborhood $U_n(q) = \{x = q + p^n y\}$ of a rational point q of M^4, where y has a unit p-adic norm and select the values of fields at different points q_1 and q_2 freely as long as the spheres $U_n(q_1)$ and $U_n(q_2)$ are disjoint (these spheres are either identical or disjoint by p-adic ultra-metricity).

   The points in the p-adic continuum part of these solutions are at an infinite distance from q in M^4. The points which are well-defined in real sense form a discrete subset of rational points of M^4. The p-adic space-time surface constructed in this manner defines a discrete fractal hierarchy of rational space-time points besides the original points inside the p-adic spheres. In real sense the rational points have finite distances and could belong to disjoint real space-time sheets. The failure of the strict non-determinism for the field equations in the real sense gives hopes for gluing these sheets partially together (say in particle reactions with particles represented as 3-surfaces).

3. All rational points q of the p-adic space-time sheet can be interpreted as real rational points and one can solve the field equations in the real sense in the neighborhoods $U_n(q) = \{x = q + p^n y\}$ corresponding to real numbers in the the range $p^n \leq x \leq p^{n+1}$. Real smoothness and continuity fix the solutions at finite rational points inside $U_n(q)$ and by the phenomenon of p-adic pseudo constants these values can be consistent with p-adic field equations. Obviously one can can continue the construction process indefinitely.

p-Adic scalings act only in M^4 degrees of freedom

p-Adic fractality suggests that finite real space-time sheets around points $x + p^n$, $x = 0$, are obtained as by just scaling of the M^4 coordinates having origin at $x = 0$ by p^n of the solution defined in a neighborhood of x and leaving CP_2 coordinates as such. The known extremals of Kähler action indeed allow M^4 scalings as dynamical symmetries.

One can understand why no scaling should appear in CP_2 degrees of freedom. CP_2 is complex projective space for which points can be regarded as complex planes and for these p-adic scalings act trivially. It is worth of emphasizing that here could lie a further deep number theoretic reason for why the space S in $H = M^4 \times S$ must be a projective space.

What p-adic fractality for real space-time surfaces really means?

The identification of p-adic and real M^4 coordinates of rational points as such is crucial for p-adic fractality. On the other hand, the identification rational real and p-adic CP_2 coordinates as such would not be consistent with the idea that p-adic smoothness and continuity imply p-adic fractality manifested as long range correlations for real space-time sheets

The point is that p-adic fractality is not stable against small p-adic deformations of CP_2 coordinates as function of M^4 coordinates for solutions representable as maps $M^4 \to CP_2$. Indeed, if the rational valued p-adic CP_2 coordinates are mapped as such to real coordinates, the addition of large power p^n to CP_2 coordinate implies small modification in p-adic sense but large change in the real sense so that correlations of CP_2 at p-adically scaled M^4 points would be completely lost.

The situation changes if the map of p-adic CP_2 coordinates to real ones is continuous so that p-adically small deformations of the p-adic space-time points are mapped to small real deformations of the real space-time points.

1. Canonical identification $I : x = \sum x_n p^n \to \sum x_n p^{-n}$ satisfies continuity constraint but does not map rationals to rationals.

2. The modification of the canonical identification given by

$$I(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{11.12.2}$$

   is uniquely defined for rational points, maps rationals to rationals, has a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$.

3. The form of this map is not general coordinate invariant nor invariant under color isometries. The natural requirement is that the map should respect the symmetries of CP_2 maximally. Therefore the complex coordinates transforming linearly under U(2) subgroup of SU(3) defining the projective coordinates of CP_2 are a natural choice. The map in question would map the real components of complex coordinates to their p-adic variants and vice versa. The residual $U(2)$ symmetries correspond to rational unitary 2×2-matrices for which matrix elements are of form $U_{ij} = p^k r/s$, $r < p, s < p$. It would seem that these transformations must form a finite subgroup if they define a subgroup at all. In case of $U(1)$ Pythagorean phases define rational phases but sufficiently high powers fail to satisfy the conditions $r < p, s < p$. Also algebraic extensions of p-adic numbers can be considered.

4. The possibility of pseudo constant allows to modify canonical identification further so that it reduces to the direct identification of real and p-adic rationals if the highest powers of p in r and s ($q = p^n r/s$) are not higher than p^N. Write $x = \sum_{n\geq 0} x_n p^n = x^{N)} + p^{N+1} y$ with $x^{N)} = \sum_{n=0}^{N} x_n p^n$, $x_0 \neq 0$, $y_0 \neq 0$, and define $I_N(x) = x^{N)} + p^{N+1} I(y)$. For $q = p^n r/s$ define $I_N(q) = p^n I_N(r)/I_N(s)$. This map reduces to the direct identification of real and p-adic rationals for $y = 0$.

5. There is no need to introduce the imaginary unit explicitly. In case of spinors imaginary unit can be represented by the antisymmetric 2×2-matrix ϵ_{ij} satisfying $\epsilon_{12} = 1$. As a matter fact, the introduction of imaginary unit as number would lead to problems since for $p \ mod \ 4 = 3$ imaginary unit should be introduced as an algebraic extension and CP_2 in this sense would be an algebraic extension of RP_2. The fact that the algebraic extension of p-adic numbers by $\sqrt{-1}$ is equivalent with an extension introducing $\sqrt{p-1}$ supports the view that algebraic imaginary unit has nothing to do with the geometric imaginary unit defined by Kähler form of CP_2. For $p \ mod \ 4 = 1$ $\sqrt{-1}$ exists as a p-adic number but is infinite as a real number so that the notion of finite complex rational would not make sense.

Preferred CP_2 coordinates as a space-time correlate for the selection of quantization axis

Complex CP_2 coordinates are fixed only apart from the choice of the quantization directions of color isospin and hyper charge axis in SU(3) Lie algebra. Hence the selection of quantization axes seems to emerge at the level of the generalized space-time geometry as quantum classical correspondence indeed requires.

In a well-defined sense the choice of the quantization axis and a special coordinate system implies the breaking of color symmetry and general coordinate invariance. This breaking is induced by the presence of p-adic space-time sheets identified as correlates for cognition and intentionality. One could perhaps say that the cognition affects real physics via the imbedding space points shared by real and p-adic space-time sheets and that these common points define discrete coordinatization of the real space-time surface analogous to discretization resulting in any numerical computation.

Relationship between real and p-adic induced spinor fields

Besides imbedding space coordinates also induced spinor fields are fundamental variables in TGD. The free second quantized induced spinor fields define the fermionic oscillator operators in terms of which the gamma matrices giving rise to spinor structure of the "world of classical worlds" can be expressed.

p-Adic fractal long range correlations must hold true also for the induced spinor fields and they are in exactly the same role as CP_2 coordinates so that the variant of canonical identification mapping rationals to rationals should map the real and imaginary parts of of real induced spinor fields to their p-adic counterparts and vice versa at the rational space-time points common to p-adic and real space-time sheets.

Could quantum jumps transforming intentions to actions really occur?

The idea that intentional action corresponds to a quantum jump in which p-adic space-time sheet is transformed to a real one traversing through rational points common to p-adic and real space-time sheet is consistent with the conservation laws since the sign of the conserved inertial energy can be also negative in TGD framework and the density of inertial energy vanishes in cosmological length scales [D5]. Also the non-diagonal transitions $p_1 \to p_2$ are in principle possible and would correspond to intersections of p-adic space-time sheets having a common subset of rational points. Kind of phase transitions changing the character of intention or cognition would be in question.

1. Realization of intention as a scattering process

The first question concerns the interpretation of this process and possibility to find some familiar counterpart for it in quantum field theory framework. The general framework of quantum TGD suggests that the points common to real and p-adic space-time sheets could perhaps be regarded as arguments of an n-point function determining the transition amplitudes for p-adic to real transition or $p_1 \to p_2$-adic transitions. The scattering event transforming an p-adic surface (infinitely distant

real surface in real M^4) to a real finite sized surface (infinitely distant p-adic surface in p-adic M^4) would be in question.

2. Could S-matrix for realizations of intentions have the same general form as the ordinary S-matrix?

One might hope that the realization of intention as a number theoretic scattering process could be characterized by an S-matrix, which one might hope of being unitary in some sense. These S-matrix elements could be interpreted at fundamental level as probability amplitudes between intentions to prepare a define initial state and the state resulting in the process.

Super-conformal invariance is a basic symmetry of quantum TGD which suggests that the S-matrix in question should be constructible in terms of n-point functions of a conformal field theory restricted to a subset of rational points shared by real and p-adic space-time surfaces or their causal determinants. According to the general vision discussed in [C1], the construction of n-point functions effectively reduces to that at 2-dimensional sections of light-like causal determinants of space-time surfaces identified as partonic space-time sheets.

The idea that physics in various number fields results by algebraic continuation of rational physics serves as a valuable guideline and suggests that the form of the S-matrices between different number fields (call them non-diagonal S-matrices) could be essentially the same as that of diagonal S-matrices. If this picture is correct then the basic differences to ordinary real S-matrix would be following.

1. Intentional action could transform p-adic space-time surface to a real one only if the exponent of Kähler function for both is rational valued (or belongs to algebraic extension of rationals).

2. The points appearing as arguments of n-point function associated with the non-diagonal S-matrix are a subset of rational points of imbedding space whereas in the real case, where the integration over these points is well defined, all values of arguments can be allowed. Thus the difference between ordinary S-matrix and more general S-matrices would be that a continuous Fourier transform of n-point function in space-time domain is not possible in the latter case. The inherent nature of cognition would be that it favors localization in the position space.

3. Objection and its resolution

Exponent of Kähler function is the key piece of the configuration space spinor field. There is a strong counter argument against the existence of the Kähler function in the p-adic context. The basic problem is that the definite integral defining the Kähler action is not p-adically well-defined except in the special cases when it can be done algebraically. Algebraic integration is however very tricky and numerically completely unstable.

The definition of the exponent of Kähler function in terms of Dirac determinants or, perhaps equivalently, as a result of normal ordering of the modified Dirac action for second quantized induced spinors might however lead to an elegant resolution of this problem. This approach is discussed in detail in [B4, D1]. The idea is that Dirac determinant can be defined as a product of eigenvalues of the modified Dirac operator and one ends up to a hierarchy of theories based on the restriction of the eigenvalues to various algebraic extensions of rationals identified as a hierarchy associated with corresponding algebraic extensions of p-adic numbers. This hierarchy corresponds to a hierarchy of theories (and also physics!) based on varying values of Kähler coupling constant and Planck constant. The elegance of this approach is that no discretization at space-time level would be needed: everything reduces to the generalized eigenvalue spectrum of the modified Dirac operator.

4. A more detailed view

Consider the proposed approach in more detail.

1. Fermionic oscillator operators are assigned with the generalized eigenvectors of the modified Dirac operator defined at the light-like causal determinants:

$$\begin{aligned} \Psi &= \sum_n \Psi_n b_n \ , \\ D\Psi_n &= \Gamma^\alpha D_\alpha \Psi_n = \lambda_n O \Psi_n \ , \ O \equiv n_\alpha \Gamma^\alpha \ . \end{aligned} \tag{11.12.3}$$

Here $\Gamma^\alpha = T^{\alpha k}\Gamma_k$ denote so called modified gamma matrices expressible in terms of the energy momentum current $T^{\alpha k}$ assignable to Kähler action [B4]. The replacement of the ordinary gamma matrices with modified ones is forced by the requirement that the super-symmetries of the modified Dirac action are consistent with the property of being an extremal of Kähler action. n_α is a light like vector assignable to the light-like causal determinant and $O = n_\alpha\Gamma^\alpha$ must be rational and have the same value at real and p-adic side at rational points. The integer n labels the eigenvalues λ_n of the modified Dirac operator, and b_n corresponds to the corresponding fermionic oscillator operator.

2. The condition that the p-adic and real variants Ψ if the Ψ are identical at common rational points of real and p-adic space-time surface (the same applies to 4-surfaces corresponding to different p-adic number fields) poses a strong constraint on the algebraic continuation from rationals to p-adics and gives hopes of deriving implications of this approach.

3. Ordinary fermionic anti-commutation relations do not refer specifically to any number field. Super Virasoro (anti-)commutation relations involve only rationals. This suggest that fermionic Fock space spanned by the oscillator operators b_n is universal and same for reals and p-adic numbers and can be regarded as rational. Same would apply to Super Virasoro representations. Also the possibility to interpret configuration space spinor fields as quantum superpositions of Boolean statements supports this kind of universality. This gives good hopes that the contribution of the inner produces between Fock states to the S-matrix elements are number field independent.

4. Dirac determinant can be defined as the product of the eigenvalues λ_n restricted to a given algebraic extension of rationals. The solutions of the modified Dirac equation correspond to vanishing eigen values and define zero modes generating conformal super-symmetries and are not of course included.

5. Only those operators b_n for which λ_n belongs to the algebraic extension of rationals in question are used to construct physical states for a given algebraic extension of rationals. This might mean an enormous simplification of the formalism in accordance with the fact that configuration space Clifford algebra corresponds as a von Neumann algebra to a hyper-finite factor of type II_1 for which finite truncations by definition allow excellent approximations [C7]. One can even ask whether this hierarchy of algebraic extensions of rationals could in fact define a hierarchy of finite-dimensional Clifford algebras. If so then the general theory of hyper-finite factors of type II_1 would provide an extremely powerful tool.

11.13 The most recent view about cognition and intentionality at level of basic physics

In this section, which is probably somewhat too technical for the reader without strong background in quantum TGD, I try to describe the most recent view (the date while I am writing this is 30 July 2006) about quantum TGD, and how it leads to a rather detailed view about cognition and intentionality as basic elements of physics even at elementary particle level.

Forgetting technicalities the first message is that in TGD Universe all quantum states have vanishing net conserved quantum numbers and decompose into positive and negative energy parts with positive energy part identified as ordinary matter in the usual ontology. This makes possible to identify p-adic-to-real transition as a transformation of intention to action.

The so called infinite primes [O2] were one of the first mathematical fruits of TGD inspired theory of consciousness. The hypothesis has been that they code for the space-time correlates of quantum states. The second message is that a detailed view about this coding is possible and reveals the difference between the space-time correlates of intentions and cognitions besides showing that quantum classical correspondence relates to each other the identification of the p-adic space-time sheets as space-time correlates of cognition and the identification of fermionic degrees of freedom as correlates of Boolean cognition.

11.13.1 Zero energy ontology, cognition, and intentionality

One could argue that conservation laws forbid p-adic-real phase transitions in practice so that cognitions (intentions) realized as real-to-padic (p-adic-to-real) transitions would not be possible. The situation changes if one accepts what might be called zero energy ontology [C1, C2].

Zero energy ontology classically

In TGD inspired cosmology [D5] the imbeddings of Robertson-Walker cosmologies are vacuum extremals. Same applies to the imbeddings of Reissner-Nordström solution [D3] and in practice to all solutions of Einstein's equations imbeddable as extremals of Kähler action. Since four-momentum currents define a collection of vector fields rather than a tensor in TGD, both positive and negative signs for energy corresponding to two possible assignments of the arrow of the geometric time to a given space-time surface are possible. This leads to the view that all physical states have vanishing net energy classically and that physically acceptable universes are creatable from vacuum.

The result is highly desirable since one can avoid unpleasant questions such as "What are the net values of conserved quantities like rest mass, baryon number, lepton number, and electric charge for the entire universe?", "What were the initial conditions in the big bang?", "If only single solution of field equations is selected, isn't the notion of physical theory meaningless since in principle it is not possible to compare solutions of the theory?". This picture fits also nicely with the view that entire universe understood as quantum counterpart 4-D space-time is recreated in each quantum jump and allows to understand evolution as a process of continual re-creation.

Zero energy ontology at quantum level

Also the construction of S-matrix [C2] leads to the conclusion that all physical states possess vanishing conserved quantum numbers. Furthermore, the entanglement coefficients between positive and negative energy components of the state define a unitary S-matrix. S-matrix thus becomes a property of the zero energy state and physical states code by their structure what is usually identified as quantum dynamics.

Also the transitions between zero energy states are possible but general arguments lead to the conclusion that the corresponding S-matrix is almost trivial. This finding, which actually forced the new view about S-matrix, is highly desirable since it explains why positive energy ontology works so well if one forgets effects related to intentional action.

At space-time level this would mean that positive energy component and negative energy component are at a temporal distance characterized by an appropriate p-adic time scale and the integer characterizing the value of Planck constant for the state in question. The scale in question would also characterize the geometric duration of quantum jump and the size scale of space-time region contributing to the contents of conscious experience. The interpretation in terms of a mini bang followed by a mini crunch suggests itself also.

Hyper-finite factors of type II_1 and new view about S-matrix

The representation of S-matrix as unitary entanglement coefficients would not make sense in ordinary quantum theory but in TGD the von Neumann algebra in question is not a type I factor as for quantum mechanics or a type III factor as for quantum field theories, but what is called hyper-finite factor of type II_1 [C7]. This algebra is an infinite-dimensional algebra with the almost defining, and at the first look very strange, property that the infinite-dimensional unit matrix has unit trace. The infinite dimensional Clifford algebra spanned by the configuration space gamma matrices (configuration space understood as the space of 3-surfaces, the "world of classical worlds") is indeed very naturally algebra of this kind since infinite-dimensional Clifford algebras provide a canonical representations for hyper-finite factors of type II_1.

The new view about quantum measurement theory

This mathematical framework leads to a new kind of quantum measurement theory. The basic assumption is that only a finite number of degrees of freedom can be quantum measured in a given measurement and the rest remain untouched. What is known as Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of von

Neumann algebras allow to realize mathematically this idea [C7]. $\mathcal{N}$ characterizes measurement resolution and quantum measurement reduces the entanglement in the non-commutative quantum space $\mathcal{M}/\mathcal{N}$. The outcome of the quantum measurement is still represented by a unitary S-matrix but in the space characterized by $\mathcal{N}$. It is not possible to end up with a pure state with a finite sequence of quantum measurements.

The obvious objection is that the replacement of a universal S-matrix coding entire physics with a state dependent unitary entanglement matrix is too heavy a price to be paid for the resolution of the above mentioned paradoxes. Situation could be saved if the S-matrices have fractal structure. The quantum criticality of TGD Universe indeed implies fractality. The possibility of an infinite sequence of Jones inclusions for hyperfinite type II_1 factors isomorphic as von Neumann algebras expresses this fractal character algebraically. Thus one can hope that the S-matrix appearing as entanglement coefficients is more or less universal in the same manner as Mandelbrot fractal looks more or less the same in all length scales and for all resolutions. Whether this kind of universality must be posed as an additional condition on entanglement coefficients or is an automatic consequence of unitarity in type II_1 sense is an open question.

The S-matrix for p-adic-real transitions makes sense

In zero energy ontology conservation laws do not forbid p-adic-real transitions and one can develop a relatively concrete vision about what happens in these kind of transitions. The starting point is the generalization of the number concept obtained by gluing p-adic number fields and real numbers along common rationals (expressing it very roughly). At the level of the imbedding space this means that p-adic and real space-time sheets intersect only along common rational points of the imbedding space and transcendental p-adic space-time points are infinite as real numbers so that they can be said to be infinite distant points so that intentionality and cognition become cosmic phenomena.

In this framework the long range correlations characterizing p-adic fractality can be interpreted as being due to a large number of common rational points of imbedding space for real space-time sheet and p-adic space-time sheet from which it resulted in the realization of intention in quantum jump. Thus real physics would carry direct signatures about the presence of intentionality. Intentional behavior is indeed characterized by short range randomness and long range correlations.

One can even develop a general vision about how to construct the S-matrix elements characterizing the process [C2]. The basic guideline is the vision that real and various p-adic physics as well as their hybrids are continuable from the rational physics. This means that these S-matrix elements must be characterizable using data at rational points of imbedding space shared by p-adic and real space-time sheets so that more or less same formulas describe all these S-matrix elements. Note that also $p_1 \to p_2$ p-adic transitions are possible.

11.13.2 Infinite primes, cognition and intentionality

Somehow it is obvious that infinite primes must have some very deep role to play in quantum TGD and TGD inspired theory of consciousness. What this role precisely is has remained an enigma although I have considered several detailed interpretations, one of them above.

In the following an interpretation allowing to unify the views about fermionic Fock states as a representation of Boolean cognition and p-adic space-time sheets as correlates of cognition is discussed. Very briefly, real and p-adic partonic 3-surfaces serve as space-time correlates for the bosonic super algebra generators, and pairs of real partonic 3-surfaces and their algebraically continued p-adic variants as space-time correlates for the fermionic super generators. Intentions/actions are represented by p-adic/real bosonic partons and cognitions by pairs of real partons and their p-adic variants and the geometric form of Fermi statistics guarantees the stability of cognitions against intentional action. It must be emphasized that this interpretation is not identical with the one discussed above since it introduces different identification of the space-time correlates of infinite primes.

Infinite primes very briefly

Infinite primes have a decomposition to infinite and finite parts allowing an interpretation as a many-particle state of a super-symmetric arithmetic quantum field theory for which fermions and bosons are labelled by primes. There is actually an infinite hierarchy for which infinite primes of a given

level define the building blocks of the infinite primes of the next level. One can map infinite primes to polynomials and these polynomials in turn could define space-time surfaces or at least light-like partonic 3-surfaces appearing as solutions of Chern-Simons action so that the classical dynamics would not pose too strong constraints.

The simplest infinite primes at the lowest level are of form $m_B X/s_F + n_B s_F$, $X = \prod_i p_i$ (product of all finite primes). The simplest interpretation is that X represents Dirac sea with all states filled and $X/s_F + s_F$ represents a state obtained by creating holes in the Dirac sea. m_B, n_B, and s_F are defined as $m_B = \prod_i p_i^{m_i}$, $n_B = \prod_i q_i^{n_i}$, and $s_F = \prod_i q_i$, m_B and n_B have no common prime factors. The integers m_B and n_B characterize the occupation numbers of bosons in modes labelled by p_i and q_i and $s_F = \prod_i q_i$ characterizes the non-vanishing occupation numbers of fermions.

The simplest infinite primes at all levels of the hierarchy have this form. The notion of infinite prime generalizes to hyper-quaternionic and even hyper-octonionic context and one can consider the possibility that the quaternionic components represent some quantum numbers at least in the sense that one can map these quantum numbers to the quaternionic primes.

The obvious question is whether configuration space degrees of freedom and configuration space spinor (Fock state) of the quantum state could somehow correspond to the bosonic and fermionic parts of the hyper-quaternionic generalization of the infinite prime. That hyper-quaternionic (or possibly hyper-octonionic) primes would define as such the quantum numbers of fermionic super generators does not make sense. It is however possible to have a map from the quantum numbers labelling super-generators to the finite primes. One must also remember that the infinite primes considered are only the simplest ones at the given level of the hierarchy and that the number of levels is infinite.

Precise space-time correlates of cognition and intention

The best manner to end up with the proposal about how p-adic cognitive representations relate bosonic representations of intentions and actions and to fermionic cognitive representations is through the following arguments.

1. In TGD inspired theory of consciousness Boolean cognition is assigned with fermionic states. Cognition is also assigned with p-adic space-time sheets. Hence quantum classical correspondence suggests that the decomposition of the space-time into p-adic and real space-time sheets should relate to the decomposition of the infinite prime to bosonic and fermionic parts in turn relating to the above mention decomposition of physical states to bosonic and fermionic parts.

   If infinite prime defines an association of real and p-adic space-time sheets and this association could serve as a space-time correlate for the Fock state defined by configuration space spinor for given 3-surface. Also spinor field as a map from real partonic 3-surface would have as a space-time correlate a cognitive representation mapping real partonic 3-surfaces to p-adic 3-surfaces obtained by algebraic continuation.

2. Consider first the concrete interpretation of integers m_B and n_B. The most natural guess is that the primes dividing $m_B = \prod_i p^{m_i}$ characterize the effective p-adicities possible for the real 3-surface. m_i could define the numbers of disjoint partonic 3-surfaces with effective p_i-adic topology and associated with with the same real space-time sheet. These boundary conditions would force the corresponding real 4-surface to have all these effective p-adicities implying multi-p-adic fractality so that particle and wave pictures about multi-p-adic fractality would be mutually consistent. It seems natural to assume that also the integer n_i appearing in $m_B = \prod_i q_i^{n_i}$ code for the number of real partonic 3-surfaces with effective q_i-adic topology.

3. Fermionic statistics allows only single genuinely q_i-adic 3-surface possibly forming a pair with its real counterpart from which it is obtained by algebraic continuation. Pairing would conform with the fact that n_F appears both in the finite and infinite parts of the infinite prime (something absolutely essential concerning the consistency of interpretation!).

   The interpretation could be as follows.

   i) Cognitive representations must be stable against intentional action and fermionic statistics guarantees this. At space-time level this means that fermionic generators correspond to pairs of real effectively q_i-adic 3-surface and its algebraically continued q_i-adic counterpart. The quantum jump in which q_i-adic 3-surface is transformed to a real 3-surface is impossible since

one would obtain two identical real 3-surfaces lying on top of each other, something very singular and not allowed by geometric exclusion principle for surfaces. The pairs of boson and fermion surfaces would thus form cognitive representations stable against intentional action.

ii) Physical states are created by products of super algebra generators. Bosonic generators can have both real or p-adic partonic 3-surfaces as space-time correlates depending on whether they correspond to intention or action. More precisely, m_B and n_B code for collections of real and p-adic partonic 3-surfaces. What remains to be interpreted is why m_B and n_B cannot have common prime factors (this is possible if one allows also infinite integers obtained as products of finite integer and infinite primes).

iii) Fermionic generators to the pairs of a real partonic 3-surface and its p-adic counterpart obtained by algebraic continuation and the pictorial interpretation is as fermion hole pair. Unrestricted quantum super-position of Boolean statements requires that many-fermion state is accompanied by a corresponding many-antifermion state. This is achieved very naturally if real and corresponding p-adic fermion have opposite fermion numbers so that the kicking of negative energy fermion from Dirac sea could be interpreted as creation of real-p-adic fermion pairs from vacuum.

If p-adic space-time sheets obey same algebraic expressions as real sheets (rational functions with algebraic coefficients), the Chern-Simons Noether charges associated with real partons defined as integrals can be assigned also with the corresponding p-adic partons if they are rational or algebraic numbers. This would allow to circumvent the problems related to the p-adic integration. Therefore one can consider also the possibility that p-adic partons carry Noether charges opposite to those of corresponding real partons sheet and that pairs of real and p-adic fermions can be created from vacuum. This makes sense also for the classical charges associated with Kähler action in space-time interior if the real space-time sheet obeying multi-p p-adic effective topology has algebraic representation allowing interpretation also as p-adic surface for all primes involved.

iv) This picture makes sense if the partonic 3-surfaces containing a state created by a product of super algebra generators are unstable against decay to this kind of 3-surfaces so that one could regard partonic 3-surfaces as a space-time representations for a configuration space spinor field.

4. Are alternative interpretations possible? For instance, could $q = m_B/n_B$ code for the effective q-adic topology assignable to the space-time sheet. That q-adic numbers form a ring but not a number field casts however doubts on this interpretation as does also the general physical picture.

Number theoretical universality of S-matrix

The discreteness of the intersection of the real space-time sheet and its p-adic variant obtained by algebraic continuation would be a completely universal phenomenon associated with all fermionic states. This suggests that also real-to-real S-matrix elements involve instead of an integral a sum with the arguments of an n-point function running over all possible combinations of the points in the intersection. S-matrix elements would have a universal form which does not depend on the number field at all and the algebraic continuation of the real S-matrix to its p-adic counterpart would trivialize. Note that also fermionic statistics favors strongly discretization unless one allows Dirac delta functions.

11.13.3 Cognition, logic, and p-adicity

There seems to be a nice connection between logic aspects of cognition and p-adicity. In particular, p-valued logic for $p = 2^k - n$ has interpretation in terms of ordinary Boolean logic with n "taboos" so that p-valued logic does not conflict with common sense in this case. Also an interpretation of projections of p-adic space-time sheets to an integer lattice of real Minkowski space M^4 in terms of generalized Boolean functions emerges naturally so that M^4 projections of p-adic space-time would represent Boolean functions for a logic with n taboos.

2-adic valued functions of 2-adic variable and Boolean functions

The binary coefficients f_{nk} in the 2-adic expansions of terms $f_n x^n$ in the 2-adic Taylor expansion $f(x) = \sum_{n=0} f_n x^n$, assign a sequence of truth values to a 2-adic integer valued argument $x \in \{0, 1, ..., 2^N\}$ defining a sequence of N bits. Hence $f(x)$ assigns to each bit of this sequence a sequence of truth values which are ordered in the sense that the truth values corresponding to bits are not so important p-adically: much like higher decimals in decimal expansion. If a binary cutoff in N:th bit of $f(x)$ is introduced, B^M-valued function in B^N results, where B denotes Boolean algebra fo 2 elements. The formal generalization to p-adic case is trivial: 2 possible truth values are only replaced by p truth values representable as $0, ..., p-1$.

p-Adic valued functions of p-adic variable as generalized Boolean functions

One can speak of a generalized Boolean function mapping finite sequences of p-valued Boolean arguments to finite sequences of p-valued Boolean arguments. The restriction to a subset $x = kp^n$, $k = 0, ..., p-1$ and the replacement of the function $f(x)$ with its lowest pinary digit gives a generalized Boolean function of a single p-valued argument. If $f(x)$ is invariant under the scalings by powers of p^k, one obtains a hologram like representation of the generalized Boolean function with same function represented in infinitely many length scales. This guarantees the robustness of the representation.

The special role of 2-adicity explaining p-adic length scale hypothesis $p \simeq 2^k$, k integer, in terms of multi-p-acidic fractality would correlate with the special role of 2-valued logic in the world order. The fact that all generalizations of 2-valued logic ultimately involve 2-adic logic at the highest level, where the generalization is formulated would be analog of p-adic length scale hypothesis.

$p = 2^k - n$-adicity and Boolean functions with taboos

It is difficult to assign any reasonable interpretation to $p > 2$-valued logic. Also the generalization of logical connectives AND and OR is far from obvious. In the case $p = 2^k - n$ favored by the p-adic length scale hypothesis situation is however different. In this case one has interpretation in terms B^k with n Boolean statements dropped out so that one obtains what might be called $\hat{B}^k$. Since n is odd this set is not invariant under Boolean conjugation so that there is at least one statement, which is identically true and could be called taboo, axiom, or dogma: depending on taste. The allowed Boolean functions would be constructed in this case using standard Boolean functions AND and OR with the constraint that taboos are respected: in other words, both the inputs and values of functions belong to $\hat{B}^k$.

A unique manner to define the logic with taboos is to require that the number of taboos is maximal so that if statement is dropped its negation remains in the logic. This implies $n > B^k/2$.

The projections of p-adic space-time sheets to real imbedding space as representations of of Boolean functions

Quantum classical correspondence suggests that generalized Boolean functions should have space-time correlates. Since Boolean cognition involves free will, it should be possible to construct space-time representations of arbitrary Boolean functions with finite number of arguments freely. The non-determinism of p-adic differential equations guarantees this freedom.

p-Adic space-time sheets and p-adic non-determinism make possible to represent generalization of Boolean functions of four Boolean variables obtained by replacing both argument and function with p-valued pinary digit instead of bit. These representations result as discrete projections of p-adic space-time sheets to integer valued points of real Minkowski space M^4. The interpretation would be in terms of 4 sequences of truth values of p-valued logic associated with a finite 4-D integer lattice whose lattice points can be identified as sequences of truth values of a p-valued logic with a set of p-valued truth value at each point so that in the 2-adic case one has map $B^{4M} \to B^{4N}$. Here the number of lattice points in a given coordinate direction of M^4 is M and N is the number of bits allowed by binary cutoff for CP_2 coordinates. For $p = 2^k - n$ representing Boolean algebra with n taboos, the maps can be interpreted as maps $\hat{B}^{4M} \to \hat{B}^{4N}$.

These lattices can be seen as subsets of rational shadows of p-adic space-time sheets to Minkowski space. The condensed matter analog would be a lattice with a a sequence of p-valued dynamical

variables (sequence of bits/spins for $p = 2$) at each lattice point. At a fixed spatial point of M^4 the lowest bits define a time evolution of a generalized Boolean function: $B \to B$.

These observations support the view that intentionality and logic related cognition could perhaps be regarded as 2-adic aspects of consciousness. The special role of primes $p = 2^k - n$ could also be understood as special role of Boolean logic among p-valued logics and $p = 2^k - n$ logic would correspond to B^k with n axioms representing logic respecting a belief system with n beliefs. Recall that multi-p p-adic fractality involving 2-adic fractality is possible for the solutions of field equations and explains p-adic length scale hypothesis.

Most points of the p-adic space-time sheets correspond to real points which are literally infinite as real points. Therefore cognition would be in quite literal sense outside the real cosmos. Perhaps this is a direct correlate for the basic experience that mind is looking the material world from outside.

Connection with the theory of computational complexity?

There are interesting questions concerning the interpretation of four generalized Boolean arguments. TGD explains the number $D = 4$ for space-time dimensions and also the dimension of imbedding space. Could one also find explanation why $d = 4$ defines special value for the number of generalized Boolean inputs and outputs?

1. Could the general theory of computational complexity allow to understand $d = 4$ as a maximum number of inputs and outputs allowing the computation of something related to these functions in polynomial time? For instance, complexity theorist could probably immediately answer following questions. Could the computation of the 2-adic values of CP_2 coordinates as a function of 2-adic M^4 coordinates expressed in terms of fundamental logical connectives take a time which is polynomial as a function of the number of N^4 pinary digits of M^4 coordinates and N^4 pinary digits of CP_2 coordinates? Is this time non-polynomial for M^d and S_d, S_d d-dimensional internal space, $d > 4$. Unfortunately I do not possess the needed complexity theoretic knowhow to answer these questions.

2. The same question could make sense also for $p > 2$ if the notion of the logical connectives and functions generalizes as it indeed does for $p = 2^k - n$. Therefore the question would be whether p-adic length scale hypothesis and dimensions of imbedding space and space-time are implied by a polynomial computation time? This could be the case since essentially a restriction of values and arguments of Boolean functions to a subset of B^k is in question.

Some calculational details

In the following the details of p-adic non-determinism are described for a differential equation of single p-adic variable and some comments about the generalization to the realistic case are given.

1. One-dimensional case

To understand the essentials consider for simplicity a solution of a p-adic differential equation giving function $y = f(x)$ of one independent variable $x = \sum_{n \geq n_0} x_n p^n$.

1. p-Adic non-determinism means that the initial values $f(x)$ of the solution can be fixed arbitrarily up to $N + 1$:th pinary digit. In other words, $f(x_N)$, where $x_N = \sum_{n_0 \leq n \geq N} x_n p^n$ is a rational obtained by dropping all pinary digits higher than N in $x = \sum_{n \geq n_0} x_n p^n$ can be chosen arbitrarily.

2. Consider the projection of $f(x)$ to the set of rationals assumed to be common to reals and p-adics.

   i) Genuinely p-adic numbers have infinite number of positive pinary digits in their non-periodic expansion (non-periodicity guarantees non-rationality) and are strictly infinite as real numbers. In this regime p-adic differential equation fixes completely the solution. This is the case also at rational points $q = m/n$ having infinite number of pinary digits in their pinary expansion.

   ii) The projection of p-adic x-axis to real axis consists of rationals. The set in which solution of p-adic differential equations is non-vanishing can be chosen rather freely. For instance, p-adic ball of radius p^{-n} consisting of points $x = p^M y$, $y \neq 0$, $|y|_p \leq 1$, can be considered. Assume

$N > M$. p-Adic nondeterminism implies that $f(q)$ for $q = \sum_{M \leq n \leq N} x_n p^n$, can be chosen arbitrarily. For $M \geq 0$ q is always integer valued and the scaling of x by a suitable power of p always allows to get a finite integer lattice at x-axis.

iii) The lowest pinary digit in the expansion of $f(q)$ in powers of p in defines a pinary digit. These pinary digits would define a representation for a sequence of truth values of p-logic. $p = 2$ gives the ordinary Boolean logic. It is also interpret this pinary function as a function of pinary argument giving Boolean function of one variable in 2-adic case.

2. Generalization to the space-time level

This picture generalizes to space-time level in a rather straight forward manner. y is replaced with CP_2 coordinates, x is replaced with M^4 coordinates, and differential equation with field equations deducible from the Kähler action. The essential point is that p-adic space-time sheets have projection to real Minkowski space which consists of a discrete subset of integers when suitable scaling of M^4 coordinates is allowed. The restriction of 4 CP_2 coordinates to a finite integer lattice of M^4 defines 4 Boolean functions of four Boolean arguments or their generalizations for $p > 2$. Also the modes of the induce spinor field define a similar representation.

11.13.4 What really distinguishes between future and past?

Our knowledge about geometric future is very uncertain as compared to that about geometric past. Hence we usually use words like plan/hunch/hope/... in the case of geometric future and speak about memories in the case of geometric past. We also regard geometric past as something absolutely stable. Why we cannot remember geometric future as reliably as the geometric past? Is it that geometric future is highly unstable as compared to the geometric past? Why this should be the case? This provides a possible TGD based articulation for the basic puzzles relating to time experience. These questions have been already discussed in this chapter but I want to close the chapter with considerations inspired by the latest progress in the understanding of quantum TGD.

Is p-adic-to-real phase transition enough?

The basic idea is that the flow of subjective time corresponds to a phase transition front representing a transformation of intentions to actions and propagating towards the geometric future quantum jump by quantum jump. All quantum states have vanishing total quantum numbers in zero energy ontology which now forms the basis of quantum TGD [C2] and this ontology allows to imagine models for what could happen in this process.

This starting point is the interpretation of fermions as correlates for cognition bosons as correlates for intentions/actions [E1]. Fermions correspond to pairs of real and p-adic space-time sheets with opposite quantum numbers with p-adic space-time sheet providing a cognitive representation of the real space-time sheet. Bosonic space-time sheets would be either p-adic or real and thus represent intentions or actions. Fermionic world and its cognitive representations would be common to future and geometric past and the asymmetry would relate only to the intention-action dichotomy.

Geometric future contains a lot of p-adic space-time sheets representing intentions which transform to real space-time sheets allowing interpretation as desires inducing eventually neuronal activities. Time mirror mechanism for intentional action assumes that the phase transition gives rise to negative energy space-time sheets representing propagation of signals to geometric past where they induce neuronal activities. From Libet's experiments relating to neuronal correlates of volition the time scale involved is a fraction of second but an infinite hierarchy of time scales is implied by fractality.

Conservation of quantum numbers poses strong conditions on p-adic-to-real phase transition. Noether charges are in the real context given by integrals over partonic 2-surfaces. The problem is that these integrals do not make sense p-adically. There are two options.

1. Give up the notion of p-adic Noether charge so that it would not make sense to speak about four-momentum and other conserved quantum numbers in case of p-adic space-time sheet. This implies zero energy ontology in the real sector. All real space-time sheets would have vanishing conserved quantum numbers and p-adic-to real transition generates real space-time sheet complex with vanishing total energy. Negative energy signal must be somehow compensated by a positive energy state.

2. It might be however possible to assign charges to p-adic space-time sheets. The equations characterizing p-adic space-time sheet representing intention and corresponding real space-time sheet representing action are assumed to be given in terms of same rational functions with coefficients which are algebraic numbers consistent with the extension of p-adic numbers used so that the points common to real and p-adic space-time sheets are in this extension. If real charges belong to the algebraic extension used, one could identify the p-adic charges as real charges. Zero energy ontology requires the presence of positive energy real space-time sheets whose charges compensate those of negative energy space-time sheets. One possibility is that real and corresponding p-adic space-time sheets appear in pairs with vanishing total quantum numbers just as fermionic space-time sheets are assumed to occur [E1]. In the case of fermions p-adic-to-real phase transition is impossible by Exclusion Principle so that a stable cognitive representation results.

The minimal option would be that p-adic space-time sheets possess negative energy and are transformed to negative energy signals inducing neuronal activities. The flow of subjective time would involve a transformation of the universe to zero energy universe in the sense that total conserved quantum numbers vanish in the real sense in bosonic sector but in fermionic sector real and p-adic charges compensate each other.

This picture is probably too simple. Robertson-Walker cosmology has vanishing density of inertial energy. Hence it would seem that real bosons and fermions should appear in both positive and negative energy states and the arrow of time defined by the direction of the propagation of the intention-to-action wave front would be local.

The transition of the geometric past back to intentional phase would involve transformation of real bosons to p-adic ones and is in principle possible for this option. For the first option the transition could occur only for real states with vanishing total quantum numbers which would make this transition highly improbable and thus imply irreversibility.

The basic criticism is that since intentions in the proposed sense do not involve any selection, one could argue that this picture is not enough to explain the instability of the geometric future unless the instability is due to the instability of p-adic space-time sheets in quantum jumps.

Does intentional action transform quantum critical phase to non-quantum critical phase?

It is far from clear whether the proposed model is not able to explain the uncertainty of the geometric future and relative stability of the geometric past related very intimately to the possibility to select between different options. TGD based view about dark matter as a hierarchy of phases characterized by M^4 and CP_2 Planck constants quantized in integer multiples of minimum value $\hbar_0$ of $\hbar$ [C9] suggests a more refined view about what happens in the quantum jump transforming intention to action.

1. The geometric future of the living system corresponds to a quantum critical state which is a superposition of (at least) two phases. Quantum criticality means that future is very uncertain and universe can be in dramatically different macroscopic quantum states.

2. Experienced flow of time corresponds to a phase transition front proceeding towards the geometric future quantum jump by quantum jump. In this transition intentional action represented by negative energy bosonic signals transforms the quantum critical phase to either of the two phases present. This selection between different phases would be the basic element of actions involving choice. The geometric past is stabilized so that geometric memories about geometric past are relatively stable. This picture applies always in some time scale and there is an entire hierarchy of time and spatial scales corresponding to the hierarchies of p-adic length scales and of Planck constants. Note that Compton length and time are proportional to $\hbar$ as is also the span of long term memories and time scale of planned actions.

The (at least) two phases present at quantum criticality would have different values of Planck constants. In the simplest case the values of M^4 and CP_2 Planck constants for the second phase would correspond to the minimal value $\hbar_0$ of Planck constants. For instance, cell could be in quantum superposition of ordinary and high T_c super-conducting phase, with high T_c superconductor characterized by a large M^4 Planck constant.

Intentional action would induce a transition to either of these two phases. Sub-system would chose either the lower or higher level in the hierarchy of consciousness with level characterized by

the values of Planck constants. This unavoidably brings in mind a moral choice. Intentional actions involve often a choice between good and bad and this choice could reduce to a choice between values of Planck constant. Good deed would lead to higher value of Planck constant and bad deed to a lower one. This interpretation conforms with the earlier view about quantum ethics stating that good deeds are those which support evolution. The earlier proposal was however based on the assumption that evolution means a gradual increase of a typical p-adic length scale and seems to be too restricted in the recent framework.

For instance, in cell length scale the cells of the geometric future could be in quantum critical phase such that large $\hbar$ phase corresponds to high T_c super-conductivity and low $\hbar$ phase to its absence. In quantum jump cell would transform to either of these phases. The natural interpretation for the transition to low $\hbar$ phase is as cell death since the communications of the cell to and quantum control by the magnetic body are lost. Ageing could be seen as a process in which the transitions to small $\hbar$ phase begin to dominate or even the quantum criticality is lost. A model for the quantum criticality based on zeros of Riemann zeta developed in [E1, C1, J1] allows a more quantitative view about what could happen in the phase transition.

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Part IV

PARANORMAL PHENOMENA

Chapter 12

Quantum Model of Paranormal Phenomena

12.1 Introduction

The violent encounters with skeptics have demonstrated to me that surprisingly many skeptics refuse to even consider the possibility of taking paranormal phenomena seriously because they take the materialistic-reductionistic world view as the final truth. Usually the discussions reduce to the attempt to give me a label of a pseudoscientist because I do not possess an influental position in the scientific community; because I have not published my work in respectable journal; etc..., and it is very difficult to dig even a single bit of information relating somehow to the actual contents of my work. Regrettably this seems to be the case for most of arguments used by those who appear publicly as skeptics. Needless to say, skepticism in this sense has nothing to do with skepticism in the real sense of the word. Just the opposite, these 'skeptics' identify themselves as the mind police of the dominating materialistic-reductionistic science and see as their holy goal the identification and ridiculization of the scientific dissidents as pseudo scientists. For instance, I have been blamed for super-naturalism because I have been forced to introduce the notion of quantum jump between quantum histories forcing in turn to give up the notion of observer independent objective reality. The attempts to defend this vision by telling that this is the only possible logically consistent view about quantum jump forced by General Coordinate Invariance alone and solving the basic paradoxes of modern physics have been waste of time.

There are of course notable exceptions to this rule of thumb: Susan Blackmore represents an example of an intellectually honest skeptic who respects also the different world views and takes materialistic dogma only one possible view about world which must be also subjected to testing.

The basic objection against paranormal phenomena by skeptic researchers such as Susan Blackmore, is that there is no theory of paranormal phenomena making possible meaningful experimental tests so that the minimal working hypothesis is that these phenomena do not exist. The absence of a theory certainly makes experimental approach extremely difficult: a good analogy of the situation is provided by the high energy elementary particle physics where the enormous amount of data and noise makes possible only the detection of signatures predicted by various theories by comparing highly detailed Monte Carlo simulations of model world with the data.

Personally I however see this attitude as counter productive: I agree with someone who said that the worst form of ignorance is to regard un-explainable as a synonym of impossible. I find it also very entertaining to play 'what if this is true' games with thoughts rather than adopting the somewhat boring role of a serious scientist. These thought games also often lead to ideas which need not be even related to the original question. I however hasten to admit that my attitude does not derive from a mere open-mindedness and mere desire to play thought games but from the simple facts of life: TGD indeed provides a conceptual framework in which paranormal phenomena might be understood and studied; secondly, as an eternally unemployed scientific dissident I really do not have anything to lose anymore.

12.1.1 Development of ideas about paranormal

During years I have developed several ideas about paranormal phenomena and, believing that there must be very few general principles behind these phenomena, I try to combine these ideas into a single coherent conceptual framework in this chapter. For the convenience of the reader it is good to summarize the evolution of the basic concepts briefly.

1. On the experimental side the most important boosts came from the lecture of Cyril Smith about homeopathy in CASYS'2001 conference [62] and from the contact with Lian Sidoroff and from reading her articles related to remote vision and healing [63]. Also the work of Gariaev's group on wave aspects of DNA [33] was important for the concretization of the ideas. Of course, without the already existing view about living matter as symbiosis of MEs, superconducting magnetic flux tubes and ordinary biomatter at atomic space-times sheets, which was inspired the information about effects of ELF em fields on brain [44] and by the strange findings challenging the notions of ionic pumps and channels [21] these developments would not have been possible.

2. On the theoretical side the realization that p-adic physics provides the physics of cognition and intention was a decive breakthrough. The lectures of Peter Marcer about quantum holographic brain provided an important stimulus leading to the realization that MEs (massless extremals) serve among other things also as quantum holograms. The ideas about magnetic mirrors (ME-parallel magnetic flux tube pairs) acting as electromagnetic bridges between living subsystems and about liquid crystal blobs representing and amplifying the rotational, vibrational, etc. spectra of molecules, are the most recent newcomers in the zoo of ideas.

3. The resulting concrete view is that living organisms at all levels of the hierarchy are connected by the magnetic mirrors serving as electromagnetic bridges between them and making possible high precision directed communication, remote sensing, sensory representations using magnetic sensory canvas, memory as communication betweeen the geometric past and geometric now, and remote control. Even the claimed communications with deceased can be seen as being based on the same mechanism as long term memory. Besides classical signalling with light velocity quantum entanglement (also timelike) mediated by MEs is key element of model and makes possible sharing of experiences. By fractality the same basic mechanisms are at work in all length scales: water memory and our long term memory are the same phenomenon but in different length scales. Similarly, the miraculous molecular recognition mechanisms and remote healing and vision are also phenomena based on the same basic mechanisms.

4. A further strong support for the idea that biosphere is a fractal organic whole came from the realization that the notion of psychological time leads to paradoxes unless one assumes that psychological time corresponds to the space-time region at which macroscopic volition is concentrated: this front of volition proceeding in the direction of future is where the p-adic-to-real phase transition changing intention to macroscopic action dominantly occurs. Psychological time must be also common to me and my fellow human beings, probably for entire biosphere: otherwise strange paradoxes result.

12.1.2 Topics to be discussed

The flow diagram for this chapter looks like following.

1. I propose a general vision about the mechanisms behind the paranormal phenomena based on the ideas briefly summarized. This involves the new, more precise view about psychological time, p-adic physics as the physics of cognition and intention, the notion of magnetic mirrors, LC crystal water blobs as mimicking electromagnetically molecules and amplifying signals em signals, field representation of the genetic information based on magnetic mirrors, a general model for remote mental interactions, and the proposal that stochastic resonance serves a universal amplification mechanism.

2. Some paranormal phenomena in biological length scales are considered: in particular ideas about the memory of water (discussed more thoroughly in [K5]), healing by time reversal, and a TGD model explaining the functioning of the delaWarr camera are discussed.

3. Parapsychological phenomena like extrasensory perception, precognition, psychokinesis, near-death experiences, and communications between living and dead are discussed: remote healing and vision are discussed also in t [K5].

4. A TGD based model for the instrumental transcommunication (ITC), in particular electronic voice phenomena (EVP), is developed in more detail (I am grateful for Adrian Klein for informing me about these phenomena).

5. Adaptive robots of Mark Tilden behave very much like living creatures and the possibility that this might actually be the case is considered.

I want to emphasize again to the blood-thirsty skeptics that I am not believer nor non-believer. These phenomena, be they actual or not, are extremely stimulating for a theorist with a trait to creative thinking and have helped me to understand what in the TGD universe is new and impossible in the reductionistic and materialistic universe of the skeptic. Certainly the ability to explain these not-finally established phenomena does not make TGD pseudo science. In the same way, the ability of TGD based vision to say something nontrivial about religious experience and consciousness after the physical death does not mean that TGD replaces scientific explanation with a religious dogma (also this point I have been forced to explain again and again to some of my very skeptic friends).

12.2 General view about paranormal phenomena

12.2.1 General view about psychological time

A natural resolution of the problems related to the preferred role of single moment of time for conscious experience is based on the idea that biological growth and self-organization is a 4-dimensional phase transition proceeding in the direction of the geometric future quantum jump by quantum jump. And, in particular, that the dominating contribution to the conscious experience comes from the front of the phase transition where the volition is. More concretely:

1. There is electromagnetic body serving as a template around which ordinary matter self-organizes by phase transition and at the same time modifies this template. The phase transition front proceeds from the moment of birth to the geometric future in a manner analogous to the polymerization process or to the gradual build-up of a protein in mRNA-protein translation process. Electromagnetic body could correspond to the electromagnetic part of the genetic information hypothesized to be coded by transversal magnetic mirror structures (massless extremals parallel to magnetic flux tubes [K5]. The motivation for this hypothesis comes from the TGD based quantum models for biocontrol and sensory representations, from the data about homeopathy and puzzles related to genome, from the mysteries of the biochemical self-organization, and from the experimental work related to phenomena like remote vision and healing. Among other things this model explains processes like molecular recognition which remain mysterious in the framework of standard biochemistry.

2. Each choice made during life cycle is analogous to an addition of a new protein in mRNA-protein translation process. There is a lot of freedom of choice associated with the addition of the new building blocks to a growing protein. The freedom to modify the already existing structure is however relatively restricted. The already existing part of protein can adopt a highly restricted repertoare of conformations but the ordering of the component aminoacids remains essentially fixed as also the chemical structure of the individual aminoacids. Translating this to the level of evolution of individual: presumably only the non-determinism associated with various sensory and cognitive representations is present whereas the non-determinism associated with say macroscopic motor actions and decisions affecting dramatically future is absent in our geometric past. Thus the classical (and also quantum) non-determinism is concentrated at the phase transition front propagating towards the geometric future quantum jump by quantum jump. As a consequence, also the contents of conscious experience are concentrated around the value of the geometric time characterizing the location of this front.

3. Quantum criticality of TGD universe suggests that also the reverse phase transitions can occur and could proceed most naturally towards geometric past like the depolymerization of a protein

(later a more convicing support for this hypothesis will be discussed). Fractality of the TGD universe in turn suggests that these phase transitions and their reversals occur in all length and time scales.

4. The idea that 4-D body is kind of a 4-D sculpture constructed gradually by trial and error proces suggests that the 4-D growth process proceeds by trial and error and when dead end appears the reverse of the phase transition (counterpart of depolymerization) occurs (or can occur) and proceeds backwards in the geometric time to the moment when the wrong choice was made. Thus our life would not end at the physical death but would be an iterative process starting again and again from the moment when things went wrong.

5. Physical death means that the 4-D body becomes mature and could survive at least for some time in a state in which conscious experience does not contain the dominating input from the phase transition zone. Some kind of a meditative, timeless form of consciousness should be in question. This vision conforms with the idea that physical life is only one stage in much longer lastic process of conscious evolution. These 4-D bodies can in principle communicate with the living ones and long term memories about the deceased might represent one form of this communication. The communications would be based on the same mechanism as long term memories in general: by looking at magnetic mirror with length of order lightlife or more I can see, not only me of the past, but also my fellow (not only) human beings. At quantum level this means timelike quantum entanglement making possible to share experiences.

6. What is this fundamental phase transition giving rise to what we call life? We know that the front of phase transition corresponds to volitional consciousness. We also know that volition as a transformation of intention to action in TGD universe corresponds to the p-adic-to-real phase transitions of space-time space-time sheets taking place in quantum jumps. Thus the natural conclusion is that p-adic-to-real phase transition is the fundamental phase transition inducing the biological self-organization. This phase transition could occur for massless extremals (MEs) and perhaps also for the flux tubes of wormhole magnetic fields (and thus for magnetic mirrors) representing the plan for the evolution of the biological system and induce biological self-organization of matter around the resulting electromagnetic hologram like templates.

7. At least the selves at the same level of self hierarchy possess same value of psychological time. It might even be that the entire living biosphere could be seen as a phase transition front proceeding to the direction of the geometric future. This conclusion is of utmost importance since it leaves no other possibility that to accept that even biosphere defines conscious self and we correspond to only single level in the self hierarchy. In particular, the notion of collective consciousness is more or less 'a must' in this framework.

The fractality of TGD Universe suggests that there are phase transition fronts inside phase transition fronts each with their characteristic span with respect to the geometric time and age with respect to subjective time suffering the 4-dimensional analogs of cell decay and regeneration. One can imagine a fractal hierarchy of phase transition fronts in which subselves experience a common psychological time and experience the systems, whose psychological time is in the geometric future, more or less as dead because the degree of non-determinism in the geometric past of the four-dimensional body is low. Perhaps what we call non-living matter corresponds to life for which self-organization front is in the distant geometric future. Also the idea about gradual build-up of four-dimensional sculptures by 4-D phase transitions and their reversals at all levels of the self hierarchy looks attractive.

12.2.2 Paraphysics and p-adic–to real phase transitions

p-Adics–real phase transitions [H8] could provide a general explanation for a large class of paranormal phenomena. The very fact that experimenters usually do their best to eliminate subjective elements from the experimental arrangements might explain why paranormal phenomena are so poorly reproducible. Field bodies apply naturally to personal biological body basic mechanisms of remote mental interactions and the evolution of a kind of immune system preventing the access of foreign field bodies to personal biological body looks very natural. It is also quite possible that in the statistical averaging these phenomena indeed disappear and it might be more reasonable to concentrate on the character of the fluctuations around the average. An interesting analogy is the research of Shnoll related to the

fluctuations of radioactive and chemical rates which demonstrated clear periodicities in fluctuations correlating with astrophysical periods [71]. Perhaps this approach might be applied also to the claimed paranormal phenomena.

p-Adic space-time sheets bring in mind the notion of ectoplasm often used in spritistic circles. One could of course ask whether the claimed materializations of persons and material objects by mediums are real in *some* sense, and could be regarded as p-adic-to-real phase transitions. For instance, the communications between deceased and alive could be based on the transformation of memes to real sensory space-time sheets making possible collective sensory hallucinations (of course, hallucination is a somewhat misleading notion in this context). Similar anecdotal stories abound also around yogies and everyone knows the stories about ghosts. A possible interpretation of these space-time sheets would as field quanta. In zero energy ontology their generation would be indeed possible.

12.2.3 Magnetic mirrors

Magnetic flux tubes and MEs are basic structures in TGD based model of biosystems based on the symbiosis of MEs, magnetic flux tubes and ordinary biomatter at atomic space-time sheets. Magnetic flux tubes are topological field quanta of magnetic field whereas MEs ('massless extremals') are topological field quanta of radiation field, 'light rays'.

Magnetic mirrors formed by the magnetic flux tube-ME pairs occur in many different contexts in TGD inspired theory of consciousness. For example, magnetic mirrors of length of order lightlife appear in the model of long term memory. Classically: when I look at sufficiently distant mirror I see the me of the geometric past. Quantum mechanically: timelike quantum entanglement made possible by the magnetic mirror makes it possible for the self of the geometric now to share the experience of the subself of the geometric past. Magnetic mirrors are crucial for the model of the sensory canvas and there seems to be no sharp difference between different types of memory which suggests that there is an entire hierarchy of memories in various p-adic time scales. Magnetic mirrors play a key role in the model of frequency imprinting and provide a general molecular recognition mechanism. Magnetic mirrors allow also a generalization of manysheeted DNA so that magnetic mirrors represent genetic information in electromagnetic form [K5].

In accordance with the fractality of consciousness, the wide applicability of the magnetic mirror notion suggests that various functions associated with the magnetic mirrors are different aspects of the same basic phenomenon. Magnetic mirrors would thus provide sensory canvases, long term memory mirrors and recognition mechanism at all length scales. Even manysheeted DNA would possess sensory canvas and long term memories, perhaps an entire hierarchy of them. Taken the ideas of fractality and quantum hologram to extreme, one can even consider the possibility that our long term memories are average of those associated with genes associated with various neurons! Nothing precludes the possibility that magnetic mirrors can also serve as electromagnetic bridges between different organisms (even the notion of organism must be generalized if the idea of multibrained magnetic selves is taken seriously). This could make possible effects similar to observed at DNA level (such as self assembly and translation of RNA to proteins made possible by electromagnetic recognition mechanism based on em bridges).

12.2.4 How water represents and amplifies?

What the role of the atomic space-time sheets in the representations of frequencies provided by MEs and magnetic flux tubes might be, is suggested by the fact that the matter at the atomic space-time sheets should have the role of an amplifier of em fields associated with MEs.

1. The generation of space-time sheets containing water in liquid crystal form with a rotational frequency spectrum mimicking that of the homeopathic potency is a further aspect of this mimicry and could amplify the otherwise weak signal molecular by amplifying the em fields associated with MEs serving as topological correlates for photons emitted in the transitions of the molecule. The water domain could be also seen as a mental image (subself) about the chemical at atomic space-time sheet. In principle all the rigid body aspects of the molecule can be mimicked in this manner. Mimicking water domains can also control the transitions of the biomolecules or vice versa.

2. Not only rotational spectrum but also vibrational spectrum (such as conformal vibrations of molecules) can be mimicked since any system near equilibrium reduces to a collection of harmonic oscillators: the sound waves propagating in LC water blobs would provide the representation. It is known that the water in cell interior and near to the cell membrane transforms routinely between sol and gel (LC) states in response to various stimuli: this transformation would have an interpretation as a formation of a conscious representation for something, perhaps some event or object outside the cell.

3. Note that by the scaling law $f_h/f_{ELF} = 2 \times 10^{11}$ proposed by Cyril Smith in [62], the characteristic neuronal frequency $f_{ELF} = 1$ kHz corresponds to $f_h = 10^5$ GHz and to a ME with a length of 3 micrometers, which corresponds to the thickness of the magnetic flux tube. Thus kHz frequency is maximal if ME is required to extend outside the magnetic flux tube. Perhaps this ME could be involved with a sensory representations at the cell level. For human vision the wavelengths of photons are in the range of $10^{-6} - 10^{-7}$ meters and corresponding ELF length scale is $10^4 - 10^5$ meters if scaling law is assumed.

4. The requirement that LC water blob has size not larger than about one micron implies that that the lowest ELF frequency corresponds to a time period of about $T = 1000$ years so that all time scales relevant for human consciousness are covered and MEs with frequencies relevant to human long term memories can be amplified by intracellular LC water space-time sheets. If the scaling law $f_h/f_{EEG} = 2 \times 10^{11}$ is taken literally, one obtains $f_h = 20$ Hz at the upper bound: this corresponds to the lowest audible frequency which suggests that also sound waves serve representative purposes.

5. Fractality suggests that LC water space-time sheets in turn form liquid crystals in longer length scale giving rise to secondary representations and that there exists entire hierarchy of these representations.

12.2.5 Field representation of the genetic information

TGD leads to the notion of manysheeted DNA in which DNA is accompanied by transversal magnetic mirror pairs which, besides coding 4 different DNA nucleotides to pairs of polarizations, also give rise to field representation of the genetic information by classical em and Z^0 fields associated with MEs as well as by the holograms generated by the electromagnetic MEs in active state. What is remarkable that the sizes of these MEs are can quite well be of same order as body size. In fact, the known facts from homeopathy suggest that ELF frequencies $f_{ELF}$and high frequencies f_h with ratio $f_h/f_{ELF} \simeq 2 \times 10^{11}$ appear as pairs such that f_h imprinting implies f_{ELF} imprinting and vice versa [62]. f_h can vary up to body size whereas f_{ELF} corresponds to length scales with typical unit given by Earth size. The interpretation would be that MEs represent 'spirit' and 'flesh', that is code for magnetic sensory canvas or magnetic body and for physical body. Electromgnetic representation of genetic information solves the mystery of introns (the portion of chemically silent DNA is the higher the higher the organism is in the evolutionary hierarchy and is rougly 95-98 per cent for human genome): introns would not be electromagnetically silent.

The most naive guess is that the field representation is simply a 4-dimensional photograph about body part, that is dynamical hologram, and that the DNA in the cells which express the formation of a given body part contain this kind of representation. The cells in which the genes are expressed could contain this kind of representation serving as a template and biological control command. Thus body part would contain its own image in each of its cells. The time reversal (phase conjugate) of the 4-D hologram would in turn naturally act as a time reversal of the control command and provide a universal mechanism making possible healing and self repair. Entire hierarchy of representations in various length scales might be involved providing dynamical photographs abot the planned evolution or various biomolecules, subcellular structures, cells, etc... This sounds utterly simplistic but one can ask what else? The representation for the development of the body structures must be based on very simple and concrete code since the cells building it during morphogenesis are very simple creatures and see only the light telling where to go!

12.2.6 General model for remote mental interactions

The properties of the magnetic mirrors suggest also a general model for the remome mental interactions (including phenomena like remote viewing and healing, telepathy and psychokinesis) defying standard science explanations. The article of Lian Sidorov [63] and its references give a thorough view about remote healing and viewing. One particular healing method goes under name Qigong (see the article [42]). Qigong is a general term for a large variety of traditional Chinese energy exercises and therapies. Qigong is generally considered as a self-training method or process through Qi (vital energy) and Yi (consciousness or intention) cultivation to achieve the optimal state of both body and mind. The traditional Chinese medicine postulates the existence of Qi, which could be regarded as a kind of subtle energy circulating around the physical body.

In TGD framework the energy associated with MEs and supracurrents flowing along magnetic circuitry would be a natural counterpart of Qi. Yi would in turn would translate to p-adic cognitive representations representing also intentions, perhaps p-adic variants of MEs or even magnetic mirrors. Internal Qigong refers to self healing whereas external Qigong means directing Qi energy or intention to help others by opening Qi blockages or inducing the sick Qi to get out of body, or helping to achieve Qi balance. The physiological, chemical and electromagnetic effects of both internal and external Qigong have been studied ([63] contains large number of related references). Also the effects of Qigong healing on cancer has been studied [42].

In TGD framework remote mental interactions can be understood using a model generalizing the vision about endogenous biocontrol so that the sender and receiver of the control signal can be different organisms. Thus independently whether the claimed effects are replicable not, this kind of effects are more or less predicted by TGD framework.

The general model for remote mental interactions is following.

1. Magnetic mirrors connecting the sender and receiver make possible a universal mechanism for the transfer of intent (Yi) and action (Qi). p-Adic MEs represent the transfer of a mere intent and real MEs represent a transfer of action. p-Adic ME can be transformed to real ME either by receiver or some higher level magnetic self.

2. The transfer of intent gives rise to mechanism of remote interaction which can act both endo- and exogenously. Magnetic mirrors characterized by their fundamental frequencies make possible bridges between sender and receiver (say healer and healee) and allow a resonant interaction in which healer can initiate various control commands acting as 4-dimensional templates represented as holograms. Also smaller MEs can be send along the MEs serving as bridges (this is like throwing balls with light velocity!).

3. The ME-magnetic flux tube pair connecting sender and receiver acts as a reference wave which can initiate an arbitrarily complex hologram representing biological program. Sender has the ability to generate and amplify the frequencies which induce holograms representing the control commands. In particular, sender can initiate complex biological programs without knowing anything about their functioning.

4. Magnetic mirrors make possible also feedback and this feedback could make possible learning. For instance, in psychokinesis (especially so in micro PK), this learning would be crucial and analogous to that what occurs when we learn to drive a car. In healing this kind of feedback might help to find the healing frequency by trial and error.

5. It is quite possible that also multibrained and -bodied higher level magnetic selves actively participate in the process. This makes possible coherent amplification effects (TEM, prayer groups) and also makes available information resources of all brains involved with the group. This could for instance explain the ability of a remote viewer to see an object on basis of data which need not have any meaning for her. Fast amplitude modulation of alpha waves introducing higher harmonics to the carrier wave is a good candidate for mediating communication between brains and higher level multibrained selves. Mesoscopic 'features' in brain involve precisely this kind of amplitude modulation [26] and might represent just this kind of messages [M5]. Interestingly, also speech is produced by fast amplitude modulation of 10 Hz basic vibration frequency of speech organs.

This model explains a wide variety of observations related to remote healing and vision [63]: these observations are discussed in [K5]. Since magnetic mirrors can connect also living organisms and 'dead' mater, say electronic instruments, the model can be applied to explain also phenomena like micropsychokinesis, causal anomalies related to machine-animal interaction, and so called instrumental transcommunications.

12.2.7 Stochastic resonance as a mechanism of amplification

EVP research support the view that certain background noise is necessary for receiving messages. On basis of this observation it has been proposed that stochastic resonance (the article [17] is an excellent review about the principles and applications of the stochastic resonance) is the mechanism of EVP. Stochastic resonance requires a bistable system (for instance, double potential well) or an excitable system having metastable states. An essentially nonlinear phenomenon is in question.

Stochastic resonance

Stochastic resonance works if the message to be amplified is represented as an amplitude modulation of a carrier wave with a basic frequency f and serves as a harmonic perturbation of a bistable system which is also subject to white noise. In the resonance, f must be one half of the average frequency $f(spont)$ for the jumps between two states of the bistable system: $f = f(spont)/2$. This condition has a simple physical interpretation: the height of the potential barrier separating the two potential wells varies periodically with a period which is half of the period defined by f, and the best opportunity to get to another potential well is to hop when the potential barrier is lowest possible. For the mechanical analog system the rate $f(spont) = r_0 A$ is proportional to an 'Arrhenius factor' $A = exp(-\Delta V/D)$, where ΔV is the height of the potential barrier and D characterizes the intensity of the white noise. $f(spont)$ is also proportional to a factor $r_0 = \omega\omega_b/\gamma$ where ω is the frequency of small oscillations at either bottom of the symmetric potential well, ω_b is the analogous quantity at the top of barrier, and γ characterizes the linear dissipative force (overcritial damping is assumed).

Thus, when the white noise has a correct intensity, a weak harmonic perturbation with a given frequency is amplified in the sense that the Fourier expansion of the system's time development regarded as jumps between the two states contains a peak at the multiples of the frequency of the amplitude modulated harmonic perturbation. Neuroscientists refer to this phenomenon as a phase locking. The peaks for the higher multiples of the input frequency f are exponentially suppressed. The notion of stochastic resonance makes sense also in the quantum context: now quantum tunneling replaces the jumps induced by the stochastic noise.

Stochastic resonance and brain

There is a considerable empirical support for the hypothesis that stochastic resonance is responsible for both the so called temporal coding of the sensory inputs to neurons (see the references in [17, 25]) and for the ability of the brain to extract very weak signals from a noisy bacground. For instance, crickets seem to detect the signals caused by their predators from a strong background noise using this mechanism. More generally, stochastic resonance is a very attractive candidate for a quantum level neuronal mechanism for amplifying very weak EEG waves to a firing pattern in turn amplifying the original EEG waves amplified again by the stochastic resonance... citeeegII. Amplification of em fields associated with ELF MEs is analogous to physical growth would be basically in question and p-adic MEs (memes) could use any means to achieve this. The development of individual indeed involves the gradual emergence of higher frequency ELF waves above the delta band background.

Stochastic resonance and people seeing elves and auras

It is interesting to apply the stochastic resonance model also to other experiences usually believed to be hallucinatory and purely brain generated. Some of us claim to have the ability to see elves and auras, and an interesting question is whether one could artificially induce this kind of ability by tuning the noise level of the visual perceptive field suitably. My own strange and often frightening OBE type experiences induced by the noise of refrigerator or central heating batteries could be partially understood in terms of stochastic resonance. From the visual hallucinations during my great experience I remember the strange conviction that this what I see is always present in the visual field and that I

have in some strange manner only become conscious about its presence, much in the same manner as one suddenly becomes conscious of a well-defined pattern in the autostereogram containing only what looks random points.

A stochastic resonance created by the brain itself and making possible the perception of an already existing weak visual input would conform with this interpretation. The same general explanation might apply as such to the case of EMDR experiences: the EMDR method could optimize the level of the background visual noise making possible to amplify weak signals always present in the visual and other perceptive fields. Finally, the claimed encounters with the deceased induced by the presence of a medium could also be explained by the ability of medium to induce a situation in which an actual weak visual signal is amplified to a conscious perception.

It is easy to guess the reaction of a skeptic to these unconventional interpretations, and it might well be that pattern completion indeed generates information which it is not actually present originally. It is however good to remember that until quite recently the dominating theory about dreams was that cortex does its best to cook up something from a random input coming from the brain stem. For a non-skeptic person with some spiritual traits and taking his/her dreams as an essential part of the personal subjective existence this kind of interpretation seems highly absurd and even humiliating. The revision of this view has been forced by the accumulating knowledge supporting the view that dreaming is a cognitive ability learned before the age of eight, and also by the observation that dreaming as a virtual world life has an obvious survival value. Continuining in spirit of this section, one might even see the role of brain stem as a producer of the background noise making possible the amplification of the weak signals from the higher levels of the self hierarchy to dreams (at least in some cases).

$1/f$ noise amplifying itself via white noise?

What are the physical correlates of the MEs representing memes and being perhaps amplified by both brain and by the electronic instruments in ITC? Besides white noise there is also $1/f$ noise encountered practically everywhere [18]. The origin of the $1/f$ noise is poorly understood. In TGD framework $1/f$ noise could be seen as a signature of real mindlike space-time sheets (giving rise to sensory qualia). $1/f$ noise is a good candidate for the physical correlate for the real counterparts of memes realized as MEs with the information represented by an amplitude modulated carrier wave. Also EEG could be seen as resulting from the amplification of $1/f$ noise (delta band for EEG resembles the spectrum of the so called spherics [31]). The real counterparts of these opportunistic memes would correspond to amplitude modulated ELF waves using all possible means of self expression and using also stochastic resonance mechanism to amplify remote mental interactions (this brings in mind the mysterious sea in the scifi novel 'Solaris' of Stanislaw Lem!).

12.3 Paranormal phenomena in biological systems

12.3.1 Memory of water

The prediction that cognition is present in all length scales means quite a dramatic deviation from the standard prejucides of the standard skeptic. One of the basic implications suggesting itself is a new view about evolution. The chemical evolution might quite well have preceided by a cognitive evolution of water culminating in the discovery leading to the use of biomolecules as tools to generate p-adic–real transformations making possible to use them as both sensory and motor organs. In this view the visions about life emerging from sea and from the self-organization of clay induced by a water flow acting as an external energy feed, could be seen as special cases of the same phenonenon. The cognitive evolution of water leads to the point were tools, proteins or some of their predecessors, are discovered. As in human cognitive development, and in accordance with the fractal view about cognition, the next discovery would have been the discovery of symbols and would have led to the emergence of the genetic code.

Memory is perhaps one of the simplest mental functions. Homeopathy, which could be understood as evidence for water memory, has for a long time been one of the evergreens in the skeptic's list of pseudosciences. An interesting twist in the story came when Benveniste reported about evidence for water memory in Nature [28]: no errors were found in the experimental setup of Benveniste but the attempts to replicate the experiment failed. Benveniste lost his laboratory, his funding and his

reputation. Then came Prof. Madeleine Ennis and the independent experiments performed in four laboratories gave completely unexpected support for the observations of Benveniste. The reactions of the skeptics in my own country have been highly emotionally charged, to put it mildly. One of the arguments, represented quite seriously, has been that these experiments do not even deserve a serious inspection because skeptics have honoured Benveniste twice with a special Nobel of pseudoscience!

The experiments of Benveniste and Ennis

Citating freely the article of Guardian [51], the story goes as follows. In 1985, Benveniste began experimentation with basophils, which are human white blood cells involved in allergic reactions. Basophils possess tiny granules containing substances such as histamine, partly responsible for the allergic response. The granules can be stained with a special dye, but they can be decolourised (degranulated) by a substance called anti-immunoglobulin E or aIgE. The sensational claim of Benveniste was that he continued to observe basophil degranulation even when the aIgE had been diluted out below a detectable concentration, but only as long as each dilution step, as with the preparation of homoeopathic remedies, was accompanied by a strong agitation. In 1988 Benveniste managed to publish his work Nature, speculating that the water used in the experiments must have retained a "memory" of the original dissolved aIgE. Water memory could provide the long waited hard evidence for homeopathy. Celebration was short-lived. Spearheaded by a Nature team that famously included a magician (who could find no fault with Benveniste's methods - only his results), Benveniste was pilloried by the scientific establishment. A British attempt (by scientists at London's University College, published in Nature in 1993) to reproduce Benveniste's findings failed. Benveniste has been striving ever since to get other independent laboratories to repeat his work, claiming that negative findings like those of the British team were the result of misunderstandings of his experimental protocols.

Then Prof. Madeleine Ennis and the pan-European research effort entered the stage. A consortium of four independent research laboratories in France, Italy, Belgium, and Holland, led by Professor M. Roberfroid at Belgium's Catholic University of Louvain in Brussels, used a refinement of Benveniste's original experiment that examined another aspect of basophil activation. The team knew that the activation of basophil degranulation by aIgE leads to powerful mediators being released, including large amounts of histamine, which sets up a negative feedback cycle that curbs its own release. So the experiment planned by the pan-European team involved comparing inhibition of basophil aIgE-induced degranulation with "ghost" dilutions of histamine against control solutions of pure water. In order to guarantee that no bias was introduced into the experiment by the scientists from the four laboratories involved, they were all "blinded" to the contents of their test solutions. In other words, they did not know whether the solutions they were adding to the basophil-aIgE reaction contained ghost amounts of histamine or just pure water. The ghost histamine solutions and the controls were prepared in three different laboratories that had nothing further to do with the trial. The whole experiment was coordinated by an independent researcher who coded all the solutions and collated the data, but was not involved in any of the testing or analysis of the data from the experiment. Hence there was not much room for fraud or wishful thinking.

The results were a complete surprise. Three of the four labs involved in the trial reported a statistically significant inhibition of the basophil degranulation reaction by the ghost histamine solutions compared with the controls. The fourth lab gave a result that was almost significant, so the total result over all four labs was positive for the ghost histamine solutions. There was still one possible loophole for a human factor to enter the game. The basophils were stained with a dye and then hand-counted those left coloured after the histamine- inhibition reaction. Perhaps the human error might enter at this stage. So a previously developed counting protocol that could be entirely automated was applied. The activated basophils were tagged with a monoclonal antibody that could be observed via fluorescence and measured by machine. The result, to be shortly published in Inflammation Research, remained the same: histamine solutions, both at pharmacological concentrations and diluted below detectable concentrations, lead to a statistically significant inhibition of the basophile activation by aIgE, confirming the previous work in this area.

Is water constructing cognitive representations about the molecules it contains?

There is no need to emphasize that the results of the experiments of Benveniste and Ennis could force a thorough re-evaluation of the basic assumptions of biochemistry and pharmacology. The results are

not so difficult to understand if one takes seriously the possibility that biomolecules are accompanied by their own cognitive representations. One can also assume that these representations are formed when biomolecules are dissolved in water. I have already earlier [J5] proposed this kind of model but without any special reference to the connection between p-adic physics and cognition. The treatment of the water during the dilution (involving strong shaking at each step) could imply that the cognitive space-time sheets representing the dissolved molecules remain in the diluted water and provide a representation of the properties of the molecule relevant for the effect caused by the molecule.

The most plausible candidates are frequencies and more generally, electromagnetic field patterns associated with MEs. The p-adic-to-real transformations of these MEs could in turn lead to the homeopathic effect. Benveniste and his group report [29] that it is possible to code the electromagnetic signals characterizing the information about the effects of the biologically active molecule in a digital form and transmit the information via, say, internet to another side of the globe, and that the effect of the reconstructed electric signals is the same as of the biomolecule itself. This is of cause by no means mysterious even in the standard physics framework: charged particles experience the effects of the biomolecules via the electromagnetic fields generated by them, and it is quite possible that the molecule can be fooled to believe that other molecule is present by using only that part of em field to which it responds strongly.

This said without any intention to irritate skeptics, I find it rather strange that skeptics are fighting even against Maxwell who has been dead and buried for more than a century. Benveniste and collaborators report that the presence of the water is essential for the formation of the electromagnetic representation of biomolecule in terms of frequencies, and my belief is that here the new physics emerges and relies on MEs. Probably also amplification phenomenon by quantum phase transitions are involved. Rather remarkably, the important frequencies are reported to be in the range 20-20.000 Hz which is the range of audible frequencies and also the most relevant frequency range in the TGD inspired model of qualia relying strongly on the observations about the effects of ELF em fields on living matter by Blackman and others [44] (see [M3]). Thus the later experiments of Benveniste and his group provide direct support also for the basic ideas of TGD based theory of qualia. I have proposed an analogous mechanism as an explanation of the so called phantom DNA effect in [J5]. In [K5] a mechanism of homeopathy and water memory based on the model of biocontrol in terms of many-sheeted ionic flow equilibrium is briefly discussed.

The analysis of the data provided by Cyril Smith in his lecture in CASYS'2001 conference in Liege [62] led to a detailed model for the frequency imprinting and entrainment and to the idea that space-time sheets associated with liquid crystal water blobs provide real world representations for the rotational, vibrational, etc. spectra of molecules [K5]. This is however only one kind of representations and should be regarded more like symbolic, externalized representations analogous to written language rather than cognitive or sensory representations. Of course, DNA would involve also this kind of externalized representations. MEs and perhaps also magnetic flux tubes could be also in p-adic state and provide thus cognitive representations for external world.

The $f_h/f_l = 2 \times 10^{11}$ scaling law [62] states that the imprinted frequencies appear in pairs having a constant ratio such that the presence of the high frequency f_h implies the presence of the low frequency f_l and vice versa. TGD explains the ratio of the frequencies as the ratio $\Delta E/E_c$, where $\Delta E = \pi^2/2mL^2(137)$ is the reduction of the zero point kinetic energy for a singly ionized ion dropping from $k = 137$ atomic space-time sheet to a magnetic flux tube having much larger size, and $E_c = eB/m$ is the cyclotron energy of the ion. There exists a simple mechanism explaining why f_h implicates f_l. A photon with frequency f_h kicks an ion from the magnetic flux tube to the atomic space-time sheet wherefrom it drops back to a high n cyclotron state at the magnetic flux tube. This state in turn decays by the emission of photons with energies coming as multiples of E_c. The mechanism transforming f_l to f_h requires more assumptions and it seems that several frequencies f_l can be mapped to f_h.

There is also a deep connection with the TGD based model of metabolism in which the liberation of the metabolic energy takes place via the dropping of proton to the magnetic flux tube of magnetic body with strength of $\simeq .2$ Gauss which is 2/5 times the nominal value .5 Gauss of Earth's magnetic field (.49 eV of zero point kinetic energy is liberated as a usable energy per single proton). The dropping is followed by the 'kicking' of the proton back to the atomic space-time sheet by using the metabolic energy (this involves simultaneous generation of ATP molecule which is essential for the process but does not really act as universal energy currency as usually believed).

12.3.2 Healing by time reversal

Temporal reflection of the p-adic MEs is allowed by p-adic conservation laws and generates a time reversed ME, which in turn can be transformed to real ME by the p-adic–real phase transition. The creation of the time reversed MEs is possible at least in the case that MEs appear in pairs of opposite time orientation having vanishing net energy.

In quantum optics time reversal is known as a phase conjugation [20] and is one of the basic notions of holography. MEs act as both quantum holograms and receiving and sending quantum antennae [J4]. MEs can generate reference waves of coherent photons interacting with other MEs and activating dynamical holograms of coherent light. If the reference wave is phase conjugated, the resulting hologram is time reversed. What makes this so interesting is that MEs are at the highest level of quantum control in the TGD based view about biosystem as a symbiosis in which MEs control superconducting magnetic flux tubes controlling ordinary matter at atomic space-time sheets via the manysheeted ionic flow equilibrium. The coherent light pattern emitted by ME resulting from the interaction of ME with the reference wave (its phase conjugate) could act as a control command (time reversed control command) inducing process (time reversed process). Conjugate reference waves would thus provide an incredibly simple and general mechanism of healing by time reversal allowing the living matter to fight against second law. This would be like a general initiating a war by just nodding or shaking his head.

Of course, one can ask what one precisely means when one says that biological program runs backwards.

1. Does the program run in standard direction of the geometric time but the commands are realized in the reverse order?

2. Or is also the direction of time's arrow changed? Both options are possible. The latter option is suggested by the idea about 4-D body being constructed iteratively by constructive phases during which p-adic-to-real phase transition proceeds towards the geometric future and by de-constructive phases during which real-to-p-adic phase transition proceeds towards the geometric past and what followed from wrong decision is undone. Miraculous healings in which healing occurs instantaneously could be understood if this interpretation is correct.

There is also some empirical support for the idea about healing by time reversal coming already from the period when only Soviet scientists knew about phase conjugation. In 1960's and 1970's French Antoine Priore built and tested electromagnetic healing machines of startling effectiveness [76]. Tom Bearden has in this website document "The Priore Machine and Phase Conjugation" which I recommend for an interested reader for a more detailed exposition [77] besides the material that can be found from the homepage of Tom Bearden.

In hundreds of rigorous tests with labotory animals, Priore's machine cured a wide variety of the most difficult kinds of terminal, fatal diseases known today. Many of the experiments and tests were done by prestigious members of the French Academy of Sciences. The operation of the Priore machine was incomprehensible for both the inventor and orthodox French scientists. Into a tube containing a plasma of mercury and neon gas, a pulsed 9.4 GHz wave modulated by a frequency of 17 MHz was introduced. The waves were produced by radio emitters and magnetrons in the presence of a 1200 Gauss magnetic field. Experimental animals were exposed to this magnetic field during irradiation, and the mixture of waves (about 17 or so) coming from the plasma tube and modulating and riding the magnetic field passed through the animals' bodies.

Interestingly, the magnetic field used corresponds to magnetic length of order 10^{-7} meters. It is equally interesting that a combination of magnetic fields and radiation was involved: this conforms nicely with the vision about biosystems as manysheeted ionic flow equilibrium controlled by MEs. It is known that phase conjugated waves can be produced in plasmas. The so called four-wave interaction of waves of equal frequency is the simplest manner to amplify weak wave in the effective dynamical diffraction grating defined by the interference of two waves propagating in opposite directions. If a phase conjugate wave with a correct frequency results in this kind of situation, it could act as a reference wave acting with ME and initiate a complex time reversed biological programs at subcellular level.

In particular, it could induce the time reversal of the 'develop-cancer' program controlling the development of the cancer cell population and lead to healing. p-Adic length scale hypothesis inspires

more detailed guesses about the mechanism of healing. The p-adic length scale $k = 157$ corresponds to a magnetic field of .2 Tesla if Earth's magnetic field .5 Tesla corresponds to $k = 169$ (flux quantization for cylindrical flux tubes). This corresponds to the same p-adic order of magnitude as .12 Tesla magnetic field. The cyclotron frequency of proton in the magnetic field of .12 Tesla is 1.8 MHz, which is however by an order of magnitude below the 17 MHz modulation frequency. The zero point kinetic energy of ion of mass number A at space-time sheet k is $E_0 = n \times \pi^2/(2Am_pL^2(k))$ (n is some numerical constant not far from unity). For proton at $k = 151$ space-time sheet one has $E_0 = n \times 2^{-15}$ eV, which corresponds to the frequency $n \times 7.5$ GHz, which is not too far from 9.4 GHz. This would suggest that the flow of protons between $k = 151$ space-time sheet associated with chromomose's basic structure and $k = 157$ space-time sheet associated with chromosome's coiling, is involved with the healing mechanism. A correction of the genetic error responsible for the cancer program by time reversal might thus be in question.

According to the quantum model of metabolism [K6], ADP-ATP cycle corresponds to a cyclic flow of protons between some larger space-time sheet (say $k = 169$) and $k = 137$ atomic space-time sheet. The so called $F_0 - F_1$ machine transforming ADP to ATP drives the biological Karma's cycle kicking protons to the atomic space-time sheet, where they dissipate their energy and drop back to the magnetic flux tubes liberating their zero point kinetic energy of about .5 eV. One is led to postulate the existence of metabolisms associated with other ions and between other space-time sheet pairs, and the universal energy currencies of these metabolisms are characterized by the zero point kinetic energies of the ion in question.

Another crucial frequency is the cyclotron frequency of the ion: cyclotron frequency MEs are space-time correlates of quantum entanglement, and the MEs with frequencies corresponding to zero point kinetic energies propagate along these MEs and induce self-organization at the receiving end. Standard metabolism is a particular example of this general process, and there might exist analogs of $F_0 - F_1$ machines corresponding to other metabolisms.

Healing process could correspond to the functioning of these machines in a time reversed mode: the generator becomes a motor. Even ordinary metabolism might become time reversed temporarily during healing process. Remote mental interaction would be also involved since negative energy MEs can be regarded as space-time correlates for the generation of bound state entanglement. The liberation of binding energy as a usable energy would replace ordinary metabolism in the time reversed mode. Perhaps the fact that metabolism is minimized during rest, would allow also $F_0 - F_1$ generators to temporarily run in the time reverse mode. Four-wave interaction is believed to be involved with the generation of the phase conjugates of microwaves. The direct irradiation by the phase conjugates of a microwave beam at critical frequency might be a simpler manner to induce the healing process at DNA level.

By its extreme generality this mechanism could apply to almost any disease which is a disease of the highest level quantum biocontrol. This mechanism could be also used to induce de-differentiation of cells. The de-differentiation of cells to stem cells could be controlled by a similar mechanism. One can also wonder whether this kind of mechanism could make possible eternal youth (or rather eternal life) at cell level. An interesting question is whether the phase conjugates of EEG waves or time reversals of nerve pulse patterns could induce time reversals of brain functions.

12.3.3 DelaWarr camera and field representation of genetic information

In CASYS'2001 symposium Peter Marcer [30] told about the British engineer George DelaWarr wyo built a remote imaging camera in the 1950s (radionics is the term used). Using only a test object provided from the subject such as a small blood, sputum, or hair sample, this device is reported to photographically image the subjects internal conditions at a distance, with a high degree of accuracy. A unique feature of the DelaWarr system is claimed to be that it is able to detect diseases in the pre-clinical stages prior to detection by conventional techniques such as physical examination, X-ray, CT scan, or Magnetic Resonance Imaging. The photographs taken by DelaWarr camera at fifties were treated by Susan Benford by modern image processing techniques and she claims that these photographs contain the information needed to reconstruct three-dimensional holograms [30]. The proposed explanation was that the test object (adjunct) contains a hologrammic representation about the patient.

The functioning DelaWarr camera looks highly mysterious even when one takes seriously the idea that DNA generates holograms of the body parts it codes for. Therefore it is better to introduce the

ingredients of the model as questions rather than hypothesis.

1. Was the intent of the photographer all that was needed and did other levels levels of the self hierarchy take care of the rest as they do when I make the decision to raise my hand? Could the intent of the photographer have generated a reference wave at some very special frequency acting on the adjunt and activating a hologram giving rise to a photograph about the desired body part or inducing a sequence of events leading eventually to the generation of the photograph?

2. Was the visible light giving rise to the photograph generated in the adjunct? Does the DNA of each cell of body and thus also of the adjunct contain electromagnetic representations for the body parts and are these representations more or less equivalent with holograms? Certainly direct hologrammic images about body parts would provide the simplest manner to realize the field part of the genetic code as proposed.

3. Did the adjunct serve as a relay station (somewhat like thalamus in brain) mediating the information from the patient via magnetic flux tube-ME pairs to the camera projecting it to the camera as a coherent light generating an ordinary photograph? Was the image realized as a coherent light propagating along the MEs connecting adjunct and patient serving as bridges?

12.4 Parapsychological phenomena

In this section various parapsychological phenomena are discussed in the general framework introduced in the previous section.

12.4.1 Extrasensory perception, precognition, and other parapsychic effects

The general model for paranormal effects relies on same basic ideas as the model of quantum biology.

1. The transformation of p-adic [H8] space-time sheets makes possible transformation of intentions to actions. Since p-adic space-time sheets have literally infinite size in real sense, distance does not matter. The set of points in the intersection of p-adic and corresponding real space-time sheet obeying same algebraic equations consists of rational and possibly also algebraic points common to real and p-adic variants of imbedding space.

2. The idea about field body serving effectively as intentional agent is second element of the model. The topological light rays representing negative energy signals propagating into geometric past created by a transformation of p-adic space-time sheet to a real one might be said to represent the "desire" inducing neural activities in the brain of geometric past. This mechanism provides not only a model for how magnetic body uses biological body as a motor instrument but also for PK.

   MEs acting as bridges between different organisms would mediate em oscillations and allow a directed transmission of smaller MEs behaving effectively as particles moving with light velocity. These MEs could be both real and p-adic and using the terminology of Qigong practice, would represent qi (action) and yi (intention) respectively. An essential element would be resonance: sender and receiver in should be accompanied by MEs characterized by the same fundamental frequency: only these MEs could resonantly connect healer and healee. Healer must have ability to continuously vary the healing frequency.

3. Sensory input generates sensory representations based on real mind-like space-time sheets possibly accompanied by p-adic cognitive space-time sheets. Zero energy ontology and new view about time allows to assume that sensory qualia are at the level of sensory organ (objections such as phantom leg phenomenon can be circumvented) and that symbolic representations of of objects of perceptive field and their attributes reside in brain.

   Field body can share these mental images by quantum entanglement and also receive sensory information as classical signals involving using frequency coding and coding by temporal patters. These latter representations would correspond to cognitive and emotional aspects associated

with the sensory input. One could even say that cognitive and emotional representations are somatosensory experiences of field body. The intersection points of real and p-adic space-time sheet would determine the physical cognitive representation and would be always discrete. The analogy with the discreteness of numerics should be noticed. Since this model would apply also to extrasensory perception, the attribute "extrasensory" becomes somewhat misleading attribute.

Extrasensory perception could also result from the direct electromagnetic perturbation of the sensory magnetic canvas outside the body and the sounds generated by auroras and meteors might be genuine "extrasensory" perceptions of this kind [M5]. The frequency spectrum for the sounds produced by meteors and detected both sensorily and electronically in in the range $37 - 44$ Hz [16], which is the range of thalamocortical resonance frequencies associated with sensory representations in magnetic sensory canvas model. The sounds are several orders of magnitude more intense than they should be unless em perturbations propagate to Earth in a channelled manner. Only few meteors generate these sounds. These observations suggest that a resonant amplification of the em perturbations by magnetic mirrors of the sensory canvas channelling the em field to the surface of Earth are in question.

4. One might argue that if memes are not universal, remote cognition is not very useful. An interesting question is therefore whether memes are really species-spesific. The ability of shamans to transform at the level of conscious experience to animals suggests that this might not be the case. There is also a famous real life story about a student who spend several days in the experiental world of dog. Various identification phenomena would very probably involve also magnetic mirrors acting as bridges between say shaman and animal (or possibly multibody collective self defining 'species self') and making possible to share the experience of animal. Same mechanism as in the case of long term memories would be in question but with personal memories being replaced with the experiences of another species.

The fact that p-adic space-time sheets have literally infinite size suggests that cognition and intentionality are cosmic phenomena and that there might be cosmic pool of shared cognitive mental images. Hence memes could be completely universal.

12.4.2 Psychokinesis

Below I briefly discuss an early TGD inspired model of PK, a general model of PK assuming time mirror mechanism of ordinary intentional action but applied by the magnetic body of the operator to a system different from the biological body, and a more specific model for machine-human interactions. Also concrete examples of various kinds of PK effects are discussed.

A possible model for psychokinesis with non-machine targets

In [J5] a mechanism of psychokinesis based on the generation of wormhole magnetic field configurations making possible levitation was proposed. Although this mechanism was yet general it deserves a discussion and reader is recommended to see [J5] for details. Basic mechanism is the levitation of diamagnetic substances in an external magnetic field: the force results when the diamagnetic substance repels external magnetic field from its interior. The force is essentially the gradient of the net magnetic energy inside the volume defined by the object.

The mechanism is purely TGD based and relies on the generation of a pair of space-time sheets having opposite time orientations, and carrying opposite magnetic fields and opposite energy densities, and the subsequent interaction of the second space-time sheet with the object moved in the psychokinesis. Exactly the same mechanism applies in case of MEs (massless extremals) and could be used to generate coherent locomotion of organism resulting as a recoil effect when the second ME is absorbed by the body part. MEs provide a candidate for the mechanism of psychokinesis.

TGD based general view about PK

A general TGD based explanation psychokinesis relies on the same fundamental mechanism as ordinary intentional action, long term memory, and remote metabolism. The model applies more or less as such also to telepathy and could also allow to understand the notion of water memory explaining homeopathic effects.

1. The basic mechanism of PK and retro PK relies on quantum jumps transforming the p-adic space-time sheets representing intentions to real space-time sheets representing desires represented as negative energy signals to the geometric past. These signals modify the output of say random number generator to a non-random one. Magnetic flux quanta would realize the bridges along with the negative energy signals would propagate. The mechanism would favor retro PK if the operator is in active role. Genuine PK is also possible but in this case target would be active sucking metabolic energy provided by the operator.

2. Negative energy signals could consists of dark phase conjugate photons or even massless W bosons since TGD allows scaled up variants of electro-weak gauge bosons with large Planck constant and arbitrarily small mass scales. Dark W bosons are especially interesting since they can induce charged entanglement and purely non-local charge transfer mechanism and have been proposed to play a key role in the generation of the nerve pulse.

3. Magnetic flux quanta are the bridges making possible (presumably) unconscious feedback so that the operator can unconsciously learn how to affect the machine. How intentions can have effect on system whose functioning is unknown to the operator is actually the basic mystery of, not only psychokinesis, but of remote healing and remote mental interaction in general, as also of the phenomena labelled as instrumental transcommunications (ITC). The learning by feedback, much analogous to that happens when we learn to drive bicycle, would solve this mystery. The effects of group activity could be understood if groups tend to form collective selves so that coherent amplification of the effect occurs.

4. The ability of the PK able person to imagine the desired effect is important and could correspond to the ability to generate p-adic space-time sheets representing the intention. The desire about the action represented by the corresponding real space-time sheet should induce the effect optimally. In personal discussions with a PK-able psychic I indeed learned that he always tried to imagine in every possible detail how he moved the physical object (say a box of matches). The role of imagination is important also in remote healing [63]. Perhaps the p-adic pseudo constants made possible by the non-determinism of p-adic differential equations should be in a good approximation genuine constants.

5. The optimal targets are initial value sensitive. This favors quantum critical systems such that several values of Planck constant are possible with large values of $\hbar$ assignable to negative energy signals mediating the desire of the PK-able person. PK requires energy and this favors systems, which can utilize standardized metabolic energy quanta liberated in the dropping of particles to larger space-time sheets. Water would be an optimal system from the point of PK and retro PK. Homeopathy might indeed involve PK like aspects. Benveniste's experiments

   [28, 29] gave support for the notion of water memory but could not be replicated when the experimenters did not know in which bottles the treated water was. The preservation of water memories represented in terms of many-sheeted lasers for with 1/0 corresponds to a population inverted state/ground state, requires metabolic energy feed and the system might suck this metabolic energy from the biological body of the experimenter [K5].

6. As noticed, this model is extremely general and seems to apply to almost any paranormal phenomena. For instance, the claimed re-incarnation cases could be understood in terms of the general mechanism for long term memory. The person who remembers having lived in past could share mental images of a person in the geometric past by time like entanglement (episodal memory), or could be able to communicate with negative energy signals to the brain of a person on geometric past memory recall and thus receive declarative memories. It is quite possible that survival of fittest in our culture has led to an evolution of an immune system preventing sharing of mental images and communications with other brains.

Machine-mind interactions

Machine-mind interactions represent a modern branch of parapsychological research and nowadays methodologically highly advanced. These interactions are studied several groups and individuals: mention only the Princeton Engineering Anomalies Research (PEAR), which is a group directed by

Prof. Jahn, the Anomalous Cognition Project of Dick Bierman, and the retropsychokinesis work of Helmut Schmidt. In the sequel some aspects of this work are discussed.

1. Retro psychokinesis with random number generators

The analysis of experiments [45, 35, 36] discussed in the [H5] suggests that the geometric past can change in the time scale of a fraction of second. Both the work done at PEAR [54] and the work of Helmut Schmidt with retro psychokinesis [61] provide support for the change of the geometric past in much longer time scales. PEAR experiments demonstrate the anomalous effect also in the direction of future. For instance, the experiments of Schmidt done 1992 discussed in New Scientist [41] demonstrate that martial art students were able to affect the visual display determined by pre-recorded random numbers. The probability for this kind of deviations from non-randomness was about 1/1000. Henry Stapp proposed an explanation for this in his paper published in Phys. Rev. A [24] based on nonlinear quantum mechanics.

The change of also geometric past in the quantum jump between quantum histories implies the notion of a four-dimensional physical reality and forces to regard three-dimensionality of reality as illusion created by the 3-dimensionality of our sensory experience (recall the notion of the association sequence). This implies that our geometric past is changing all the subjective time and that communications to the geometric past and future are possible and are consistent with the weak causality violation hypothesis of Schmidt [61]. What this hypothesis implies that in the newest quantum history generated by RPK all separate records contain the pre-recorded random numbers are altered in the same manner in RPK. Schmidt has tested weak causality hypothesis by using two separate cassette tapes containing the pre-recorded random numbers, one used in the PK experiment and another one kept locked in a safe. The records were indeed found to be identical after the experiment.

The results of Schmidt suggest also classical signalling to the direction of the geometric past. Real space-time sheets with negative time orientation could serve as the geometric correlates for these signals.

2. The work of Princeton Engineering Anomalies Research group

The study of anomalies in human-machine anomalies provide a highly sophisticated and controlled manner to study psychokinesis in its various forms. For instance, in the experiments carried out in PEAR group (Princeton Engineering Anomalies Research) [54] operators try to affect various kinds of electronic, mechanical, acoustical, optical and fluid devices. In unattended calibrations these devices yield random output whereas in the experimental situation operator tries intentionally to affect the output so that non-randomness results. Each input that operator tries to affect consists of 200 bits formed from a random physical signal and operator can have either the intention to increase the number of 1:s (high) , the number of 0:s (low) or have no intention at all (baseline). Operators can exert their efforts from a distance of thousands of miles, before or after the the actual operation of the devices. Over the laboratory's 20-year history, thousands of such experiments, involving about 100 millions of trials, have been performed by several hundred operators.

The observed effects can be summarized as the average for the sum of bits which is 100.026 for high and 99.984 for low. The effect is by a factor 3.6 higher than the expected margin of error. Effects are thus quite small, of the order of a few parts in ten thousand on average, but they are statistically repeatable and compound to highly significant deviations from chance expectations. Effects are highly operator specific and there are significant disparities between male and female performances. The random devices respond also to the group activities of large numbers of people and are especially sensitive to the effect of small intimate groups, group rituals, sacred rites, musical and theatrical performances, and charismatic events.

Time mirror mechanism suggests the following model for the machine-human interactions encountered in say PEAR experiments.

1. The effect of intention could be on the generator of random noise, on bit sequence represented in the computer memory, or even on the recorded value of the sum of bits. A possible mechanism in the latter two cases is the reversal of electromagnetically represented bit.

2. The general mechanism of intentional action involves negative energy signals inducing a change in the charge distribution determining the value of bit. Negative energy photon could induce a dropping of ions to a larger space-time sheet. Also the emission of negative energy dark W

bosons (appearing in TGD based model of nerve pulse) could induce a change in the net charge. In both cases the sign of charge would correlate with the character of intention and for the first mechanism there would be asymmetry between "high" and "low" (proton, electron).

3. The work of William Tiller

Tiller [67, 68, 69, 70] has performed experiments involving intentional imprinting of targets such as water. The imprinting manifested itself as temporal and spatial oscillations of pH and temperature. The surprising finding was conditioning: also the air around intentionally imprinted device exhibited these oscillations. Also computer could be conditioned. The Fourier transform of the correlation function for bit sequences of random number generator demonstrated peaks at harmonics of $f = 1/T$, $T = 113.778$ min. This obviously represents a different kind of machine mind interaction. Could large energy dark cyclotron photons with these frequencies induce a periodic perturbation of the random bit sequence?

Robots, chickens, rabbits and men

The interaction between random number generators and humans or animals is one form of psychokinesis. For a few years ago the issue 62 of "Network", the journal of the Scientific Medical Network [55] contained a report about the experiments carried out by Dr. Rene Peoch, working at Fondation ODIER at Nantes. In these experiments chickens and rabbits apparently influenced signals composed by a random-number generator for a robot close to them, and human subjects apparently influenced the movements of the robot even though its signals had been generated by a random-number computer program six months earlier.

Chickens stayed close to the robot "imprinted" on it as their mother and followed it about. The robot had a random-number generator inside it controlling its movements, which checks showed to be truly random. The chickens were then removed and one placed so it could see the robot but could not follow it. Under these circumstances the robot spent measurably more time close to the chicken than away from it. The effect was that the chick was influencing the robot's generator. The generator was then removed to a computer away from the experimental area. The same effect occurred. "Non-imprinted" chickens however had no apparent effect on the robot.

In the rabbit experiment, baby rabbits were frightened by the robot and kept away from it. When the rabbits' movement was inhibited, the robot's movements became non-random and it kept away from them. However, when one rabbit was starved and food was placed on the robot, this behavior was reversed and the robot brought the food to the rabbit. It was found that humans likewise could influence the robot.

Also humans were invited to influence the robot as before, but in fact it was being driven by a code generated six months earlier and recorded on a CD, now being played back. The robot was influenced as in the contemporary study. The CD was then examined and it was found that the first half of its code was indeed non-random, but the unused code was truly random. This gave the effect that the computer somehow "knew" six months earlier not only that half the code would be used for such an experiment, but also the general direction of the movements that would be required.

The interpretation of the reported results in terms of psychokinesis and human-animal-machine symbiosis suggests itself. The experiment with humans can also be interpreted as a dramatic verification for the prediction that in quantum jumps between quantum histories also the geometric past changes: the recent experiment suggests that the change occurred in a time scale of six months. If the crucial assumption about the randomness of the random number generator is correct, the effect is also very strong. This could mean that we are changing our geometric past all the subjective time in macro-temporal time scales, as indeed suggested by the paradigm of four-dimensional brain. A further suggestion is that this hypothesis can be indeed tested empirically by developing further these experimental arrangements.

To better comprehend what might be involved, recall that in TGD subjective time and geometric time are not one and the same thing. Accordingly, subjective memories are memories about conscious experiences and geometric memories are memories with respect to the geometric time for which time is in a precisely same position as space: geometric memories give prediction of the future and past changing quantum jump by quantum jump like weather broadcasts (except that one usually is not interested in the predictions of what weather will subjectively be in geometrically last summer). The

crucial point is that the contents of say computer files representing purely geometric memories (such as number sequencies) can change in the quantum jumps whereas the possible subjective memories about their contents can remain unchanged. This peculiar contradiction between subjective and geometric memories, which I have christened as 'tribar effect', serves as a possible experimental test for the reality of notions of the subjective and geometric time. These experiments are bound to involve human memory as a subjective element: nothing however prevents several human subjects store to their memory the original memory to guarantee objectivity in a statistical sense.

If the randomness of the original random number series produced six months before the experiment involving human-robot interaction has not been checked, it can be argued that random number generators (if genuine) accidentally produced a number series which was not random in the time scale involved. This problem could be circumvented by modifying the experiment by checking already six months earlier whether the number series is really random or not. Humans can indeed remember whether the series is genuinely random or not although they are not able to remember long number series. On the other hand, if the non-randomization effect appears only under special conditions (effect is present for the imprinted chickens only), one has even without the check good reasons to believe that machine-mind interaction has occurred.

An important question of principle is whether the random number generators are genuine or whether the numbers are generated by some algorithm yielding only pseudo random numbers. If genuine randomness is due to quantum phenomena at atomic or molecular level, then intentional action could affect physics at atomic and molecular level. Of course, the success of p-adic mass calculation and interpretation of p-adic physics as physics of cognition and intention forces the same conclusion. If some algorithm produced them and there is no noise affecting the outcome, the only changes which can occur is the modification of the algorithm or of the initial conditions for the algorithm. In the latter case the production of the desired behavior might however be impossible since the algorithm need not even allow the needed regular behavior of the random number sequence. This of course could be checked.

p-Adic space-time sheets representing intentions/memes should be transformed to their real counterparts realized as negative energy signals and able to interact with random number generators. If the p-adic memes are actually chicken's intentions mediated by magnetic mirrors and transformed to real ones when intention is realized, the interaction mechanism is basically ordinary electromagnetic interaction with the machine. The question about the detailed mechanism allowing chicken's volition to affect the geometric past of the robot allows endless variety of answers. One possibility suggested by the more precise views about psychological time is that the robot has primitive consciousness and that the p-adic-to-real phase transition of robot proceeding to the direction of geometric future is undone by the reverse real-to-padic phase transition down to the moment when the random numbers were generated and regeneration of them occurs and gives rise to a new chicken friendly behavior. Again trial and error might be involved.

The results of experiments, if replicable, suggest that animal-machine anomalous interactions might be much stronger than human-machine interactions, perhaps because animal is totally confident that the desired interaction happens (Blessed are the meek since they will inherit the kingdom of Heaven!). One could imagine experimental arrangements analogous to the chicken-robot experiments in which the chicken is replaced by a human who genuinely believes that the robot can do what (s)he wishes: this could be achieved by telling the subject person that machine is programmed to deduce her/his wishes, from say EEG. Various modifications of the imprinting mechanism could be applied in more complicated situation. The results might be also used as guidelines in the attempts to generate artificial life. The systematic use of genuine random number generators as control tools of robotic motion suggests itself as a basic principle to guide the attempts to build artificial life. This would optimize the flexibility of the robot behavior so that it could be affected by the p-adic intentions.

Adaptive robots as an electronic life form?

The construction of artificial life by building initial value sensitive robots might be a possible breakthrough application of the p-adic cognition. What would be needed is just initial value sensitivity: p-adic memes would take care of the resst.

Mark Tilden is a wellknown builder of robots working in the nuclear physics laboratory of Los Alamos. Tilden builds his robots by using pieces of used electronics. The robots do not run any computer program so that the basic philosophy is more or less a diametrical opposite of AI. Rather,

the wiring of the robots is such that in a new situation robot tries for different behaviors. For instance, if robot leg gets stuck, the robot changes the orbit of motion of leg. What is remarkable that the robots seem to behave like living organisms in some aspects.

Unfortunately, I do not have any scientific articles about Tilden's work apart from short description in his homepage [64]. In fact, I encountered competely accidentally about Tilden's work by reading an article in the Finnish version of Reader's Digest August 1998 after having seen Stetsoned Tilden and his tiny robots in a popular science program in Finnish TV telling about the recent situation in robotics, AI, and artificial life. The robots of Tilden have surprising abilities to adapt and compete for energy which they get from the sunlight. Robots seem to literally fight for the sunlight. For instance, an electronic fellow called Turbot, kills other robots from his territory and collects them to form a wall against the invasion of other invaders!

The claimed adaptive feats of these robots suggest that a primitive lifeform is in question and this is also the belief of Mark Tilden. A general handwaving explanation for the adaptive behavior is that these systems are at the borderline between chaos and order and adaptive behavior 'emerges'. Of course, what 'emergence' means is a complete mystery in the deterministic physics with quantum effects absent in macroscopic length scales.

That primitive life form might be in question, fits nicely with the TGD view. First of all, all forms of self-organization involve quantum jumps and consciousness, and the question is only how important is the role of cognitive consciousness in the behavior of the system. Cognitive consciousness can become important only if the system is sufficiently flexible and initial value sensitive so that the realization of intentional motor actions becomes possible by p-adic-to-real transformations inducing critical perturbations to the initial-value sensitive behavior.

The in-built flexibility of the robot behavior (a strict opposite of pre-programmed behavior), and initial value sensitivity make in principle possible self-organization by quantum jumps and effective quantum control. For instance, robots could contain modules controlled by genuine random number generators which would be affected by p-adic memes. If p-adic physics is physics of cognition, Nature itself guarantees, that robots form cognitive representations, and by the flexibility of their motor system, they are able to transform cognitive representations to motor actions. If p-adic space-time sheets are indeed memes floating around and waiting for the opportunity to materialize themselves to action, the robots of Tilden could provide an excellent opportunity for a meme to reincarnate!

The extreme generality of the p-adic physics means that one cannot exclude the possibility that electronic systems could quite generally develop p-adic cognitive representations about itself. If so, can one guarantee that the old electronic components recycled by Tilden do not differ cognitively from electronic components coming directly from fabric? If they do, two identical robots built from old and new components might behave differently. Thus a test for whether the robots have mentality and some kind of developing personality is whether two physically identical robots behave differently under similar circumstances.

Quite generally, one can identify p-adic cognitive representations as the mechanism which gives the physical system personality and allowing to distinguish even between two electrons p-adically: of course, Fermi statistics does not allow a state consisting of two electrons in states differing only cognitively. Quite generally, this kind of test could be the counterpart of Turing test allowing to deduce whether physical system has cognitive self or not.

Telekinesis and electrostatics

In the book "Mind at Large" edited by Tart, Puthoff, and Targ there is an article "An Investigation of Soviet Psychical Research" by Wortz *et al* reporting among other things the research related to the electrostatic aspects of telekinesis. The article mentions the work done by Vasiliev and associates with Nina Kulagina and the work of Adamenko with Alla Vinogradova, another highly gifted person in telekinesis. Kulagina and Vinogradova are said to have been able to move objects of .1 kg along table. Interestingly, according to the article PK able persons tend to be women. Adamenko has tried to understand the phenomenon theoretically and has proposed that the static charges of objects and electrostatic forces generated by the subject might explain the effects.

Adamenko's work

The objects moved by subject persons were located at a table which was a di-electric cube with of side length of .5 meters in Adamenko's experiments.

1. Vinogradova was able to induce an electric charge in cube and then move objects located at the cube. With biofeedback training also other subjects were able to replicate Vinogradova's feat.

2. To move the object the static friction (friction coefficient between .1 and .3) must be overcome. Adamenko theorizes that there is kind of buyonancy force caused by the flow of air molecules involved and that the electric field somehow induces this force.

3. The reported electric field was 10 kV/cm and corresponds to the voltage at which a di-electric breakdown occurs in a dry air. The reported movement of the air could correspond to a corona wind resulting at strong electric fields.

4. Adamenko assumes that the objects had either static charge or that they were polarizable and developed a dipole moment in the external electric field. The electrostatic interaction with the electric field induced by Vinogradova would have been the cause of the movement.

TGD based model

TGD based model for phenomena is based on the general mechanism of mind-matter interactions allowed by the many-sheeted space-time concept. There are three questions to be answered: How the table and possibly also object were charged?; How the motion of the object was caused?; How the object was lifted from table to circument friction force? *How the table and object were charged?*

The charging of the table is certainly crucial for the PK effect. Vinogradova could have emitted "topological lightrays" (MEs), as a matter fact high frequency (microwave) MEs propagating like particles within low frequency (ELF) MEs. Negative energy ELF MEs could have served as correlates for entanglement. Entanglement is however not necessary in this case since conscious telepathy is not involved. Microwave MEs would have induced bridges between the atomic space-time sheets of the object and super-conducting magnetic flux tubes of Earth. The bridges would have made possible ionic and electronic currents between these space-time sheets and led to the charging of the table and possibly of also object. A suitable intentional targeting of MEs would allow to control the charge distributions of the table and object and therefore the pattern of the induced electrostatic fields.

What could have produced the motion of the object?

The interaction of the object with the electrostatic field of the table is a possible explanation for the PK effect. The distribution of the charges of the table and object would allow to control the field pattern and thus the direction of the electrostatic force. This is however not the only mechanism. Ionic currents from the magnetic flux tubes to the atomic space-time sheets of the object produce recoil effect (momentum is conserved only in many-sheeted space-time, not for single space-time sheet), and this could have been the fundamental mechanism of motion (essentially the mechanism of rocket motion). In both cases the subject would have produced only the ME bridges taking care of the control of motion but would not have provided the energy and momentum.

The experiments of Modanese and Podkletnov [75] provide support for the mechanism. Modanese and Podkletnov studied capacitor at a rather low temperature and at a voltage near the di-eleectric breakdown voltage. The second electrode was a super-conducting disk. The resulting discharge was large and coherent and accompanied by radiation pulses of unknown type. The pulses induced the motion of the air and kicked test penduli. The force was proportional to the mass of the penduli. The effect caused by the pulses did not weaken with distance. This supports the view that the pulses were TGD counterparts of the Tesla's scalar waves and induced temporary bridges between test penduli and magnetic flux tubes inducing the flow of ions and the recoil effect. The same mechanism should be at work as a microscopic and incoherent version in the case of lifters.

How to circumvent the friction?: a connection with the physics of lifters

Lifters exhibit the called Biefeld-Brown effect [G2]. Lifters are asymmetric capacitors consisting typically of a wire electrode and planar electrode, are in a voltage slightly above the voltage causing di-electric breakdown. Lifters move in the direction of the smaller electrode. Also the flow of air from the small electrode to the large one is involved. On basis of the experimentation and guide the findings of Juha Hartikka, I ended up with a simple model of lifters. What would happen is that there is an electric discharge in the form of small plasmoids (discharge sparks would be analogous

to ball lightnings), whose emission from the small electrode causes the recoil effect. The emission of the scalar wave pulses could induce the motion of the air by Modanese-Podletnov recoil mechanism. Since the table is charged, there should be a strong electric field also in the narrow space between the object and table. Therefore electronic discharges from the object could occur, and lead to a small scale lifter effect lifting the object slightly above the table. This does not require the object to carry a net charge.

Could the remote EEG sensor of Sergeyev be based on the same mechanism as PK?

In the same article also the remote EEG sensor invented by the mathematician Sergeyev claimed to remote sense EEG from a distance of 5 meters is described. Unfortunately, the information related to the invention of Sergeyev is classified. What is however known from the existing literature is that the sensor is surprisingly simple, consisting of a metal disk suspended into water and coated with a semiconductor. The immersion in water is reported to double the effectiveness of the sensor. According to the report, the ordinary EEG sensors can detect EEG only up to a distance of few centimeters since the noise of the environment masks the (Maxwellian) EEG at larger distances. Furthermore, the amplifying effect of water is not consistent with the high value of the di-electric constant of water if ordinary Maxwellian electrodynamics is behind the sensor.

Sergeyev's explanation for the functioning of the sensor utilizes bio-plasma hypothesis. The use of the term bio-plasma is remarkable since professional physicists know that plasma state at the temperatures and densities of living matter is not possible in standard physics universe. In TGD framework super-conducting ions leaking from the magnetic flux tubes of the Earth's magnetic field can give rise to what might could be called bio-plasma, and Sergeyev's sensor is indeed said to produce bio-plasmagram. Also maser (microwave laser) effect in bio-matter producing ions and electrons flowing into air is mentioned.

All this suggests that EEG MEs containing microwave MEs inducing a leakage of the ions from magnetic flux tubes to the atomic space-time sheets of the metal disk and in this manner generate plasma. The strength of the resulting electric signal would be modulated by the intensity of the net flux of EEG MEs so that information about EEG would indeed result. EEG MEs would not topologically condense at atomic space-time sheets but propagate as bridges connecting the boundaries of the magnetic flux tubes and atomic $k = 151$ (cell membrane thickness) space-time sheets. This would explain the dissipation free propagation. For positive energy MEs the effective phase velocity would be of the same order as the alpha wave phase velocity since these MEs would tend to "stuck" (in quantum sense). The basic sensing mechanism would be very much the same as explaining the generation of nerve pulse. Also Z^0 MEs could be involved and would usually have a very weak interaction with the environment. The ability of water to act as a many-sheeted maser, presumably crucial for the functioning of living matter, could explain why the water amplifies the effectiveness of the sensor.

Also the remote sensing of the pulsating magnetic fields produced by Nina Kalugina and having strength nearly equal to that of the Earth's magnetic field are mentioned in the article. The possible significance of the pulsating magnetic fields for PK is still poorly understood in the TGD framework: the problem is that solutions of field equations representing this kind of field configurations are not known. One might however think that the pulsating magnetic fields carry also supra-currents, and that their presence intensifies the leakage of charged particles to the atomic space-time sheets of the remote sensor device.

12.4.3 Near death experiences

Near death experiences are rather commonly experienced, say by the victims of various accidents. These experiences are known for centuries but it was the best-selling book "Life after Life" of Raymond Moody which brought these experiences known to the general public [52].

1. What NDEs are?

NDEs seem to possess invariantly the same characteristic features. There are feelings of peace and joy, time speeded up, heightened sense, lost awareness of body, seeing bright light, entering another world, encountering a mystical being or deceased relatives and coming to a point of no return. The experiences seem to proceed in quite universal manner. First comes a loud buzzing or ringing noise and a long dark tunnel. Patient sees his own body from outside and does not feel any pain or agony anymore. Patient meets others and a being of light who shows his life in its entirety as a kind of

playback to evaluate. Then comes the point of no return, and although patient feels peace, joy, and love, the patient has to return to continue his life. Often these experiences induce very profound changes in the subsequent life of the patient. The claims of Moody have been supported by subsequent research and hardly anyone, even the most foolhardy skeptic, denies the reality of these experiences.

The latest twist in the development emerged when University of Southampton research team announced the result of a one-year study of NDEs of victims of a heart attack supporting the view that consciousness and mind exist after the brain has ceased to function and the body is clinically dead. The resuscitated patients were various times clinically dead, with no pulse, no respiration and fixed dilated pupils. Independent EEG studies have confirmed that brain's electric activity, and hence brain function (according to standard dogmas of neuro science) ceases in this kind of situation. 11 per cent of patients who survived the heart arrest however recalled emotions and visions during this state. This announcement has created considerable excitement in various consciousness related discussion groups and the question whether some of the basic dogmas of neuroscience are badly wrong has been raised by the neuroscientists themselves.

2. TGD based view about life after death very concisely

It is good to summarize the latest TGD based view about consciousness after physical death before comparison with other theories and detailed analysis of NDEs. The view, which is certainly not the only possible one can imagine, is supported by the improved view about psychological time.

The basic notion is that of 4-D body involving both the physical body and the magnetic mirror structures associated with it. 4-D body is gradually carved like an artwork via p-adic-to-real phase transitions representing the progress of front of volition to the geometric future and by the reverse phase transitions deconstructing the 4-D body or its parts. This fractal trial-and-error construction of the 4-D body occurs in various time and length scales. Gradually increasingly stable 4-D body results. The volition is concentrated to the front of the p-adic-to-real phase transition so that the experience of 4-D body for which deconstruction processes occurs only in the time scales short compared to the duration of lifecycle, would be about entire lifecycle and in this sense 'timeless'.

The simplest view assumes that the front of volition does not propagate after the physical death. One could however consider the possibility that the front of volition continues to propagate by transforming p-adic magnetic mirror structures to real ones: volitional life would continue in electromagnetic form. This would make possible the communications of the deceased with living since the resulting real magnetic mirrors could connect the deceased with the living. On the other hand, the repertoare of possible p-adic mgentic mirror structures would be very wide because of the p-adic non-determinism.

Since magnetic mirror structures are fundamental for the field realization of the genetic code, one can quite well consider the possibility that this process induces also the self-organization of the ordinary living matter around the magnetic mirror structures. This would have interpretation as a reincarnation. Buddhas able to resist the temptation to reincarnate would continue their life at the field level. Interestingly, the development of physics from Newtonian physics of the material bodies to Maxwellian physics of fields would mirror the evolution of consciousness from concrete biological life to life at the field level.

3. Astral plane theories for NDEs

There are several theories of NDEs. A theory enjoying popularity in New Age circles is based on the notions of the astral projection and next world stating that we have another body that is vehicle of our consciousness which leaves the body at the moment of death. Although completely respectable as such, this kind of theory is not based on existing or even postulated physics, and is therefore hard to test. The notions of 'higher vibrational level' and 'astral plane' are simply devoid of a physical meaning.

In TGD framework the idea about 'vibrational levels' generalizes in an astonishing concreteness to an entire hierarchy of electromagnetic life forms and electromagnetic bodies whose sizes vary to astronomical length scales [K3, M5]. In this framework the idea about brain as a seat of consciousness is an illusion resulting from the fact that sensory data is mostly about the immediate region around body. Of course, even the idea that consciousness (as opposed to its information contents) can be localized to some part of space-time, is basically wrong in TGD approach.

A possible test for the astral projection theories is a weighing of the body after death to deduce the weight of the astral body (assuming of course that astral planes obey ordinary physics!). If

'astral planes' correspond to the p-adic space-time sheets, this test of course does not make sense. Magnetic mirror structures are obvious candidates for astral body and are real but their separation from body is impossible so that this kind of measurents do not make sense. The notion of 4-D body also suggests that the physical body remain in the geometric past in the physical death wherefrom it can communicate with the living ones via the magnetic mirrors of magnetic body which continues to be generated by p-adic-to-real phase transition.

Extrasensory perception via astral bodies is a second possible test. This test might make sense if extrasensory perception can be generated by patterns of ELF em fields as supposed in the TGD inspired model of qualia. Magnetic mirrors connecting organisms to each other and also to 'nonliving' matter make possible ESPs. Also direct electromagnetic perturbations of the magnetic sensory canvas can give rise to ESPs: in [N1] the possibility that the strange sounds produced by meteors [16] could correspond to ESPs is discussed.

4. Tunnel experience

The theory of Grof and Halifax [47] is based on the observation that NDE involves elements which might be assigned to the moment of birth. Perhaps NDE is reliving the moment of birth. The counter argument is that the newly born baby does not see anything unless she is able to perceive extrasensorily. 'Nothing but hallucinations' theories are of course no explanations at all and belong to the same category as 'consciousness as mere illusion' theories. In neuroscience framework also the wake-up reality is seen basically as a hallucination produced by brain and coupled with sensory input to guarantee correspondence with what is out there.

The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline. I have also personal 'tunnel experiences' every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. Earlier this experience was not stable and tends to fade away all the time, and after few minutes I was not anymore able to achieve it. Situation has changed quite recently: I can have the experience almost anytime in peaceful state of mind. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. It has been suggested that the physiology of brain could explain the properties of near death experiences [22]. The theory of Cowan [22] states that the tunnel results from a failure of the inhibition leading to brain induced activity yielding visual experiences. What is however questionable is why person would feel falling into the tunnel, to say nothing about meeting deceased relatives. Blackmore and Troschienko have proposed a theory in which also the motion along tunnel could be understood as a visual illusion [39].

TGD based explanation for tunnel experience might be simply as a direct visual experience about magnetic flux tube structures resulting from the perturbation of the magnetic sensory canvas outside body. Thus a genuine ESP would be in question. Magnetic field obeys indeed same basic equation as incompressible liquid flow. Both retinas and pineal gland ('third eye' literally since it contains retinal pigments and serves as a genuine third eye in some species [K3] are magnetic structures. The practically always present vortex in center ('third eye' in my private terminology) could correspond to the magnetic flux tube structure emanating from the pineal gland whereas the very dynamical flow could correspond to the contribution of retinas. If the magnetic mirrors are universal electromagnetic bridges connecting us to other living beings, in particular to our friends and relatives, the meeting of the 4-D bodies of the deceased relatives would happen at the level of fields.

The movement along the tunnel could correspond to the propagation of p-adic-to-real phase transition along this kind of magnetic mirror structure transforming it from p-adic to real: thus the tunnel would be created after the physical death. During lifetime these em bridges would be p-adic and physical death be followed via the transformation of these bridges to real ones.

5. OBE aspect

Blackmore explains OBEs [32] as resulting from the replacement of ordinary self-center experience of world with bird's eye of view model where brain sees own body from above. Bird's eye of view is only a memory model so that extrasensory perceptions are predicted to be impossible during OBEs. There

is however some evidence that patients can report very precise visual perceptions during OBE. It has been indeed argued, that some other senses than vision, namely hearing [32], could create indirectly these perceptions. It is however difficult for even the most hardborn materialist to understand how a clinically dead person could be able to effectively see by hearing, since this feat is impossible for even completely healthy person.

The idea of Blackmore about bird's eye of view is very attractive as such and can be interpreted in TGD framework in quite different manner. Cognitive maps based on the canonical identification map [E6] typically exterior to inside and vice versa. Thus both a p-adic map of the external world realized inside brain and a p-adic map of body and its surrounding realized outside the body are possible and would give models of the external world and self. The inside-to-exterior map could provide a bird's eye of view about body and its immediate surroundings.

Both exterior→interior and interior→exterior maps could contribute to the conscious experience even under the normal wake-up consciousness and the exterior contribution would thus represent genuinely extrasensory contribution to the conscious experience. When the ordinary sensory input and volitional activity ceases as during NDE, the contribution of the model of external world to the conscious experience becomes negligible. The ability to experience tunnel unstably during relaxed wake-up consciousness with eyes closed is consistent with the interpretation that these two components are competing. It is quite possible that during sleep the bird's eye of view component also dominates but that no memories about this period are generated for the simple reason that the brain functions necessary for the generation of the memories are not active. My own remembrances about the long depressive period after the great experience caused by the extreme dullness of the normal wake-up consciousness suggest at least to me that these kind of memories might make it too painful to continue the daily life.

The notion of magnetic sensory canvas implies that we actually see at ELF frequencies. Same applies to other senses. This implies the possibility of experiences without any sensory input or even without any neuronal activity. The needed ELF MEs acting as sensory projectors would be generated in the dropping of ions from atomic space-time sheets to the magnetic flux tubes of magnetic body carrying field strength .2 Gauss (Earth's magnetic field has nominal value .5 Gauss). If the ion drops in high n cyclotron state the subsequent decay of the state by cyclotron transitions generates a bundle of parallel ELF MEs giving rise to the sensory projection. This representation can be generated by the entire body and would give rise to a three-dimensional vision about body as seen by the environment. There is some evidence for this kind of anomalous vision.

1. Yogis have reported altered states of consciousness in which they see their own body three-dimensionally, that is simultaneously from all directions.

2. Becker tells in his book "Cross currents" [29] about a young cancer patient who told that he can see the interior of his own body. The patient could locate the calcium deposit left as tumor vanished. This supports the view that ELF MEs could project from the entire body to the sensory canvas.

3. Also the OBE experiences, for instance those associated with NDEs, could have a similar interpretation. The sensory input from eyes and even the input from neural activity could be absent during NDEs so that the visual experience should be determined by the background ELF component emanating from the brain and body. The third person perspective associated with OBEs might be always present but be masked by the strong sensory input.

What has been said applies also to other senses. Interestingly, I often wake-up partially and realize that I hear my own snoring as an outsider. Sometimes I have an experience which might be interpreted by saying that the hearing in the first perspective is superposed with the hearing in the third person perspective. The third person hearing has a time lag so that a kind of double breathing results.

Sensory canvas hypothesis provides a more concrete view about the situation. p-Adic-to-real phase transition of a p-adic magnetic sensory canvas to real one could also be part of the fundamental volitional process. The magnetic mirrors connecting brain to sensory canvas should be there also in the absence of sensory input. Could it be that the out of body view is always involved but masked by the from the body view and after the physical death only out of body view remains?

The competition between bird's eye of view and sensory view has also EEG correlate. Delta waves in the EEG spectrum are natural EEG correlates for the external part of cognition. The reason is that

this part of EEG frequency spectrum has a shape and intensity very similar to that for the so called sferics [31], which correspond to meteorological electromagnetic perturbations typically associated with thunder storms. Could sferics be the electromagnetic correlates of discarnates?! The degree of the sensory alertness correlates directly with the the ratio of the EEG net intensities in the delta band and in higher EEG bands [31]. This is consistent with the competition predicted by NMP. Certainly in the NDE experiences studied by the Southampton team only delta band is present in EEG. Note that delta waves dominate also during deep sleep.

Also alpha band is a good candidate for communicating sensory information to higher level selves having magnetic sensory canvas receiving sensory input from several brains simultaneously. It is indeed alpha band in which detectable changes occur in remote vision and remote healing [63]. Could it be that higher than alpha consciousness somehow transforms to alpha consciousness in physical death and could it be that alpha consciousness relates with the fact the lowest Schumann frequency associated with the perturbations of Earth's magnetic field is in the alpha band? It might be that magnetic transition frequencies are involved with the 'vertical' communications from brain to the sensory canvas whereas Schumann resonances would be involved with the lateral communications between different sensory canvases. The fact that hypnagogic experiences involving also identification with other persons (personal experience) appear in the borderline between wake and sleep when dominating EEG frequencies are around 7.8 Hz supports this view.

6. Life review

Blackmore explains the life review as an effect analogous to the lively episodal memories generated by stimulating temporal lobes. This explanation leaves open what exactly happens in the stimulation of the temporal lobes and what episodal memories are. To say nothing about the systematic review and evaluation.

In TGD framework brain and perceptive field are four-dimensional and it is quite possible that episodal memories are multitime experiences involving input which comes from the moment of the geometric time when the recalled experience happened and happens again at the level of sensory representation but not as real life event since this would involve macroscopic volition and induce miracle life events in the geometric future. The notion of 4-D body makes this idea concrete. In the physical death 4-D body becomes in some sense mature (about possible de-construction processes in shorter time scales). The volitional contribution essential for the illusion that world is 3-dimensional is not anymore present and entire 4-D body is experienced as a whole. Perhaps this is just what life review is.

Since geometric memories are in question, the review is only a narrative since our geometric past changes all the subjective time and the review is about geometric past subjectively now. Life review would be a temporal counterpart of the OBE experience in the sense that one sees one's geometric life history from outside in a 4-dimensional sense. This is possible since p-adic cognitive representations are four-dimensional and four-dimensional bird's eye of view could begin to dominate at the moment of death.

Also genuine subjective memories about time interval equal to the wake-up period of self and of order lifetime could be in question. This requires the occurrence of what might be called a p-adic phase transition to higher level self with much longer subjective memory: this view is in accordance with the vision about the physical death as a birth to a life in 'other world'. p-Adic phase transition could mean that the p-adic magnetic mirrors after the geometric time after physical death correspond to higher value of p and quite concretely, have lengths which are longer than during the physical life. This makes possible both geometric and subjective memories in much longer time scale.

7. Positive emotions

With the motivation coming from the OBEs associated with the temporal-lobe epilepsy, it has been suggested that brain-stress near NDE episode leads to the release of neuropeptides and neurotransmitters (in particular endogenous endorphins) which are responsible for positive emotional states like joy, peace, and love. Again the question concerns about the deeper mechanism. Presumably these neurochemicals are only correlates for the experiences in which extra-sensory component of the experience begins to dominate. It has been also suggested that the lack of oxygen is what gives rise to the NDE experiences [32]. The observations of the Southampton team seem to exclude these explanations. Of course, one could claim that some core parts of brain are working even when the patient is clinically dead (no respiration, no heart beat, dilated pupils) and that these functioning parts of

brain are able to generate NDE. If so, spiritual experiences would represent the lowest possible levels of consciousness, and even reptiles would have them: perhaps a vulgar skeptic could applaude here but I do not find this idea very convincing.

In TGD framework clinical death naturally implies that extrasensory component of the conscious experience begins to dominate. This picture is consistent with the view about brain as p-adic–real transformer rather than the seat of the entire conscious experience. The dominance of the positive emotions would simply mean that the negative emotions coming from sensory input would be absent.

8. Other worlds

The experiencing of 'other worlds' requires a considerable amount of hand weaving in the standard neuroscience framework. Blackmore claims that imagined worlds are experienced as real because these experiences are the most stable. I believe that Blackmore is right in the sense that mental images (subselves) correspond to self-organization patterns which are stable asymptotic states of self-organization. I do not however believe that this is an essential point, and certainly Blackmore's explanation fails if the interpretation of the Southampton team about NDEs is correct.

In TGD framework the other worlds might correspond to the emergence of magnetic mirror structures which correspond to higher value of p-adic prime than during the physical life. They would have much longer lengths and give rise to much longer subjective and geometric memories. Note that the MEs associated with magnetic mirrors are classical representation for light (which brings in mind Tibetan book of death!) so that one could say that the deceased becomes a light being in a well-defined sense. The meeting of the light being might mean an ability to communicate with and sensorily experience the presence of other light beings, natural if the deceased herself has transformed to a light being (but having still 4-D body in the geometric past, this is perhaps why angels have human body!).

Note also that the absence of sensory and corresponding cognitive mental images during NDE is analogous to the empty mind free of mental images which is the goal of the meditation practices. Perhaps soul could be identified as a self having no subselves, 'irreducible self' as suggested in[H3].

9. After effects

The after effects induced by the spatio-temporally extended consciousness in which one sees one's own life from outside are often dramatic. It is difficult to reduce these after effects to brain pharmacology.

My own great experience had many aspects common to NDEs and induced profound (not at all pleasant!) changes in my own life. In my case the direct experience of the higher levels of reality made possible the realization how magnificent the almost-boring everyday reality really is when seen through sharpened senses, how pathetically narrow the zone of wake-up consciousness is, and how ridiculously little the celebrated big science tells about reality. This realization resulted in a strong conviction that I am on a right track, and has given the courage to work these fifteen years as a ridiculed scientific dissident in a country in which vulgar skepticism is in the role of a scientific state religion and vulgar skeptics have taken the role of the mind police of science.

12.4.4 Are communications between living and deceased possible?

The vision about psychological time suggests that the life after the physical death could be purely electromagnetic so that the memes and memeplexes represented by p-adic cognitive space-time sheets (magnetic mirrors say) associated with the organism continue to transform to their real counterparts after the physical death. Since these magnetic mirrors can connect the 4-D body of the deceased to living physical bodies, communications between deceased and living become possible and the mechanism of communications is same as the mechanism of long term memories. It is also possible that the transformation of the magnetic mirror structures to real form induce generation of biological organisms around them and this would give rise to re-incarnation.

In the language used in the spiritistic circles, 4-D bodies of the deceased together with the magnetic mirror structure associated with them also after the physical death would correspond to 'discarnate' or 'ethereal' entities belonging to the 'etheric level'. Perhaps the proper interpretation for p-adic space-time sheets representing thoughts and intentions is as not-yet-born entities.

Since the p-adic copies of all real physical systems are possible, even the most far-fetched claims of psychics about materialization and communication phenomena could in principle make sense. It how-

ever seems that what is materialized by p-adic-to-real transition is the plan for organism represented by magnetic flux tube structures.

Mediums and materializations

In spiritualistic circles mediums have been traditionally seen to mediate communications between deceased and alive. This includes also claimed materializations of physical objects besides the bodies of the deceased. Often direct voices emerging from empty space are claimed to been heard during the sittings: trumpets and accordions flow in the air and produce music. Analogous direct voice phenomena are associated with the claimed poltergeist phenomena. The explanation goes that medium is able to somehow to draw 'ectoplasm' from her (quite often her) own body and from the bodies of the participants which then materializes as the bodies of deceased and as material objects.

For a physicist this explanation is empty as long as a physical and mathematical definition of the ectoplasm is lacking. In TGD frame work mediums could be seen as persons able to act as relay stations communicating with both deceased and with the participants of the sitting via magnetic mirror bridges. Perhaps these bridge already exist or in p-adic form or are generated during sitting (recall the inherent non-determinism of p-adic physics) and medium helps to transform them to real form so that communications along these bridges become possible.

The transformation of the p-adic space-time sheets to real ones is of course the natural candidate for the materialization process. Accordingly, ectoplasm could be identifed as p-adic space-time sheets or their materializations. My own great experience, which involved several parapsychological elements, was a parade of deep ideas, and one of them was the notion 'flogiston' as something new for the existing physics and absolutely essential for the living matter. According to the vision, living organisms were fighting and killing to get 'flogiston', and the greatest minds had been able to get it (even steal!) more than the lesser souls. I have considered several identification of this mysterious 'flogiston' and p-adic space-time sheets are certainly the most elegant identification I have ended up hitherto.

One cannot exclude the possibility that the transformation of the p-adic plan for a material body represented by magnetic mirror structures could induce a self-organization of the ordinary matter around this template to form material objects or at least mimicries of them. This is essentially what biological growth is assumed to be. I however find it difficult to take seriously materialization of entire physical objects by p-adic-to-real transitions (the phenomenon would have enormous technological impact!). It would seem more probable to me that memes transform directly to real space-time sheets causing what are usually regarded as hallucinatory experiences, which is now however completely real communication. If this can happen, it could happen also collectively so that all participants have the same paranormal experience. This does not look strange if one accepts the possibility of magnetic sensory canvases receiving sensory input from several brains and also inducing hallucinatory perceptions.

Usually the spiritistics sittings have been held in the darkness and this allows excellent opportunities for a fraud. On the other hand, alpha band in EEG begins to dominate in darkness and might make possible the communications. There are several reasons to think that it is fast amplitude modulation of alpha frequencies producing harmonic multiples of the alpha frequency, which could be the communication mechanism between our level and higher levels of self hierarchy. The so called mesoscopic features appearing in EEG correlates and corresponding to 1-2 cm areas of cortex [26] could be direct physical correlates for these communications [M5]. The model of bicameral mind based on the notion of semitrance relies on the same idea [N5]. Note that the minimization of the sensory input (sittings are arranged in dark room) might be just what is needed for the extrasensory input to dominate.

EMDR method as a mechanism to communicate with deceased

Near-death experiences are not the only manner to get convinced about life after death. So called eye-movement desensitization and reprocessing (EMDR) discovered by Francine Shapiro [60, 21] induces what could be interpreted as after-death communications. The experiences of subject persons can be induced by this therapy in highly reliable manner: according to [21] 98 per cent of patients willing to participate the therapy had after death communication experience It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades

in past. The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular thythmic fashion while at the same time attending to a particular aspect of the traumatic memory. How EMRD works is poorly understood as yet: possibly the fact that the shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams.

A possible explanation is that EMDR experiences could involve communication with the 4-D bodies of the deceased ones located possibly in the geometric recent or past via the magnetic mirrors associated with them. One might think that rapid thythmic eye movements induce fast modulations of some alpha frequency and generate the above mentioned features which somehow help to get a contact with deceased, perhaps rhythmic eye movements somehow induce the p-adic-to-real transition of the p-adic magnetic mirror bridges. Essentially the same mechanism as involved with long term episodal memories would be in question: the only difference would be that the magnetic mirrors now mediate information not from own 4-D body from the 4-D body of the deceased.

12.5 TGD based model for instrumental transcommunications

12.5.1 Introduction

The so called instrumental transcommunications (ITC) and electronic voice phenomena (EVP) [58, 43] belong to the borderline of even paranormal phenomena, and skeptically oriented scientists probably find it rather difficult to take the claimed phenomena seriously. Personally I do not have any strong opinions and I am just interested in finding whether TGD view about paranormal phenomena might allow the claimed phenomena. Quite generally, ITC can be defined as messages communicated by some conscious entities other than humans using various kinds of electronic instruments. Electronic voices (EVP) are only a special case of the claimed communications and can be realized as signals appearing in a magnetic tape, as voices heard directly from radio receivers, or even phone calls from dead. Also images appearing in a computer screen are reported. The article of Ralf Determayer in the ITC journal [43], whose chief editor Anabela Cardoso is also ITC experimenter, helps to get an overview about the ITC phenomena.

Friedrich Jurgenson is usually mentioned as the pioneer or EVP. In 1959 Jurgenson recorded bird song in the morning to a tape recorder and to his surprise found that the tape contained also something else. He started a systematic research of the voices which he interpreted as messages from deceased. This work materialized in two books, "Voices from Space" and "Radio-link with the Dead". Kostantin Raudive, professor of philosophy and psychology and a student of Carl Jung met Jurgenson in 1965, got interested in the phenomenon, and started an intensive recording and study. He published his results in book "Breakthrough" [58]. As a matter fact, Jurgenson and Raudive had predecessors, Raymond Bayless, Attila Szalay published 1959 an article about the phenomenon in Journal of the American Society of Psychical Research, few months before Jurgensen made is discovery. Later begun experimenting also with other forms of EVP and ITC [43]. EVP involves recorded phone calls from deceased, direct radio voices, voices both heard by experimenter and tape recorded, and "paranormal" voices not heard but recorded. ITC involves also also other communication modes such as receival of images via computer screen. If one takes seriously all these reports, it would seem that both analog and digital communications are involved.

EVP and ITC very briefly

My own knowledge abut EVP and ITC is very restricted. According to the articles published in ITC journal, for instance the articles [43, 56, 57] there seems to be a consensus about the following aspects of ITC.

1. The role of the experimenter is important. The ability to receive messages is learned only gradually. The receiving system which works for one experimenter does not work for another. For instance, if two radios are used simultaneously they usually work at different frequencies. This all suggests that experimenter serves as a kind of medium, relay station, or "radio link".

2. The naive idea about spirits serving as radio stations is not probably correct [56, 57]. The voices from radio receivers tend to be located in silent periods containing only the background noise

and somehow the sender is able to use the energy of the noise to generate the message. This suggests that stochastic resonance in which a weak signal is amplified using noise to provide the energy might be involved. The transformation of noise to voice raises the question about the possible breaking of the second law of thermodynamics, and TGD indeed allows breaking of second law below p-adic time scales [K6].

3. The spectral analysis of the electronic voices by Paolo Presi [57] shows that usually the voices have an acoustical structure similar to that of human voices. The temporal sequence of vowels, their duration, the duration of the pauses, and the accent of certain vowels of the voices determine a speech thythm similar to ours. The transfer of information is based exclusively on the sequence of the vowel formants and the integration, made by listener, of the missing consonants. Consonants are produced by a sudden interruption of the air flow coming from the lugns or by an obstruction of the vocal tract. The spectrograms contain no fundamental frequency [56, 57] unlike speech for which the fundamental frequency defines the pitch. In principle this does not mean a loss of information but together with the absence of the consonants would mean that the primary source of the message is probably not speech organs. This makes hoax as an explanation of the voices less plausible.

Questions

There are several questions to be answered. *1. How could one tell whether the ITC messages are real or not?*

Brain tries to generate standard percepts from sensory inputs: by looking at clouds at the sky one realizes that brain almost inevitably tends to see faces or other patterns. Therefore this question is highly non-trivial. One can try to answer the question by analyzing whether (say) the electronic voices have spectra resembling that of human voices, and carry the minimum information to be recognized as a speech. It is relatively easy to distinguish an artifact produced by an intelligent life-form (say quartz clock) from a "dead" matter (say a piece of rock). In the similar manner, the differences between the electronic voices and "dead sounds" provide a criterion for whether they are produced intentionally. The information content of the signal is an obvious criterion for this but it is far from trivial, how to define and measure the information content.

Standard real-number based statistical physics allows only the notion of entropy. Entropy is always non-negative so that the information defined as negentropy would be non-positive always: the best one can achieve would be to know nothing! TGD inspired theory of consciousness strongly encourages a number theoretic modification of the standard notion of information, which is based on Shannon's definition of entropy [H2]. The resulting p-adic entropies (one for each prime p) obey the same axioms as the Shannon's entropy but can have both positive and negative values, and depending on the sign can be interpreted as measures of either dis-information or information. These information measures might apply to the analysis of EVP messages. The conclusion of Paolo Presi [56, 57] on basis of his analysis is that the voices represent a real attempt to communicate. In the following I will assume the messages are real and look whether TGD based view about remote mental interactions allows to model the phenomenon.

2. What could we speculate about the senders of the messages?

In TGD Universe everything is conscious and consciousness can be only lost by quantum entangling. Thus everything is living, and the question is only about how effectively system can control its own state and the state of its environment and about the time scale of the control.

1. Ordinary humans could send these messages unconsciously: human brain and body act as both receiving and sending electromagnetic antennae and in view of the topological quantization of classical em field, it would not be too surprising if these electromagnetic messages could be received electronically under some conditions.

2. TGD predicts that our electromagnetic bodies will survive so that the conscious experience of a discarnate receives a contribution from the 4-dimensional body of the deceased (life review reported in near death experiences) plus a contribution from electromagnetic body still existing.

3. Also the magnetosphere is predicted to be a conscious entity containing collective multi-brained selves.

4. The model for crop formations [N2, N3] leads to rather detailed ideas about exotic life-forms residing at various boundary layers of the magnetosphere, where energy currents driving self-organization are strong. In particular, the mantle-core and core-inner core boundary layers are good candidates for the seats of lifeforms (intra-terrestrials, ITs) quantum-controlling the liquid and/or liquid-crystal phases of quartz or iron from very cold and super-conducting space-time sheets.

3. What is the communication mechanism? TGD based model of remote mental interactions is based on same mechanism as communications inside biological organisms. The mechanism involves quantum entanglement having low frequency MEs (massless extremals, "topological light rays") as a space-time correlate, and remotely induced self-organization based on high frequency MEs propagating along low frequency MEs like mass-less particles. If magnetic mirrors act as bridges between the deceased and the experimenter and between the experimenter and the electronic instrument so that the experimenter takes the role of a relay station (or medium), the phenomenon ceases to look totally implausible. Long term memory, telepathy, remote healing,..., and communications with exotic life-forms and deceased become special cases of the same general phenomenon. For instance, TGD predicts mechanisms for how body and brain seem can act as lasers in wavelength range extending from ELF range to visible and UV wavelengths. This kind of laser action could amplify the incoming signal, say microwaves at GHz region, which could the be detected in turn by the electronic instrument with which the experimenter has quantum entanglement bridges, and then transformed to sounds.

4. How the sender can handle modern information technology to generate the desired messages?

In case of a tape recorder or telephone the electric signal is only em variant of sound wave but in case of radio situation changes. The carrier frequency of the sound changes and amplitude modulation can be replaced with frequency modulation. If signal is to be transformed to visual images, a transformation to binary code is needed. The question is where this technological knowhow comes? There are two possibilities.

1. A feedback from the electronic instrument via the brain of experimenter listening say the magnetotape and thus trial-and-error learning of how to send desired messages becomes possible. The simplest feedback is based on the sharing of the mental images of the experimenter by quantum telepathy. TGD allows also history editing, which means that the message to the instrument in the geometric past is modified again and again so that a repeated listening of the message could make it more comprehensible.

2. The existing knowledge about remote mental interaction suggests that they often involve magnetospheric multi-brained selves acting as kind of relay stations. For instance, remote viewer knows only the coordinates of the target, which as such are completely meaningless numbers to her: it is enough that the person who gave the coordinates of the target to the viewer knows their meaning. If ITC occurs in this manner, the information about how to translate the message to say bit sequences in the computer memory might be available. A direct remote mental interaction with the electronic system might be involved at least in some cases and the question is how the proposed general scenario allows to realize this.

5. How the intention of the sender is realized as action?

Remote mental interactions involve also the transformation of intention to action. In TGD framework this corresponds to p-adic-to-real transformation for some space-time sheets. Natural candidates are systems for which the energy of the resulting real system is small so that external energy feed can provide it. If the primary message comes from the magnetic body of the deceased, p-adic MEs are perhaps the most natural candidates for the representations of intentions. These p-adic MEs must first be transformed to real MEs; the real MEs interact with the magnetospheric self; the real MEs originating from the magnetosphere interact with the brain and/or body of experimenter, which in turn interacts with the receiving instrument.

Detailed models for the transformation of the p-adic ME to a basic signal (represented by light or sound) or directly to an electric signal (say in magnetic tape recorder) are not possible at this stage. The mere occurrence of this transformation involves an active volition, and here the role of the experimenter who believes and wants that the transformation occurs, might be decisive. If this is the case, the phenomenon might be also regarded as a particular form of psychokinesis and disappear if the experimenter has a skeptic attitude. Also feedback via the brain of the experimenter to the sender is required and is strongest when the experimenter listens or sees whether the message is there and possibly recognizes it.

12.5.2 Universe as a conscious hologram and a general mechanism remote mental interactions

The idea about brain and perhaps all bio-matter, and even Universe, as a hologram in some sense (see for instance, the articles of Miller and Webb [50] and of Gariaev *et al* [31]) has a long history but the question in which precise physical sense this holds true has remained without a satisfactory answer. The notion of conscious hologram provided by TGD approach allows to understand bio-control and remote mental interactions as particular cases of the same basic interaction. The notion of conscious hologram leads also naturally to the notions of magnetic body and magnetospheric sensory representations.

The general model of remote mental interactions

The mechanism of remote mental interaction involves two parts. The entanglement, which made possible by low frequency ME in even astrophysical length scales, means that sender and receiver of the message become effectively a single system. This is enough to explain remote viewing as sharing of mental images implied by the fusion of mental images of viewer and target system. The active remote realization of intention requires high frequency MEs propagating like mass-less particles along the low frequency ME and inducing the leakage of the supra currents from larger to smaller space-time sheets, dissipation and possibly also amplifying laser action. This mechanism works also in ordinary bio-control: remote mental interaction is now between some biostructures such as cells or organs.

The scaling law of homeopathy, stating that high and low frequency MEs accompany each other and the frequencies are in some fixed proportions, plus p-adic length scale hypothesis make the hypothesis highly predictive. There is no need to emphasize that the reduction of both homeostasis and remote mental interaction to the same basic mechanism gives support for the reality of the remote mental interactions.

The notion of conscious hologram

The concrete Maxwellian idea about hologram plate resulting as a result of interference of the reference beam and light scattered from an object can serve only as a guiding metaphor. First of all, coherence occurs only in what are called coherence regions and the problem is that Maxwellian theory does not really provide a first principle definition for the coherence regions. In quantum theory similar problem is encountered. Secondly, in living matter it is not at all clear whether reference beam exists at all. Third, living matter is a dynamic granular structure and far from a homogeneous hologram plate. Fourth, the idea about storing memories, one of the basic motivations of the hologram paradigm, has its own problems although multi-holograms are certainly possible.

In TGD framework topological quantization provides a precise first principle description of coherence. Topological field quanta are the coherence regions of the classical field and classical decoherence means the splitting of the space-time surface to topological quanta. This process gives rise to the granular structure of matter and space-time sheets in various length scales are excellent candidates for basic units of hologrammic structures at the this level of the p-adic length scale hierarchy. At quantum level bound state quantum entanglement having join along boundaries bonds as a space-time correlate is responsible for the macroscopic and macrotemporal quantum coherence. The notion of conscious hologram combines two dual aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition

on the other hand. In nutshell, the notion of conscious hologram follows from the topological field quantization.

1. Classical fields and matter form a Feynmann diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules,...), and virtual bosons are replaced by topological light rays ("mass-less extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

2. The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to 'real photons' are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by 'virtual photon' MEs also analogous to laser beams. Hence also 'self-holograms' with no laser beam from external world are possible (brain without sensory input). The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as mass-less particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length.

3. The particle like high frequency MEs induce 'bridges' between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competition.

4. Also the notion of laser action finds its place: many-sheeted space-time provides natural mechanism of laser interaction: when the system is irradiated with coherent light with a frequency which corresponds to the energy difference for the ions at the space-sheets corresponding to different p-adic primes, induced dropping of the ions to a larger space-time sheet occurs and implies a stimulated emission. Thus the light beam can be amplified.

5. At the level of conscious experience the fusion of subselves gives rise to a fusion of mental images. In case of right and left visual fields this fusion gives rise to stereovision analogous to what results in hologram. In the general case kind of stereo consciousness results if the mental images are sufficiently similar.

Magnetic sensory canvas hypothesis

The magnetic sensory canvas hypothesis is perhaps the most radical hypothesis of TGD inspired theory of consciousness. It states that sensory representations are realized outside brain at magnetic flux tube structures associated with brain and have sizes measured perhaps in the size scale of Earth. The realization is based on the same mechanism as remote mental interactions: the simple feeling of existence mental images fuses with the more complex mental images produced in brain.

Possible extra-sensory perceptions induced by atmospheric phenomena might provide support for this hypothesis. Auroras are known to induce sounds not detected by electronic means: could these be extrasensory perceptions induces by auroras on sensory canvas. Also meteors could induce sounds [16]. If one takes very seriously the model for sensory representations, one can imagine that the meteors could kick electromagnetically the magnetic flux tube-ME pairs of sensory canvas and force them to resonantly oscillate at harmonics of the thalamocortical resonance frequencies in interval 37-44 Hz.

These magnetic mirrors might also mediate the electric perturbations to Earth in a channelled manner so that no attenuation would be involved. The mirrors could mediate un-attenuated or even amplified ELF waves also also to electronic instruments. And what is of special interest now, if electronic instruments couple to the magnetic sensory canvas, machine-man interactions would

become possible. The test is to look whether meteors induce sounds heard without time lag due to finite propagation velocity of sound and whether also electronic instruments detect these sounds.

Amazingly, there is evidence just for this kind of strange effects. For centuries it is known that meteors can generate audible 'pop' like sound. Sound is heard instantaneously so that either we hear it as ESP through magnetic sensory canvas or ELF em waves are transformed to sounds at Earth and heard after that. Quite recently also electronic instruments have detected these sound [16]. Amazingly, the frequencies were 37-44 Hz range contrary to the expectation that they would be in the range 20-20.000 Hz and have much weaker intensity. The generation of sounds with the observed intensity is theoretically possible only if the electric perturbations from ionosphere have propagated to Earth as essentially unattenuated (along magnetic mirrors) or being even selectively amplified (magnetic mirrors as wave cavities).

Thus there is some support, not only for the sensory canvas hypothesis, but also for the machine-mind interactions at thalamocortical resonance frequencies. One could also look whether there are correlations between human EEG and electromagnetic perturbations of electromagnetic instruments in thalamocortical frequency range (and perhaps also at the higher harmonics of it). This interaction might be of fundamental technological important since it might make possible to control electronic instruments directly by thought.

12.5.3 Who are the senders?

In TGD Universe everything is conscious and consciousness can be only lost. Therefore it is possible to imagine several kinds of senders.

Deceased and/or living humans?

In some messages the senders tell that they are deceased. There are two possibilities: either the senders live in the geometric now in some other than the usual physical form or they live in the geometric past where their physical body still exists. Both options seem to be possible.

1. The conservation of magnetic flux suggests that the magnetic flux tube structure associated with the electromagnetic body survives the physical death so that both the 4-dimensional physical body of the deceased in the geometric past and also electromagnetic body in geometric present would exist. If the p-adic MES associated with the electromagnetic body continue to transform from p-adic to real form, electromagnetic bridges between the 4-D body of the deceased and physically living creatures or electronic instruments could make possible ITC.

2. Also the entanglement with and signals from the geometric past from the physical bodies of the deceased must be considered (say the communications by Kostantin Raudive). TGD based model of long term memories (all memories, even water memory) is based on the mirror idea: when I remember I look at me at a magnetic mirror located at a huge distance of light years. Therefore I see the me of the geometric past in the mirror [H6]. Magnetic mirrors can however connect me to some other person and this means communications with the persons having 4-D body in the geometric past, receiving their memories. This communication is more probable between persons have had (and still have) a close relationship generating the required magnetic mirror bonds.

3. Also the brains and bodies of living could act as sending antennae and generate unconsiously ITC messages. Thus one cannot expect that all messages would have a deep spiritual tone.

Magnetospheric selves?

The model for the sensory representations realized at magnetic bodies of astrophysical size inspires the hypothesis that also the magnetosphere of Earth acts as sensory magnetic canvas and is a living, conscious system. Magnetosphere could be a seat for multi-brained conscious entities receiving information from human and other brains and bodies serving as neurons of these life-forms. Various EEG frequencies correlate for various parts of the magnetosphere by resonance conditions. Especially interesting seats for em life-forms are various boundary layers of the magnetosphere, such as the plasma sheet at the night side magnetosphere and magnetopause serving also as a kind of magneto-immune system.

Remote mental interactions such as remote viewing involve aspects which suggests that they proceed via the mediary of multi-brained selves providing information necessary for the localization of the target not possessed by the remote viewer herself. Also ITC might involve these collective levels of consciousness. Empirical support for the notion of multi-brained collective levels of consciousness comes from the experiments of Mark Germine [46].

An operator and a subject person were involved. The stimulation of the subject person consisted of a sequence of identical sounds containing now and then an odd-ball stimulus (now silence). The odd-ball stimulus generated an event related potential (ERP) visible in EEG and reflecting the conscious reaction. The operator was in a second room and by simple toss of coin decided whether to observe the stimuli in the computer monitor or not. The stimuli appeard in the computer monitor one second before they were heard by the subject person. What was found that when the operator saw the odd ball stimulus from the computer monitor, the ERP was weaker on the average. An 11 Hz periodicity was the major component in the difference profiles. The simplest explanation is that the brains of both the operator and of the subject person belong to a larger multi-brained self and that the evoked response represented partially the reaction of this self. When this multi-brained self had already seen the stimulus through the operator's eyes, it was not so surprised to hear this stimulus again through the ears of the subject person, and ERP was weaker. The appearance of the 11 Hz periodicity suggests that this frequency is an important correlate for the entanglement of the subject person's mental images with those of the multi-brained magnetospheric self.

ETs and/or ITs?

The interior of Earth contains almost empty and cold space-time sheets and the magnetic flux tube structure in the core of Earth serves as a kind of thalamus like relay station. The cavity resonance frequencies associated with core and inner core are in the range 14-15 Hz and 40-50 Hz and correspond to two important frequencies of EEG. Thus also the interior of Earth might be important for consciousness.

The general TGD based view about life implies that various boundary layers containing strong energy currents driving self-organization are optimal for the emergence of life. The mantle-core and core-inner core boundary layers containing possibly liquid-crystal phases of quartz (glass) and iron, are especially interesting seats for life-forms controlling the hot liquid-crystal phase from larger space-time sheets which are very cold and super-conducting. A support for these speculations comes from the strange findings associated with crop circles. In particular, Chilbolton and Crabwood crop formations [73, 74] can be interpreted as messages providing information about these life forms: even the genetic codes of these life-forms can be deduced and a general model for our genetic code emerges as a by-product [N2, N3]. One cannot exclude a quantum symbiosis between us and these life-forms based on a telepathic sharing of mental images, and this kind of symbiosis conforms with shamanistic and religious mythologies and the Freudian super-ego-ego-id trinity. Therefore one must consider the possibility that the senders of ITCs are ITs (intraterrestrials). Of course, quantum entanglement mechanism allows also ETs as the senders of the messages.

12.5.4 Knowhow problem

How it is possible to code the information sent by the discarnate entity to say computer picture. It is difficult to imagine that the sender would be able to same as a group of IT specialists and computer engineers. There are two manners to overcome this problem.

Higher level multibrained selves acting as relay stations

Higher level multi-brained magnetospheric selves could act as relay stations entangling the sender of the message with the experimenter in turn entangled with the electronic instrument. The knowhow about how to encode the primary signal to various forms such as AM or FM modulated radiowave or even signal represented as a binary code could be possessed by some brains of this higher level self.

Feedback and history editing

The proposed model is consistent with the fact that EVP and ITC skills develop only gradually and require patience and that some persons are more gifted than others. The generation of the magnetic

mirror bridges between senders and experimenter and experimenter and electronic instrument require time. Also the sender must learn by feedback how to code desired messages to the electronic instrument. The simplest form of feedback is a sharing of the mental images generated by say the listening of the magnetic tape in the experimenter's brain.

History editing provides quite a science fictive sounding manner to make corrections to the message. Each quantum history changes the geometric past so that history editing becomes possible in principle. There is an experiment in which a chicken confined to move in small area became imprinted to a robot [55]. The motion of the robot was coded to a random number sequence half year before. After the imprinting the motion the robot tended to stay near the chicken which suggests that the bleak chicken was able to alter the random number sequence and thus edit history in a time scale of half year. Our long term memories are unstable and can be altered by suggestions. In TGD framework also this can be regarded as history editing applied to the sensory representations of the brain of the geometric past.

During the listening period the sender of the message could receive the information about the conscious experience of the experimenter by the sharing of the mental images induced by the message. The sender could make a quantum jump to a new history which would imply a modification the message to the electronic instrument located in the geometric past (the geometric past changes in each quantum jump in TGD framework), the experimenter would perceive the improved message, and so on. This iterative loop would lead finally to a message which generates the experience of recognition of message in the receiver. During repeated sessions sender would learn the code and would be able to send messages more easily.

12.5.5 Experimenter as a medium and amplifier of the signal

Experimenter could act as receiver of the ITC signal, amplify it, and send it further to the receiving instrument. Experimenter might also make possible feedback from the instrument to the sender. Both various experimental findings and TGD based view about bio-systems lend support for this hypothesis.

Magnetic mirror as electromagnetic bridge

The experimenter in ITC seems to play a role similar to that of the medium in spiritistic sittings. The idea about experimenter as a relay station between electronic instrument, making possible both the sending of the classical message to the instrument, and receiving the conscious response of the receiver during the reading/listening session, might indeed help to understand ITC at general level.

Magnetic mirrors are by definition magnetic flux tubes accompanied by MEs parallel to them. The Alfwen waves, which represent oscillations of magnetic flux tube analogous to those of violin string, resonate with the classical em wave propagating along ME and amplify the signal. To be precise, one should speak about a mirror pair: the mirrors are the points of magnetic flux tube where ME is attached to the flux tube. The existence of magnetic mirror bridges between experimenter and electronic instrument would not be surprising. MEs and magnetic flux tubes represent topological field quanta of electromagnetic field and it would be more surprising if they would not interact with electronic instruments since these instruments interact already in Maxwell theory with external electromagnetic fields. What is new is that MEs make possible channelled transfer of energy and information: in Maxwell's theory signals would be transmitted to all directions as 'mass communications' and distance would be the limiting factor unlike in case of MEs. The presence of kind of interaction would suggest that humans and electronic instruments are already now in an intense interaction and that the electronic revolution is more like a symbiotic process in which both machines and men are active participants.

The generation of electronic (and also acoustic) signal requires energy. Magnetic mirror quantum entangles the discarnate, experimenter, and the electronic instrument. Only bound state entanglement is preserved in quantum jump and thus binding energy is liberated when bound state entanglement is generated. This energy is usable energy and could provide the energy needed to generate the signal. If stochastic resonance is involved, the noise acts as an amplifier of the signal. In the case of an acoustic signal the body of the experimenter could generate the sound and energy could come from metabolism.

Body and brain as antennae

TGD based view about living systems indeed predicts that brain and body act as receiving and sending quantum antennae in a very wide range of frequencies. For instance, EEG can be regarded as radiation emitted by brain acting as an antenna. TGD predicts that EEG MEs are accompanied by high frequency MEs, most probably at microwave frequencies and induces self-organization at magnetic body and thus give rise to sensory representations. For instance, microwave hearing [24] lends support for the hypothesis that brain is a receiving microwave antenna. The microwave frequency spectrum relevant for microwave audition is in the range $.2-3$ GHz. A receiving antenna can also act as sending antenna and it is known that at the sunset a microwave static of unknown but presumably biological origin emerges and correlates strongly with the so called taos hum [26]. Taos hum is a humming sound heard during night time, which can become intolerable and has no identified origin. The most plausible explanation of taos hum is as a special case of the microwave hearing.

Are alpha waves in special role?

The general communication mechanism between the sender and experimenter could be based on fast amplitude modulation of alpha waves involving higher harmonics of ~ 10 Hz wave (this is like adding small riples in long wavelength water wave). This mechanism could in fact be equivalent with the propagation of higher frequency MEs inside 10 Hz ME serving as the quantum entangler. Schumann resonance frequencies correspond to cavity resonances in size scale of Earth and thus might mediate telepathic communications between different selves. The lowest Schumann frequency of about 7.8 Hz is especially interesting in this respect.

Our speech uses the same mechanism (10 Hz frequency is the basic vibration frequency of speech organs, which is not the fundamental frequency which is above 20 Hz) and so called features [26] identified recently in EEG patterns can be also regarded as a fast amplitude modulation of the alpha wave (low amplitude higher harmonics of the alpha wave appear as ripples of the alpha wave). The structure of the mesoscopic features of EEG [26] suggests that the harmonics up to the 8:th harmonic of alpha wave are present. This amplitude could modulate a carrier wave which should have frequency above 80 Hz: the presence of the carrier wave is however not absolutely necessary (the fundamental frequency defining the pitch of the voice and produced by speech organs indeed tends to be absent in EVP [57]). Interestingly enough, the frequency interval for so called taos hum is in in the interval 40-80 Hz [M5].

These features could communicate information to higher level multibrained selves. It has been found, that healer's alpha wave activity intensifies during healing process and magnetic emissions in ELF range have been observed. Also correlations and synchronization between alpha wave activities of Qigong masters and healees has been reported [63]. If the brain of the experimenter serves as a relay station, the deceased (identifiable as the electrommagnetic body remaining after the physical death or as the physical body in the geometric past) could use the same code as it has used while controlling its own material body from magnetic sensory canvas during life time to both send and receive mental images. If magnetic sensory canvas is able to produce visual hallucinations and dreams it might be also able to produce visual images by sending similar commands to the brain of the experimenter serving as a relay station and preserving the topological structure of images.

Could the body and brain act as lasers?

According to the experimental findings of Peter Gariaev and his group, the irradiation of DNA by visible laser light induces radiowave emission at frequencies ranging from ELF frequencies to MHz range [31]. The TGD based model of the phenomenon relies on the hypothesis brain and body could act as a laser in a wide range of frequencies extending from EEG frequencies up to UV. The idea is simple: when an ion drops from a smaller to a larger space-time sheet it liberates the difference for the energies of the initial and final state. For free ions this energy is in the simplest situation essentially the difference of zero point kinetic energies. For magnetic flux tubes it is the difference of magnetic energies, which is very small and can correspond to even ELF frequencies. This leads to a many-sheeted laser mechanism: if the system is irradiated with a radiation, whose frequency is same as for the radiation liberated in the dropping, stimulated emission occurs and incoming coherent radiation can be amplified. The difference with respect to the ordinary laser is that the ions does not drop from a higher to a lower energy state of an atom but from a smaller to a larger space-time

sheet. The many-sheeted laser could make possible for a body and/or brains to amplify the incoming ITC signal represented by high frequency MEs propagating along low frequency MEs generating the entanglement.

Stochastic resonance

An important question is how the message is amplified and filtered from the background noise possibly present. A possible answer to this question is stochastic resonance. Stochastic resonance could occur in the receiving instrument and/or in the brain of the receiver. ITC, in particular EVP research indeed supports the view that certain background noise is necessary for receiving messages. On basis of this observation it has been proposed that stochastic resonance (the article [17] is an excellent review about the principles and applications of the stochastic resonance) is the mechanism of EVP.

Stochastic resonance requires a bistable system (for instance, double potential well) or an excitable system having metastable states. An essentially non-linear phenomenon is in question. Signal is in a role of the harmonic external force: the output of the bistable system is interpreted as a transformed signal. If one takes seriously the claim about the positive effects of the white noise on tape recordings, bistable system must reside either in the electronic system transforming sound signal to an electric signal or in the brain of the experimenter serving as a relay station between the sender and electronic instrument in the proposed model.

TGD Universe is quantum spin glass which means that any system should be characterized by fractal spin glass energy landscape containing valleys (energy minima) inside valleys inside... This of course means that there is plenty of bistable systems. TGD also predicts new kinds of dynamical degrees of freedom not predicted by standard physics, so called zero modes, which typically characterize the shape and size of 3-surface and also so called Kähler field (essentially Maxwell type field) of space-time surface. These new degrees of freedom could provide the required new degrees of freedom possibly making also the relevant parts of electronic instruments bistable systems.

1. Does the brain of the receiver contain the bistable systems?

Skeptic would argue that the noise used to promote the receival of the messages is what cheats the brain of the poor pseudoscientist to recognize a feature which is not actually present in the incoming signal. The skeptic might be quite right although after listening the some of recordings I have a tendency to believe that there are actual messages there. One could however turn around the argument of skeptic. Perhaps it is indeed the brain of the experimenter where the bistable system resides and amplifies the very weak signal from the sender and sends it to the electronic instrument in electronic form. Stochastic resonance in experimenter's brain would be involved also with the receival of the feedback signals from the instrument by the sender of the message. This model has several satisfactory features.

i) The model is consistent with the latest facts about brain science [17, 25]. The model is also universal in the sense that if does not require discarnate entities to be ingenious electric engineers: they can learn by trial and error how to generate desired messages by affecting the electronic instrument.

ii) The model would explain why some experimenters are better than the others in receiving messages. They are like crickets able to distinguish very weak input from the high noise. If feedback from experimenter's brain to the sender is involved this in turn helps the sender to learn to generate desired messages. The model is also consistent with the fact that the highly tuned system which works perfectly for a particular experimenter, does not work for the other experimenters. Note that the magnetic mirror bridges between experimenter and electronic instrument are essential part of the system.

The hypothesis could be tested by purposefully building EVP and ITC instruments for which the background noise can be varied.

2. Do electronic systems contain bistable systems?

The hypothesis that the electronic system contains the bistable system is subject to so strong additional constraints that it does not look too plausible in standard physics framework. If the leakage of ionic currents from the magnetic flux tubes to the wires of the electronic induced by MEs gives rise to the electronic signal, stochastic resonance is perhaps not needed since the background noise is very weak. It must be however emphasized that many-many-sheeted space-time plus spin glass degeneracy might provide new physics mechanisms of transforming the ITC signal to electronic

signal.

The very fact that the electronic information transfer systems should not induce large distortions of the signal, requires that the system is effectively linear. Bistable systems are highly non-linear systems unless the signal fed into the system represents sufficiently strong external force in which case system is analogous to a one-dimensional particle in an external harmonic force: archetypal model is the potential well $V(x) = -x^2 + x^4$. In case of magnetic tape the direction of magnetization would naturally represent the two potential wells and hopping of the particle between wells would correspond to the changing direction of magnetization. Thus, if bistable systems are involved, ordinary signals must represent strong external forces for which the system is effectively linear and non-linearity can be important only for very weak signals. In case of EVP this requires that possible messages should be contained by the portions of the magnetic tape, where ordinary signal is reduced to mere noise and the noise is sufficiently weak. Already this requirement might kill the hypothesis.

To test this option, one should find whether the electronic system transforming the sound to electric current contains portions modellable as bistable systems fed by an external signal for sufficiently weak input signals. If this is the case, then model could be tested by varying the intensity of the external noise to see whether this has any effect on the probability of receiving the messages.

12.5.6 How the signal is transformed to a signal in electronic instrument

One should also understand how the transformation of the ITC signal to the signal appearing in electronic instrument such as tape recorder, telephone, or radio receiver occurs.

Direct radio signal

The simplest situation is direct radio signal. It is known that the voices tend to appear in the silent portions of radio signal containing only noise. This is of course natural since in this manner the masking of the signal can be avoided and might allow also stochastic resonance. If the sender or magnetospheric multi-brained conscious entity has managed to code the signal to AM or FM radiowave, and if the brain or body of the experimenter has managed to amplify it and redirect it to the instrument, then the transformation to an audible signal is not a problem.

"Paranormal" signal to a magnetic tape

The first possibility is that primary messages appear as ME having a Fourier decomposition resembling sufficiently that of the sound wave, and giving rise to the required vibrations of atoms. MEs are the basic candidates for the carriers of these waves and the Fourier spectrum of the voice with respect to frequency could be coded into the Fourier spectrum of em or Z^0 fields associated with ME. Hence ELF frequency range would be in question. Phase information is crucial: anyone can easily verify that a reversed speech usually consists of a gibberish despite the fact that the Fourier spectra are same for speech and reverse speech. This suggests an amplitude modulation of the carrier wave or fast amplitude modulation producing ripples to the carrier wave as a candidate for the representation of the information contained by ME.

The sound frequency range involved with the sounds heard by humans is in the interval $20 - 20.000$ Hz meaning the lengths of ME would vary between Earth radius and 10 kilometers. This spectrum is also claimed to be important for water memory and the mechanism of homeopathy [28].

A concrete model for the process might look like following.

1. The signal is first transformed to an electric current, which subsequently induces a shortlasting magnetization of a soft electromagnet which in turn induces a permanent local magnetization of hard ferromagnet (magnetic tape). The strength and sign of the local magnetization depends on the strength of the current which in turn codes the strength of the sound signal. A similar transformation to an electric current occurs also for the signal in case of visual ITC.

2. A concrete manner to generate the electric current inducing the magnetization would be by inducing a leakage of a supra current from magnetic flux tubes to the atomic space-time sheets of the current wire responsible for the magnetization of the soft electro-magnet. This leakage could be induced by microwaves by a mechanism discussed in [K5]. The modulation of the microwave by sound wave would imply the modulation of the current automatically. An analogous mechanism could be at work for the radio receiver.

Transformation of em signal to sound signal before entering the tape recorder

Classical EVP suggests that the basic signal enters to the magnetic tape as an electric signal. On the other hand, the experimental results reported by Alec MacRae [49] are consistent with the assumption that real sounds generate the signal and that electromagnetic signal does not generate a signal in the microphone. The latter conclusion comes from the observation that Faraday cage around microphone does not affect the communication. In TGD framework this conclusion cannot be made since Faraday cage is not expected to affect MEs. The acoustic insulation of another microphone however weakens the voice so that it seems that a genuine acoustic signalling is in question. This does not of course imply that the generation of real sounds is the only mechanism: in the presence of feedback the best communication mode available could be used.

TGD based model for the real sounds generated by meteors heard both directly and recorded by microphones is based on electromagnetic signals coming along magnetic mirrors associated with the sensory magnetic canvas and acting as wave guides and transformed to ordinary sounds via the coupling with objects at the surface of Earth. Whatever the details of em signal-sound transformation are, it certainly exists, and could be involved also now: the electromagnetic signal could come either from the magnetic sensory canvas of the experimenter, of the sender, or from the magnetosphere containing the multi-brained self serving as a relay station. Higher harmonics of the frequencies 37-43 Hz appearing in case of meteors [16] would be however required to generate the voices or shorter magnetic mirrors should be involved.

One can imagine several mechanisms for the transformation of the primary signal to sounds.

1. The mechanism transforming electromagnetic signal to sound wave could rely on piezo-electricity and frequency resonance. Quartz crystals are excellent piezo-electrets and used in radio receivers and senders. Also body acts as a piezo-electret and the body of the experimenter could transform the signal to sound. Human body could act also as a Z^0-piezo-electric transforming the Z^0 signal to an ordinary sound. The so called oto-acoustic sounds (audible sounds emanating from ears) could result in the same manner. Also material objects of the acoustic environment could serve the same purpose.

2. The phenomenon of microwave hearing suggests that brain and/or body could also transform microwave signals propagating along ELF ME to ordinary sounds.

12.5.7 Tests for the model of ITC

Most tests of the ITC reduce to tests for the general mechanism of remote mental interactions, which should be also at work in length scales below body size (bio-telepathy) and for sensory representations realized at the magnetic body. This is good news in the sense that good models usually explain many apparently unrelated phenomena and bad news in the sense that predictions are not ITC specific.

1. Tests for the motion of electromagnetic bridges.

1. Since the development of the magnetic mirror bridges between experimenter and electronic instrument takes time, the replacement of the magnetic tape in EVP with identical one, might make the performance poorer.

2. One could test the importance of the magnetic flux tubes by varying the strength of the local magnetic field (note that magnetic tape has a natural coupling to the magnetic flux tube structures of Earth's magnetic field) to see whether Earth's magnetic field plays a role in the effect. One could test whether the appearance of ITC messages and perturbations of magnetic field appearing at Schumann frequencies correlate. The correlations of paranormal phenomena with sunspot activity are well-known and could be tested in case of ITC.

3. Maxwell's electrodynamics, which is not equivalent with TGD, would suggest that MEs cannot penetrate Faraday's cage so that ITC would not be possible inside Faraday cage. In many-sheeted space-time this argument is lost because MEs by definition are em bridges outside the atomic space-time sheets where the Faraday cage acts. If MEs cannot penetrate Faraday cage, the TGD based model for sensory representations would fall down since it would predict that person in ideal Faraday cage could not have sensory experiences! Be as it may, one can test this aspect by putting the experimenter and/or the instrument in Faraday cage.

4. One should also test directly whether body and brain act as laser like amplifiers of em radiation at, say, audible frequencies. The work of Gariaev [31] shows that irradiation of DNA with visible light produces radiowaves also at audible frequencies. The work of Blacman and others [44] shows that the irradiation with ELF waves at EEG frequency range induces biological effects.

2. Tests for the ionic leakage mechanism. For instance, the appearance of ions not originally in the system by the leakage of the supra currents and the dissipative effects caused by the leakage would be a good signature for the effect. These tests are discussed in [K5]. In the recent case one such system would the current wire inducing the magnetization of the magnetic tape.

3. Tests for the ideas about the communication method.

1. In remote healing the changes of alpha waves in EEG are reported to correlate with the intentions communicated by the healer. Alpha waves dominate when sensory input is absent, in particular the closing of eyes stimulates alpha waves. This is consistent with the fact that EVP requires silent and dark room. A possible test would be to record the EEG of the experimenter and look whether there is a clear change in the activity in alpha band both when the tape is on and when the tape is listened to and find whether there are recognizable changes of alpha activity. In particular, one could see whether alpha activity changes at the time when the message appears to the magnetic tape. The lowest Schumann frequency 7.8 Hz is especially interesting in this respect. On basis of the experiments of Mark Germine, also the 11 Hz frequency is interesting [46].
2. The sounds detected from meteors [16] are in the thalamocortical 37-44 Hz frequency band [M5] suggesting that magnetic sensory canvas mediates ELF perturbations to both brains and to electronic instruments at this frequency range. One could in principle test whether thalamocortical resonance band in the EEG of the experimenter contains something correlating with the received message.
3. Are persons able to receive the ITC messages also able to hear microwaves.
4. Are the sounds in EVP are received electronically or acoustically. Both mechanisms might be involved. Alec MacRae has demonstrated and in his experiments signal is received as a sound [49]. One could also test whether the pitch of the sound correlates with the acoustic environment (big room–small room).
5. One could test the role of the stochastic resonance by varying the level of the acoustic or radio noise. Here explicit formulas for the noise optimal for a signal of given frequency are available [17].

4. Tests for the notion of magnetospheric selves.

The notion of magnetospheric selves might be crucial for the solution of the knowhow problem and the experiments of Mark Germine [46] can be seen as a pioneer work in the testing of this hypothesis.

5. Tests for the notion of history editing. History editing is not necessary for understanding of ITC but one could test whether it is involved. Let an outsider, presumably not able to act as a relay station, listen to the magnetic tape first and document whether he/she received any message. Suppose that he/she detects no recognizable message. Next let the experimenter listen the same tape, and report what he/she found: during this session the feedback mechanism could transform the message to a recognizable form by affecting the geometric past at the moment the magnetic tape was on. Suppose that the experimenter indeed recognizes a message. Let an outsider listen the tape again to see whether there is any recognizable message now. If the proposed mechanism is correct, the outsider who did not hear any message in the first trial, should hear now a clear message. Note that one cannot replace external person with a computer since the computer records change in quantum jumps too! Note also that even the geometric memories of the external person might change if they are comparable to mechanical records: genuine subjective memories are required. Also the repeated listening of the tape by the experimenter could improve the quality of the message and the above experimental arrangement could be iterated.

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Chapter 13

TGD Based Model for OBEs

13.1 Introduction

Out-of-body experiences (OBEs) [34, 35, 32, 33] are often understood as experience of seeing oneself from a position outside of the body. According to Susan Blackmore [32], OBEs are rather common: from 5 to 35 percent of subjects reports of having had at least one OBE. According to studies persons having OBEs seem to be perfectly healthy. OBEs are poorly understood in the framework of neuro science and pose a challenge for the reductionistic world view.

In TGD framework the notion of magnetic body provides an attractive starting point in attempts to understand what OBEs and related experiences are. The basic idea is that magnetic body serves effectively as a mirror defining a third person view as a cognitive representation also in ordinary wake-up state and that during OBEs this representation becomes sensory representation. Magnetic body need not always be a personal magnetic body but could correspond to a magnetic body receiving information from several brains (collective consciousness), magnetic body of another person, or be even associated with "dead" matter.

The progress in identifying dark matter as a phase of matter with large value of Planck constant making possible macroscopic quantum coherence has led to the vision about dark matter at magnetic flux quanta as quantum controller of ordinary matter in living systems. The Bose-Einstein condensates of dark photons decaying via decoherence to ordinary photons mediate interactions between ordinary and dark matter and the hypothesis is that dark photon "laser" beams from body and brain reflected at magnetic flux quanta give rise to third person aspect of consciousness which in OBEs and related experiences are realized as sensory representations. The identification of bio-photons as end products of the de-coherence of dark photon beams is natural.

The model leads also to a model for dreams, hallucinations, sensory feedback from brain to sensory organs, and directed attention. Concrete models for how dark photons can give rise to experiences in various sensory modalities such as vision, hearing, olfaction, and tactile senses, are proposed.

I am grateful for Tiaan Brink for sending a little summary about OBEs. This article inspired the attempt to fuse the TGD inspired ideas related to OBEs to a coherent theory.

13.2 OBEs, autoscopy, heautoscopy, and other strange experiences

13.2.1 Phenomenological characterization

The phenomenological characterization of OBEs has been discussed in [33]. A precise definition of OBE is to have sensation of being outside the body. Autoscopic experience involves a also a sensation of seeing a mirror double of the body or part of it or at least experiencing its presence. There is a form of AS in which some internal organs are perceived. In one form form of AS only the presence of double is experienced. AS experiences are often accompanied by physical difficulties such as migraine episodes and epilepsy.

Heautoscopy refers to an experience of meeting one's alter ego, doppelganger. The main differences to AS is that in AS the double is mirror image and that alter ego is experienced to have also duplicated

features of psychological self.

OBEs are classified to parasomatic and asomatic experiences according to whether the person experiences of having body or not. In aparasomatic experience a detachment from both the physical and parasomatic body is experienced. Blackmore suggest that OBE starts when sensory input from the body ceases while person remains conscious [32]. This brings in mind the notion of subtle body of spiritual practices identified as the body experienced during lucid dreaming [17]. The notions of guardian angle and ba-ka double of ancient Egypt, could relate to the double body too.

There is also a classification of OBEss to asensory, naturalistic and supernaturalistic ones. Asensory experience lacks sensory percepts about environment, naturalistic one involves perception of familiar surroundings, and supernaturalistic other-worldly realms like heaven or visits to other planets and contacts with aliens.

One can distinguish between natural and enforced OBEs. Natural OBEs are triggered by exhaustion, illness, traumatic events, NDEs, meditation, etc.. Enforced experiences can result from intoxication, anesthesia, hypnosis, etc..

13.2.2 OBEs induced by electric stimulation

Relatively recently OBEs and AS experiences have been produced by an electric stimulation of the angular gyrus [36]. Angular gurus is located in the parietal lobe, near the superior edge of the temporal lobe, and is involved in processes related to verbal communication and cognition and also with the transformation of written language to internal monologue. The experience developed to a full fledged OBE as the intensity of electric stimulation was increased. The electric stimulation induced responses in vestibular and sensory-motor systems, two of three systems which govern body balance.

According to experimenters, OBE and AS frequently involves what they call pathological sensations of position, movement and perceived completeness of one's own body. These include vestibular sensations such as floating, flying, elevation and rotation, visual body-part illusions (illusory shortening, transformation or movement of an extremity) and the experiences of seeing one's body only partially during OBE or AS. Authors believe that these experiments yield neurological evidence about the common neurological mechanism behind OBEs and AS experiences.

Neppe [37] has criticized the interpretation of experiments.

1. Only single subject person was studied. She suffered from temporal lobe epilepsy and the epileptic region was at distance of about 2 cm from angular gyrus. Hence one can ask whether genuine OBEs were in question and whether the results generalize to healthy persons.

2. The OBE was not typical. For instance, body was seen only partially and the conscious attempt of the subject person to examine it more closely led to its disappearance. The environment was not perceived.

3. The claimed localization of the spot inducing OBEs to angular gyrus might be an illusion. Same researchers have represented results in which the OBE is induced in a different manner. Interestingly, the experience is associated with the generation of 4 Hz theta wave, which corresponds to the dominating EEG band during sleep.

4. The reductionistic conclusion that OBEs can be reduced to neuropathology and are thus "only" hallucinations is not justified. What has been shown is that electric stimulation of angular gyrus helps to induce the OBE and this leaves a lot of room for theorizing.

13.2.3 Explanations of OBEs and related experiences

The explanations for OBEs can be divided to two classes.

1. Something is assumed to leave the body.
   This something could be something physical or non-physical ("astral"). In some cases people who have had OBE share reported of having perceived objects that were actually there and having experienced events and dialogue that truly happened. Charles Tart has documented the case of Miss Z [35] who in controlled experiments was able to deliver the randomly selected five digit number which was in a position which could be seen only from the position out of her body. Telepathy would be an alternative explanation for this.

2. Nothing leaves the body.
   Parapsychological explanations involve remote sensing and hallucinations. Psychological explanations regard OBEs as basically hallucinations. The observation that electrical stimulation generates both AS and OBE could be seen as a support for this interpretation. Of course, one can ask what hallucinations really are. Furthermore, the reports about seeing internal organs during AS experience [29] are not easily explainable as hallucinations.

TGD based model does not fit into either category. The model involves the notion of magnetic body serving as the third person receiving visual stimulus from the body and reflecting it back to the brain where its is processed. In this model the conflict between hallucinatory character of AS and OBEs and a real perception of body from outside is only apparent. The basic mechanism allows to develop also a more detailed model for dreams, hallucinations, third person aspect of wake-up consciousness, and directed attention.

13.3 TGD inspired model for OBEs and related experiences

It is good to develop the model for OBEs by first listing the basic TGD specific ingredients of the model and then proceed by making questions (I hope that reader does not feel them to be leading).

13.3.1 Basic ingredients of the TGD inspired model

The model of OBEs involves several ingredients that are specific to TGD.

1. Magnetic bodies and field bodies are excellent candidates for the "third person" seeing the ordinary body. Magnetic body could receive a visual stimulus from ordinary body and reflect it back as a visual stimulus during OBE processed by the brain of the subject person. Thus body would see itself from the perspective of the magnetic body. Also dreams and hallucinations might involve the same mechanism. In the case of hearing sounds created by subject person could be reflected back to her ears or more plausibly, microwave hearing [24] could be involved.

2. Topological light rays ("massless extremals", MEs) are an element of TGD having no counterpart in Maxwell's ED and play a key role in TGD inspired theory of consciousness. The interpretation of MEs has remained somewhat obscure. The development of TGD based model for dark matter residing at magnetic flux tubes and characterized by large value of Planck constant implying quantum coherence in even macroscopic length and time scales changed the situation in this respect. The model for dark matter as macroscopically quantum coherent phase is discussed briefly in this book in chapter [I5] and more extensively in the book "Genes, Memes, Qualia, and Semitrance" [J6]. MEs can be identified as space-time correlates of Bose-Einstein condensates ("laser beams") of dark photons. It is however still unclear whether ordinary laser beams actually correspond to dark photon Bose-Einstein condensates and become visible only in de-coherence to ordinary photons. Negative energy MEs can be identified as correlates for phase conjugate laser beams of dark photons. The so called time mirror mechanism is universal building block of basic biological and brain functions [K1].

3. Bio-systems as conscious holograms is one of the key ideas of TGD approach [K4]. Bio-holograms [22] suggest themselves as primary sensory stimuli quite generally. Biological body could generate dark photon "laser beams" received by magnetic bodies and reflected back to retina or perhaps to pineal gland [18], the "third eye". This would explain AS as well as the images of internal organs [29]. Also other systems, at least living systems, could be seen from the perspective of the magnetic body. Remote vision hypothesis testable by using living targets not visible in ordinary sense. This would give also rise to telepathy if reflection occurs from magnetic bodies of another person.

4. In TGD framework sensory organs are identified as seats of primary sensory experience and brain only constructs symbolic representations about percept, in particular identifies objects of perceptive field. This does not exclude a considerable back projection to sensory organs modifying the sensory input. Dreaming involves back projection to sensory organs inducing artificial sensory experiences as simulation. One possibility is that dreams and hallucinations

represent direct back projection to sensory organs along neural pathways. An alternative view is that the projection involves dark photon beams generated by brain and reflected back from the magnetic body. If OBEs are hallucinations, the visual sensory memories of the subject person about herself could serve as building blocks to generate simulation about what person looks like when seen from outside.

5. Sharing and fusion of mental images is one of the basic notions of TGD inspired theory of consciousness [K1, K4]. One can ask whether OBE involves sharing of the visual experience of other persons involved about subject person. If this were the case, the presence of other persons would be necessary to have OBE. Sharing of mental images would explain the case of Miss Z as telepathy.

13.3.2 Where the information processing giving meaning to what is seen is carried out?

Seeing is much more than just receiving the photons on retina, since a lot of information processing is needed to give meaning to what is seen. This essentially involves a decomposition of visual input to recognized objets having relations to each other and to the past of perceiver. This applies also to the visual percepts during OBEs. The most natural candidate for the system processing the visual stimulus and giving it meaning is the brain of the subject person.

Sharing of mental images allows to consider an alternative interpretation based on telepathy. The sensory organs in other bodies receive the visual stimulus and and other brains do the information processing. For instance, "unconscious" victim of accident could share the fused mental images of people around the place of accident. This would explain the case of Miss Z studied by Tart [35] as telepathy.

13.3.3 Are OBEs "only" hallucinations?

In TGD framework the first possibility is that the sensory stimulus is always artificial and comes from brain to eyes and other sensory organs by back projection. OBE would be a dream like cognitive representation, simulation rather than a real percept. REM is expected to always accompany OBEs in this case.

There is an objection against this idea. If person is unconscious or has NDE, it is questionable whether she is able to construct such high level cognitive representation as the representation of the state of her own body as seen by outsider is, and even transform it to a sensory representation. One can also ask what hallucinations really are. In TGD framework hallucinations must be generated by an artificial sensory stimulus so that hallucinations and genuine OBEs might involve the same basic mechanism.

13.3.4 Does OBE originate from an actual sensory stimulus?

The well-known fact that body parts indeed contain holograms about other body parts [22] (see the discussion in [K5]) and the TGD view about the relationship between dark and living matter [J6] allows to consider seriously the possibility that OBE originates from an actual sensory stimulus.

The dark photon laser beams emanating from the body would be received by a magnetic body containing dark matter at some level in the hierarchy of magnetic bodies and would be reflected back to the receiving sensory organs along MEs possibly parallel to magnetic flux tubes rather than space-time sheets along which ordinary visual input arrives.

It is quite possible that several magnetic bodies in the hierarchy are involved. The magnetic bodies involved need not always correspond to a personal magnetic body and could receive input from several biological bodies and remote vision and telepathy might involve signals from brain reflected to a second brain via multi-brainy magnetic body. Magnetic bodies could be associated also with "dead" matter.

In this picture the case of Miss Z could be understood in two alternative manners. A dark photon beam possibly created by the visual representation of the random number (does "dead" matter generate sufficiently intense beams of this kind?) and reflected by personal magnetic body could be in question. Alternatively, the magnetic body involved could receive the information about random number from the brain of the experimenter and reflect it to the brain of the subject person.

13.3.5 Why electrical stimulation induces OBEs?

Electrical stimulation of angular gyrus induces OBEs just as the stimulation of neurons of temporal lobe induces long term sensory memories. In neurological "brain only" approach the interpretation would be that the responses in the vestibular and somatosensory system induce the AS and OBE as hallucinations. In TGD framework the response in vestibular and somatosensory system would be interpreted as a response to an actual experience of being in a detached position and orientation, and brain would processes genuine sensory data about being in detached position.

One might think that the temporal ordering between the experiences and these responses would allow to decide which causes what. In TGD framework negative energy signals propagating backwards in the geometric time are however a basic element of brain functioning and this criterion need not be apply.

One imagine two mechanism generating OBEs.

1. The mechanism inducing visual OBE and related experiences could simply turn off the ordinary sensory input so that only the dark photon beams from the magnetic body would contribute to the visual stimulus. This would occur automatically during dreams and NDE experiences.

2. The sensory input from the magnetic body could be amplified. Time mirror mechanism could be responsible for this amplification [K1]. During epilepsy strong electric fields generated by brain during epilepsy induce starvation of neurons and the electrical stimulation of angular gyrus could have the same effect. Starving neurons would generate a beam of phase conjugate (negative energy) dark photons received by magnetic body in order to get metabolic energy. The magnetic body would be in a state analogous to a population inverted (possibly many-sheeted) laser defining a hologram like representation of the body. The receival of negative energy photons would induce a cascade like induced return to the ground state and amplify the dark photon beam arriving from magnetic body so that it would not be masked by the ordinary visual input anymore and would give rise to a percept.

13.3.6 A more detail model for OBEs

In the following a more detailed model for various aspects of OBEs is developed.

Do bio-photons result from the de-coherence of dark photon beams?

Bio-holography provides support for the body as a hologram (more precisely, dark photon hologram). For instance, an electric stimulation of ear during Kirlian imaging of a finger tip creates a Kirlian photo from which it is possible to abstract a hologram of ear [22] (for a TGD based model see [K4, K5]). This suggests that body parts can in some sense "see" each other. In particular, brain can "see" body parts (note that bacteria possess a primitive IR vision based on micro-tubules): this of course need not correspond to a conscious vision at our level of self hierarchy.

The biological function of bio-photons [23] is poorly understood, and they are an excellent candidate for ordinary photons resulting when dark photon beam de-coheres. TGD based model of bio-photons can be found in [K6] and the identification as dark photons is discussed in [J6]. The findings of Peter Gariaev about the effects of visible laser light on DNA [31] and so called phantom DNA effect [30] provide a further support for the biological importance of biophotons (see the discussions in [K6, J6]).

What is the mechanism of out-of-body hearing?

Mechanism could be even more general and work also in the case of other qualia. In particular, hearing might involve similar reflection of sound waves at larger space-time sheets from the magnetic body and heard as "other-worldly" sounds.

A more plausible option is that the auditory sensation is generated by dark microwave photons reflected back from magnetic body. Microwave hearing [24] is indeed a well-known but poorly understood phenomenon and the generation of microwaves by plants after sunset correlates also with taos hum [26] (see the discussion in [M1]) which does not generate any response in microphones but reflects the features of the acoustic environment.

The auditory and visual hallucinations of schizophrenic persons would represent in this framework a genuine sensory input. The notion of bicameral mind introduced by Jaynes [16] discussed in TGD framework in [N6] would fit also nicely with this picture. The "god" controlling the behavior of bicameral by giving explicit commands would correspond to some magnetic body, not necessarily that of the subject person, but a magnetic body receiving input from several brains in the social group and representing collective consciousness.

Where are the sensory receptors giving rise to the primary sensory experience?

The simplest guess is that the visual stimulus from the magnetic body is received by eyes. The fact that REM accompanies visual dreaming supports this view in the case of dreams. The receiving sensory organ could be also pineal gland [I3, M5], "third eye", the seat of the soul according to Descartes [18]. Pineal gland is known to contain retinal pigments and its counterpart in more primitive animals is known to function as a genuine eye. A simple test in the case of artificial OBEs is to look whether the electric stimulation of OBEs generates also REM.

If OBE hearing is indeed microwave hearing, the identification of the primary sensory receptors is not obvious, although their existence cannot be denied.

The insect olfaction relies on infrared light as discovered by Callahan [27] (see the discussion in [K3]). One might therefore wonder whether also humans possess olfactory receptors sensitive to IR light, and whether the emission of dark IR photons reflected from magnetic body could play some role in olfaction and in the generation of olfactory hallucinations. One can even ask, whether the molecular recognition mechanism underlying chemical senses relies on IR light. It is known that human nose contains so called vomeronasal organ [19] sensitive to odors having sexual or social meaning but that these odors do not give rise to a conscious experience.

It is known that blind persons can learn to "see" when their skin is stimulated by electromagnetic fields representing the environment. Perhaps dark photon beams could induce also tactile sensations. Quite generally, the earlier proposal that information in all sensory modalities can be transformed to field patterns represented by MEs could sharpen to the hypothesis that the information in various sensory modalities allows a representation as dark photon beams inducing corresponding sensory qualia in the interaction with appropriate sensory receptors.

What is the mechanism causing the kinesthetic sensations during OBEs?

The model should also explain sensations of lifting, flying experiences, and the experiences of being in translational or rotational motion. The motion of the magnetic body with respect to the physical body should induce this kind of sensations. The basic idea is simple: generalize the mechanism allowing to hear the motion of a sound source. Generalizing from sound waves to dark photon beams, the sensation in question would be basically due to the Doppler shift of the dark photon beams travelling between biological body and the moving magnetic body. The change of the dynamical hologram resulting in the interference of a bodily reference beam and Doppler shifted reflected beam in quantum jumps could be responsible for the sensation.

This model could also resolve an objection against the hypothesis that sensory receptors experience the primary qualia. The objection is based on train illusion. When you sit on a train and look at second train which starts to move, you can have an illusion that it is your train that moves. The illusion is not a mere belief but involves a sensation of acceleration in the entire body. There are two options.

1. The sensation is a response to various bodily activities induced by the belief of being in an accelerated motion.

2. The sensation is caused by a primary sensory input induced by the acceleration. This sensory input must be produced artificially in the case of train illusion.

Consider first a genuine accelerated motion of the biological body. One could argue that in absence of visual, auditory or other sensory information about being in accelerated motion, there is no belief about being in accelerated motion so that acceleration is not perceived at all for option a). This makes option a) implausible. For option b) the acceleration of the biological body with respect to the object defining the rest system is directly perceived. The Doppler shift of the dark photon beams radiated

from biological body and reflected back from the rest system would induce the sensation. Reflection could occur either from the rest system or a magnetic body associated with it.

One can imagine two mechanisms creating an illusory acceleration for option b).

1. If the fixation of the attention to the moving train means the presence of dark photon laser beams connecting biological body and train or a magnetic body associated with it, the Doppler shift of dark photon beams could induce the sensation of acceleration.

2. Directed attention could cause a personal magnetic body to mimic the motion of train so that the relevant part of it deforms in the direction of moving train to keep the distance to the moving train fixed. This would induce train illusion by the same mechanism as in case 1).

For both mechanisms the reflection of dark photon beams becomes the fundamental mechanism of directed attention. Attention would mean a formation very concrete bonds between subject and object or a representation of object at the personal magnetic body: the rays connecting the eyes of cartoon characters would represent a very profound idea about consciousness. Both views about attention mean a clear-cut deviation from the prevailing neuro-scientific thinking according to which the experienced world is virtual and completely detached from the real world.

Cliff illusion might be an appropriate name for the disgusting feeling in stomach which one feels on the brink of a precipice. Sensory imagination about falling down is in question and could be induced by the deformation of the personal magnetic body such that it mimics free fall.

The floating sensations and strange deformations of personal body during OBEs could also correspond to the deformation dynamics of the magnetic body which could be also caused by external influences. If the size of the magnetic body is measured using Earth radius as a natural unit and if the personal magnetic body co-rotates with Earth, the variation of the effect of the solar wind could induce periodic deformations of the magnetic body as in the case of Earth's magnetic field. This could reflect itself as diurnal alterations in the shape of the body experienced during OBEs: a contraction during day time and an elongation during night time. Sunspot maxima induce magnetic storms and these could have strong effects on the shape of the body perceived during OBEs.

What is the mechanism making possible to see internal organs?

Becker tells in his book "Cross currents" [29] about a young cancer patient who told that he can see the interior of his own body. The patient could also locate the remnant of the tumor correctly. The simplest explanation is that magnetic body at some level of hierarchy reflects the dark photons emitted by the internal organs.

Usually this does not occur and one should understand why the emission occurred in the case of the cancer patient. There is evidence that bio-photons leak out from non-healthy organs [23]: this might mean that organs send more intense dark photon beams reflected at the magnetic body.

Time mirror mechanism involving time reflection instead of ordinary reflection suggests itself as an alternative explanation. The cells suffering starvation generated phase conjugate dark photon beams in order to get metabolic energy. This in turn induced a cascade like emission of positive energy dark photon beams from the magnetic body instead of mere time reflection.

13.3.7 The relationship of EMDR experiences to OBEs

Near-death experiences are not the only manner to get convinced about life after death. So called eye-movement desensitization and reprocessing (EMDR) discovered by Francine Shapiro [21] induces what could be interpreted as after-death communications (see the discussion in [H9]). The experiences of subject persons are claimed to be induced by this therapy in a highly reliable manner: according to [21] 98 per cent of patients willing to participate the therapy had after death communication experience. It does not matter what the religious convictions of the subject person are and the experiences are actually rather easy to induce. It does not matter if the loss is traumatic or not or whether it is recent or occurred for decades in past.

The experiences resemble near death experiences (light tunnels, beautiful landscapes) and involve spiritual contact with the deceased. The EMDR technique involves getting the patient to move his or her eyes in a particular rhythmic fashion while at the same time attending to a particular aspect of the traumatic memory. How EMRD works is poorly understood as yet: possibly the fact that the

shifting of eyes leads to increased brain processing is of importance. Notice that rapid eye movements REM are also involved with dreams.

A possible explanation is that EMDR experiences involves visual communication using dark photon beams and/or their phase conjugates with the 4-D magnetic bodies of the deceased ones located possibly in the geometric recent or past via the magnetic mirrors associated with them. Essentially the same mechanism as involved with long term episodal memories could be in question: the only difference would be that the magnetic mirrors now mediate information not from own 4-D body from the 4-D body of the deceased.

13.4 The role of the magnetic body in the case of other brain functions

During the construction of the model of OBEs it became clear that the reflection of dark photon beams from the magnetic body could serve as a building block of several ordinary brain functions. If has been already found that dark photon beams could define a fundamental mechanism of directed attention.

13.4.1 Dreams and hallucinations and magnetic body

The reflection of dark photon beams from the magnetic body could be involved also with dreams and hallucinations so that the neurological similarity of AS experiences and OBEs does not mean that both are hallucinatory. The "subtle body" assigned by many spiritual traditions with the dreaming state (for a nice summary see [17]) would correspond to the magnetic body. In this case mental images constructed in brain would induce dark photon beams sent to magnetic body and reflected back. The mechanism would also naturally explain autoscopic and heautoscopic experiences, in particular the ability to see internal organs.

13.4.2 Third person aspect of conscious experience

Our conscious experience involves so called third person aspect giving a symbolic bird's eye of view about ourselves. Magnetic body could could take the role of the third person. At the fundamental level this representation could be based on sensory stimuli originating from body and reflected back to sensory organs. It would be completely masked by the ordinary sensory input in wake-up state but distilled by brain from the dominating sensory input and coded to a cognitive representation to minimize the amount of irrelevant information. A strong interference of this kind of sensory representation with ordinary sensory input would be obviously highly undesirable. The third person aspect could be present always and be based on the reflection of dark photons along MEs paralle to magnetic flux tubes.

13.4.3 Feedback to primary sensory organs via reflection from magnetic body

One objection against the hypothesis that primary sensory organs are seats of sensory qualia is that that sensory stimuli are only the raw material sculptured into actual sensory perceptions and that directed attention chooses what aspects of sensory stimulus are amplified and which neglected. I have proposed that there is a feedback by projections to the primary sensory organs from brain generating artificial sensory stimuli modifying the primary sensory input. This feedback could be realized also as a reflection of artificial dark photon beams generated by brain from the magnetic body and received as such by eyes or received by brain and channelled to eyes via MEs parallel to visual pathways.

13.4.4 Does imagination involve feedback via magnetic body?

One can wonder, whether also imagination could involve reflection of dark photon beams from the magnetic body. In TGD framework the hypothesis that sensory qualia are generated at primary sensory organs and brain constructs only symbolic representations about experiences circumvents the basic objections such as the experience of phantom leg. In this framework imagination and cognition

can be identified as symbol generating activities which are not initiated at sensory organs but at some higher level of the hierarchy starting from sensory organs and ending at the associative areas of cortex.

Imagination could however involve also transformation of symbolic representations to dark photon beams reflected back from the magnetic body. This input would not contribute to sensory input but might be abstracted from the sensory input and might serve as a kind of feedback. In absence of ordinary sensory stimuli the input from the magnetic body would dominate and imagined mental images would transform to dreams or hallucinations.

13.4.5 Sensory memories and magnetic body

In some exceptional cases often associated with a serious damage in cognitive areas of brain the feedback from the magnetic body could give rise to a genuine sensory representation making possible direct sensory memories. Examples are autistic persons with ability to remember visual scenes music pieces in every detail and also reproduce them.

One explanation is sharing of sensory mental images of geometric past. An alternative explanation is that the information about sensory memory is communicated from the geometric past in symbolic form and transformed to a dark photon beam reflected back from the magnetic body. The fact that angular gyrus is involved with the translation of written language to internal speech and the abstraction of meaning of visual metaphors supports the view that a transformation of linguistic statements to concrete images projected to the magnetic body occurs in this process.

I have proposed a mechanism [H4] explaining synesthesia. The association of different sensory modalities could also occur via a transformation of sensory input in given modality to dark photon beam reflected from magnetic body and generating a sensation in another modality. Synesthetes are also known to be capable of amazing sensory memory feats [20] and I have proposed an explanation based on time mirror mechanism [H4]. Also in this case neurons in certain region of left brain hemisphere suffer starvation which should be lethal by standard wisdom.

As a matter fact, the starvation mechanism seems to be a very general mechanism: Callahan has found evidence that insects find more easily the plants suffering from under nutrition [28] (see the discussion in [L1]). Even the fasting common in spiritual practices could be seen as a method to get body entangled with magnetic bodies by using time mirror mechanism.

13.5 The interpretation of my own OBE type experiences in terms of the proposed model

My own personal experiences have served as a test bed for the basic ideas of TGD inspired theory of consciousness. I find it practical to divide these experiences into two classes. The first class of experiences have repeated relatively often during years after the great experiences. The Great Experiences in turn involved a rich spectrum of experiences which I group into the second class. There is some overlap between these categories.

13.5.1 Visual experiences and kinesthetic sensations

The first class of strange experiences involves several kinds of visual experiences and kinesthetic sensations.

1. When I lightly close my eyes during ordinary wake-up consciousness and in calm state of mind, I see dimly a complex flow in the visual field. This flow brings in mind time dependent magnetic field or incompressible flow of fluid. The direction of flow can be either inwards or outwards and can change. The flow can be also colored. The straightforward interpretation would be as a visual stimulus from the magnetic body which does not give rise to concrete images.

2. I have had many AS experiences in which I have seen my body in strangely deformed state and have had a sensation of floating. This experience is often followed by the experience of raising to the roof and I have made attempts to test whether the levitation is real or not. The experiences have ended to a wake-up to ordinary state of consciousness. Quite concrete sensations of what I have identified as "electrical storms in temporal lobes" have often accompanied these experiences.

3. I have had also flying experiences: typically there is some critical height which I cannot exceed. I have had also experiences about being in completely dissipation free spinning or translational motion, which bring strongly in mind what purely quantal motions of this kind feel like. The translational motion has been possible only in a finite volume defined typically by the walls of the room. I have also experienced my children to bring me back when I have tried to go too far. A possible interpretation is that my magnetic body is bound to that of room so that it is not possible to leave it.

4. I have often experienced quite concretely a return to my own body during wake-up as a kind of contraction somewhat like djinn returning to a bottle. After a visit to Holland where I was subject to a treatment by a healer, I waked up to a rather long-lasting experience in which I felt that the entire room was part of my body. The world around me was strangely peaceful and calm, somewhat like the world in the pictures I saw in fairy tales in my childhood.

5. Two illusions analogous to train illusion but involving a 2- or 3-dimensional wave motion instead of linear motion deserve also to be mentioned. I sat in a calm state of mind on cliff on beach and enjoyed looking the waves. Suddenly I got a long lasting sensation that the cliff is in a wave like motion as if I had seen the cliff from the perspective of the moving surface of sea and thus in a wave like movement with respect to it. The explanation would be magnetic body began to mimic the wave motion somewhat like a person listening very attentively begins to mimic the facial expressions of the speaker. Since magnetic body also serves also the dual role of a sensory canvas to which sensory mental images are projected [M1], the situation would be like projecting sensory mental images to a deformable screen along which deformation waves propagate. The projected sensory images such as the visual image about cliff would inherit the wavy character.

Anyone who has enjoyed free floating in a windy sea for a sufficiently long time has probably experienced a sensation about a wave like motion inside the body after the return to the shore. The sensation continues surprisingly long time. As far as I can remember, this experience is absent during free floating. Also this experience might relate to the fixation of bodily attention to the wavy sea inducing a mimicry of wave motion by a relevant magnetic body as in the previous case and continuing for a considerable time after the return to the shore. During free floating in sea this sensation is weak since the relative motion is minimal but at the shore the situation changes since the body is in a relative 3-D motion with respect to the magnetic body.

13.5.2 OBE type auditory sensations

Also OBE type auditory sensations have often occurred.

1. The AS experience have often started usually by a gradual amplification of sounds such as the sound of refrigerator and have involved the rather frightening sensation that the refrigerator attracts me towards it and wants to fuse my self with its own (for this reason I have been forced to minimize this sound). A possible explanation is that magnetic body in this kind of situation contributes to the auditory stimulus the secondary sound representing the sensory stimulus that it has received from the body and a positive feedback loop is generated. Representation as microwaves is perhaps the most plausible option.

2. When I wake up during night-time, I can sometimes hear a kind of wind blowing and often I realize that ordinary wind is not in question when I see that there is completely calm outside. This wind has preceded sometimes a loss of consciousness. A microwave stimulus arriving from magnetic body along magnetic flux tubes and transformed to auditory sensation could be in question. Obviously this sensation would be direct auditory counterpart for the flow in visual field experienced during wake-up.

3. To listen one's own snoring during sleep or just before wake-up as an outsider is a rather bizarre experience and often it takes time to realize that it is really me. The interpretation in terms of microwave dark photon beams modulated by the snoring and reflected back from the magnetic body would be the simplest one.

4. Sometimes I also hear my own breathing as double with a time laps of a fraction of second between the copies. This gives some idea about size of the magnetic body possibly involved. For microwave hearing the size of magnetic body would correspond to a wavelength of typical EEG wave and would be of the order of Earth circumference for 7.8 Hz. If ordinary sound waves are in question the size of magnetic body involve would be of order 10 meters.

13.5.3 OBEs associated with "Great Experiences"

Second group of experiences I had during what I call Great Experiences (two of them).

1. I saw my thoughts as images superposed to the strange flow already mentioned. The optimum situation was achieved which lightly closed eyes. This stimulated a conversation with what I called Great Mind. I wrote first my questions to monitor and experimentation with the transformation of written words into visual images during great experience. This would conform with the view that brain, perhaps angular gyrus, transforms written words to visual symbols by generating dark photon beams reflected back from the magnetic body. During the original experience I had a deep conviction that this visual representation is an essential part of language and thinking.

   At some stage I found that writing of my questions is not anymore necessary and I also began to realize that the Great Mind in some sense is just me, in some sense I was a God. One of the most important answers I received was that death is only an illusion. An interpretation in terms of a direct communication with some magnetic body in the hierarchy, not necessarily mine, looks natural.

2. I experienced several variants of OBEs. There was an heautoscopic experience in which I did not only see me as an outsider but experienced how my body language directly reveals to an outsider my sociophoby.

   During the stay in hospital I left my body and walked out from hospital. I was surprised that the personnel did not notice this at all, as if I had been invisible. I walked along sunny street (it was very beautiful day of May) and felt myself extremely happy. I did not get too far since persons from the staff of hospital brought me back. This might be an example of experience involving remote viewing in which magnetic body reflects dark photons from external world to the physical body. Again it would seem that my magnetic body was bound to some larger one and could not leave it.

   There was also an experience of wandering in worlds totally different from our physical world. Learning that this kind of worlds exist was a little bit irritating for my theoretician's vanity since I had thought that the ordinary physical universe predicted by TGD is all that exists!

   Finally there was experience that the hospital building itself is a conscious entity having some kind of experiences and that I had somehow identified with it or that I somehow received visual information about the structure of the building.

3. During second Great Experience I experienced what might be called tactile remote sensing. I "saw" at the skin of my leg an emotionally highly painful event and interpreted it as remote viewing. This would support the view that also tactile sensations might be generated by dark photons in some wave length range. Hearing and tactile sensing are indeed closely related.

13.5.4 Dark matter hierarchy, zero energy ontology, and OBEs

The identification of dark matter as a hierarchy of quantum phases labelled by the values of Planck constant [C9] provides additional insights about OBE experiences. Planck constant is quantized and can have arbitrarily large values and since Compton length and other analogous quantum lengths and times scale as Planck constant, this means macroscopic and macro-temporal quantum coherence and a reduced rate of dissipation.

Also the magnetic body controlling biological body (actually onion-like hierarchy of them) is assumed to carry dark matter and dark matter becomes the agent responsible for the quantum control of ordinary matter in living systems. The value of Planck constant becomes also a measure for the

evolutionary level of the living system and great leaps in evolution can be identified as transitions increasing the maximum value of $\hbar$ in "personal" hierarchy of magnetic bodies [M3].

Zero energy ontology is second new element of quantum TGD and states that all physical states have vanishing net values of conserved quantum numbers. Zero energy ontology provides a firm justification for the notion of negative energy signals consisting of (say) phase conjugate photons propagating to the geometric past. These negative energy signals are crucial element of the time mirror mechanism playing a central role in the general mechanism for intentional action, remote metabolism, and long term memory.

A general model for the remote mental interactions follows from a model for the living matter by assuming that also other biological bodies can serve as targets for the control action of the magnetic body or communicate sensory information to the magnetic body. Of course, the target need not be restricted to be a biological system. Ordinary intentional action would represent a particular case of remote mental interaction in this framework.

Consider now OBEs in this general framework. During OBE experiences the mental images constructed by brain about biological body could be absent due to the absence of the metabolic energy feed to the appropriate parts of brain taking care of the construction of cognitive mental images about biological body and communications of them to the magnetic body. The simplest representation would be in terms of bit sequences with bit 1/0 represented in terms of population inverted state/ground sate of many-sheeted laser. Negative energy signals to the geometric past would be used to read these signals by inducing partial reduction of the population in inverted states. In absence of metabolic energy feed 1:s would gradually transform to 0:s.

In absence of these cognitive mental images to the magnetic body, magnetic body would not anymore provide strict cognitive representations of biological body and virtual world experiences would result. Since only magnetic body contributes to the bodily experience, the low rate of dissipation due to large value of $\hbar$ would explain the pleasant experience about the absence of the sensory noise.

It is perhaps not an accident that during OBE like experiences I saw my thoughts as vivid pictures and that people experiencing OBEs are known to have exceptionally vivid visual imagination. This might relate to redirected metabolism. Construction of mental images and their communication requires metabolic energy feed. During OBEs the metabolic energy usually spent to the formation and communication of the cognitive representations about the state of the biological body to the magnetic body could be redirected to the visual cortex allowing to construct the vivid visual representations of thoughts. The distorted bodily image due to neural disorders in temporal lobes seems to correlate with OBEs: perhaps the disorder does not allow metabolic energy to be used to construct cognitive representations about biological body during these disorders and it is redirected to the visual cortex. Also during dreams and in the transition states between sleep and awake the metabolic resources could be redirected in this manner and lead to a generation of vivid visual mental images.

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A-1 Basic properties of CP_2

A-1.1 CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-1.1}$$

Here λ is any nonzero complex number. Note that CP_2 can also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homoeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^4".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [2] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-1.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi + \Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi - \Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-1.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connec- ted, with Euler number 3, Pontryagin number 3 and second Betti number $b = 1$.

A-1.2 Metric and Kähler structures of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \rightarrow exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5. The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-1.4}$$

where the Hermitian, in fact Kähler, metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-1.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= lnF \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-1.6}$$

The representation of the metric is given by

$$\frac{ds^2}{R^2} = \frac{(dr^2+r^2\sigma_3^2)}{F^2}+\frac{r^2(\sigma_1^2+\sigma_2^2)}{F} \ , \tag{A-1.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2-\xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2-\xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi^1}+\xi^2 d\bar{\xi^2}) \ . \end{aligned} \tag{A-1.8}$$

The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2\sum_A e_k^A e_l^A \ , \tag{A-1.9}$$

are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , \quad e^1 = \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , \quad e^3 = \tfrac{r\sigma_3}{F} \ . \end{aligned} \tag{A-1.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , & e^1 &= \tfrac{r(sin\Theta cos\Psi d\Phi+sin\Psi d\Theta)}{2\sqrt{F}} \ , \\ e^2 &= \tfrac{r(sin\Theta sin\Psi d\Phi-cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 &= \tfrac{r(d\Psi+cos\Theta d\Phi)}{2F} \ . \end{aligned} \tag{A-1.11}$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 = dr^2/F^2+(r^2/4F^2)(d\Psi+cos\Theta d\Phi)^2+(r^2/4F)(d\Theta^2+sin^2\Theta d\Phi^2) \ . \tag{A-1.12}$$

The vierbein connection satisfying the defining relation

$$de^A = -V_B^A\wedge e^B \ , \tag{A-1.13}$$

is given by

$$\begin{aligned} V_{01} &= -\tfrac{e^1}{r} \ , & V_{23} &= \tfrac{e^1}{r} \ , \\ V_{02} &= -\tfrac{e^2}{r} \ , & V_{31} &= \tfrac{e^2}{r} \ , \\ V_{03} &= (r-\tfrac{1}{r})e^3 \ , & V_{12} &= (2r+\tfrac{1}{r})e^3 \ . \end{aligned} \tag{A-1.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{aligned} R_{01} &= e^0\wedge e^1-e^2\wedge e^3 \ , & R_{23} &= e^0\wedge e^1-e^2\wedge e^3 \ , \\ R_{02} &= e^0\wedge e^2-e^3\wedge e^1 \ , & R_{31} &= -e^0\wedge e^2+e^3\wedge e^1 \ , \\ R_{03} &= 4e^0\wedge e^3+2e^1\wedge e^2 \ , & R_{12} &= 2e^0\wedge e^3+4e^1\wedge e^2 \ . \end{aligned} \tag{A-1.15}$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -ig_{a\bar{b}}d\xi^a d\bar{\xi^b} \ , \tag{A-1.16}$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J^k_{\ r} J^{rl} \;=\; -s^{kl} \;\; . \tag{A-1.17}$$

The form J is integer valued and by its covariant constancy satisfies free Maxwell equations. Hence it can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling). Locally one has therefore

$$J \;=\; dB \;\; , \tag{A-1.18}$$

where B is the so called Kähler potential, which is not defined globally since J describes magnetic monopole.

It should be noticed that the magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{aligned} B &= 2re^3 \;\; , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F} sin\Theta d\Theta d\Phi \;\; . \end{aligned} \tag{A-1.19}$$

The vielbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1,1).

Useful coordinates for CP_2 are the so called canonical coordinates in which Kähler potential and Kähler form have very simple expressions

$$\begin{aligned} B &= \sum_{k=1,2} P_k dQ_k \;\; , \\ J &= \sum_{k=1,2} dP_k \wedge dQ_k \;\; . \end{aligned} \tag{A-1.20}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \;\; , \\ P_2 &= \frac{r^2 cos\Theta}{2(1+r^2)} \;\; , \\ Q_1 &= \Psi \;\; , \\ Q_2 &= \Phi \;\; . \end{aligned} \tag{A-1.21}$$

A-1.3 Spinors in CP_2

CP_2 doesn't allow spinor structure in the conventional sense [5]. However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R^A_B e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0,1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R^A_B(v)$

defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallelly propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the nonallowed -1- factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential $exp(i2\Phi)$, where Φ is the the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

A-1.4 Geodesic submanifolds of CP_2

Geodesic submanifolds are defined as submanifolds having common geodesic lines with the imbedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h^k_α (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [3] a general characterization of the geodesic submanifolds for an arbitrary symmetric space G/H is given. Geodesic submanifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-1.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic submanifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The nonequivalence of these submanifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2 Identification of the electroweak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the

electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [4] and in particular that the right handed neutrinos decouple completely from the electroweak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.1}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \times \gamma_5$, $1 \times \gamma_5$ and $\gamma_5 \times 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electroweak group: $SO(4) = SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \tag{A-2.2}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{aligned} V_{01} &= -\tfrac{e^1}{r} \ , & V_{23} &= \tfrac{e^1}{r} \ , \\ V_{02} &= -\tfrac{e^2}{r} \ , & V_{31} &= \tfrac{e^2}{r} \ , \\ V_{03} &= (r - \tfrac{1}{r})e^3 \ , & V_{12} &= (2r + \tfrac{1}{r})e^3 \ , \end{aligned} \tag{A-2.3}$$

and

$$B = 2re^3 \ , \tag{A-2.4}$$

respectively. The explicit representation of the vielbein is not needed here.

Let us first show that the charged part of the spinor connection couples purely left handedly. Identifying Σ_3^0 and Σ_2^1 as the diagonal (neutral) Lie-algebra generators of $SO(4)$, one finds that the charged part of the spinor connection is given by

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 \ , \tag{A-2.5}$$

where one have defined

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{aligned} \tag{A-2.6}$$

A_{ch} is clearly left handed so that one can perform the identification

$$W^\pm = \frac{2(e^1 \pm ie^2)}{r} \ , \tag{A-2.7}$$

where $W^\pm$ denotes the charged intermediate vector boson.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quanties

$$\begin{aligned} X &= re^3 \ , \\ Y &= \frac{e^3}{r} \ , \end{aligned} \tag{A-2.8}$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$\begin{aligned} \bar{\gamma} &= aX + bY \ , \\ \bar{Z}^0 &= cX + dY \ , \end{aligned} \tag{A-2.9}$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$\begin{aligned} A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\ &+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ . \end{aligned} \tag{A-2.10}$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5\Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d \ . \tag{A-2.11}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.12}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$\begin{aligned} Q_{em} &= \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\ I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ . \end{aligned} \tag{A-2.13}$$

The fields γ and Z^0 are defined via the relations

$$\begin{aligned} \gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\ Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \ . \end{aligned} \tag{A-2.14}$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.15}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electroweak interactions.

The determination of the value of Weinberg angle is a dynamical problem. The angle is completely fixed once the YM action is fixed by requiring that action contains no crossterm of type γZ^0. Pure symmetry nonbroken electroweak YM action leads to a definite value for the Weinberg angle. One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) \ , \tag{A-2.16}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{A-2.17}$$

in terms of the fields γ and Z^0 (photon and Z- boson)

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.18}$$

Evaluating the expressions above one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{03} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.19}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.20}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + fJ^{\alpha\beta}J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2}Tr(F^{\alpha\beta}F_{\alpha\beta}) \ , \end{aligned} \tag{A-2.21}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 crossterm (this coefficient must vanish) the expresssion

$$\begin{aligned} X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\ K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ , \end{aligned} \tag{A-2.22}$$

In the general case the value of the coefficient K is given by

$$K = \sum_i \left[-\frac{(18 + 2n_i^2)sin^2\theta_W}{9}\right] \ , \tag{A-2.23}$$

where the sum is over the spinor chiralities, which appear as elementary fermions and n_i is the integer describing the coupling of the spinor field to the the Kähler potential. The cross term vanishes provided the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18 + n_i^2))} \quad . \tag{A-2.24}$$

In the scenario where both leptons and quarks are elemantary fermions the value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \quad . \tag{A-2.25}$$

The bare value of the Weinberg angle is 9/28 in this scenario, which is quite close to the typical value 9/24 of GUTs [6].

A-2.1 Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:
a) Symmetries must be realized as purely geometric transformations.
b) Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [1].

The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0\Psi \quad . \tag{A-2.26}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \quad , \\ \xi^k &\rightarrow \bar{\xi}^k \quad , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \quad . \end{aligned} \tag{A-2.27}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \quad , \\ \Psi &\rightarrow \Psi^\dagger\gamma^2\gamma^0 \otimes 1 \quad . \end{aligned} \tag{A-2.28}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Space-time surfaces with vanishing em, Z^0, Kähler, or W fields

In the sequel it is shown that space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP_2 projection, only vacuum extremals and space-time surfaces for which CP_2 projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy.

A-3.1 Em neutral space-times

Em and Z^0 neutral space-times are especially interesting space-times as far as applications of TGD are considered. Consider first the electromagnetically neutral space-times. Using spherical coordinates (r, Θ, Ψ, Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta) d\Phi) + \frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-3.1}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta) d\Phi) + (3+p)\frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \tag{A-3.2}$$

where Θ_W denotes Weinberg angle.

The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2 F}(d(r^2)/d\Theta)(k + cos(\Theta)) &+ (3+p) sin(\Theta) = 0 \ , \end{aligned} \tag{A-3.3}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$\begin{aligned} r &= \sqrt{\frac{X}{1-X}} \ , \\ X &= D\left[\left| \frac{(k+u)}{C} \right| \right]^{\epsilon} \ , \\ u &\equiv cos(\Theta) \ , \ C = k + cos(\Theta_0) \ , \ D = \frac{r_0^2}{1+r_0^2} \ , \ \epsilon = \frac{3+p}{3+2p} \ , \end{aligned} \tag{A-3.4}$$

where C and D are integration constants. $0 \leq X \leq 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \leq 1$ and $r = \infty$ to $X = 1$ giving $|u + k| = [(1 + r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$sign(u + k) \times [\frac{1 + r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \leq k + 1 \ ,$$

where $sign(x)$ denotes the sign of x.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned} \Psi &= \omega_2 m^0 + k_2 m^3 + n_2 \phi + \text{Fourier expansion} \ , \\ \Phi &= \omega_1 m^0 + k_1 m^3 + n_1 \phi + \text{Fourier expansion} \ . \end{aligned} \tag{A-3.5}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which the electromagnetically neutral imbeddings become ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global imbedding for, say a constant magnetic field. Although global imbedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteing the absence of edges are satisfied.

The vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \tag{A-3.6}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

The expression for the Kähler form and Z^0 field of the electromagnetically neutral space-time surface will be needed in sequel and is given by

$$\begin{aligned} J &= -\frac{p}{3 + 2p} X du \wedge d\Phi \ , \\ Z^0 &= -\frac{6}{p} J \ . \end{aligned} \tag{A-3.7}$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

The effective form of the CP_2 metric is given by

$$\begin{aligned} ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2k s_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta} d\Theta^2 + s^{eff}_{\Phi\Phi} d\Phi^2] \ , \\ s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1 - u^2)}{(k + u)^2} \times \frac{1}{1 - X} + 1 - X \right] \ , \\ s^{eff}_{\Phi\Phi} &= X \times \left[(1 - X)(k + u)^2 + 1 - u^2 \right] \ , \end{aligned} \tag{A-3.8}$$

and is useful in the construction of electromagnetically neutral imbedding of, say Schwartchild metric. Note however that in general these imbeddings are not extremals of Kähler action.

A-3.2 Space-times with vanishing Z^0 or Kähler fields

The results just derived generalize to the Z^0 neutral case as such. The only modification is the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F}du \wedge d\Phi$ is useful.

Also the generalization to the case of vacuum extremals is straightforward and corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$\begin{aligned} Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u}du \wedge d\Phi = (k+u)du \wedge d\Phi \ , \\ r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\ \gamma &= -\frac{p}{2}Z^0 \ . \end{aligned} \tag{A-3.9}$$

For vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

For vacuum extremals with vanishing induced Kähler form classical em field γ and Z^0 field satisfy

$$\gamma = -\frac{sin^2(\theta_W)}{2}Z^0 \simeq -\frac{Z^0}{8}$$

for $\sin^2(\theta_W) = .23$.

A-3.3 Induced gauge fields for space-times for which CP_2 projection is a geodesic sphere

For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \ .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

For homologically trivial geodesic sphere a standard representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

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