Physics beyond the Standard Model: a Reductionistic Approach

The most beautiful fate of a physical theory is to point the way
to the establishment of a more inclusive theory,
in which it lives on as a limiting case.
Albert Einstein

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Abstract

The Standard Model (SM) is the best present theory of elementary particle interactions. Unfortunately, the SM cannot be unified with the theory of general relativity (GR) and has a number of *ad hoc* parameters. A certain ultimate unifying theory "beyond the SM" is long time expected. The present letter analyzes the SM from the materialistic philosophical position and shows the fundamental inconsistencies within the elementary set of particles. In order to be truly elementary, all the particles in this set should be stable and "unbreakable", which requires the set reduction. It is logical to expect that the successful unification concept will support the proposed reduction the elementary set. Unfortunately, no quantum field theory can support such reduction, on the contrary, all those theories expected to replace the SM including string theories actually tend to increase, not decrease the number of elementary particles.

The modified Einsteinian concept of curved spacetime, the General Principe of Interaction (GPI) proposed recently actually supports the proposed reduction. The GPI-based unification allows, in general, combining the quantum field mathematical descriptions of the particle interactions (methodologically similar to the SM) with the classic field descriptions of the gravitation (the GR). In addition, this approach is shown useful in solving the number of important philosophical problems of quantum physics.

1. Moving beyond the SM

The Standard Model (SM) remains the best-known theory of elementary particle interactions [1]. It shows ultimate reliability for all kinds of relevant experiments. However, SM fails to provide unification for all types of physical interactions as it is incompatible with the theory of general relativity (GR) and does not unify the strong interaction with the electroweak theory. In addition, SM requires a number of *ad hoc* parameters and cannot explain masses of hadrons and leptons naturally, without the special Higg's mechanism.

Although the SM elementary particle set looks like a short list (Fig.1), it actually includes 61 components: 36 quarks (the six quarks appear in three different "colors", and each quark has an antiquark), 12 leptons (each of the six leptons has an antiparticle), and 13 bosons (the gluon appears in eight different variations, and W boson has two forms: W^+ and W^-).

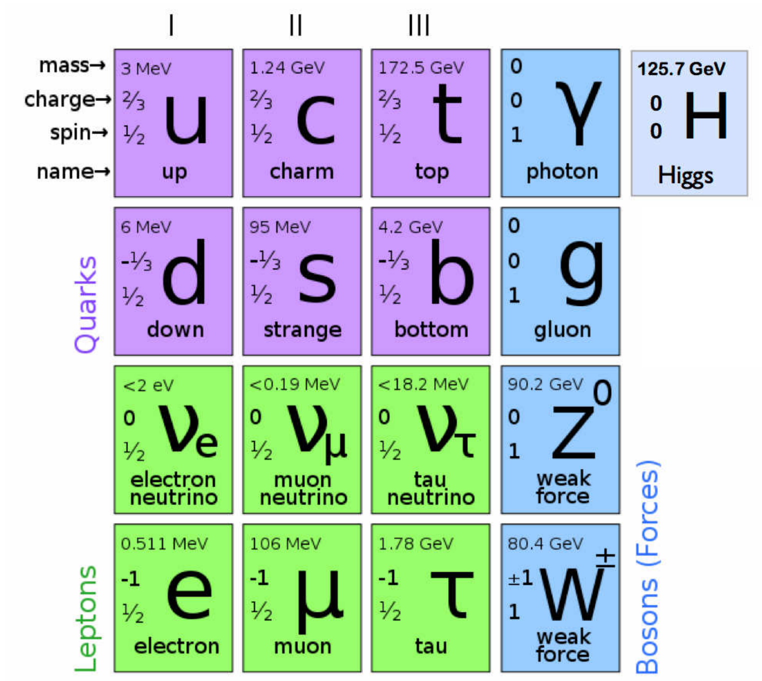

Figure 1: The Standard Model's elementary particle set. Considering all antiparticles, all different variations of quarks and gluons, and two types of W boson, the set actually contains 61 components.

From the materialistic philosophical grounds, an elementary entity should be ultimately stable and cannot decay or be "broken" into parts. Surprisingly, some quarks and leptons do not meet these conditions, as they decay spontaneously. In the quark family, only the u quark is stable. The d quark decays and can be thought as a combination of the u quark and the electron. All the heavy quarks (c, s, t, and b) decay into the light quarks (u or d). Heavy leptons (tau and muon) both decay into an electron. Notably, the rest mass is the only observable parameter that differs the heavy quarks from the light quarks (c and t from u; s and b from d), and the heavy leptons (tau and muon) from the electron. Assuming the mass increase is due to an additional energy, the heavy quarks and leptons can possibly be thought as higher energy states of the light quarks and leptons.

Moreover, not all bosons are stable. The Higg's boson and the three weak-interacting bosons (W^+, W^- and Z) decay spontaneously. Notably, these unstable bosons are purely virtual and undetectable in principle (only the products of their decays can be detected experimentally). Another example of a purely virtual particle is the neutrino. In 1930, a new particle (later named neutrino) was proposed by Pauli to explain the continuous energy spectrum of beta-rays in the beta decay. However, this spectrum [2] can be alternatively explained by the Bremsstrahlung effect: the emitted electrons (beta-rays) slow down after interacting with protons from neighbor atomic nuclei and lose energy via emitted photons (gamma-rays). As the electrons' trajectories vary, they lose various amounts of energy during the interaction and show the continuous energy spectrum. Notably, the Bremsstrahlung photons were completely ignored in the early neutrino experiments as the detectors were typically shielded from gamma-rays [2]. Interestingly, the neutrinos are not indispensable for the experimental calculations (e.g., for protons and electrons, the weak forces are calculated based on their electric charges). Unlike other leptons, neutrinos have no electric charge, and more generally, there is no any special "charge" identified with the weak interaction. Therefore, the avoidance of neutrinos would actually simplify the theory. Notably, in the experiments, the unstable bosons and neutrinos are "detected" only via the secondary effects (decay products), which cannot be considered as an evidence from the strictly materialistic philosophical position. Thus, the introduction of the unstable bosons (Higg's boson, W^+, W^- and Z) and neutrinos seems artificial, breaking the Occam's razor rule and hence questionable.

By removing all the unstable (see above) and unnecessary (e.g. neutrinos) particles, the SM elementary set can be reduced down to the six truly elementary particles: quark u, its antiquark ū, electron, positron, gluon, and photon (Fig. 2). These six "nature elements" seem sufficient to compose any kind of matter and radiation in the observable Universe (except dark matter and dark energy). Moreover, photons and gluons might be considered composite, if the electron-positron annihilation is thought as a kind of synthesis when one half-entity combines with another half-entity producing a full entity, the photon. Similar reasoning generally applies to the quark-antiquark annihilation. The proposed reduction of SM elementary set can be useful, if simplifies the theory and increase the explanatory and predictive powers.

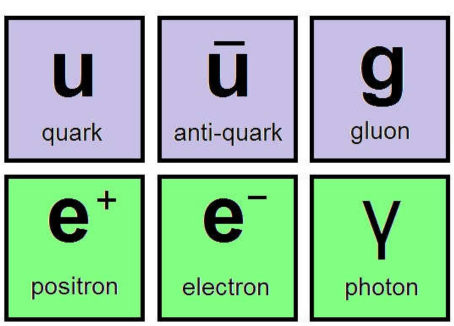

Figure 2: The six "nature elements" of the SM: the elementary charges (quark, antiquark, positron and electron), which do not decay and are not virtual (i.e. can be detected directly), and the two stable bosons (photon and gluon, i.e. an electron-positron combination and a quark-antiquark combination, respectively.

Thus, it is reasonable to expect that the 'beyond the SM' theories should lead to the reduction of the SM elementary particle set. Surprisingly, all presently known theories expected soon to replace the SM move in the opposite direction further increasing methodological complexity and raising the number of elementary components. This irrationality would be perfectly acceptable in case those theories exceed (or at least promise to exceed) the SM in terms of explanatory and predictive powers and solve (or at least promise to solve) its main problems, i.e. unification of all forces and explanation (or removal) of *ad hoc* parameters and assumptions. However, despite the many decades of collective effort, no physical theory can overcome these difficulties and succeed the SM. Unfortunately, all presently known unifying theories, including all superstring theories [3, 4], have zero explanatory and predictive power. These theories are not unique, i.e. the number of possible mathematical descriptions they provide is unimaginably great, and it is absolutely unclear how to choose the unique one that describes our Universe.

Some theorists have realized this deep crisis analyzing the problems of the ongoing unification attempts [4, 5]. In 2013, Neil Turok of the Perimeter Institute said: "There've been grand unified models, there've been super-symmetric models, super-string models, loop quantum gravity models…Well, nature turns out to be simpler than all of these models...The extensions of the Standard Model, like Grand Unified Theories, they were supposed to simplify it. But in fact, they made it more complicated. The number of parameters in the Standard Model is about 18. The number in Grand Unified Theories is typically 100. In super-symmetric theories, the minimum is 120. And ... string theory seems to predict 10 to the power of 1000 different possible laws of physics. It's called the Multiverse. It's the ultimate catastrophe: that theoretical physics has led to this crazy situation where the physicists are utterly confused and seem not to have any predictions at all... We have to get people to try to find the new principles that will explain the simplicity" [6].

2. Revising the foundations

This "dead end" situation in theoretical physics calls for some extraordinary measures. Perhaps theorists have to re-examine the very basic fundamental theoretical principles in order to remove all flaws and inconsistencies. Only a perfectly balanced foundation may hold a skyscraper, and only perfectly self-consistent basic principles may support a successful unified theory beyond the SM. Surprisingly, modern physics has no such foundation, as the philosophical concept of particle interaction in the SM is completely different from the Einsteinian understanding of gravitational interaction. Unfortunately, the gauge transformation principle of the SM is incompatible with the concept of curved spacetime used in the theory of General Relativity (GR). Moreover, these two main philosophical concepts are not only different, they are mutually exclusive! Indeed, the vacuum cannot be simultaneously a passive medium (as in the SM) and an active origin of interaction (as in the GR). Hence, only one of these two principles can serve as a foundation for the unified theory.

As pointed above, the ongoing mainstream search for the universal quantum field theory based on the gauge transformation principle was fruitless for quite a long time. The unification itself is likely a solvable problem; however, the tremendous complexity and non-uniqueness of the unified theory will likely “kill” its usefulness. Moreover, although the gauge transformation principle had become a dogma over the years, the brief survey of the main SM problems (see §1) makes its superiority questionable. Notably, this principle does not support the advanced Einsteinian definition of vacuum (spacetime). The Newtonian understanding of space and time as “empty coordinate net” used in the SM seems a bit outdated and philosophically limited (as it cannot support a background-independent theory). The most questionable basic feature of the gauge transformation principle is the involvement of virtual interacting particles (virtual bosons). These virtual “messengers” of interaction cannot be detected in principle rendering the whole concept non-deterministic. Thus, it does not seem beneficial to sacrifice the advanced Einsteinian understanding of spacetime and the fully deterministic definition of vacuum (with no virtual interactions) for the sake of a quantum field theory of gravitation compatible with the SM.

On the other hand, the Einsteinian understanding of interaction in its pure GR’s version cannot be universal as well. The fact that Einstein was unable to develop a successful unified theory points out that the Einsteinian concept is very likely limited and cannot explain any non-gravitational interaction. The fact that no GR extension was able to succeed the SM points out that all types of geometrical deformations of the 4D spacetime (three-dimensional space plus time) can induce gravitation only. If so, what kinds of spacetime deformation induce electromagnetism and nuclear forces? In order to answer this question one can modify the Einsteinian concept of interaction by assuming that the nongravitational forces are defined by certain geometrical deformations of vacuum that occur not in the 4D spacetime, but in the “unseen” extra dimensions. This modified concept of curved spacetime, the General Principe of Interaction (GPI) was recently proposed [7]. GPI postulates that the spacetime includes three separate “subspaces” (bound to one time dimension), each of which is responsible for one of the three fundamental types of interaction: gravitational, electroweak and strong. Thus, vacuum deformations in the 4D spacetime induce the gravitational field, deformations in the extra fifth dimension induce electroweak field, and deformations in the additional “nuclear” dimensions induce the strong field. Although the original extra-dimensional deformations cannot be directly detected in the 4D spacetime, they do induce certain secondary effects that can be detected as the 4D electromagnetic and strong fields.

Although the GPI requires a more complex spacetime description, it supports the reduction of the elementary set down to the four "natural elements" as predicted (see §1). As a bonus, it predicts additional three types of "pure" gravitational OST deformations, which can explain the dark matter. Then, the elementary set should include the nine components (Fig. 3).

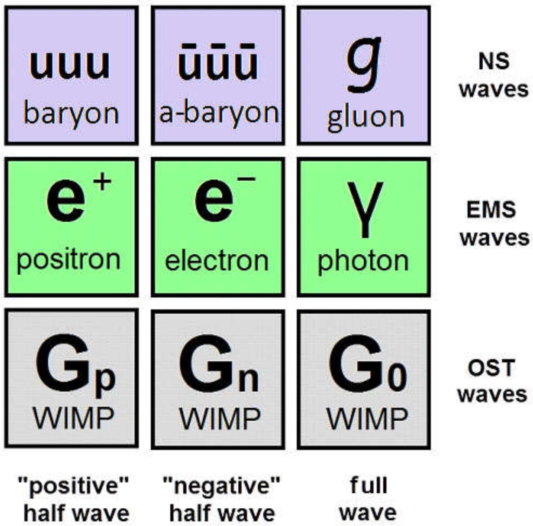

Figure 3: The GPI-based complete set of elementary wave-like spacetime deformations [7]. Top row: elementary deformations of the "nuclear" part of the "extended" spacetime responsible for strong interactions (three-letter notifications reflect three-dimensionality of the deformations), middle row: elementary deformations of the fifth extra dimension responsible for electroweak interactions, bottom row: hypothetical elementary deformations of the 4D spacetime matching the definition of WIMPs (weakly interacting massive particles). Left column: "positively-curved" solitons (positive half-waves), middle column: "negatively-curved" solitons (negative half-waves), right column: combined solitons (full waves). Each full wave consists of the two half waves (i.e. g = uuuūūū, $\gamma = e^+e^-$, and $G_0 = G_pG_n$).

A successful theory "beyond the SM" should satisfy the three conditions: 1) unify all four types of interaction possibly including the SM and the GR as limiting cases; 2) have greater explanatory and predictive powers; 3) be formulated in a simplest possible way. The GPI-based unified field theory promises to satisfy all these conditions [7]. The GPI and the concept of extended spacetime ensure the full unification of all forces (condition #1) with overall simplification of the main concept (condition #3). The GR will be included as a limiting case for the 4D spacetime with no torsion. Although the SM cannot be included as a limiting case due to the rejection of the gauge transformation principle, the unified theory has to use the quantum field methodology essentially repeating or matching all major calculations. For instance, the GPI-based electrodynamics should be able to repeat the major achievements of the quantum electrodynamics but avoiding the renormalization problem [7]. By describing the electron and the positron as certain “geometrical” waves in the “unseen” fifth dimension, it seems possible to construct the GPI-based theory of electromagnetism as a minimal extension of the Einstein-Cartan (EC) theory in 5D spacetime [7]. This theory will be quantized naturally with the assumption of integer wavelengths of the extra-dimensional “geometrical” waves. Notably, this theory cannot be classical like Einstein’s unification theories [8, 9] used the Kaluza’s brilliant mathematical description of the fifth dimension, but were limited by the cylinder condition [10]. Due to the “unseen” nature of the fifth dimension, both the 5D geometry and the 5D electromagnetic field are undetermined in principle and thus require complex operator-based mathematical descriptions, i.e. the methodology of quantum electrodynamics. It is expected that the GPI-based electrodynamics will be able to describe the electron motion with a form of Klein-Gordon equation [7]. A similar approach can be used to construct a GPI-based chromodynamics by extending the theory with additional “nuclear” dimensions [7].

Thus, the Einsteinian concept of curved spacetime (extended with extra dimensions) seems very useful for the full unification. Below, we analyze whether the GPI-based approach will actually increase the explanatory and predictive powers (condition #2).

3. Discussing the future advantages

Although the mathematical development of the unified GPI-based theory remains an open question, it is nevertheless useful to analyze the main philosophical aspects and predictions of the GPI-based approach. Below, we discuss how this approach would simplify and clarify basic understandings of interactions, energy, vacuum, and matter; whether it can solve philosophical problems of quantum field theories and explain the dark matter and energy.

3.1 Wave-particle duality. Historically, physics tended to describe sub-atomic objects as point-like particles. However, all the elementary particles show wave-like behavior (e.g. diffraction, interference, De Broglie's wavelength). A classic example of the wave-particle duality is the double slit experiment with electrons. The electrons passing through the slits interfere as waves, but each electron produces a discrete point (as a particle or quantum) while detected on the screen. In general, the main argument for the particle nature of subatomic objects is their quantization. However, a quantum still can be a wave. If electrons are described as standing waves (localized in the atom) or solitons (while propagating), they can be quantized with the assumption of integer wavelengths. With the GPI-based approach (see §2), the electrons should be described as wave-like vacuum deformations in the fifth dimension [7] that can be "seen" as the "electron clouds" in the 4D spacetime, and are indeed detected in the hydrogen atom [11]. This definition excludes the particle description.

3.2 Quantum peculiarities. The convenient interpretation of Schrödinger equation states that the wavefunction is not generally associated with any real physical wave but is proportional to the probability of finding the particle in a certain position [12]. This explanation causes a core discrepancy: an "unreal" wavefunction describes a real particle. When the peculiar properties of the wavefunction are transferred to the particle's behavior, it provokes a number of confusing concepts of philosophical significance, such as uncertainty, wavefunction collapse, and the observer's influence [13]. All these issues are still being debated without an ultimate consensus. Allowing these concepts "as is" may be dangerous, as it leads to a general rejection of determinism and causality, the fundamental philosophical rules supporting all modern sciences. Luckily, the GPI-based approach (see §2) does promise a simple solution. For any 4D observer, the electron is an "unreal" wave as it originates in the "unseen" extra dimension (see §3.1), and hence only an "unreal" wavefunction can describe it. This change of the basic definitions simply explains the quantum peculiarities from a strictly deterministic position. The "unreal" behavior of the wavefunction actually reflects the "unreal" nature of the electron, which requires one to imply the complex operator-based mathematics in order to account for the "hidden" fifth coordinate. Thus, the Schrödinger's wavefunction is actually a way to describe the "unreal" electron presented as a wave in the fifth dimension. Due to the impossibility to measure the actual 5D parameters of this wave, a 4D observer may only obtain its 4D projection parameters, which are always incomplete. This explanation answers the Einstein's famous question about the "hidden parameters" in quantum mechanics [14]. Similar reasoning should be generally applied to the strongly interacting particles assuming that quarks and gluons are three-dimensional waves originating in the "nuclear" part of the spacetime. Thus, by postulating the undetectability of extra dimensions, the peculiarity of the quantum world gets a purely deterministic explanation.

3.3 Uniqueness of the laws. The main criticism of the philosophical models trying to explain the paradoxes of quantum mechanics is focused on the inability to generally preserve determinism and locality. The Copenhagen interpretation [13] has rendered the probability to be treated as a natural property of the quantum objects rejecting the determinism in general. The two unpleasant consequences of this assumption are: 1) particle interactions are non-local (e.g. famous EPR paradox [14]) and 2) an observation is inevitably subjective (i.e. any measurement induces wavefunction collapse, therefore, changing actual particle's parameters). These difficulties can be resolved with the GPI-based approach (see §3.2) or with the Everett many-worlds interpretation [15]. The latter, however, leads to the admittance of tremendous complexity of the "multiverse" and impossibility to describe our Universe in a unique way (in terms of basic laws of physics). Thus, the probabilistic nature of the quantum world is not removed but rather transferred from one level (observational probability) to another (probability of laws of physics). The GPI-based approach explains the incompleteness of quantum laws by the undetectability of the extra dimensions, as the observer is bound to the 4D spacetime. Thus, the introduction of "unseen" extra dimensions secures the both important philosophical conditions: 1) preservation of determinism and locality, and 2) preservation of uniqueness of the laws of physics, thus overcoming both the above-mentioned interpretations.

3.4 Renormalization. Certain types of quantum field calculations that should match with the finite experimental values actually give infinite numbers. In quantum electrodynamics, these unpleasant infinities can only be removed by a certain *ad hoc* procedure, the renormalization. The convenient interpretation states that when particles interact, the vacuum creates an infinite number of virtual particle pairs. The infinite number of interactions of the electron (or photon) with these virtual particles inevitably leads to the calculational infinities requiring renormalization. The GPI-based approach rejects the gauge transformation principle and consequently renders the existence of virtual particles unnecessary, thereby removing the renormalization issue as a matter of course [7].

3.5 Particle's masses. One of the main SM flaws is the requirement the *ad hoc* Higg's mechanism in order to explain particles' masses. With the GPI-based approach particles' masses may come naturally. Assuming that the three subspaces of the "extended" spacetime have a certain hierarchy, any deformation of its "nuclear" part always induces a secondary deformation in the fifth (electroweak) dimension, and any electroweak deformation, in turn, induces a secondary deformation in the 4D spacetime. Thus, all quarks have "induced" electric charges and masses, and all charged leptons have "induced" masses. On the other hand, gluon (g = uuuūūū) and photon ($\gamma = e^+e^-$) cannot have masses as they induce average (in time) deformations of zero (as the deformations induced by their two parts cancel each other).

The avoidance of Higg's mechanism does not reject the fact of a new particle discovery interpreted as the Higg's boson [16]. As a possibility, the 126 GeV intermediate could be an excited state of a baryon (uuu, uud or udd) bound to an energetic gluon responsible for its elevated observed mass (mass-energy).

3.6 Dark matter and dark energy. Notably, the SM completely lacks an ability to explain the dark matter and dark energy, which together account for the vast majority of the total energy of the Universe. The GPI-based approach again may lead to some interesting suggestions. The reduced list of six truly elementary particles (see §1) seems incomplete without elementary wave-like deformations of the 4D spacetime, i.e. "gravitational charges". By assuming such elementary 4D deformations (which are not induced by any extra-dimensional deformations), one may present a set of purely gravitational objects being perfect candidates for the dark matter. Those three hypothetical types of gravitational waves (one “positive”, one “negative”, and one combined) compliment the complete set of GPI-compatible elementary objects (Fig. 3). Such gravitational waves (or solitons) indeed satisfy the both conditions for being dark matter: 1) coldness and collisionless, 2) stability. Due to the lack of electric and “color” charges, they can interact only gravitationally thus assuring the first condition. The second condition is also satisfied in case the Universe contains only one type of these gravitational waves or a combination of either one “charged” and the “neutral” gravitational waves. The latter case seems preferable by the analogy with the electron/photons abundance and the baryon/gluon abundance in the Universe.

Dark energy is the most tantalizing mystery of the Universe. It only reveals itself at a very large (cosmological) scale and accounts for about 70% of the total energy of the Universe. It is also called the vacuum energy, as it cannot be associated with any type of matter. The most common explanation for the dark energy is a constant energy density evenly distributed throughout the space, also called the cosmological constant or lambda. The observational data from a number of various space experiments had revealed that the cosmological constant value is an unimaginably small, yet non-zero number [17]. That creates a mystery of how such “fine tuning” was possible at the Big Bang stage, especially considering the probabilistic nature of the initial quantum fluctuations. The SM does not explain either the nature of the dark energy or the “fine-tuning” problem. With the GPI-based approach, however, the both questions can be answered in principle.

Obviously, dark energy has a gravitational nature; hence, it is created by a certain type of vacuum deformation. One possible explanation is that the dark energy is induced by 4D torsion. As torsional deformation is typically associated with the rotational movement, the 4D vacuum torsion may reflect the fact that the whole Universe slowly spins. Notably, the unexpected alignment and preferred handedness of galaxy spins observed astronomically [18] can be considered as an argument for the spinning Universe. However, torsion in the 4D spacetime typically has a very little gravitational effect and may not be enough to explain the lambda. Another explanation is that the lambda in the 4D spacetime is induced by the geometry of the 5D vacuum (in the case of high background deformation of the EMS) [7].

3.7 Ultimate unification. The main general advantage of the GPI-based approach is the simple universal understanding of interaction providing a self-consistent deterministic basis for the full unification [7]. As shown above, it is sufficient to explain all types of forces and energies (including the dark matter and the dark energy). Moreover, it goes even deeper unifying matter, energy, and vacuum at a deeply fundamental level.

Assuming that each kind of matter is a certain type of geometrical alteration of the "extended" spacetime (i.e. an elementary wave-like vacuum deformation), one may conclude that the Universe contains nothing but vacuum, empty spacetime altered geometrically. This leads to a universal definition of energy as an increased vacuum deformation (curvature and/or torsion). Postulated separation of the three parts of the "extended" spacetime ensures separation of the three types of forces (strong, electroweak, and gravitational forces). The number of fundamental fields consequently reduces to just three fields defined as geometrical deformations of the three distinct subspaces of the "extended" spacetime.

This concept leads to a revised description of the Big Bang. At the beginning of the Universe, the spacetime was compactified down to a very small (but finite) size. At that state, all spacetime dimensions were forming a symmetrical manifold with all dimensions equal and only one universal interaction present. However, extreme deformation (i.e. high energy) of this "primordial ball" had forced it to "unroll" some of the dimensions thus creating the present inequality and separation of the three subspaces. At present, the 4D spacetime has expanded to a flat (or almost flat) state, the fifth dimension responsible for the electroweak interactions has expanded less (and has a certain remaining background curvature), and the other three dimensions responsible for the strong interactions have remained compactified.

4. Conclusion

The materialistic reductionistic analysis of the SM suggests a promising direction for the development of an ultimate unified theory as an extension of the EC in the 8D spacetime [7]. Although detailed mathematical description and analysis of this unified field theory are not given, the GPI-based approach simplifies and unifies the basic concept of interaction at all levels. Additionally, it supports the reduction of the SM set of elementary objects. The analysis of the main philosophical aspects of the GPI-based approach reveals a great potential for solving all the core philosophical problems of modern theoretical physics (see §3). The GPI-based approach does come with a price requiring highly complex mathematical methods and serious revisions of the philosophical foundations of the quantum physics (including rejection of the gauge transformation principle, the existence of virtual particles, and the background-dependent formulations). In return, it shows the way to build a self-consistent universal theory of interaction based solely on the geometry of the "extended" spacetime and combining the quantum field mathematical descriptions of the extra-dimensional interactions (generally similar to the SM) with the classic field descriptions of the gravitation (the GR and the EC).

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