An Alternative Model for Cosmology and Particle Physics

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1. Introduction

All existing or once existed models for cosmology are based on a fundamental belief that the pressure of non-relativistic matter is approximately zero while that of radiation is one third of its energy density. It is true as long as the boundary of the spatial region in our question is practically static. However, when we are interested in the energy balance between our observable universe and its exterior, all internal forces cancel out. The only legitimate viewpoint is to focus on how all the constituents of our observable universe interact with its cosmological event horizon, which is receding not only from us at the speed of light, but from all its constituents alike, according to the special relativity. Now the effective pressure of all types of energy exerted at the cosmological event horizon shall be uniformly negative one third of their energy density, as the situation can be rightly regarded as a reversed case of photon gas. According to the Friedmann equation, such a universe whose pressure is negatively one third of its energy density should expand at a constant pace instead of accelerate or decelerate, which is the first astonishing possibility we would like to point out in this paper. The fact that the current Hubble radius is $\sim 10^{60}$ times of the Planck length while the current energy density of the universe is $\sim 10^{-120}$ times of the Planck density strongly supports our proposal in which the energy density of the universe shall be proportional to the inverse square of its radius according to the Friedmann equation. Note that this relationship applies to black holes as well, as a general feature of all gravitational systems. It is too unlikely (and too naïve to believe) that we are living in a miraculous era when the density of ordinary matter, dark matter and dark energy meet at roughly the same order.

Another dogma that has long been believed is that throughout the cosmic expansion, the number of baryon and lepton are both conserved and the mass of elementary particles remain constant. However, scrutinizing carefully, we may find that it is theoretically impossible for both of them to be true at the same time. Unless the pressure of those fermionic matter is exactly zero, or there is a miraculous mechanism structurally assures that the decrease of their total energy due to their slightly positive pressure (since $\rho \propto a^{-3(1+w)}$, according to the Friedmann equation) to be exactly compensated via interactions with other types of energy, the evolution of the mass density of those fermionic matter in a dynamic universe cannot be exactly proportional to the inverse cube of the cosmic scale factor. In short, the current cosmology rests on two incompatible premises. At least one of them must evolve in accordance with the cosmic expansion, which is the second astonishing possibility we must point out. All previous attempts to explore the possibility that certain physical constants may vary over time, including Sir Paul Dirac's well-known proposal [1], have been unsuccessful so far. However, we should not consider the matter settled. On the contrary, from the aforementioned perspective, this question deserves our serious attention. Studies on the Oklo natural nuclear fission reactor implied that the fine structure constant α remains a true constant for billions of years (thus is highly likely to be constant throughout the cosmic history) [2]. However, they still cannot exclude the possibility that the building blocks of α may coordinately evolve underneath in a latent manner.

It is well-known that the powers of $\sim 10^{20}$ play a pivotal role in the so-called hierarchy problems of theoretical physics. Firstly, $\sim 10^{40}$ is the magnitude gap between electromagnetism and gravity. Secondly, the Hubble radius, Hubble mass and Hubble time are respectively $\sim 10^{60}$ times of their Planck-scale counterparts. Thirdly, the notorious Eddington's number is $\sim 10^{80}$. And lastly, the Planck density is $\sim 10^{120}$ times of the energy density of the universe. Instead of asking why those figures differ from the scales we are familiar with by such astounding orders, the right question might be: What kind of mechanism may allow them to evolve synchronously such that their present values are not special?

We all celebrate that cosmology has long entered the era of precision. However, it does not guarantee accuracy, as Jim Peebles famously cautioned [3]. His warning is now more prescient than ever before in light of the persistent Hubble tension which shows no sign of resolution. On the contrary, the crisis is rather deepening [4], urging us to fundamentally re-examine our existing cosmological models, and even raising the unsettling possibility that neither side of the tension holds the true answer.

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On the other hand, turning our eyes to particle physics, though the standard model boasts an unmatched power in predicting the outcomes of high energy collision experiments, the majority of theoretical physicists refuse to accept it (more like a 21st century revival of the Ptolemy's epicycle with tens of God given parameters) as the final destination of our scientific exploration for the holy grail in the subatomic world. Moreover, how to understand (not philosophically but purely physically) the inherently probabilistic quantum mechanical phenomena remains an active battle field of intense debates.

Again, we would like to point out another simple but often over-looked fact that the concept of entropy and the second law of thermodynamics as explanation for the arrow of time, when scrutinized carefully enough, is actually contradictory with the existence of physical laws in the first place. If we can distinguish particles of the same kind by the tiniest difference, there can no longer be any high entropy or low entropy state at all. Being totally unable to relate two particles in a couple of time-lapse snapshots (namely, two observations), one as precursor, the other as descendant, the notions of trajectory or history of a particle just become nonsense. Thus, any physical law that is believed to govern the motion of particles shall merely be our wishful illusion, at best.

How can elementary particles that are too slim to have any deeper inner structure respond to gravitational fields described by second partial differential equations or gauge fields governed by unitary Lie groups? This was the central idea when John Wheeler came upon with his famous catch copy "Law without law", about 40 years ago [5]. 6 years later, he conceived another popular catch copy "It from bit" [6], realizing that all kinds of existence can only be defined in contrast to non-existence, and that all physical realities can be reduced to a collection of binary choices between 0 and 1 of ultimate abstraction. However, in this paper we propose that it is not the bit information carried by the binary digits, but instead the degree of spatial asymmetry of such a binary digital field that gives rise to all physical realities.

2. Theoretical Preparation

Suppose there is a field comprised of discrete cells that take value of either $+1$ or -1 (namely, two opposite states) with equal probability (1/2 each), and that two adjacent cells in opposite states would annihilate each other, erasing both of their values back to zero. It follows from the well-established mathematics of Bernoulli trials that we can expect a surplus favoring one side over the other by a magnitude proportional to the square root of the total number of cells, which cannot find partners for annihilation. It is noteworthy that such a stochastic symmetry breaking is rightly a spontaneous symmetry breaking, since the asymmetrical outcome is inevitable from a totally symmetric theoretical setup. Let us simply denote the surplus side as 1, hereafter. Finally, there will be a binary field comprised of 1 and 0. A field with perfect symmetry where all its constituent cells (spatial quanta, hereafter) take value 0 instead of 1, has nothing existent in it. Physicists have no need to worry about such a deadly quiet universe with no subjects at all, and there is no room for physics in the first place. We can take such symmetry breaking as granted, without asking "Why does the symmetry breaking occur?", which should rather be a question of theology.

It is equivalent to regard the surplus as a probabilistic flip of a spatial quantum from its ground state to excitation state, which is more convenient for our discussion hereafter. The field should have 3-D, 2-D and 1-D probability of quanta flipping from 0 to 1, namely, per how many quanta on average do we need to search in 3-D, 2-D or 1-D space in order to hit another 1 as the closest neighbor of the existing one. We can quantify the degree of symmetry breaking in the binary field, using the mathematics of exponential distribution with a 1-D probability density function $f(x) = \lambda e^{-\lambda x} = (e^{-x/L})/L$, where $L = 1/\lambda$.

No matter how complicated a specific configuration might be, and regardless of the number of spatial dimensions of the binary field, it can be ultimately broken down to a collection of bilateral pairs of 1 (quanta pair, hereafter). The extreme abstractness of the spatial quantum, as we postulated, leads that all flipped ones must equally take the value 1 (there are no values such as 1.5 or π). Since every pair has two flipped quanta alike, the distance between them is the only variable to distinguish those pairs. The mathematics of exponential distribution dictates that the distance (length, hereafter, measured in multiples of a unit length we will introduce shortly) between two flipped quanta shall have an expectation $E(x) = 1/\lambda = L$, and upside accumulative probability $P(x \geq R) = e^{-\lambda R} = e^{-R/L}$. The natural logarithm of the upside accumulative probability, a calculation qualitatively equivalent to that of entropy, gives a linear function of R, which can be utilized to quantify the rareness of a specific quanta pair out of the total population, as the asymmetry the pair has added to the binary field.

$$S(R) \coloneqq \ln P(x \geq R) = -\frac{R}{L} \tag{1}$$

In addition to S(R) which is proportional to the length, it is now natural to define another barometer that is inversely proportional to the length. Let us assign coefficients as below, somehow all of sudden but of course for good reasons.

$$T(R) \coloneqq -\frac{R}{c} \propto S(R) \propto R \tag{2}$$

$$E(R) \coloneqq -\frac{\hbar c}{2R} \propto R^{-1} \tag{3}$$

such that

$$E(R)T(R) = \frac{\hbar}{2} \tag{4}$$

As the evidence supporting our proposal will be introduced later, E(R) and T(R) are highly likely to be the origin of time and energy respectively. The stochastic breaking of spatial symmetry in the binary field creates negative wells of time and energy, which await to be leveled up in the direction of entropy increase. E(R), as a potential energy, its negative gives rise to the energy of the particle defined by a quanta pair with length R.

It is highly likely that what the quantum mechanical wavefunction eventually describes is nothing but the probability density of the flipping of spatial quanta. The circulating phase of the wavefunction in an abstract complex space shall represent the stochastic transition of the state value of a spatial quantum between the binary choices. The reason why it is the squared amplitude of wavefunction that dictates the probability density to detect a fermion, is due to the very fact that fermions are defined by two flipped quanta. Two flips have to occur simultaneously in the vicinity of a specific locus. Neither can we define the degree of asymmetry using only one flipped spatial quantum (without knowing how it is isolated from its closest flipped neighbor), nor do we need three or more flipped quanta (as mentioned, no matter how complicated a configuration of flipped quanta might be, it can be broken down to bilateral relationships). Therefore, quanta pair is both the minimal and the most reasonable unit for us to focus on.

Given that the potential energy of a quanta pair is defined inversely proportional to their length, the force acting between any two spatial quanta, from the definition of force as the negative gradient of potential energy, shall be inversely proportional to the square of the length, regardless of the number of spatial dimensions. It is this very nature of the interaction between spatial quanta that ultimately rules that only 3-dimensional binary field can stably and self-consistently exist, instead of the reversed logic that has long been wrongly believed.

$$F = -\nabla E(R) = -\frac{\hbar c}{2R^2} \tag{5}$$

The negative sign suggests the force is universally attractive. As the final result of such an attraction, we may expect a situation in which two back-to-back quanta form a kind of binary star system with a diameter twice the expanse of a spatial quantum. The diameter of spatial quanta ($\widehat{D}$, hereafter) can be reasonably calculated supposing if two spatial quanta are brought within a spherical region with diameter $\widehat{D}$, they will instantly form a mini-black hole according to our definition of energy. In other words, $\widehat{D}/2$ is rightly the Schwarzschild radius of a black hole with energy $-E(\widehat{D})$.

$$M(\widehat{D}) \coloneqq -\frac{E(\widehat{D})}{c^2} = \frac{\hbar}{2\widehat{D}c} \tag{6}$$

$$\frac{\widehat{D}}{2} = \frac{2GM(\widehat{D})}{c^2} = \frac{G\hbar}{\widehat{D}c^3} \quad \rightarrow \quad \widehat{D} = \sqrt{\frac{G\hbar}{2c^3}} = \frac{l_{PL}}{\sqrt{2}} = 1.14 \times 10^{-35}[\mathrm{m}] \tag{7}$$

From now on, $\widehat{D}$ serves as the minimal indivisible length unit in the binary field, accompanied by a series of quantized mass as integer partitions of a unit mass $\widehat{M}$ defined in below, corresponding to the possible discrete binary star systems whose diameter is only allowed to be multiples of $\widehat{D}$.

$$\widehat{\mathrm{M}} := -\frac{\mathrm{E}(\widehat{\mathrm{D}})}{\mathrm{c}^2} = \frac{\hbar}{2\widehat{\mathrm{D}}\mathrm{c}} = \frac{\mathrm{m_{PL}}}{\sqrt{2}} = 1.54 \times 10^{-8}[\mathrm{kg}] \tag{8}$$

3. Particle Physics Part

The hierarchy gap between the magnitude of electromagnetic force and gravity, in the extreme case, namely, the electron-electron interactions, is $e^2/4\pi\varepsilon_0 G m_e^2 = 4.16 \times 10^{42}$. The final culmination of the aforementioned binary star system has a diameter of $2\widehat{D}$ and thus a combined mass of $\widehat{M}/2$. Since each spatial quanta occupies 1/8 of the volume of the sphere with diameter $2\widehat{D}$, it is reasonable to postulate that each quanta carries a mass of $\widehat{M}/16$, thus shall rotate around each other at a speed of $c/4$ according to Newtonian calculation.

$$\frac{G\frac{\widehat{M}}{16}}{\widehat{D}^2} = \frac{v^2}{\widehat{D}} \quad \rightarrow \quad v = \sqrt{\frac{G\widehat{M}}{16\widehat{D}}} = \frac{1}{4}\sqrt{\frac{Gm_{PL}}{l_{PL}}} = \frac{c}{4} \tag{9}$$

Suppose there is a tiny seed within each of the mass lump $\widehat{M}/16$, upon which a much stronger repulsive force (whose magnitude exactly equals to that of electromagnetic force) is acting to balance with the gravity between the spatial quanta. Then, we may find that the combined mass of the two seeds, $2\widetilde{m}$, is very close to the electron mass m_e being inversely adjusted by the Lorentz factor of $c/4$, which is unlikely to be a mere coincidence. (The reason why our detectable rest mass of electron needs an inverse Lorentz adjustment from $2\widetilde{m}$ will be revealed shortly.)

$$G\left(\frac{\widehat{M}}{16}\right)^2 = 4.16 \times 10^{42} G\widetilde{m}^2 \quad \rightarrow \quad 2\widetilde{m} = \frac{\widehat{M}/8}{2.04 \times 10^{21}} = 9.43 \times 10^{-31}[\mathrm{kg}] \approx \frac{m_e}{\sqrt{1-\left(\frac{1}{4}\right)^2}} \tag{10}$$

It is highly likely that electric charge as a vector physical property is rightly rooted from this rotating motion of spatial quanta pair. The two mass lumps acquire electric charge of the same sign, by rotating around each other in a synchronized mode at a speed of $c/4$. (In a 3-dimensional space, there are two essentially distinct modes of rotation whose axis may be tilted toward any arbitrary direction. For example, name the three spatial dimensions as X, Y and Z. Take a unit vector pointing the north pole of the axis of rotation (in whose eyes the rotation of the two spatial quanta looks counter-clockwise), if the values of its X, Y and Z components in descending order are X-Y-Z or Y-Z-X or Z-X-Y, then define the rotation mode as positive, for the other three cases, X-Z-Y or Z-Y-X or Y-X-Z, define the mode as negative.)

It is this electromagnetic repulsion instead of centrifugal force (which is rather a notion of classical mechanics that probably does not exist in such a quantum mechanical scale) that the universal gravitation between the mass lumps is actually acting against. Moreover, as will be revealed shortly, the rotation and its velocity are imaginary. Unlike their counterpart used to describe detectable particles, they are rather concepts that belong to an abstract space to describe the behavior of spatial quanta, which is hidden in a deeper layer beneath our observable realities.

Note that the hierarchy gap we adopted here was actually the extreme case, between the electron-electron interactions, instead proton-proton interactions. Similar calculation does hold in the latter case, however, as we shall see later, it is the hierarchy gap between electron-electron interactions that turns out to be the key to unveil the secret behind gravity and electromagnetism. Just as we could have never found the relationship between the Planck-scaled physical quantities and that of elementary particles, as long as we only pay attention to the Planck length and the Planck mass without the critical divisor $\sqrt{2}$.

As mentioned earlier, the flipped quanta could be regarded as the unannihilated surplus after a series of Bernoulli trials choosing one out of two opposite states with 50%:50% probability. Keeping in mind that the increase of the total number of spatial quanta within our universe is a gradual process, layer by layer as the cosmological event horizon expands, let us see how the probability of quanta flipping may evolve over time. Suppose that at a specific cosmic age, the Hubble radius is N times the diameter of the spatial quantum ($N_{now} \sim 10^{60}$). Then, on the surface of the cosmological event horizon at that specific cosmic age, there should be a number of spatial quanta proportional to N^2. According to the mathematics of Bernoulli trial, the expected surplus should be proportional to its square root, namely, N. An integral over N up to N_{now} gives a total number of flipped quanta proportional to $N_{now}{}^2$, thus the averaged 3-D probability of quanta flipping should always be inversely proportional to N_{now} ($N_{now}{}^2$ divided by $N_{now}{}^3$), and the 1-D probability shall be inversely proportional to the cubic root of N_{now}.

The magnitude gap between gravity and electromagnetic force shall be a reflection of the very fact that the current 1-D probability of quanta flipping is $1/(2.04 \times 10^{21})$, the inverse square root of 4.16×10^{42}. In other words, the L in the aforementioned exponential distribution is $2.04 \times 10^{21}\widehat{\mathrm{D}} = 4.65 \times 10^{-14}[\mathrm{m}]$, currently. The above calculation of the mass of electron suggests that it is always of the order of $\widehat{\mathrm{M}}$ (the divisor 8 is qualitatively unimportant here) multiplied by the 1-D probability of spatial quanta flipping. We will explain later how the mass of proton can be obtained via a similar mechanism.

Let us present some profoundly interesting and non-negligible facts that support the validity of our hypothesis, though we do not have concrete enough physical images of what is actually happening behind the calculations.

1) <u>Mean lifetime of free neutron</u>

Taking the figure τ_{beam} ≈880 [s] measured by the so-called beam method, it shall hardly be a coincidence that

$$\frac{\pi\widehat{\mathrm{D}}\dfrac{m_n}{\widetilde{m_e}}}{c\tau_{beam}} \approx \left(\frac{1}{2.04 \times 10^{21}}\right)^2 \tag{11}$$

where m_n is the rest mass of neutron, $\widetilde{m_e}$ is the relativistic electron mass adjusted by Lorentz factor of $c/4$. This calculation implies that beta-decay (and maybe the weak interaction in general) might be a phenomenon which is rightly characterized by the stochasticity of the stochastic symmetry breaking in the binary field.

Moreover, there is a well-known conundrum that the mean lifetime of free neutrons measured by the so-called bottle method is $\tau_{nbottle}$ ≈887 [s], which is inexplicable within the range of experimental error. We noticed that this gap is a well enough approximation of the Lorentz factor of $c/8$, which is a velocity we may obtain supposing two quanta rotate with a diameter of $4\widehat{\mathrm{D}}$ instead of $2\widehat{\mathrm{D}}$. It might have something to do with the participation of two additional quanta, which cannot get closer than $4\widehat{\mathrm{D}}$ due to the existing stand-by free neutron. The case may be that in the bottle method, the focus is on those undecayed stand-by neutrons without additional quanta, while in the beam method, the focus is on the decayed neutrons thus with the disturbance from the additional quanta with velocity $c/8$, which may in turn bring about an extra mass into the system and prolong its lifetime. The discrepancy may be caused by the fact that we were actually observing two slightly but intrinsically different phenomena. We will further discuss the possible mechanism of the beta-decay based on our model in the next chapter, when the meaning of the two additional quanta and the velocity $c/8$ will become clear.

2) <u>Mean lifetime of the Higgs boson</u>

As the latest figure, $\tau_{Higgs} = 2.1(+2.3/-0.9) \times 10^{-22}[\mathrm{s}]$ agrees well enough with the calculation in below which has a clear similarity with the case of free neutron.

$$\frac{\pi\widehat{\mathrm{D}} \times 2.04 \times 10^{21}}{c} = 2.43 \times 10^{-22}[\mathrm{s}] \qquad \text{or} \qquad \frac{\pi\widehat{\mathrm{D}}/c}{2.43 \times 10^{-22}[\mathrm{s}]} = \frac{1}{2.04 \times 10^{21}} \tag{12}$$

This calculation strongly suggests that the Higgs mechanism might be a rephrase of the stochastic symmetry breaking of the binary field.

Hereafter, we will introduce the implications of our newly proposed theoretical paradigm to particle physics. Let us begin with the strong interaction. In particular, we first purely mathematically calculate the mass of up quark and down quark, and then reveal the physics behind the color charges, together with the true underlying mechanism of the asymptotic freedom or the so-called quark confinement.

As mentioned earlier, our calculation that has implied the possible mechanism letting electron behave as an electric charge applies to proton as well, by adopting the hierarchy gap of proton-proton interactions. The fact implies a mass-independent general relationship which can be put into the equation in below.

$$\frac{e^2}{4\pi\varepsilon_0\left(\frac{\hbar}{2\times 2\tilde{m}_e c}\right)^2}\approx\frac{Gm_e^2}{\left(2\widehat{D}\right)^2} \tag{13}$$

It suggests that the electromagnetic repulsion between two elementary charges separated by a distance correspondent to the energy required for a pair production of two Lorentz adjusted masses (by the factor of $c/4$) always balances with the gravitational attraction between the rest masses sitting at a distance of $2\widehat{D}$. Such a mass-independent relationship can be simplified into a more general form, which may have revealed the secret behind the fine structure constant. $1/\alpha\approx 137.036$ is highly likely to be 128 adjusted by the square of the Lorentz factor of $c/4$, probably plus some higher order refinements.

$$\frac{e^2}{4\pi\varepsilon_0}\approx\frac{\hbar c}{128}\left(1-\left(\frac{1}{4}\right)^2\right)\quad\text{or}\quad 128\alpha\approx 1-\left(\frac{1}{4}\right)^2 \tag{14}$$

As another implication from the equation, the inversely proportional relationship

$$\frac{e^2\left(2\widehat{D}\right)^2}{4\pi\varepsilon_0}=Gm^2\left(\frac{\hbar}{4\tilde{m}c}\right)^2=\text{const.} \tag{15}$$

hints that if the $2\widehat{D}$ part of a particle were altered for some reason, the remaining $e^2/4\pi\varepsilon_0$ part that governs the strength of electromagnetic force exerted by that particle should also change accordingly to make ends meet.

As for how could the $2\widehat{D}$ part be variable, the first idea came up to our mind was that the mechanics of rigid body is much richer than that of mass point. What if proton and neutron are a kind of rigid-body-type particles while electron is a mass-point-type particle? Note that we have already excluded the concept of zero distance in our binary field, therefore, even for mass points, they still have a minimal diameter of $2\widehat{D}$ (consists of two spatial quanta). Point just means they do not have any rotational degree of freedom. Moreover, we may reasonably postulate that the span of a rigid-body-type degree of freedom is π times that of a mass-point-type one, as if the latter is locked in its diameter instead of its circumference.

During high energy hadron collision, suppose that smashed nucleons may instantly degenerate one or two of its rigid-body-type degree of freedom to mass-point-type. If we define an effective span of a particle by taking the geometric average of the span on all the three dimensions,

1 dimension degenerated $$\sqrt[3]{\frac{\left(2\pi\widehat{D}\right)^2 2\widehat{D}}{\left(2\widehat{D}\right)^3}}=\pi^{2/3}$$

2 dimensions degenerated $$\sqrt[3]{\frac{2\pi\widehat{D}\left(2\widehat{D}\right)^2}{\left(2\widehat{D}\right)^3}}=\pi^{1/3}$$

these fractional powers of π indicate how bulgy the partially degenerated rigid-body-type particle still is, compared with their genuine mass-point type counterpart. The inversely proportional relationship implies that a larger effective span shall diminish the electromagnetic reactivity of a particle. Thus, each partially degenerated state of nucleon shall respectively have an inferior electromagnetic reactivity by a factor of $1/\left(\pi^{2/3}\right)^2=1/4.60$ and $1/\left(\pi^{1/3}\right)^2=1/2.15$ respectively, compared with mass-point-type electrons. Suppose that two spatial quanta evenly contribute to the electromagnetic reactivity of the fermion that they collectively define, each spatial quantum would have an electromagnetic reactivity further inferior to that of electron, by factors of $1/9.2$ and $1/4.3$ respectively. A lesser electromagnetic reactivity means a larger mass is required to behave as an electric charge, thus the theoretical mass of a singular spatial quantum in the partially degenerated rigid-body-type particles shall be 9.2 and 4.3 times of the mass of electron (0.511MeV), respectively. They are exactly the theoretical mass of the valence down (~4.7MeV) and up (~2.2MeV) quark!

The discussions so far strongly suggest that the entity of quark might be one of the two spatial quanta within a partially degenerated rigid-body-type particle (i.e. hadron) during high energy collision. They transiently interact with one of the two spatial quanta that collectively define the bullets (i.e. lepton), and let them scatter. Quark, as a singular spatial quantum in transiently degenerated hadrons, can only exist together with its partner spatial quantum. The notion of quark does not make sense outside of hadrons. After all, detectable fermions are defined by a pair of spatial quanta, there is simply no such things as independent quark. This shall be the secret of the so-called quark confinement.

The color charge of quark might be a reflection of the degenerated dimension(s) in the collided nucleon. If one dimension of a nucleon has degenerated, the resulted quark has a fractional charge of $-1/3$. If two dimensions have degenerated, the charge would be $+2/3$. The alternating sign can be formulated by the powers of negative one, or the mathematics of parity (electron can be regarded as all the three dimensions have degenerated, thus has a charge of $-3/3$, in this context). For degenerated anti-nucleon, the sign of charge shall be inverted. A possible way to assign the color is shown in the below tables, just for an example. Only the colorless combination of quarks and/or anti-quarks may result in detectable hadrons that have synchronized superscript on the shoulder of X Y Z ($X^+Y^+Z^+$, $X^0Y^0Z^0$, $X^-Y^-Z^-$, $X^{++}Y^{++}Z^{++}$, $X^{--}Y^{--}Z^{--}$). In high energy (thus high resolution) collision, hadron behaves as a superposition of all possible degenerated states, and only the colorless sets make ends meet.

Proton ($X^+Y^+Z^+$)

	RED	GREEN	BLUE
uud	X^+Y^+	Y^+Z^+	Y^-
udu	X^+Y^+	X^-	Z^+X^+
duu	Z^-	Y^+Z^+	Z^+X^+

Anti-proton ($X^-Y^-Z^-$)

	anti-RED	anti-GREEN	anti-BLUE
$\overline{uud}$	X^-Y^-	Y^-Z^-	Y^+
$\overline{udu}$	X^-Y^-	X^+	Z^-X^-
$\overline{duu}$	Z^+	Y^-Z^-	Z^-X^-

Neutron ($X^0Y^0Z^0$)

	RED	GREEN	BLUE
udd	X^+Y^+	X^-	Y^-
dud	Z^-	Y^+Z^+	Y^-
ddu	Z^-	X^-	Z^+X^+

Anti-neutron ($X^0Y^0Z^0$)

	anti-RED	anti-GREEN	anti-BLUE
$\overline{udd}$	X^-Y^-	X^+	Y^+
$\overline{dud}$	Z^+	Y^-Z^-	Y^+
$\overline{ddu}$	Z^+	X^+	Z^-X^-

Next, let us unveil the secret of another key feature of the strong interaction, namely, the asymptotic freedom. As mentioned earlier, the necessity to use complex numbers in describing the dynamics of the spatial quanta may largely be due to the historical inevitability that we chose real numbers (of course not by accident) to construct the physics of the detectable particles with which we are much more familiar. Now the mathematical property of imaginary number turns out to be the final sentence to the QCD, as we have found a strikingly simple explanation for how nucleons are held together within atomic nuclei.

Imagine a homogeneous sphere with a uniformly positive charge density ρ, as an approximation of atomic nuclei. The equation of radial motion, after a simple integration (let the integration constant be zero, which is equivalent to let the conserved mechanical energy be zero, as an idealized situation) gives an equation of the velocity.

$$m\frac{d^2r}{dt^2} = \frac{1}{4\pi\varepsilon_0}\frac{4}{3}\pi r^3\frac{\rho e}{r^2} = \frac{\rho_0 r_0^3 e}{3\varepsilon_0 r^2} \quad (\rho r^3 = \rho_0 r_0^3) \quad \rightarrow \quad \frac{m}{2}v^2 = -\frac{\rho_0 r_0^3 e}{3\varepsilon_0 r} = -\frac{\rho e}{3\varepsilon_0}r^2 \quad \rightarrow \quad \frac{v}{r} = \sqrt{\frac{2\rho e}{3\varepsilon_0 m}}\,i \quad (16)$$

At first glance, the equation looks nonsense in conventional context, as the square of velocity is negative. However, being free from all kinds of prejudice, if imaginary velocity is allowed, what will happen? A direct consequence shall be that the Lorentz factor could be smaller than one. Having paved the way for quite a while, we believe that now an idea that this imaginary number velocity represents the motion of spatial quanta may not sound abrupt.

Substitute the actual figures (the elementary charge, the proton mass, the permittivity of the vacuum, half the charge density of proton as approximate average charge density of atomic nuclei) into the equation. Then multiply the resulted "Hubble constant in atomic nucleus" with $\sim 10^{-15}$[m] as the order of the radius. Surprisingly, we may notice that the imaginary velocity falls exactly to the same order with the speed of light! At such a nonnegligible velocity, the aforementioned smaller-than-one Lorentz factor would rightly result in a relativistic mass lighter than the rest mass by a few percentage points, which matches well enough with the binding energy per nucleon for those elements of double-digit atomic number. This approximation may not apply to the atomic nuclei of light elements, since their charge density shall be far from homogeneous. The imaginary velocity is proportional to the distance of nucleons from the center of the atomic nucleus. The magnitude of relativistic mass reduction (thus the level of binding energy) increases with the radius, which finally comes to an end when the imaginary velocity reaches ci. This should rightly be the underlying mechanism of the short ranged nuclear force that shares similarity with the asymptotic freedom of quarks, a concept that was earlier demonstrated to be unnecessary in explaining the quark confinement and therefore could now be completely abandoned.

As for the motion of spatial quanta within atomic nuclei, the most reasonable explanation should be that they switch their “owners” just like the free electrons in metals. It is by such a sharing of spatial quanta that nucleons reach a less massive and thus more stable state. Once the electromagnetic repulsion between protons is overcome by certain extreme conditions such as ultra-high temperature, the effect of this relativistic mass reduction would become dominant to hold the nucleus stable. The fact that there is no atomic nucleus made of electrons (while the calculation perfectly holds for negatively charged particles in a uniform negative charge density) may due to the sharing of spatial quanta can only occur among the bulgy rigid-body-type particles.

The discovery of imaginary velocities urges us to slightly correct our previous equations. Instead of multiplying the Lorentz factor of $c/4$ or $c/8$, we should divide that of $ci/4$ or $ci/4$, which do not make too much difference except we may obtain a closer approximation of the fine structure constant. We have intentionally ignored the slight difference, since the time would only be ripe at this stage to reveal the secret in behind. In short, the rest mass of elementary particles needs an inverse adjustment from pure theoretical calculation because the rest mass in our perspectives is the relativistic mass from the view point of spatial quanta, the former is always lighter than the latter due to the imaginary velocity.

$\sqrt[3]{1.5}\dot{m} \approx 1107 \rightarrow \Lambda^0$ (1116)

$\sqrt[3]{2.5}\dot{m} \approx 1312 \rightarrow \Xi^0, \Xi^-$ (1315~1322)

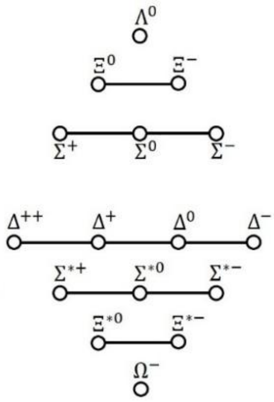
$\sqrt{1.5}\dot{m} \approx 1184 \rightarrow \Sigma^+, \Sigma^0, \Sigma^-$ (1189~1197)

$\sqrt[3]{2}\dot{m} \approx 1218 \rightarrow \Delta^{++}, \Delta^+, \Delta^0, \Delta^-$ (1232)

$\sqrt[3]{3}\dot{m} \approx 1395 \rightarrow \Sigma^{*+}, \Sigma^{*0}, \Sigma^{*-}$ (1383~1387)

$\sqrt[3]{4}\dot{m} \approx 1535 \rightarrow \Xi^{*0}, \Xi^{*-}$ (1532~1535)

$\sqrt[3]{5}\dot{m} \approx 1654 \rightarrow \Omega^-$ (1672)



The discussions so far have almost revealed major secrets of the strong force. However, without explaining the origins of the great variety of baryons and mesons, our hypothesis may not acquire full credit. Now let us cope with it. Adopting the Lorentz factor adjusted proton mass $\dot{m} \approx 967[\mathrm{MeV/c^2}]$ as one unit of standard nucleon mass in hadron collisions, we may find with great surprise that the mass of the 16 baryons (other than proton and neutron) that supposedly to consist of u/d/s quarks [7] align in an extremely simple and elegant pattern as shown in the above. It strongly implies that those baryons are highly likely to be transient states of nucleons during high energy collision, expanding one of its spatial dimensions in a discrete manner, half integer means the expanded diameter is an odd multiple of $\widehat{D}$, while integer means the expanded diameter is an even multiple of $\widehat{D}$. Compared with proton, the electromagnetic reactivity of each expanded state should be, by the same logic in our calculation of the quark mass, inversely proportional to their effective span, which explains their mass is larger than proton and neutron. The effective span should be reasonably calculated by equally distributing the span of the expanded dimension onto all three dimensions, thus the cubic roots of half-integers or integers. The reason why square root of 1.5 gives rise to sigma baryons, and why the cubic roots of integers correspond to spin 3/2 baryons while the cubic roots of half-integers give rise to spin 1/2 baryons await to be further elucidated.

Unlike the deep inelastic scattering in which physicists could only indirectly presume that nucleons have inner structures from the scattering of electrons without actually detecting any independent quark, hadron collider does actually churn out numerous detectable baryons and mesons. The difference is, the short-lived hadrons are nonetheless made of quanta pair, thus are genuine rigid-body-type particles as carriers of electric charge.

In summary, quark is one of the two quanta that collectively define a nucleon in which one or two of its three spatial dimensions transiently degenerated from the rigid-body-type degree of freedom to the mass-point-type one.

Gluon is highly likely to be the spatial quantum exchanged in transitions between those different states of degeneration. The various baryons are nucleons transiently expanded along one of its three dimensions, while mesons are highly likely to be the spatial quanta exchanged during transitions among those different states of expansion. The dazzling varieties of the cascades of hadron decay shall reflect the probable transitions among all possible states, which should be explained without problem in the context of our model.

It is interesting to note that the baryons of charm quark substitution and bottom quark substitution are roughly twice and five times massive compared with their counterparts made of only u/d/s quarks. It implies that nucleons may have three distinctive modes for the transient expansion of its spatial dimensions. One natural explanation would be that 1-dimensional expansion is the easiest, while 2-dimensional simultaneous expansion is the second easiest, and 3-dimensional simultaneous expansion is the hardest. Compared with the easiest mode of expansion that gives rise to baryons supposed to be made of u/d/s quarks, if the second and third choices may, for some unknown mechanism, result in a much weaker electromagnetic responsiveness by a factor of $\sim 1/8$ and $\sim 1/125$ (or $1/128$ or $1/136$) respectively, they will in turn give rise to baryons roughly twice and five times massive than those generated by the first mode. It is noteworthy that the ratio between the mass of tauon and muon is roughly 136:8.

Let us address the conundrum of the mass gap between proton and electron. It is well-known that $6\pi^5$ is a good approximation of 1836. Out of $1/6\pi^5$, proton as a rigid-body-type particle shall be an inferior reactor to electromagnetic force than electron by a factor of $1/\pi^2$ (since all three dimensions are rigid-body-type). The remaining $1/6\pi^3$ may be a factor reflecting a qualitative leap from mass-point-type to rigid-body-type. In other words, the logic of our calculation of theoretical mass of u quark and d quark compared with electron may only apply for particles that have at least one mass-point-type dimension. Although its mechanism needs to be further elucidated, the assumption does not sound so unreasonable either, 6 is the degree of freedom of a three-dimensional rigid body, while π^3 could be the ratio of effective volume (the product of spans over all the three dimensions) between rigid-body-type and mass-point-type particles. It is interesting to note that the theoretical mass of valence strange quark is ~ 186 times of electron mass, and 186 is a good enough approximation of $6\pi^3$.

Having accepted that protons have a weaker reactivity to electromagnetism by a factor of ~ 1836 (though we still do not perfectly understand its mechanism) such that protons need a mass rightly ~ 1836 times of electrons to behave as an electric charge, why proton and electron with such a huge difference in mass equally carry an elementary charge (what does the sign of charge ultimately mean), and how comes the asymmetry in the abundance between them and their antiparticles in the universe, remain as critically important questions that modern physics must give an answer.

In our theoretical paradigm, all physical realities can find their origin in the purely stochastic surplus out of the Bernoulli trials choosing either $+1$ or -1 with $50\%: 50\%$ probability. It is highly probable that particles in our arbitrary definition are nothing but those comprised of the surplus side, whereas anti-particles are simply those comprised of the annihilated side. Recall that in a 3-dimensional space, there are two intrinsically distinct rotation modes. Thus, one can be defined as positive, and the other as negative, unambiguously. It is then conceivable that one mode may be easier for particles to rotate, while the other is easier for anti-particles. Whether the easier mode for particles gives rise to mass-point-type or rigid-body-type quanta pair is not important here. The key is, such a difference may render the quanta pair a differed reactivity to electromagnetism, causing one type of electric charge corresponds to a heavier mass in the particle world and a lighter mass in the anti-particle world, while the other type of charge corresponds to a heavier mass in the anti-particle world and a lighter mass in the particle world.

If electron is defined by two rotating spatial quanta with value $+1$ in a mode correspondent to mass-point-type particles and negative electric charge, while proton is defined by two spatial quanta with value $+1$ rotating in the other mode correspondent to the rigid-body-type particles and positive electric charge, then what makes up neutron? A consistent explanation in line with our theoretical paradigm would be, neutron is made of two spatial quanta with value $+1$ but rotating in opposite mode, which are waiting for two additional quanta with value $+1$ also rotating in opposite mode, to break up the neutron into two particles, each of them now have synchronized rotation mode. This is exactly the underlying mechanism of beta-decay in our model. The two incoming quanta is nothing but the neutrino needed to elicit a beta-decay, which is normally described as an outgoing anti-neutrino.

The weak force is the only interaction where the number of participating spatial quanta does not conserve before and after the process. It could rather be a phenomenon that only becomes noticeable to us rightly because of the addition of newly flipped quanta to the existing physical system we had been observing. The fact that only the weak bosons possess mass may be the reflection of this non-conservation of the number of flipped quanta before and after the interaction of our question. As for why the weak interaction only acts on left-chiral particles and right-chiral anti-particles, we do not have a concrete explanation at this stage. However, it is highly probable to have something to do with the aforementioned massive weak boson and non-conservation of flipped spatial quanta.

After all, electric charge is a vectorial property generated out of the rotation of two spatial quanta as a culmination of the universal attraction between them. The strong interaction can be separated into two parts. The binding of nucleons within atomic nuclei can be explained by their sharing of spatial quanta like the free electrons in metals, where the motion of spatial quanta with imaginary velocity contributes to a relativistic mass reduction, stabilizing the atomic nucleus in the form of binding energy. Those phenomena that imply inner structures of hadrons are indeed nothing but looking at transient snapshots of collided hadrons, which should not have been even noticed unless they were smashed to each other in hadron colliders. The SU(3) symmetry in the QCD is a reflection of the fact that the three rigid-body-type dimensions of nucleons may degenerate into mass-point-type, or expand their span in a discrete manner, during high energy collision. The weak interaction should be regarded as a consequence of the stochastic symmetry breaking in the binary field, which occurs whenever two additional flipped spatial quanta are brought by the universal attraction to the vicinity of an existing particle.

Our theory explains why electromagnetism, weak force and strong force are linked with U(1), SU(2) and SU(3) groups respectively in the gauge field theory. The almighty gauge principle shall be a rephrase that homeostasis serves as the governing rule that underlies all physical phenomena. Initially, all global gauge symmetries were maintained in the perfectly symmetric field where nothing existent in it. The stochastic symmetry breaking that gives rise to physical realities corresponds to a random local phase alteration on the quantum mechanical wave function, namely, the local gauge transformation. In response to the symmetry breaking, connection fields arise, indicating how the local gauge symmetries could be achieved. The recovery of local gauge symmetries via their respective connection fields or force mediating bosons is a rephrase of the very fact that the binary field has an inherent tendency to evolve from less symmetric configurations to more symmetric ones with a higher probability of realization. The meaning of the dimension of each Lie group shall now be obvious, after the revelation of the underlying physics behind each force. The groups of abstract rotations in complex spaces describe the motion of spatial quanta that live in a deeper layer than the one the real number based detectable particles belong to. Hereby, all the fundamental interactions are unified as four aspects of a singular story based on a consistent theoretical framework, namely, the stochastic symmetry breaking of a binary field.

4. Cosmology Part

Now the time is ripe to unveil our quantum cosmological model. Adopting our view that the cosmic space is an intrinsically binary field, then, a cosmological event horizon that encloses a larger volume with more spatial quanta within it, quite understandably corresponds to a much more deterministic universe. Unlike the speed of light and the gravitational constant, the Planck constant, as a rate-limiting factor between deterministic classical physics and probabilistic quantum mechanical world, should reflect the spatial asymmetry (or in other words, accumulated complexity) of the universe, thus has good reasons to be a variable dependent on the size of the universe. Though we are unable to single out the why purely from theoretical perspective at this stage, it turns out that by postulating the Planck constant evolves in an inversely proportional manner to the cosmic scale factor, all pieces of the puzzle fit together perfectly. Besides the Planck constant, both the gravitational constant G and the speed of light c remain invariant (so do the vacuum permittivity ε_0 and vacuum permeability μ_0).

Taking into consideration the well-established experimental fact that the fine-structure constant has remained invariant throughout the history of the universe, the following is the dependence of various physical constants and key figures in our model, on the cosmic scale factor. It is important to point out that the evolution of certain physical constants in accordance with the size the universe means that every possible value shall eventually realize at a certain cosmic stage, which frees us from the mission impossible to find special meaning in their current values.

Elementary charge

$$e \propto \hbar^{1/2} \propto a^{-3/2} \tag{17}$$

Planck mass

$$m_{PL} \propto \hbar^{1/2} \propto a^{-3/2} \tag{18}$$

Planck length

$$l_{PL} \propto \hbar^{1/2} \propto a^{-3/2} \tag{19}$$

3-D probability of quanta flipping (inversely proportional to the ratio between the Hubble radius and the Planck length)

$$p_{3D} \propto \left(\frac{a}{a^{-3/2}}\right)^{-1} = a^{-5/2} \tag{20}$$

1-D probability of quanta flipping (proportional to the cubic root of p_{3D})

$$p_{1D} \propto a^{-5/6} \tag{21}$$

Mass of elementary particles (proportional to the product of the Planck mass and the 1-D probability density) (note that the mass ratio between proton and electron remains constant, $m_p \sim 1836 m_e$)

$$m_{EP} \propto a^{-3/2} a^{-5/6} = a^{-7/3} \tag{22}$$

Eddington's number (the Hubble mass divided by the mass of a nucleon)

$$N_{Eddington} \propto \frac{a}{a^{-7/3}} = a^{-10/3} \tag{23}$$

Rydberg constant

$$R_\infty \propto \frac{m_e e^4}{\varepsilon_0{}^2 \hbar^3} \propto \frac{m_e}{\hbar} \propto a^{2/3} \tag{24}$$

A smaller Rydberg constant in the past implies that the redshift z we obtain today may not correctly reflect the true expansion rate of the universe. $1 + z$ has to be reinterpreted downward to its 3/5 power. For example, a seemingly 32-fold redshift (raw $z = 31$) is indeed a spectrum emitted when the Hubble radius was 1/8 of the current length (already redshifted by 4 folds judged by today's commonsense of spectrometry) being actually redshifted by 8 folds (true $z = 7$). For small z, by simple math, the true redshift shall be 3/5 of its correspondent raw redshift.

$$1 + z_{true} = (1 + z_{raw})^{3/5} \approx 1 + \frac{3}{5} z_{raw} \quad (z_{raw} \ll 1) \tag{25}$$

By reducing the Hubble's constant to its 3/5, our hypothesis drastically lowers the critical density to its 9/25 or 36%. At first glance, this downward revision is still insufficient compared with the $\Omega_m \sim 0.31$ or $\Omega_m \sim 0.26$ obtained by WMAP and HST respectively. However, as we will quantitatively demonstrate, it is neither WMAP nor HST, but our theoretical calculation that finally resolves the Hubble tension.

Take the Hubble's constant from the latest HST result [9], $H_0 = 73.3[\text{km/s /Mpc}] = 2.38 \times 10^{-18}[\text{s}^{-1}]$, its correspondent true Hubble's constant is $H = 3H_0/5 = 1.43 \times 10^{-18}[\text{s}^{-1}]$. Thus, the current Hubble radius is $R_H = c/H = 2.10 \times 10^{26}[\text{m}]$, the current mass density is $\rho = 3H^2/8\pi G = 3.66 \times 10^{-27}[\text{kg/m}^3]$. The current Hubble mass is $M_H = 4\pi R^3 \rho/3 = 1.42 \times 10^{53}[\text{kg}]$, which is equivalent to 8.48×10^{79} times of neutron (or nucleon in general) mass.

Since the Planck length is itself inversely proportional to the 3/2 power of the scale factor, the increase of the Hubble radius as multiples of the Planck length should be proportional to the 5/2 power of the scale factor. Thus, 2/5 power of the ratio between the current Hubble radius and $\widehat{D}$ (initially, two back-to-back flipped quanta was the entire universe, the radius of the binary star system was the Hubble radius back then),

$$\frac{R_H}{\widehat{D}} = \frac{2.10 \times 10^{26}[\text{m}]}{1.14 \times 10^{-35}[\text{m}]} = 1.84 \times 10^{61} \tag{26}$$

which is 3.21×10^{24}, reflects the true expansion rate of the scale factor. Meanwhile, the Eddington's number has increased by a factor of 4.88×10^{81} ($10/3$ power of 3.21×10^{24}) from its initial value, which should be 1.74×10^{-2}. On the other hand, $1/(2.64 \times 10^{20})$ ($5/6$ power of $1/(3.21 \times 10^{24})$) is the factor by which the probability of quanta flip has decreased from its initial value. The current 1-D probability of quanta flip is the inverse square root of the magnitude gap between electromagnetic force and gravity in the electron-electron interactions, namely, the square root of $1/(4.16 \times 10^{42})$, which is $1/(2.04 \times 10^{21})$. It implies that the initial 1-D probability of quanta flip should be $1/7.73$. And astonishingly,

$$(1.74 \times 10^{-2}) \times (7.73)^2 = 1.04 \approx 1 \tag{27}$$

This calculation strongly implies that the beginning of the universe was a breaking of equilibrium where the probability of two back-to-back spatial quanta flipping simultaneously was surpassed by a fractional multiple of the mass of neutron (standby neutron as a precursor of a proton and an electron), which was equivalent to the mass of the entire universe back then. The calculation exactly equals to one, when

$$\mathrm{H_0} = 71.0[\mathrm{km/s\ /Mpc}] = 2.30 \times 10^{-18}[\mathrm{s^{-1}}] \tag{28}$$

$$\mathrm{H} = 3\mathrm{H_0}/5 = 1.38 \times 10^{-18}[\mathrm{s^{-1}}] \tag{29}$$

$$\rho = 3.41 \times 10^{-27}[\mathrm{kg/m^3}] \tag{30}$$

$$\mathrm{R_H} = 2.17 \times 10^{26}[\mathrm{m}] \tag{31}$$

$$\mathrm{R_H}/\widehat{\mathrm{D}} = (3.25 \times 10^{24})^{5/2} \tag{32}$$

$$\mathrm{M_H} = 1.46 \times 10^{53}[\mathrm{kg}] = 8.74 \times 10^{79}\mathrm{m_n} \tag{33}$$

$$(8.74 \times 10^{79})/(3.25 \times 10^{24})^{10/3} = 1.72 \times 10^{-2} \tag{34}$$

$$(2.04 \times 10^{21})/(3.25 \times 10^{24})^{5/6} = 7.64 \tag{35}$$

$$(1.72 \times 10^{-2}) \times (7.64)^2 = 1.00 \tag{36}$$

Let us carry out a quantitative analysis of the supernovae luminosity plots predicted by our hypothesis against an empty universe with $h = 0.71$ as the benchmark. The luminosity distance in the benchmark case is

$$\mathrm{d_L} = \frac{\mathrm{c}}{\mathrm{H_0}}(1 + \mathrm{z_{raw}}) \ln(1 + \mathrm{z_{raw}}) \tag{37}$$

whereas in our hypothesis, due to the $\propto a^{-3}$ evolution of the Planck constant, the luminosity distance is

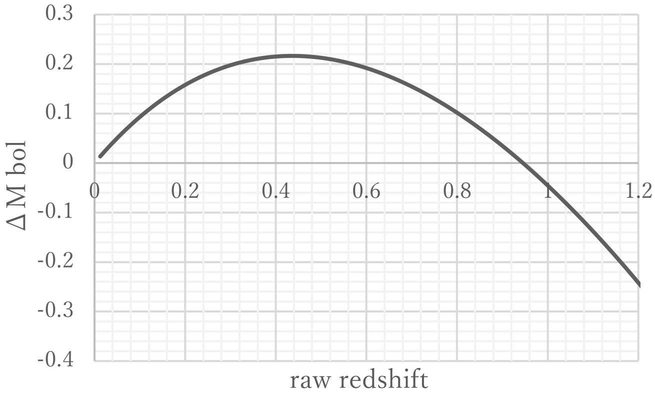
$$\mathrm{d_L} = \frac{\mathrm{c}}{\mathrm{H_0}}(1 + \mathrm{z_{true}})^{5/2} \ln(1 + \mathrm{z_{true}}) \tag{38}$$

There is another factor that needs to be taken into consideration. Our downward revision of the Hubble's constant (a lesser slow motion to be applied to the duration of distant astronomical events) suggests that the absolute luminosity of distant type Ia supernovae, which is calculated from the Phillips relationship, should be dimmer than physicists have believed. Being compared with a brighter-than-actual absolute luminosity, the distance of high redshift supernovae should have been considerably overestimated.

The plot in the next page shows the residual bolometric luminosity magnitude predicted by our model for each raw redshift, against the benchmark. Our model predicts a dimmer-than-benchmark luminosity curve for z_{raw} up to 1, peaking at $z_{raw} \sim 0.5$, reproducing the simulation by the ΛCDM model with $h \sim 0.7, \Omega_m = 0.26, \Omega_\Lambda = 0.74$ in previous studies [10].

Note that according to our model, the Chandrasekhar limit is now a variable, which may alter the absolute luminosity of very distant ($z \gg 1$) type Ia supernovae.

$$\mathrm{M_{limit}} \propto \frac{\mathrm{m_{PL}}^3}{\mathrm{m_{Helium}}^2} \propto \frac{a^{-9/2}}{a^{-14/3}} = a^{1/6} \tag{39}$$



Given that both the energy density of non-relativistic matter and relativistic radiation are proportional to the inverse square of the scale factor, there should be no such thing as the radiation dominant era, but instead

$$\frac{\Omega_b}{\Omega_\gamma} \sim \frac{5 \times 10^{-2}}{5 \times 10^{-5}} \sim 10^3 = \mathrm{const.} \tag{40}$$

Furthermore, $k_B T$ has to be inversely proportional to the $11/4$ power of the scale factor such that the energy density of black body radiation ($c^2 \rho_\gamma \propto k_B{}^4 T^4 / c^3 h^3$) could be inversely proportional to the square of the scale factor. The number density of photons shall now be $n_\gamma \propto k_B{}^3 T^3 / c^3 h^3 \propto a^{3/4}$, the total number of photons should be $N_\gamma \propto n_\gamma a^3 \propto a^{15/4}$. Recall that the mass of individual fermions is inversely proportional to the $7/3$ power of the scale factor, and their total mass is proportional to the scale factor (since $\rho \propto a^{-2}$ in the constant speed cosmic expansion). Therefore, the total number of fermions (and thus baryons) should be proportional to the $10/3$ power of the scale factor. This is the very reason why the Eddington's number is currently $\sim 10^{80}$ while the universe has only expanded by a factor of $\sim 10^{24}$. The dependence of the baryon-to-photon ratio on the scale factor should be $\eta = N_b / N_\gamma \propto a^{10/3} / a^{15/4} = a^{-5/12}$, whose initial value was $\eta_0 = 6.13 \times 10^{-10} \times (3.25 \times 10^{24})^{5/12} = 10.0$, which now settles to a much reasonable order.

Our conclusion that the number ratio between fermionic matter and photon changes over time is rather natural, considering that both of them are constantly and newly generated via the stochastic symmetry breaking of the binary field. The origination of energy via stochastic symmetry breaking in the binary field gives an energy density proportional to the inverse square of radius in a general manner. Thus, for any spatial region that is macroscopic enough, the mass enclosed within it should basically be proportional to its radius instead of its volume, which may well explain the anomaly of the rotating velocity in galactic arms.

Having got rid of the notion of radiation dominant era, together with the increasing number density of both baryons and photons as the universe expands, the CMB radiation should rather be interpreted as a mixture of photons generated not only during the recombination but also long after it (up until today), which reached in a thermal equilibrium. There should be no sharp qualitative transition from the state of baryon-photon fluid to the so-called dark era, which is a key insight for our discussion hereafter.

With all preparations done, let us recalculate the redshift of the recombination. The Saha's ionization equation shall now be

$$\frac{1 - X}{X^2} = \frac{4\sqrt{2}\,\zeta(3)}{\sqrt{\pi}} \eta \left(\frac{k_B T}{m_e c^2}\right)^{3/2} \exp(Q/k_B T) = 2.31 \times 10^{-23} (1 + z)^{25/24} \exp\left(\frac{5.80 \times 10^4}{(1 + z)^{5/12}}\right) \tag{41}$$

where Q is the binding energy of Hydrogen atoms (13.6 eV, currently), which is proportional to the inverse $7/3$ power of the scale factor, since $E_n = -hcR_\infty / n^2 \propto a^{-3} a^{2/3} = a^{-7/3}$. Other dependencies on the powers of $1 + z$ (the inverse of the scale factor) can be derived accordingly from our previous explanations. There are two solutions for $X = 0.5$. One is $1 + z = 1.05 \times 10^{22}$, shortly after the birth of the universe that began from

$$1 + z = 3.25 \times 10^{24} \quad \rightarrow \quad \frac{1 - X_0}{{X_0}^2} = 788 \quad \rightarrow \quad X_0 \approx \frac{1}{28} \tag{42}$$

the other is $1 + z = 5.62 \times 10^7$. Theoretically, the degree of ionization in the universe once surpassed 50% when $1 + z = 1.05 \times 10^{22}$ but soon dropped back to 50% when $1 + z = 5.62 \times 10^7$, then plummeted down toward zero in an exponential manner, and has been keeping it all the way up until today.

When $1 + z = 1.05 \times 10^{22}$, the baryon-to-photon ratio was $\eta = 10 \times (1.05 \times 10^{22}/3.25 \times 10^{24})^{5/12} = 0.92$, fairly close to two, which means that the Hydrogen atoms, photons, free protons and electrons were fully engaged in a reversible reaction. Recall that our theoretical Hubble's constant is $h = 0.426$ (3/5 of 0.71), whereas the PLANCK result is $h \sim 0.67$. It means that our model gives a critical density of universe 40% $(= (0.426/0.67)^2)$ that of the PLANCK result where the Ω_b is 0.048 (rightly ~1/8 of 40%). Suppose the true baryon-to-photon ratio is 8 times of our current belief, according to the Saha's equation, the initial degree of ionization X_0 should be

$$\frac{1 - X_0}{{X_0}^2} = 788 \times 8 \approx 6300 \quad \rightarrow \quad X \approx \frac{1}{80} \tag{43}$$

while $\eta_0 \approx 80 \, (= 10 \times 8)$. It is to say that in the very beginning of the universe, there were on average 79 hydrogen atoms per one pair of free proton and electron, while only one hydrogen atom among them reacts with a photon, which is in an equilibrium with its reverse reaction.

By the way, in the case of 8-folded baryon number, the smaller solution for $X = 0.5$ is $1 + z = 6.62 \times 10^7$, while the larger solution is $1 + z = 1.42 \times 10^{21}$. We are not sure at this stage if either or both of them have anything to do with the observed $\sim 10^{-5}$ CMB anisotropy.

If the above calculation is not persuasive enough, let us provide a more decisive one. Recall that we have denied the concepts of a snapshot CMB and the termination of the baryon-photon fluid state. Consequently, the event horizon of CMB should be identical to our cosmological event horizon, while the horizon of the baryonic acoustic oscillation should be determined by the speed of sound in the baryon-photon fluid which is everlasting. The energy density of the CMB photon is $c^2\rho_\gamma = 4.17 \times 10^{-14}[\mathrm{J/m^3}]$, which is equivalent to $\Omega_\gamma = 5.50 \times 10^{-5}$ ($h = 0.67$, $\rho_c = 8.43 \times 10^{-27}[\mathrm{kg/m^3}]$), whereas the energy density of the CMB neutrino is

$$c^2\rho_\nu = c^2\rho_\gamma \times 3.046 \times \frac{7}{8} \times \left(\frac{4}{11}\right)^{4/3} = 0.69c^2\rho_\gamma \tag{44}$$

Thus, $\Omega_{\mathrm{radiation}} = \Omega_\gamma + \Omega_\nu = 1.69\Omega_\gamma$

$$\frac{8\Omega_b}{\Omega_{\mathrm{radiation}}} = \frac{8 \times 0.048}{1.69 \times 5.50 \times 10^{-5}} = 4129 \tag{45}$$

$${c_s}^2 = \frac{c^2}{3(1 + 4129 \times 3/4)} \quad \rightarrow \quad c_s = \frac{c}{96.4} \tag{46}$$

The sound wave horizon in the baryon-photon fluid (which is still alive today), given that the curvature of the universe is zero, shall have a radius spanning over a visual angle of $1/96.4[\mathrm{rad}] = 0.594°$ on the celestial sphere. The angle is equivalent to $l = 303$ as theoretical major peak in the TT power spectrum of the CMB, which is equivalent to observational $l \sim 220$, exactly as the PLANCK result indicates.

Should the mass of elementary particles evolve with the cosmic age as we hypothesized, not only the validity of the cosmological parameters drawn from the observation of the CMB needs to be re-examined from scratch, but the whole chemistry should be quite different in the ancient universe. It urges us, above all, to re-examine the well-established theory of the Big Bang nucleosynthesis. As for whether our model could reproduce the relative abundance of hydrogen and helium and at the same time solve the so-called cosmic Lithium problem, due to our lack of expertise in the field, we would like to rather devote this paper as a priming water for further studies by qualified experts.

In the end, we would like to ask a favor of experimentalists to verify our hypothesis. With 22.9 billion years as the current cosmic age, an experiment measuring the elementary charge or the mass of electron or proton over a time span of one year shall find a detectable difference in the 9th digit of their significant figures. Note that the 2019 revision of SI base units has linked the standard of second, meter, kilogram and ampere with physical properties that actually evolve with the cosmic scale factor according to our hypothesis. Any experimental verification of our hypothesis should take these effects into consideration.

$$1[\mathrm{s}] \propto \frac{1}{\Delta\nu_{\mathrm{Cs}}} = \frac{h}{\Delta E_{\mathrm{Cs}}} \propto \frac{a^{-3}}{a^{-7/3}} = a^{-2/3} \tag{47}$$

$$1[\mathrm{m}] \propto \frac{c}{\Delta\nu_{\mathrm{Cs}}} \propto a^{-2/3} \tag{48}$$

$$1[\mathrm{kg}] \propto \frac{h\Delta\nu_{\mathrm{Cs}}}{c^2} \propto a^{-3}a^{2/3} = a^{-7/3} \tag{49}$$

$$1[\mathrm{A}] \propto e\Delta\nu_{\mathrm{Cs}} \propto a^{-3/2}a^{2/3} = a^{-5/6} \tag{50}$$

5. Conclusion

Our paper is all the way reaffirming the greatness of John Wheeler's insights that sharply hit the deepest truths of our mother nature. All regularities or physical laws are nothing but patterns or statements we could summarize that are true only in statistical sense. The law of large numbers and the central limit theorem assures that even out of a perfect randomness, we can still expect certain patterns to appear, as far as the sampling procedure is consistent. In other words, order comes not from the nature itself, but from the ordered actions of its observer.

"The unreasonable effectiveness of mathematics in the natural sciences" admired by Eugene Wigner, in our view, is not due to any divine power of mathematics, but because it is the only language that we human being can make use of to recognize our mother nature. Some mathematical theories are miraculously powerful in physics, simply because they happened to share certain similarities in their structures with that of the physical phenomenon in question. All successful scientific theories are nothing but a set of self-consistent logics, including but not limited to the definition of time and energy. All theories that seemed perfect but later proven to be inconsistent, for example the Newtonian mechanics, is because its logical structure had not been challenged by the hardest test. For the case of Newtonian mechanics, the problem was that the Galilean transform was inconsistent with our definition of time, while the Lorentz transform (or the invariance of the speed of light) rightly complies with our definition of time.

The uncertainty principle tells us that only when we have carried out enough number of trials may we obtain a result with a higher certainty. In his famous book "What is Life", Erwin Schrödinger had sharply pointed out that all physical laws become reliable only when they are judged by the averaged behavior of a huge enough number of atoms, which is the very reason why all living creatures have to acquire a certain macroscopic size. A search for the ultimate law of the nature will necessarily end up with "law without law". It is a conclusion that can be drawn from repetitive rounds of logical reasoning. If we worship a deterministic rule to be the final destination of scientific explorations, then what renders the deterministic character to the rule? The only way to avoid such an endless rat race is to accept John Wheeler's slogan, "law without law".

The quantum mechanical wave function is no more than an imaginary mathematical structure that can best reproduce the behavior of the intrinsically random universe, when we inspect it on macroscopic enough scale or do repetitive experiments of a large enough number. The fundamental physical constants may only seem to be invariant as we always measure them with huge enough number of trials. The random and stochastic quantum mechanical world can be alternatively interpreted as if it were instead the basic constants that are wandering. After all, it is a matter of subjective decision as for how to interpret the nature.

Eventually, our newly proposed theoretical paradigm may rephrase the almighty principle of least action as a principle of most probability, which is equivalent to least asymmetry in the space. Physical action has a unit of angular momentum whose conjugate unit in Heisenberg's uncertainty principle is dimensionless, which could be understood either as an angle or as a probability. In the latter context, the existence of a larger quantum angular momentum is equivalent to a lesser probability of occurrence of such a situation. The principle of least action is nothing but a rephrase of the rather trivial fact that it is the event of the highest probability that is most likely to happen. As the scope of our focus goes macroscopic, the predominance of the most probable event just overwhelms the runner-up, thanks to the multiplicative nature of probability. Therefore, even a mere probabilistic pattern may well look like a virtually deterministic law.

In response to Einstein's famous quote "God does not play dice", Bohr warned him "Don't tell the God what to do, Einstein." Today, we have found a better reply: "Yes, you are right, Dr. Einstein, but in the sense that the dicey character of our mother nature is the very proof that there is no God at all."

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