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 most useful 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. The full unification "beyond the SM" presents an important problem of modern theoretical physics. The SM analysis from the materialistic positions shows a number of fundamental inconsistencies of great philosophical significance. In addition to the long-debated philosophical problems of quantum mechanics, the SM has a problem of the "composite" elementary particles. If elementary, a particle should be stable and "unbreakable", which is not the case with the five quarks, two leptons, three weak bosons, and the Higg's particle. In addition, the existence of the neutrino raises questions. Thus, it is logical to expect that a successful unification concept will support the reduction of the SM elementary set. Surprisingly, no unification theory so far can support such a reduction, on the contrary, all the mainstream unifications including superstring theories tend to replace the SM set with an increased, not decreased number of elementary components.

The modified Einsteinian concept of curved spacetime, the General Principe of Interaction (GPI) proposed recently along with the Fractal spacetime concept (FSC) does support the proposed reduction. The GPI-based unification allows, in general, the understanding of all the four types of interaction with the spacetime geometry. However, the quantum field descriptions of the particle interactions required by the compact extradimensional geometry are in principle incompatible with the classic field descriptions of the gravitation required by the "normal" geometry. Thus, neither a GPI-based theory nor any other theory can bring a full unification within a single theoretical framework. Nevertheless, the GPI-based description of particle interactions will be indispensable for 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 particle experiments. However, the 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, the 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^-).

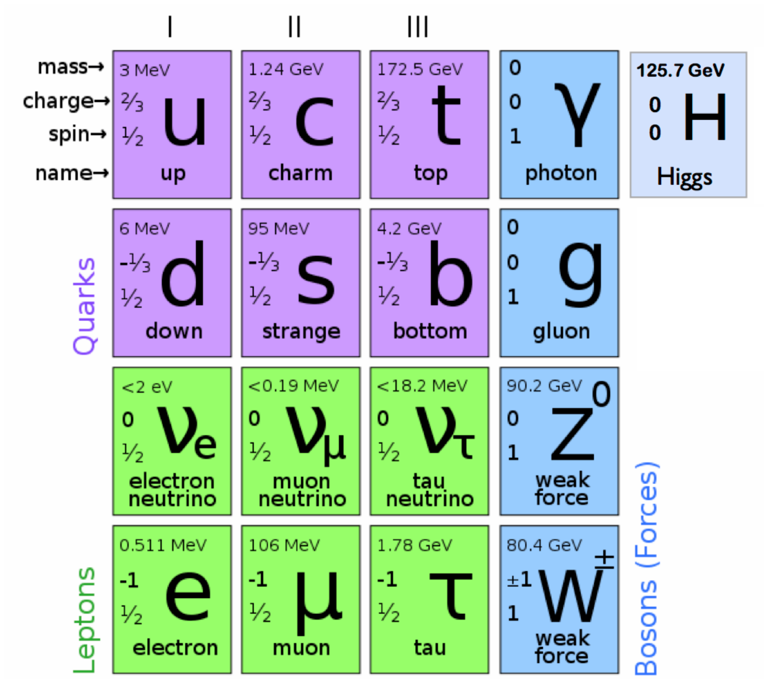

Figure 1: The Standard Model's elementary particle set. Considering all antiparticles, all different variations of quarks and gluons, and two types of W boson, the set actually contains 61 components.

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 u quark is stable. The d quark decays and can be thought as a combination of 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 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 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) must be excited initially due to the proton-neutron mass defect. They slow down after interacting with protons from neighbor atomic nuclei and lose energy emitting photons (gamma-rays). As the electrons' trajectories vary, they lose various amounts of energy during the interactions and show the continuous energy spectrum. Notably, the Bremsstrahlung photons were completely ignored even in the early neutrino experiments as the detectors were typically shielded from gamma-rays [2]. Notably, the neutrinos are not indispensable for the experimental calculations, as the weak forces are calculated based on the particles' electric and color 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 simplify the theory without principal changes in the calculation methods. 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 avoidable.

By removing the unstable bosons and the neutrinos, 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 "natural 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 increases the explanatory and predictive powers.

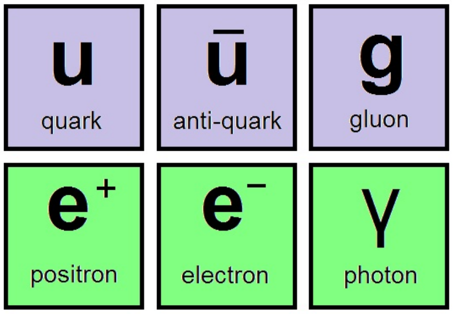

Figure 2: The six truly elementary entities of the SM: the elementary charges (quark, antiquark, positron and electron), which do not decay and are not virtual (i.e. can be detected directly), and the two stable bosons (photon and gluon, i.e. an electron-positron combination and a quark-antiquark combination, 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 to replace the SM move in the opposite direction further increasing mathematical 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 decades of collective effort, no physical theory can overcome these difficulties and succeed the SM. Unfortunately, all presently known unifying approaches, including all superstring theories [3, 4], have almost 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 unclear how to choose the unique theory that describes the laws of 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 interactions in the SM is completely different from the Einsteinian understanding of gravitational interaction. Unfortunately, the gauge transformation principle interpretation used in 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 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 philosophy was fruitless for quite a long time. The tremendous complexity and non-uniqueness of the unified theories make questionable the existence of the fully unified “Theory of everything”. Although the gauge transformation principle philosophy had become a dogma over the years, the brief survey of the main SM problems (see §1) makes its superiority not so obvious. Notably, this philosophy does not support the advanced Einsteinian definition of vacuum (spacetime). The Newtonian understanding of space and time as an “empty coordinate net” used in the SM seems a bit outdated and philosophically limited, and it cannot support a background-independent theory. The gauge transformation principle philosophy is based on the existence of “unreal” interacting entities, virtual bosons. These virtual “messengers” are undetectable in principle with no materialistic explanation. The vacuum property of having spontaneous particle-antiparticle pairs appeared “from nothing” does not seem materialistic either. Philosophically speaking it does not seem beneficial to sacrifice both the advanced Einsteinian understanding of spacetime and the fully deterministic definition of vacuum (with no virtual interactions) even for the sake of the ultimate “Theory of everything”.

On the other hand, the fact that Einstein was unable to develop a successful unified theory points out that the concept of curved spacetime might be incomplete in general. The 4D spacetime geometry is altered only two ways, via curvature or torsion, which both induce gravitational forces. This raises the fundamental question: what kinds of spacetime alteration induce electromagnetism and nuclear forces? The simple solution is to modify the Einsteinian concept by assuming that the nongravitational forces are governed by certain geometrical deformations of vacuum in the compact extra dimensions. The modified concept of curved spacetime, the General Principe of Interaction (GPI) uses this assumption explaining all types of forces with the spacetime geometry [7]. Together with the Fractal spacetime concept (FSC), it extends the original Kaluza's description of the 5D spacetime [8]. The FSC 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 fields, deformations in the extra fifth dimension induce electroweak fields, and deformations in the additional "nuclear" dimensions induce the strong fields. 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 modified spacetime description, it does support the reduction of the elementary set as predicted (Fig. 2). Moreover, it predicts the additional types of purely gravitational vacuum deformations explaining the dark matter. According to the GPI, the full elementary particle set should include nine components (Fig. 3).

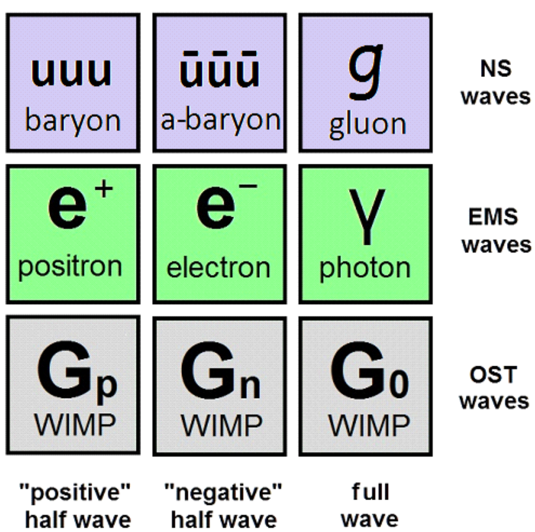

Figure 3: The GPI-based complete set of elementary wave-like spacetime deformations [7]. Top row: the elementary deformations of the "nuclear" subspace responsible for the strong interactions (three-letter notifications mean the deformations equally involve all the three "nuclear" dimensions), middle row: the elementary deformations involving the fifth dimension responsible for the electroweak interactions, bottom row: the hypothetical elementary deformations of the ordinary 4D spacetime explaining WIMPs (weakly interacting massive particles). Left column: "positively-curved" half-waves, middle column: "negatively-curved" half-waves, right column: full waves. Each full wave consists of the two half waves: 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 the 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. Unfortunately, neither the GPI-based theory nor any other unified theory is able to satisfy all these conditions. The geometry of the compact extra dimensions and the “normal” geometry of the 4D spacetime require different mathematical descriptions rendering the full unification within a single theoretical framework impossible [7]. However, the GPI-based description of particle interactions does provide the unification at the fundamental philosophical level and indeed simplify the SM (Fig.3). As the undetectable nature of the compact extradimensional geometry will require the quantum, not classical field descriptions, the SM cannot be substituted with any GR extension. Hence, the GPI-based quantum theory will have to adapt somehow to the SM methodology [7]. The theory development is a matter of a separate study.

Below, we analyze whether the GPI-based approach exceeds the SM in terms of the explanatory and predictive powers.

3. Discussing the future advantages

Although the mathematical development of the 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 interaction, energy, vacuum, and matter; whether it can solve the philosophical problems of quantum mechanics, and explain the dark matter and dark energy.

3.1 Wave-particle duality. The 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. The mystery in this experiment is why the electrons interact deterministically (as particles) with the screen while the interactions with the slits are always uncertain? With the GPI-based approach (see §2), the electrons should be described as wave-like vacuum deformations of the 5D spacetime [7] that appear as the “electron clouds” in the 4D spacetime, indeed detected in the hydrogen atom [9]. The electrons do have wave properties, e.g. diffraction, interference, De Broglie's wavelength. These waves are quantized having integer wavelengths and energies. They indeed interfere, however, the interference is only seen after the detection; it is undetectable during the interaction (passing through the slit) due to the compact nature of the fifth dimension. The interactions of moving electrons depend on their fifth coordinates and hence uncertain; however, the interaction at the screen does not (as the absorbing molecule and the electron now occupy the same point in the spacetime) and is seen as a certain single event. Thus, the 5D wave nature of the electron defines the interference; however, it plays no role during the detection, when the electron can be approximated as a point-like particle or quantum.

3.2 Quantum peculiarities. The convenient interpretation of the 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 [10]. 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 philosophical concepts, such as uncertainty, wavefunction collapse, and the observational indeterminism [11]. All these issues are being debated for many decades without an ultimate consensus. Allowing each of these concepts "as is" may be dangerous philosophically leading to a general rejection of determinism and causality, the fundamental philosophical laws of the observation-based sciences. Notably, the GPI-based approach (see §2) provides a simple explanation. For the observer (in the 4D spacetime), the electron appears as the "unreal" wave due to the undetectable nature of the fifth coordinate it depends on (see §3.1), and hence only an "unreal" wavefunction can describe the electron. This change of the basic definitions 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-valued mathematics in order to account for the immeasurable fifth coordinate. Thus, the "unreal" wavefunction is a valid way of describing the electron dynamics in a flat 3D space while the electron actually is a real wave in the "unreal" (from the observer's point) 4D space. Due to the impossibility of measuring the actual 4D space parameters of this wave, the observer may only obtain its 3D projection parameters, which are always incomplete. Similar reasoning is generally applicable to the strongly interacting particles assuming that quarks and gluons are the 8D spacetime waves also originating in the compact extra dimensions. Thus, the FSC answers the famous Einstein's question about the "local hidden parameters" in quantum mechanics [12]. The Bell's theorem [13] is indeed right stating that no "local hidden parameters" could make experimental results both local and deterministic. However, the "local hidden parameters" do exist, but only in the unreachable extra dimensions making the determinism and causality to seem broken. Thus, the quantum peculiarities caused by the undetectability of the extra dimensions do not contradict determinism and locality *per se*.

3.3 Uniqueness of the laws. The main criticism of the philosophical models aimed to explain the paradoxes of quantum mechanics is focused on their inability to preserve determinism and locality. The Copenhagen interpretation [11] had proposed 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 [12]) and 2) an observation is inevitably subjective, as any measurement induces wavefunction collapse, which can be interpreted as the observation's dependence on the observer. These difficulties can be resolved with the GPI-based approach (see §3.2) or with the Everett many-worlds interpretation [14]. The latter, however, leads to the admittance of the "multiverse" and inevitable non-uniqueness of basic laws of physics in any its part including our Universe. 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 the quantum laws by the undetectability of compact extra dimensions due to the observational limitations. Thus, the introduction of compact 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 Everett many-worlds and the Copenhagen interpretations.

3.4 Particle's masses. One of the SM flaws is the requirement of the *ad hoc* Higg's mechanism in order to explain particles' masses. With the GPI-based approach, particles' masses are explained naturally. Assuming that the three subspaces of the 8D spacetime have a certain hierarchy due to the size differences, any vacuum deformation in the "nuclear" subspace always induces a secondary deformation in the electroweak subspace, and any electroweak vacuum deformation, in turn, induces a secondary deformation in the ordinary subspace [7]. Thus, all quarks have color charge-induced electric charges, and all fermions have electric charge-induced masses. On the other hand, the gluon (uuuūūū) and the photon (e^+e^-) cannot have masses, as the two wave-like deformations induced by their two parts (particle-antiparticle) cancel each other in time.

The avoidance of the Higg's mechanism does not reject the existence of the particle discovered in 2012 and interpreted as the Higg's boson [15]. With the GPI-based approach, the unstable 126 GeV particle can be explained as a high energy baryon (quark triplet) with elevated mass-energy (if fermion) or as a high energy meson (if boson).

3.5 Dark matter. Notably, the SM completely lacks an ability to explain the dark matter and the dark energy, which together account for the vast majority of the total energy of the Universe. The GPI-based approach may again lead to some interesting suggestions. The reduced list of six elementary particles (Fig. 2) seems incomplete without elementary wave-like deformations of the 4D spacetime, i.e. "gravitational charges", which are not induced by any extra-dimensional deformations (like fermions' masses). By assuming such elementary 4D deformations exist, one may have a set of purely gravitational objects being perfect candidates for the dark matter. The three hypothetical types of gravitational waves (one "positive", one "negative", and one combined) unrelated to the ordinary matter compliment the complete set of GPI-compatible elementary objects (Fig. 3). Such gravitational objects 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 objects or a combination of either one half wave and the full wave. The latter case seems preferable by the analogy with the electron/photon abundance and the baryon/gluon abundance in the Universe. As another possibility, the gravitational full wave does not exist, if the two gravitational half waves cancel each other completely. In that case, the dark matter is a single type of the gravitational charge inducing positively curved space, which cancels the negatively curved space induced by the matter particles. This effect explains the attractive interaction between the ordinary particles and the dark matter.

3.6 Dark energy. Dark energy is the most tantalizing mystery of the Universe. It reveals itself only 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 [16]. That creates the mystery of the "fine tuning" 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 general [7].

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 [17] 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 is simply the size-determined average background curvature of the ordinary 4D spacetime. Assuming the Universe (disregarding the extra dimensions) is a 3D hypersphere with a constant positive curvature, it has a background curvature reciprocal to its squared radius. As this curvature is positive, the effect of lambda is opposite to the gravitational effect of the ordinary matter, which induces negative curvature [7].

3.7 Unification. The GPI gives the simple universal definition of interaction providing a self-consistent deterministic basis for the full unification. Unfortunately, the mathematical unification of any quantum theory including the GPI-based one and the classical GR is impossible due to the principal difference between the compact and "normal" geometries [7]. Nevertheless, the GPI is sufficient to explain all types of forces in the Universe (including the dark matter and the dark energy) with the spacetime geometry. 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 multidimensional fractal 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 the universal definition of energy as an increased vacuum deformation (curvature or torsion). The size-induced geometrical separation of the three subspaces postulated by the FSC ensures the separation of the three types of forces (strong, electroweak, and gravitational) with the size-induced differences in the subspaces' action powers. The number of fundamental fields consequently reduces to just three fields defined by the geometrical deformations in the three distinct subspaces of the fractal 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 stage, all the spatial dimensions formed a symmetrical space 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 the size of about 10^{26} m, the fifth dimension responsible for the electroweak interactions has expanded only up to the atomic size (about 10^{-10} m), and the three "nuclear" dimensions responsible for the strong interactions have expanded only to the nuclear size (about 10^{-18} m).

4. Conclusion

The materialistic reductionistic analysis of the SM's philosophical basis shows a number of flaws including the philosophical problems of quantum mechanics, non-deterministic nature of the gauge transformation principle philosophy, and *ad hoc* postulates. The GPI explaining the particle interactions with the elementary deformations of the 8D spacetime [7] may present a solution to all these questions. 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 the core philosophical problems of quantum physics, removing all the *ad hoc* postulates, and explaining dark matter and dark energy (see §3). The GPI-based approach does come with a price requiring the revision of the philosophical foundations of quantum physics, i.e. rejection of the gauge transformation principle philosophy. In return, it shows the way to convert the SM into a theory based solely on the geometry of the fractal spacetime. Although this transition cannot unify the SM and the GR mathematically, it will provide the unification of the philosophical foundations of the two great theories. The transition from the SM to the GPI-based theory remains an open question.

5. References

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