Fractal structure of the spacetime, the fundamentally broken symmetry

"Simplicity is the ultimate sophistication." – Leonardo da Vinci

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Abstract

It is expected that the full unification is achievable within a quantum field theory "beyond the SM" (Standard Model). An alternative approach is the Kaluza-Klein (KK) extension of the General Relativity (GR) with extra dimensions. However, there is a third possibility that no unification is achievable due to the specific fractal structure of the spacetime and the unique position of the observer situated inside the ordinary (gravitational) subspace and outside the compact extra dimensions, the geometry of which governs particle interactions. The Fractal spacetime concept (FSC) is proposed in order to support the General principle of interaction (GPI), which postulates that all the nature's forces with no exceptions are governed by the spacetime geometry. The FSC postulates that the spacetime includes three separate subspaces (in addition to the time dimension): the three-dimensional ordinary subspace, the atomic-sized fifth dimension sufficient to explain the electromagnetism, and the set of three nuclear-sized dimensions sufficient to explain the nuclear forces. The spacetime has a simple fractal structure: each of the three subspaces presumably has a spherical shape with the sizes decreased tremendously from one subspace to another. The size differences are responsible for the separation of the subspaces and gradually increased action powers of the three fundamental fields: gravitational, electroweak and strong fields.

The present letter shows that the SM equations actually describe the extradimensional spacetime deformations approximated as the gauge quantum fields. With the geometrical approach, the SM can be simplified, as only four types of elementary spacetime deformations (extradimensional waves) are needed: electron, positron, **uuu**, and **ūūū** quark triplets. All other elementary particles including photons and gluons are binding states or/and wave polarization modes of the above-mentioned waves. The neutrinos, the weak bosons, and the Higg's particle are avoided. All particles' interactions are governed by the positive or negative extradimensional curvatures and the spin-related torsion induced in the nuclear or electromagnetic subspace by the color or electric charges (respectively). The particles' gravitational interactions are governed by the charge-induced deformations of the ordinary subspace described by the Higg's field.

With the FSC, the GPI explains the geometry-based unified nature of all known interactions. However, a single unified field theory is not possible in principle due to the observational difference between the large geometry of the ordinary subspace and the compact geometry of the extra dimensions. Thus, in general, the FSC supports both the GR and the SM. In special cases, however, it will require quantum field descriptions of gravitational interactions.

Introduction

The full unification of all forces has become a “holy grail” of modern theoretical physics. It is a common belief that a more fundamental quantum field theory (QFT) will soon replace the Standard Model (SM). Although the SM remains the most useful set of theories describing electromagnetism and nuclear forces at the microscopic scales, it is not compatible with the theory of General Relativity (GR) describing gravitation at the large scales. The future quantum theory of gravitation is expected to solve this fundamental problem; however, the success is not so obvious. Although the full unification in form of a QFT seems possible in principle, it requires an increased complexity and numerous additional free parameters with a dismal lack of explanatory and predictive powers [1, 2]. Considering these difficulties, an attention could be given to the alternative, spacetime-geometry based unification [3, 4].

Notably, the mainstream QFT-based unification approaches rely on the basic definitions of interaction, matter and vacuum that are not compatible with the GR. Indeed, the two pillars of modern physics, the SM and the GR remain incompatible due to the principal difference in the general understanding of interaction. The gauge transformation principle explains nicely all the particle interactions, however, it can be applied to the gravity only in case the gravitational forces are quantized. Although the latter assumption seems logical and is highly anticipated, it may not be true, as the gravity is not quantized at the scales of the GR. In case the Planck-Einstein relation is applicable, the gravitational quantum, graviton should possess a tremendously low mass-energy and a very large wavelength (measured in light-years!). It is hardly imaginable how such particle can mediate interactions between microscopic objects or even planets. This inconsistency disappears only at the large energy scales when the gravitons acquire high mass-energy and small wavelength. However, under such conditions, the graviton likely becomes a photon.

The only alternative to the QFT-based unification is well known. The general idea that all the interaction types are governed by the spacetime geometry was preoccupying some theorists including Einstein since the first quarter of XX century. In order to describe forces other than gravity with the spacetime geometry, they had to admit an existence of undetectable extra dimensions. The brilliant idea of an extra spatial dimension necessary to explain electromagnetism was coined by Theodore Kaluza in 1921 [5]. In 1926, Oscar Klein had explained the undetectability of the extra dimension by its compactness [6]. Although the GR extension known as Kaluza-Klein (KK) theory does provide a unification of the GR and Maxwell’s electrodynamics within a classical field theory, the KK approach is not compatible with the SM. The Einstein’s theory describing gravitation amazingly well in the large dimensions cannot describe particle interactions in the compact extra dimensions. At a first glance, it seems feasible to extend the Einstein equations using the 5D KK framework and assuming the proper initial conditions: e.g. no cylinder condition; a proper 5D metric; a proper 5D “cosmological constant”; a proper 5D stress-energy tensor; the 4D de Sitter metric; the experimentally found 4D cosmological constant; the 4D vacuum condition. However, the 5D stress-energy tensor (if not zero) cannot be calculated in principle due to the impossibility to operate with the inner parameters of the undetectable extra dimension (even in case the 5D metric and 5D “cosmological constant” are somehow approximated). In addition, the 5D extensions generally bring an overwhelming mathematical complexity.

Unfortunately, the classical field description used in the KK theory seems irrelevant to the extradimensional geometry due to the specific properties of the extra dimensions. The extradimensional geometry is always hidden from the observer and therefore cannot be calculated directly with the second-order tensors in $\mathbf{R}^{n+1}$ (n > 3). The observer is unable to measure the extradimensional curvature and hence cannot describe its changes in each spacetime point (in $\mathbf{R}^{n+1}$), but only can detect if the field is "present" or "not present" in each point of the ordinary spacetime (in $\mathbf{R}^{3+1}$). Hence, the extradimensional spacetime deformations could be described with scalar fields. As the extra dimensions are compact and appear periodic for the observer, the fields must have certain gauge symmetries. Originated into the undetectable extra dimensions, the particle interactions have additional degrees of freedom hidden from the observer. Hence, they cannot be described with real fields. Movement along the special (extradimensional) direction appears periodic to the observer and is detected as the particle's spin, hence the particles must have wave properties. Thus, the fields induced by the elementary electromagnetic or color charges can be understood as constant uniform wave-like vacuum deformations of the multidimensional spacetime and described with gauged complex scalar fields in $\mathbf{R}^{3+1}$. Thus, the compact extradimensional geometry requires the QFT-like descriptions of the particles' interactions.

Recently, the idea of spacetime geometry-based unification was further developed into a philosophical concept, the General principle of interaction (GPI) [3]. It is expected that the GPI is applicable to all the fundamental forces, however, no theoretical framework was established until now. The GPI assumes that all the three fundamental fields (strong, electroweak, and gravitational fields) are all governed by the spacetime geometry. The Fractal spacetime concept (FSC) postulates that the spacetime has a simple fractal structure. In addition to the ordinary three spatial dimensions and one time, the spacetime includes one compact atomic-sized (fifth) dimension sufficient to explain the electromagnetism and three compact nuclear-sized dimensions sufficient to explain the nuclear forces [3]. The diameter of the first hypersphere (ordinary subspace) is extremely large (size of the Universe), whereas the sizes of the other two (electromagnetic and nuclear) subspaces are microscopic. Thus, the global space has the topology $S^3 \times S^1 \times S^3$.

As pointed above, the classical method is not applicable to the extradimensional geometry, which requires a completely different approach explained below. The present letter shows that the extradimensional spacetime deformations could be described by the SM equations (at least to a certain extent) and discusses the consequences.

"Geometrization" of the SM

Scalar electrodynamics. Based on the GPI, the electromagnetic interaction is governed by the 5D spacetime geometry the same way the gravity is governed by the 4D spacetime deformations. In order to describe the 5D spacetime dynamics, i.e. electrodynamics, one can start from the original Kaluza's description of the 5D spacetime [5] disregarding the cylinder condition. An additional geometrical condition for the 5D spacetime model is that the extradimensional 1D circles mapped to each point of the ordinary 4D spacetime are uniform and maximal sections.

As pointed above, the quantum theory of electromagnetism in principle cannot be built as a 5D KK GR extension due to the undetectable "hidden parameters" of the extradimensional geometry. Instead, one should take into the account the specific properties of the extra dimensions, undetectability and periodicity. Assuming the elementary charge-induced 5D spacetime deformations are constant and geometrically uniform, particle interactions can be understood as geometrical overlaps of these elementary deformations. A positive electric charge induces one type of deformation, e.g. positive (by an arbitrarily choice) curvature, and a negative electric charge induces the opposite type, e.g. negative curvature. These two types of the 5D spacetime curvature counteract, and the resulting curvature tends to decrease during the interaction according to the principle of minimal energy. It seems possible that these curvatures can be described with real scalar fields in $\mathbf{R}^{4+1}$. However, one cannot define the fields in $\mathbf{R}^{4+1}$ due to the undetectability condition. Hence, one needs a valid transition from $\mathbf{R}^{4+1}$ to $\mathbf{R}^{3+1}$. Furthermore, the time curvature can be disregarded for the simplicity coming with the price of the resulting theory to be non-relativistic. As the extra dimension is negligibly small, one can treat the charge-induced elementary deformation as a point-like test particle moving in 4D space along the geodesics in flat $\mathbf{R}^5$, which embeds all the curved 4D hypersurfaces. The desired transition is possible in case each point in $\mathbf{R}^3$ will be properly assigned to a closed geodesic line in $\mathbf{R}^5$ (the geodesic condition).

First, one can consider the case of a positive 4D geometrical curvature. According to the GPI, an elementary charge induces a stable curved local space in the flat 4D space, and this space can be modeled by a small hypersphere S^4. Although the global 4D space cannot be a hypersphere (as its topology presumably is $S^3 \times S^1$), the local 4D space perfectly can, if its size does not exceed the fifth dimension's diameter. In reality, this curved space may have some curvature gradient and shape imperfections, which should be disregarded due to the undetectability condition. For the simplicity, one can treat this local space as an ideal hypersphere embedded in flat $\mathbf{R}^5$. Next, one needs to find a proper transition from this local S^4 to global $\mathbf{R}^3$. First, S^4 can be mapped to S^3, the intersection of S^4 with hyperplane $\mathbf{R}^4$ containing the center of S^4. The latter condition assures that S^3 is the geodesic of S^4 and is predetermined by the Kaluza model's additional condition (see above). Then, the S^4 original scalar curvature lost in the transition can be described as a scalar field in each point of S^3. The important property of this local S^3 is that it is isometric to the global space, which is also assumed as S^3. Thus, one can substitute the local space with the global space preserving the geodesic condition. Then, the extradimensional curvature is described by the yet unknown scalar field in S^3 manifold.

Next, one can use the stereographic projection and translate S^3 into $\mathbf{RP}^3$ providing the scalar field description in the ordinary space $\mathbf{R}^3$. However, as the scalar field represents the inner parameter (curvature) of the fifth dimension, it cannot be described with any real field due to the undetectability condition. Therefore, one needs to implement a complex scalar field. Ideally, S^3 should be translated into a complex manifold that 1) accounts for the periodicity (circle symmetry) of the extra dimension, 2) preserves the geodesic condition, and 3) is isometrically embeddable in $\mathbf{R}^3$. That can be done, if one replaces S^3 with a unit sphere $S(\mathbf{C}^2)$ in the complex coordinate space $\mathbf{C}^2$ and uses the principal Hopf bundle [7] over the complex projective space: $U(1) \rightarrow S(\mathbf{C}^2) \rightarrow \mathbf{CP}^1$. The projection map: $S(\mathbf{C}^2) \rightarrow \mathbf{CP}^1$ gives a Riemannian submersion with totally geodesic fibers isometric to U(1). This Hopf bundle is a generalization of the geometrical fibration: $S^1 \rightarrow S^3 \rightarrow S^2$. As the Hopf fibration is known to assign a great circle of S^3 to each point on S^2, it maps all the geodesics of S^3 onto S^2 (projected to $\mathbf{CP}^1$) preserving the geodesic condition. Thus, $\mathbf{CP}^1$ is likely the simplest possible variant of the scalar field describing the extradimensional curvature (S^4 original scalar curvature) in the flat 3D space.

A similar construction can be used with the hyperbolic pseudosphere H^4, in case the elementary charge induces a negatively curved local 4D space. With similar reasoning, the H^4 curvature can be described by a scalar field in $\mathbf{CP^1}$, but having an opposite sign. One can take the intersection of H^4 and $\mathbf{R^4}$, which again gives S^3. The H^4 original curvature lost in the transition can be described by a scalar field in each point of S^3. Assuming the negative extradimensional curvature counteracts the positive curvature, the second scalar field should have an opposite sign compared to the above case. The Hopf fibration: $U(1) \rightarrow S(\mathbf{C^2}) \rightarrow \mathbf{CP^1}$ again translates S^3 (replaced by $S(\mathbf{C^2})$) into the complex projective space preserving the geodesic condition. Finally, one obtains the second component of the complex scalar field with an opposite sign describing the opposite elementary charge action in the ordinary 3D space.

Thus, the 4D curvature, which assumingly governs the electromagnetic field, can be described with a complex scalar field having two counteracting components, the "positive" and the "negative" fields. This complex scalar field has a Fubini-Study metric (which is indeed an Einsteinian metric), and an action:

$$S = \int d^4x (\partial\mu\phi^*)(\partial^\mu\phi) - V(|\phi|) \qquad (1)$$

Where ϕ acts as the "positively" charged field, ϕ^* acts as the "negatively" charged field, and $V(|\phi|)$ is the complex scalar field potential. By the construction, this action has a global symmetry under the group U(1), i.e. $\phi \rightarrow e^{i\alpha}\phi$, which can be translated to a local symmetry by introducing a gauge field with the gauge covariant derivative $D\mu\phi \rightarrow e^{i\alpha(x)}D\mu\phi$ (e is the elementary electric charge). One can find the gauge transformation-invariant form of the above-stated action, add the gauge field kinetic term defined by the transformation group U(1), $F_{\mu\nu}F^{\mu\nu}$ (where $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$) and write the equations of motion with respect to the gauge field. The scalar field dynamics can finally be given by the Lagrangian density:

$$L = (D\mu\phi^*)(D^\mu\phi) - V(|\phi|) - 1/4\, F_{\mu\nu}F^{\mu\nu} \qquad (2)$$

This equation is similar to the quantum electrodynamics (QED) Lagrangian, except it describes spinless charged scalar fields, not spin ½ leptons. The spin introduction is explained below.

Higg's field. The scalar electrodynamics presents a simple case allowing the Higgs mechanism [8]. The gauge field potential $V(|\phi|)$ can be interpreted as the Higg's field. In case the potential minimum occurs at a non-zero value of $|\phi|$, the gauge field behaves as a massive field, and its mass is proportional to the electron's mass. Notably, in the present model, $V(|\phi|)$ is not an independent parameter. $V(|\phi|)$ is not a unique gauge field, but a field strictly dependent on the complex scalar field describing the extradimensional curvature induced by electric charges. According to the GPI, the curvature cannot be zero ($|\phi| \neq 0$) in the presence of an electric charge. Hence, the potential minimum indeed occurs at a non-zero value of $|\phi|$. In terms of the geometry, this means that the local S^4 curvature promotes the local S^3 curvature described by the additional real scalar field $V(|\phi|)$. Thus, the Higg's field should be interpreted as an ordinary subspace curvature originated by the extradimensional curvature, i.e. electric charge-induced mass.

Relativistic approach. In order to make equations (2) relativistic, one should express the 5D spacetime curvature as a gauge field, not in $\mathbf{R^3}$ and absolute time, but in the ordinary spacetime manifold, $\mathbf{R^{3+1}}$. The charge-induced curvature of the local hypersurface in flat $\mathbf{R^{4+1}}$ can be modeled by a small hypersphere S^5. One can take the two consequent intersections of S^5: 1) S^5 with $\mathbf{R^{4+1}}$, which gives S^4 and 2) S^4 with $\mathbf{R^4}$, which gives S^3. Then, the two original curvatures of S^5 (the time curvature and the extradimensional spatial curvature) lost in the transition can be described by two separate scalar fields. For the spatial curvature description (step 2), S^3 is again mapped to $\mathbf{CP^1}$ using the Hopf fibration, and the complex scalar field is gauged, as described above. The time curvature (step 1) can be modeled by the positive hemi-circle of S^1 and translated to the flat time line as positive part of $\mathbf{RP^1}$ using the half-stereographic projection, which preserves the geodesic condition. For single charges, this two-field description is likely to equal to the procedure replacing the ordinary coordinates with four-dimensional spacetime positions **X** = (ct, **r**), which allows modifying the non-relativistic field equations with the proper Lorentz transformations. The latter approach used in the QED for single-particle states is well known [9]. Thus, the relativistic electrodynamics can be accessed with the two properly gauged scalar fields $\mathbf{CP^1}$ and $\mathbf{RP^1}$ separately describing the spatial curvature and the time curvature, respectively.

Spin. As shown above, the two types of 5D spacetime deformations induced by the two types of elementary electric charges can be described by the complex scalar field, and the scalar field Lagrangian partially similar to the QED Lagrangian. It is tempting to assume that the two parts of the scalar field describe the two leptons, the electron and the positron. However, this assumption is not valid, until the spin introduction is justified.

A point-like test particle's movement along the special direction in the 4D space appears periodic due to the small size of the fifth dimension. Hence, the 5D spacetime dynamics must have certain attributes of a wave, which is indeed a well-registered experimental fact. It is a common assumption that the elementary particles are in a constant movement. Thus, the small projection hypersphere S^3 modeled an elementary spacetime deformation constantly moves in the 4D space (global S^3). This movement can be separated into the movement in the ordinary 3D space and the movement along the special extradimensional direction. For the observer, the latter appears as a constant spin. The 3D space dynamics have been already analyzed above; however, the spin requires an additional correction of the scalar field description. Although the spin can have infinite possible directions in the 4D space, all those are reduced to just two, clockwise and counterclockwise, after the translation from the global S^3 to the planar $\mathbf{CP^1}$. As there are two parts of the complex scalar field and two possible spin directions, one must introduce certain corrections to equation (2) accounting for the proper spin direction and making the right commutation. The proper corrections are made by the Dirac matrices and the switch from the field ϕ to the bispinor field ψ. Then, the Lagrangian (2) takes the form:

$$L = \bar{\psi}(i\gamma^{\mu} D_{\mu})\psi - V(|\phi|) - 1/4\ F_{\mu\nu}F^{\mu\nu} \qquad (3)$$

where ψ is a bispinor field, i.e. electron-positron field; $\bar{\psi} \equiv \psi^\dagger\gamma^0$ is the Dirac adjoint; and γ^μ are the Dirac matrices. As pointed above, the gauge field potential minimum $V(|\phi|)_{\min}$ occurs at $|\phi| \neq 0$ in the presence of electric charge. Hence, the gauge field behaves as a massive field, and its mass is proportional to the lepton's ground state mass-energy m, i.e. conventional electron's mass. Thus, the potential can be expressed as $V(|\phi|) = \bar{\psi} m \psi$. After the proper replacement, equation (3) takes the final form of the QED Lagrangian:

$$L = \bar{\psi}(i\gamma^\mu D_\mu - m)\psi - 1/4\, F_{\mu\nu}F^{\mu\nu} \qquad (4)$$

As the two types of movement in the 4D space can be described separately, they can be interpreted as the two interconnected but separate fields, the electrostatic field representing the extradimensional curvature and the magnetic field representing the extradimensional torsional deformation due to the spin.

<u>Photon.</u> It is logical to assume that the third type of elementary electromagnetic deformation, the photon is a combination of the two elementary 4D space deformations with opposite curvatures and spins, electron and positron. In this combination, the two opposite scalar fields (curvatures) tend to cancel each other, however, the constant movement along the special direction (opposite spins) prevents that. Oscillating in counterphase due to the opposite spins, the two curvature deformations cannot disappear, but cancel each other's effect in time. Thus, photon appears spinless, chargeless, and hence, massless. The photon structure determines its dualistic behavior: photon binds both the lepton types. Photon's energy is described solely by the second, kinetic part of the QED Lagrangian (4). Thus, a free photon is quantum of "pure" kinetic energy, and an absorbed photon represents the lepton's kinetic energy.

<u>Lepton generations</u>. Due to the only two types of curvature possible in 4D space, only the two lepton types, the electron and the positron exist. As a wave, however, lepton oscillating along the special direction has three polarization modes in the ordinary 3D space: no polarization, linear polarization, and planar polarization. The lepton's kinetic energy (and hence, its mass-energy) obviously increases with a higher polarization state, although the core parameters (charge, gravitational mass and wavelength) remain the same. Thus, free leptons have two additional high energy states that differ only by the ground-state mass-energy. Notably, Vo Van Thuan has found formulae for the masses of the three lepton generations and shown a nice correlation (within 0.32 – 1.60 % relative deviation) with the experimental masses [10]. Although the Thuan's approach relies on the 6D (3D+3D) spacetime model with three spatial and three time dimensions, same formulae can be used for the 5D (4D+1D) spacetime deformations, if the Thuan's time-induced 3D+3D spacetime polarization parameter **T** [10] is interpreted as the spatial 4D+1D spacetime polarization parameter. This simple replacement makes the Thuan's formulae applicable to the polarized lepton waves.

<u>Lepton 3-state</u>. Lepton bound to a photon is present in the energetic 3-state ($e^-e^+e^-$ or $e^+e^-e^+$). It is possible that the lepton gravitating mass is lower than the ground-state mass-energy m in equation (4). Then, leptons always are in the 3-state, i.e. photon-bound. Thus, leptons can emit, re-absorb, or exchange the bound photons, which are always real. As only the two types of leptons exist in the 4D space, there is only one type of the electromagnetic boson, the photon. Rejection of neutrinos and weak bosons is discussed below.

Strong interactions. According to the GPI, the nuclear forces are governed by the extradimensional geometry originated in the compact nuclear spatial extra dimensions. The FSC assumes that the third subspace is also closed and microscopic with a size about the size of a nucleus. As there are six types of quark charges (three colors and three anti-colors), it is logical to assume that the third subspace contains three additional extra dimensions. In order to describe dynamics of the 8D spacetime deformations, one can start again from the Kaluza's description of the 5D spacetime disregarding the cylinder condition and assuming additional extradimensional 3D spheres mapped to each point of the 5D spacetime (the additional condition that the spheres are uniform and are maximal sections is applied). Once again, one should rely on the specific properties of the extra dimensions and describe the hidden geometry with the complex scalar fields. For simplicity, any time curvature is again disregarded at the expense of consequent non-relativity.

According to the GPI, an elementary color charge triplet induces a curved local space in the flat 7D space. This deformed local space can be modeled by a small hypersphere S^7 (or a small hyperbolic pseudosphere H^7) with a positive (or a negative) curvature. The local S^7 or H^7 can be mapped to local S^4, the intersection of S^7 or H^7 with hyperplane $\mathbf{R}^5$ containing the center of S^4 or H^4. The latter condition assures that S^4 is a geodesic of S^7 or H^7 and is predetermined by the 8D spacetime model (see above). Then, the S^7 (or H^7) original scalar curvature lost in the transition should be described by a scalar field with a positive (and a negative) component in each point of S^4. The local S^4 is isometric to the global S^4, which is the 4D electromagnetic subspace (time curvature is disregarded) also modeled by S^4 (see above). Thus, the local 7D space is substituted with the global 4D space preserving the geodesic condition and having the scalar field in S^4 manifold describing the additional (nuclear subspace) extradimensional curvature. Next, the S^4 curvature can be described by another scalar field in $\mathbf{CP}^1$, the same way as for the electromagnetic scalar field (see above). Overall, this two-step geometrical transition can be described with the two consequent Hopf fibrations: $S^3 \rightarrow S^7 \rightarrow S^4$ and $U(1) \rightarrow S(\mathbf{C}^2) \rightarrow \mathbf{CP}^1$. As S^3 fibers are isometric to SU(2), the total projection map: $S^7 \rightarrow \mathbf{CP}^1$ gives a Riemannian submersion with totally geodesic fibers isometric to SU(2) x U(1), which is a subgroup of SU(3). Thus, the interactions of color charges like the electromagnetic interactions can be described with the fermion fields in $\mathbf{CP}^1$, however, the gauge symmetry, in this case, should be presented by the transformation group SU(3). Based on this finding, the S^7 curvature and spin-related torsional deformations (multiple spin directions in S^7 are again translated into just two directions in $\mathbf{CP}^1$), the gauge invariant Lagrangian for quark triplets can be found matching equation (3) above with one difference: the gauge field kinetic term $F_{\mu\nu}$ having a different algebraic form defined by the group SU(3). By treating quarks in the triplets as singles and taking to the account the "always-attractive" behavior of the quark triplets, equation (3) (with the proper $F_{\mu\nu}$) can be converted into the QCD Lagrangian:

$$L = \bar{\psi_i}\, i(\gamma^\mu D_\mu)_{ij}\, \psi_j - V(|\phi|) - 1/4\, F_{\mu\nu}F^{\mu\nu} \qquad (5)$$

where ψ_i is the quark field; $\bar{\psi_i} \equiv \psi_j^{\dagger}\gamma^0$ is the Dirac adjoint; and γ^μ are the Dirac matrices. As pointed above, the gauge field kinetic term in equation (5) is not the same as in equations (3) and (4). The complex scalar field potential

$V(|\phi|)$ is proportional to the quark triplet's ground state mass-energy $V(|\phi|) = \overline{\psi_i}(m\delta_{ij})\psi_j$. After the substitution, equation (5) takes the convenient form of the QCD Lagrangian:

$$L = \overline{\psi_i}\,(i(\gamma^{\mu}D_{\mu})_{ij} - m\delta_{ij})\,\psi_j - 1/4\,F\mu\nu F^{\mu\nu} \qquad (6)$$

Induced electric charges. Notably, the above-described transition $S^7 \rightarrow \mathbf{CP^1}$ creates not one, but two scalar fields. First scalar field describes the local S^7 original curvature and is relevant to the color charges' strong interactions, and the second field describes the local S^4 curvature, which exists due to the local S^7 curvature. The second field can be interpreted as an electrostatic field induced by the strong field and described with the equations (3) or (4). This geometrical relation explains the fact that hadrons (quark triplets) possess electric charges induced by the color charges.

Confinement. The postulated 3D geometry of the nuclear subspace requires curvature induced by color charges to act symmetrically in all three nuclear dimensions producing local S^7, not S^6 or S^5. Hence, the minimal nuclear subspace deformation always seems induced by a color charge triplet. This geometrical property explains the color confinement prohibiting any single or double quark states. If triplet is the minimal quark state, the QCD Lagrangian is calculated more conveniently with the equations describing quark triplets, rather than those operating with single quarks.

NS elementary deformations. Assuming down quark is a combination of up quark and an electron, there exist only two elementary types of nuclear subspace deformations: **uuu** triplet-induced (arbitrarily positive charge) or **ūūū** triplet-induced (arbitrarily negative charge). Then, the quark-antiquark binding state, the gluon is the quark sextet **uuuūūū**. Gluon should appear seemingly chargeless and massless like photon; hence, a free gluon can only be detected when absorbed or emitted. As the **uuu** triplet has an induced electric charge equal to +2*e*, it can bind one or two electrons becoming a proton **uuu**e^- (**uud**) or a neutron **uuu**e^-e^- (**udd**), respectively. Similarly, the **ūūū** triplet has two binding states with one or two positrons. Gluon has an "induced photon", which binds any of the three electromagnetic particles converting gluon into a meson: **uuuūūū**e^- (**ūd**), **uuuūūū**e^+ (**uđ**), or **uuuūūū**e^+e^- (**dđ**). Being bosons, gluons have a wide range of energy states. Thus, the three mesons should have a number of different states with various mass-energies.

Notably, the interactions of nucleons (**uud** or **udd**) are always attractive, unlike the leptons' interactions. This fact should be explained by the extradimensional geometry. Assuming the size of the nucleons can vary and is always equal to the size of the nuclear subspace, the background curvature is always equal to the color charge-induced curvature. Consequently, the background curvature cannot drive apart the elementary deformations with same curvature (e.g. nucleons). With leptons, however, the case is different: the electromagnetic subspace background curvature is not equal to the electric charge-induced curvature, as the electromagnetic subspace is presumably much larger than the charge-induced deformations (leptons).

Quark generations. Like leptons, quarks have three generations similarly explained with the three polarization modes of the quark triplet waves moving in the ordinary 3D space. Thus, each of the **uuu**, **ūūū**, **uud**, **ūūđ**, **udd**, and **ūđđ** quark triplets has two additional high energy states: the 1D- or the 2D-polarized wave modes, respectively. The SM interprets the polarized baryons as quark triplets with a heavy quark **c**, **s**, **t** or **b**.

Weak interactions. The nuclear subspace deformations defined by the local S^7 curvature are always accompanied by the lower-dimensional "electrostatic" deformations defined by the local S^4 curvature. This geometrical property explains the ability of color charges to interact with electric charges. When the distances between hadrons and leptons exceed the nuclear subspace size (i.e. the diameter of the nucleus), the quark-induced field changes could be disregarded, and the interaction can be seen as purely electromagnetic. However, if the interaction occurs at a short distance, the quark-induced changes need to be accounted for in order to calculate the induced electromagnetic fields' dynamics. Therefore, the short-distance electromagnetic interactions involving quark triplets do require special descriptions and could be understood as the weak nuclear interactions.

As shown above, the internal symmetry between the nuclear subspace deformations and the electromagnetic subspace is given by the gauge group SU(2), and the symmetry between the electromagnetic subspace deformations and the ordinary large subspace is given by the gauge group U(1). Hence, the dynamics of the induced electromagnetic fields can be described with the SU(2) symmetry, and the interactions between these fields and leptons (or photons) can be described with the U(1) symmetry. The SM electroweak theory indeed relies on the combined symmetry SU(2) x U(1). This fact illuminates the fundamental similarity of the SM electroweak theory and the GPI-based approach. However, the geometrical understanding of interaction cannot allow the weak bosons, the neutrinos, and the Higg's mechanism.

In the GPI-based model, neutrinos should be replaced by photons. No particle, except photon, can have no electric charge and participate in the electromagnetic interactions. Thus, applying the Occam's razor, the third particle produced in the beta-decay must be a photon, and the neutron is a proton-electron binding state with some additional energy. With this assumption, the continuous electron energy spectrum in the beta-decay could be explained by the Bremsstrahlung. The emitted electron has the energy of about 1.3 MeV (equals to the neutron-proton mass defect) when emitted. However, it interacts with the neighbor nuclei, brakes down quickly and emits a photon. The electron passes the nuclei by random angles, hence, random portions of the electron's energy are taken by the photon. The photon's energy is in the range from a few KeV up to ~1.2 MeV making some of them have a high penetrating ability.

The neutron instability needs an additional explanation. Electromagnetically, the neutron is perfectly equalized like the photon, and yet the electron capture by a proton requires some additional energy. This discrepancy could be explained by the high kinetic energy of the proton's quark-induced electromagnetic deformations (the "shadow" photon and positron). In order to resonate with the "shadow" positron and stay bound, the binding electron needs to be excited to 1.3 MeV. This additional energy can come as a gamma quant (like in the Cowan–Reines neutrino experiment) or as a gluon's "shadow" photon (in spontaneous positron emission). In the former case, the photon's energy excites an electron and induces its capture by a proton. In the latter case, a "shadow" photon (presumably from an energetic gluon exchanging between the nucleons) replaces the proton's "shadow" positron and induces its emission as a real positron. Consequently, the proton becomes a neutron, and the nucleus quark-gluon system (all the nucleons are presumably in the 3-states) looses ~1.2 MeV of energy in form of a photon bound to the emitted positron.

The electroweak interactions should be described by adding the quark-induced electromagnetic elementary deformations to the quantum electrodynamics. Thus, the electroweak theory does not require any additional particle fields. The three SM's weak bosons could be replaced by the three quark-induced electromagnetic gauge fields: the proton's "shadow" positron, the antiproton's "shadow" electron, and the neutron's or antineutron's "shadow" photon. These three induced gauge fields (pseudo-particles) are induced by the strong fields (quark triplets) and hence accompany the strong fields. Interactions between the six types of electromagnetic gauge fields (two real leptons, two "shadow" leptons, real photon, and "shadow" photon) can be calculated via the QED Lagrangian. Like in the SM, the geometry-driven electroweak interactions could be calculated via the sum of the QCD and QED Lagrangians taking to the account all involved particles (quark triplets and leptons) and pseudo-particles ("shadow" leptons and photons).

Notably, the induced pseudo-particles have some special properties due to the "attached" quark triplets, i.e. they have large masses and a short range of action, the properties defined by the strong fields. Unlike the real photon, the induced photon is unstable due to the instability of the neutron or antineutron (although, the gluon's "shadow" photon is very much stable). Moreover, the "shadow" photon is induced by the two different particles, neutron or antineutron. Hence, there are actually two chiral isomers of the "shadow" photon: one consists of a "shadow" positron and a real electron, and another consists of a "shadow" electron and a real positron. This unique property of the color charge-induced electromagnetic deformations explains the parity violation.

Additional considerations

The Higg's mechanism avoidance. As pointed above, the Higg's field is an interpretation of the complex scalar field potential $V(|\phi|)$, which inevitably appears in the both QED and QCD Lagrangians due to the charge-induced extradimensional curvature. Notably, $V(|\phi|)$ is a real field, hence it does not have any extradimensional component (although it clearly has the extradimensional origin). Therefore, $V(|\phi|)$ cannot represent any strong, weak or electromagnetic interaction. It represents only the scalar curvature induced by color or electric charges in the ordinary 3D subspace (in addition to the extradimensional curvature). $V(|\phi|)$ cannot be interpreted as the mass-inducing field being itself induced by electric or color charges, which are the true origins of the particles' masses. In the SM, the masses of the weak bosons cannot be explained without the *ad hoc* Higg's mechanism. The spacetime geometry, however, explains all the particles' masses as induced avoiding the necessity of *ad hoc* mechanism. Therefore, the 126 GeV particle discovered at the LHC in 2012 and interpreted as the Higg's boson [11] must be a hadron.

The renormalization condition. The renormalizability is an important requirement of a successful QFT. Neither quantum mechanics, no QFTs provide any explanation for it. Notably, the transformation of the extradimensional geometry into the ordinary 3D subspace given by the Hopf fibration explains the renormalization requirement naturally. The extradimensional curvature induced by color or electric charge requires one to assume the elementary spacetime deformations having a spherical metric. However, this spherical geometry needs to be embedded into the flat $\mathbf{R}^3$ isometrically. However, the translations used ($S^7 \rightarrow \mathbf{CP}^1$ for nuclear subspace deformations, $S^3 \rightarrow \mathbf{CP}^1$ for electromagnetic subspace deformations) preserve the geodesic condition, but not isometry. Therefore, each calculation of a single interaction (e.g. photon emission/reabsorption by a lepton) inevitably involves a tiny error due to the non-isometric geometrical projection of a spherical surface onto a plane. This error is accumulated during multiple calculations and may lead to infinities in the absence of the renormalization procedure. Thus, the flatness of the ordinary subspace (at the sub-galactic scales) is the actual reason for the renormalization condition.

The gauge transformation principle. This principle is an important mathematical tool necessary to describe all the interactions involving compact extra dimensions. However, it is clearly not applicable to the large dimensions. The origin of any gauge symmetry is the compactness of the extra dimensions, which defines the periodicity of the global space geometrical properties. In the absence of this condition, there is simply no gauge to apply. Thus, gravitation cannot be described by a gauge field theory, except special cases when a part of the ordinary spacetime seems to be compactified for the observer (e.g. inside the black hole of at the Big Bang).

The general interpretation of this principle explaining the interaction's driving force as the exchange of virtual bosons between interacting fermions needs reevaluation. The bosonic exchange is not the origin, but a consequence of the particle interactions. The one and only driving force is the geometry defining these exchanges. In addition, the materialistic understanding of interaction allows no virtual particles. Thus, no particle can "appear from nothing", and the particle-antiparticle annihilation is actually a binding reaction producing boson. Assuming all fermions (leptons or quark triplets) always exist in the 3-state (being bound to a boson), the exchanged bosons are indeed real.

In general, the gauge transformation principle philosophy should be replaced by the GPI.

Unification. Understanding of all the interaction types as governed by the universal laws of geometry shows that the fundamental unity of all physical forces is already present in the modern physics despite the incompatibility of the GR and the SM. However, the broken geometrical symmetry of the three subspaces explained by the FSC does not allow one to describe all the interactions within a single theoretical framework. Nevertheless, all the nature forces always are unified by the spacetime geometry even though the descriptions they require are different. Unfortunately, this difference is predetermined by the specific position of the observer "inside" the ordinary subspace, but "outside" the compact extra dimensions. Therefore, the gravitation cannot be described with a quantum theory (except special cases), and the particle interactions cannot be described with a classical theory. Thus, the unification of all forces already exist and does not require any unified theory "beyond" the SM and the GR.

The background curvature. According to the FSC, the spacetime has a non-symmetrical fractal structure, which topology is likely $S^3 \times S^1 \times S^3$. At present, the three subspaces differ in size tremendously. However, it is logical to assume that at the Big Bang, all the three subspaces had existed in a state with equal geometrical parameters, i.e. they had same size and shape consequently having only one (fully symmetrical) type of inner deformations. Hence, all the interactions inside the protouniverse were equal, i.e. unified due to the geometrical symmetry of the global space. Obviously, the size of this compact hypersphere was extremely small, but nonzero, and its scalar curvature was consequently extremely large. At present, the global space is greatly asymmetrical: the ordinary (gravitational) subspace is at least 10^{26} m, the electroweak subspace is likely about 10^{-10} m, and the nuclear subspace is likely about 10^{-18} m. Although the ordinary subspace has the size of the Universe and is locally flat, it should retain an extremely small, but nonzero background curvature in order to remain its geometrical shape. Notably, the electroweak and the nuclear subspaces also have this important size-related parameter. For simplicity, one can assume the perfect spherical shape. Then, the present background curvature of the Universe is $1/R^2 \approx 10^{-52}$ m^{-2} matching the experimentally derived cosmological constant. Assuming the Universe always retains its shape, it will inevitably remain in the state with a nonzero cosmological constant, i.e. background curvature. Only this curvature, but not any kind of matter in the Universe is the fundamental primary parameter (together with the size) of the ordinary subspace. All types of matter in the Universe should be understood only as local deformations (geometrical alterations of the spacetime) and hence are always secondary. This simple, but fundamental assumption naturally explains the existence of dark energy.

Hypothetical gravitational charges. According to the GPI, all the physical forces are driven by the similar geometrical origins: electric charges alter 5D spacetime, and color charges alter 8D spacetime. Thus, it is logical to assume that the third type of charges exist that alters 4D spacetime. However, as all the matter masses are induced, no gravitational charges are known. Notably, gravitationally charged particles are not prohibited in general and would present a perfect explanation for the dark matter. The ordinary subspace deformations induced by these charges should be stable (like the extradimensional deformations) and interact with ordinary matter extremely weak (via gravitation only) thus satisfying the two main conditions for the dark matter particles [12]. Based on the similarity with color and electric charges, there should be two types of gravitational charges inducing local positive or local negative curvature in the ordinary spacetime (arbitrarily positive and negative charges, respectively). Their movement cannot have any extradimensional component, hence, these “gravitational leptons” likely have no wave properties and no spin. For the same reason, the positive charges cannot bind the negative charges making a stable “combined particle”; they likely annihilate each other forming a flat space. Thus, only one type of gravitational charge can exist in the Universe. As the ordinary matter induces negatively curved deformations in the ordinary subspace, the negative gravitational charges would repel it. Hence, the dark matter particles are likely the positive gravitational charges, which are attracted to the ordinary fermions and annihilate their “shadow” ordinary subspace deformations consequently reducing the fermions’ gravitating masses. These interactions are obviously very weak and cannot be detected at a planetary scale.

Conclusion

The FCS postulates the simple asymmetric structure of the spacetime containing three subspaces with the topology $S^3 \times S^1 \times S^3$: ordinary (gravitational) subspace, electromagnetic subspace, and nuclear subspace, and the latter two subspaces are compact. This hypothesis naturally leads to the understanding of all four types of nature’s forces as governed by the spacetime geometry [3]. Surprisingly, both the GR and the SM describe the geometry-induced properties of the spacetime, however, using the two different mathematical methods. The fundamental incompatibility of the two theoretical approaches is predetermined by the observer’s position making the geometry-driven forces to look differently in the large space and in the compact extra dimensions. Thus, the compact geometry of the electromagnetic and nuclear subspaces cannot be described with the classical GR methods. The nonclassical methods were intuitively found by the founders of quantum mechanics almost hundred years ago, however, the realization of the fundamental role of geometry in particle interactions is yet to come.

This understanding requires a revision of the gauge transformation principle's general interpretation. Although this principle is a useful theoretical tool fundamentally important for the particle interactions' descriptions, it cannot be interpreted as a universal philosophical concept of interaction. The fundamental origin of any particle interaction is the extradimensional geometry, which governs the bosonic exchange, not *vice versa*. Moreover, the gauge transformation principle is actually based on the periodicity of fields defined by compactness of the extra dimensions. Hence, the principle cannot be applied to the large ordinary dimensions. In addition, the definition of quantum vacuum and its special properties need a reevaluation as well. Given the flat geometry represents the minimum energy state, and vacuum is a maximally flat space, no particle can appear from vacuum spontaneously if the particle is an extradimensional deformation and hence is not a flat space. Assuming leptons and quark triplets always exist in the 3-state (bound to a photon or a gluon, respectively), the exchanging boson is always real, not virtual. Thus, the gauge transformation principle in its philosophical utilization should be replaced with the more general GPI.

The FSC provides a new insight into the unification problem. The very different geometrical properties of the large and the compact dimensions (towards the observer) require different descriptions of the interactions they govern. Although both gravitation and particle interactions obey the same laws of geometry, the observer experiences them differently, and hence cannot have a single universal description for the both. Alas, the FCS cannot promise the long-awaited "Theory of Everything". Unfortunately, such a theory may not be possible, and thus, the GR and the SM will remain at their positions. On the bright side, the GPI-based understanding of the interactions provides the general rule of how to treat interactions in a special case. The local space appearance towards the observer (i.e. its compactness or non-compactness) is the main criterion for choosing the right type of the theoretical description. Although gravitation typically does not require quantum descriptions, it has to be treated with the QFT methods in case the ordinary subspace or its part appears compact to the observer. For instance, a quantum field approach would be needed describing the Big Bang or an interaction of black holes inside the horizon.

Although the FSC supports the SM in general, it does require a few notable changes. With the geometry-driven forces, the number of truly elementary particles is reduced to just four: electron, positron, **uuu**, and **ūūū** quark triplets. All other elementary particles including photons and gluons are binding states or/and wave polarization modes of the above-mentioned ones. The SM simplification also involves the rejection of neutrinos (replaced by photons), weak bosons (replaced by the quark-induced electric fields), and Higg's boson (as the Higg's field is charge-induced). With the three subspaces, the number of the fundamental fields is reduced accordingly: the gravitational, the electroweak, and the strong fields. All the extradimensional interactions are governed by the positive or negative curvatures induced in the nuclear or the electromagnetic subspace by color or electric charges (respectively) and torsional deformations induced by the extradimensional movement, spin. Gravitational interactions between the particles are governed by the secondary "shadow" deformations induced in the ordinary subspace by the charges.

The FSC helps to explain a number of important questions of quantum physics: particles' wave properties, induced masses of fermions, induced electric charges of quark triplets, fermion generations, color confinement, renormalization requirement, parity violation, and dark energy (the ordinary subspace background curvature). Moreover, the GPI and the FSC help to solve the fundamental philosophical problems of quantum mechanics explaining the peculiarity of quantum objects from the strictly materialistic positions [4]. In addition, these two concepts motivate the hypothesis of gravitational charges, a special type of particles being good candidates for the dark matter.

Overall, the FSC presents a useful philosophical concept in physics. Together with the GPI, it explains the fundamental role of geometry in all types of interaction and the inevitable incompatibility of the GR and the SM.

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