General Principle of Interaction, a Philosophical Concept for Complete Unification

Truth is ever to be found in simplicity, and not in the multiplicity and confusion of things.
Isaac Newton

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Abstract

It has long been expected that a consistent theory of quantum gravity will eventually unify gravitation with particle interactions. However, there is an alternative way – explaining all four types of interactions with vacuum geometry. The General Principle of Interaction (GPI) presents a philosophical concept that extends Einstein's understanding of the geometrically deformed vacuum (spacetime) in order to explain particle interactions. Surprisingly, this simple concept remained undeveloped to this day. If spacetime includes three separate "compartments": 4D ordinary spacetime (OST), "electromagnetic space" (EMS) with one extra dimension and "nuclear space" (NS) with three extra dimensions, then each type of interaction is governed by spacetime geometrical alterations in one of these "compartments". Consequently, any fundamental interacting field (gravitational, electromagnetic, or strong) is governed by geometrical deformations originating in one of the three spacetime "compartments" (OST, EMS or NS). The weak interaction should be understood as a type of electromagnetic interaction. Thus, a future GPI-based unified theory might be able to describe all four types of interaction with the "pure geometry" of 8D spacetime. The theory should be developed as a minimal extension of Einstein-Cartan theory taking into the account both metric and torsion tensors. It is expected that elementary particles will be described as quantized curvature/torsion wave-like vacuum deformations originating in the extra dimensions with certain secondary effects in 4D (mass, electromagnetic and strong fields). Unlike gravitation, the electromagnetic and strong fields cannot be described by a classical theory, as those fields originate in the extra dimensions, which are "unmeasurable". Hence, it is likely that the new theory will adopt (to a certain extent) quantum field methodology while remaining background-independent and avoiding any virtual particles or gauge bosons and neutrinos. This concept not only promises full unification solely based on spacetime geometry but also drastically simplifies the descriptions of particle interactions by reducing the elementary particle set and the total number of interacting fields.

1. Introduction

The Standard Model (SM) is presently the most useful theory describing the three types of interactions (electromagnetism, weak and strong nuclear forces) involving elementary particles [1]. It shows ultimate reliability for observational data including all the experiments. However, SM has a number of unexplained free parameters, does not unify the strong interaction with the electro-weak theory, and is incompatible with the theory of general relativity (GR). It is a common belief that a certain "more fundamental" quantum field theory (QFT) exists "beyond the SM". This hypothetical unification theory should explain and unify all four types of interaction. Unfortunately, this "Theory of everything" has remained elusive for many decades. The present letter proposes an alternative strategy, a philosophically consistent concept of interaction explaining all types of forces which is based not on the principles of quantum physics but solely on vacuum geometry.

1.1. Problems of QFT-based unification

It has long been expected that a superstring theory, most likely the M-theory, will unify all types of interaction [2]. Unfortunately, all presently known unifying theories, including all superstring theories, have serious problems [3, 4]. For instance, superstring theories have almost no predictive power and are not unique, i.e. the number of possible mathematical descriptions is tremendously great, and it is not clear how to choose the theory that describes our Universe in particular. This long lasting theoretical crisis raises serious doubts about the ability of quantum physics to provide a philosophically consistent basis for unification. The roots of this crisis are much deeper than just methodological and mathematical difficulties with the development of a unified quantum theory. It is an overwhelming fact that the two main pillars of modern physics, GR and SM stand on two completely different basic philosophical concepts. Simply put, the basic definitions of matter, vacuum and interactions used in the descriptions of particle interactions and gravitation are completely different. In QFTs, an interaction is understood with the gauge transformation principle, i.e. quantum objects exchange a field carrier quantum – the gauge boson. Moreover, any QFT (including any superstring theory or loop quantum gravity) is based on the Newtonian definition of vacuum and matter, i.e. vacuum is an empty "set of coordinates" that is not involved in the interaction, while interacting matter (particles, quarks, strings, etc.) possesses all the properties required for interaction. Quantum vacuum is not an interacting object *per se*, although it allows for "spontaneous birth" of pairs of virtual particles that can interact. On the contrary, GR is based on the concept of curved spacetime that involves the Einsteinian understanding of vacuum and matter. Gravitational interactions are mediated directly and only by the very own property of vacuum, spacetime curvature. Thus, the vacuum in GR is the primary interacting object, and its geometrical properties define an interaction while the matter is involved only indirectly, via its ability to curve vacuum (spacetime). In a logically defined theory, vacuum either mediates interaction or not, but not both, and hence, these two basic principles of interaction are mutually exclusive, and no unification theory could allow for both of these principles simultaneously.

Thus, the two completely different unification strategies can be considered: 1) Let the GR to be converted into a QFT, and any interaction to be described with the gauge transformation principle (QFT-based unification), or 2) Let the all four types of interaction to be understood as vacuum deformations (vacuum geometry-based unification). The second approach does not involve virtual particles and relies solely on the Einsteinian understanding of vacuum and matter that is more advanced philosophically than the Newtonian definition used in QFTs. Moreover, the phenomenon of "dark energy" (an acceleration of the Universe expansion that cannot be explained using the observed amount of total matter) shows that vacuum at the scale of the Universe does possess a certain "interacting property", not fitting with the Newtonian definition. Surprisingly, all active theorists have ignored the second approach completely for many decades.

Relying on the Newtonian understanding of non-interacting vacuum and interacting matter fields, QFTs provoke a number of fundamental questions. One of them is the renormalization problem, which appears when calculations of certain finite physical values result in infinities removed by a certain *ad hoc* procedure. Richard Feynman called this mathematical procedure a "hocus-pocus… prevented us from proving that the theory of quantum electrodynamics is mathematically self-consistent" [5]. In terms of quantum electrodynamics, when an electron interacts with a photon, the vacuum creates an infinite number of secondary interactions involving virtual particles. When these "virtual interactions" are accounted for, they add infinities to the calculated values requiring renormalization in order to get finite results. If one could describe particle interactions without any virtual particles (e.g. via vacuum geometry), none of the secondary interactions would be needed, thereby removing the renormalization issue as a matter of course. Notably, a rejection of virtual particles does not contradict any observation because virtual particles cannot be directly detected by definition. However, this rejection is principally impossible for QFTs, as the gauge transformation principle relies on virtual quanta and serves as the very base of quantum physics. Other continuously debated philosophical problems of quantum physics are observational indeterminism, wave-function collapse, and wave-particle duality.

1.2. Problems of GR-based unification

An alternative to a QFT-based unification strategy would be vacuum geometry-based unification relying completely on the Einsteinian understanding of vacuum and matter. It was the greatest of Einstein's dreams to explain the "base wood" of all forces as manifestations of the "pure marble" of spacetime geometry. Einstein had studied GR-based unification extensively; unfortunately, this noble mission was never accomplished.

It is logical to assume that all possible geometrical alterations of the 4D spacetime always have gravitational nature. Hence, the only philosophically consistent way to extend GR is by assuming that spacetime contains unseen extra dimensions "responsible" for particle interactions. Einstein and co-authors [6, 7] studied this approach in an attempt to unify gravity and electromagnetism within a classical field theory by introducing 5D spacetime as suggested by Theodor Kaluza [8]. Einstein and co-authors described a charged particle as a wave propagating in the fifth dimension and curving 4D spacetime [7]. Unfortunately, the later quality made the electromagnetic field indistinguishable from gravitation as both ended up having the same action power. Although Kaluza's brilliant idea to add an unseen extra dimension to 4D spacetime made it possible to unify GR with Maxwell's theory of electromagnetism, it remained merely a mathematical trick and has not led either to a viable theory of particle interactions or to a complete unification of all forces. Neither Einstein nor Kaluza has assumed that electromagnetic interaction actually occurs in the fifth dimension and is defined by its geometry, not by the 4D geometry. Moreover, Kaluza had proposed a cylinder condition stating that physics does not depend on the extra coordinate. In 1926, Oscar Klein [9, 10] had proposed that the fifth dimension is compactified and, therefore, undetectable. Since then, all the theories extending GR by introducing a 5D spacetime (even with a non-compact fifth dimension) are called Kaluza-Klein (KK) models. Both then and now, physicists have understood electromagnetism as a field coexisting with gravitation in 4D spacetime, but not as geometrical deformations of the extra dimension. The former assumption inevitably leads to a QFT-based description of electromagnetism. Thus, all 5D GR extensions using the KK approach made before [9, 10] and after [11, 12] Einstein's 5D models [6, 7] always consider electromagnetism as a gauge field and hence are unable to support vacuum geometry-based unification.

The present ignorance of path #2 seems odd, as no formal prohibition for a GR extension based on the concept of spacetime with extra dimensions is known. However, this approach has two fundamental complications. First, a philosophically consistent concept describing all types of interaction solely with spacetime geometry was never proposed, i.e. it was never explained successfully how spacetime geometry can define any interaction other than gravitation. To resolve this issue and extend the concept of geometrically deformed spacetime for all types of interaction, the General Principle of Interaction is proposed below (see §2). Secondly, it is unlikely that GR is the best unification platform (base theory) for vacuum geometry-based unification. Although GR is currently the standard theory of gravitation, it too has a number of fundamental problems. GR cannot explain inflation of the early Universe and the "dark energy" problem; it miscalculates rotational curves of galaxies and clusters leading to the "dark matter" problem. GR cannot avoid singularities in describing black holes and the Big Bang. GR lacks any technical ability to describe intrinsic angular momentum (e.g. spinning gas in galaxies) or an exchange of intrinsic and orbital angular momentum (spin-orbit exchange). GR is a classical field theory and does not involve any quantization, which is necessary for describing particle interactions. Clearly, GR cannot be used as a unification platform until these questions are resolved or at least until a way to overcome these difficulties is shown in principle.

Notably, GR was incomplete in terms of the spacetime geometry it can describe right from the moment it was born. For the sake of simplicity, Einstein had disregarded *ad hoc* any possible torsional deformation of spacetime. For a full description of 4D geometry, a theory of gravitation needs to consider both a metric tensor (present in GR) and a torsion tensor (disregarded in GR). In 1922, Elie Cartan proposed such a theory including non-zero affine torsion and known as the Einstein-Cartan (EC) theory [13]. EC removes the technical issues of describing spin-induced gravitation or spin-orbit exchange. Interestingly, gravitational torsion helps to explain all the above-listed problems of GR, except quantization. According to EC, there exists torsional deformation (presumably induced by spinning matter) of 4D spacetime in addition to curvature. This additional gravitational force is immeasurably small in the present Universe; however, it becomes testifiable at high densities of spinning matter, e.g. in black holes and the Big Bang. Recently, Poplawski showed that EC removes central singularities in black hole models with spinning matter [14] and that gravitational torsion can induce an extremely high repulsion force, thereby explaining inflation in the early Universe [15]. Thus, gravitational torsion induced by spinning matter removes singularities and explains inflation. A similar approach has been applied in an attempt to explain the "dark energy" and the "dark matter" problems with torsion, however, it seems that the amount of spinning matter observed in the Universe is insufficient to induce the forces measured in both cases [16, 17]. These inconsistencies might be resolved by assuming that vacuum itself has a certain non-zero deformation not induced by any matter. This cannot be a curvature, as the Universe remains flat in the observable region; however, this can be a torsional deformation, e.g. in case the whole Universe spins. This spin creates an additional "vacuum" torsion, which can be added to the torsion induced by spinning matter in order to explain the "dark energy" and the "dark matter" forces. Could it be that the unexpected alignment of very large "portions" of cosmic background radiation, as well as the unexpected alignment and preferred handedness of galaxy spins observed astronomically [18] (the so-called cosmic "Axis of Evil") are actually the signs of the rotational axis of the Universe? If so, "vacuum" torsion induced by this rotation might explain the minimal orbital acceleration always observed in galaxies and calculated by MOND [19]. Further examinations of matter and background radiation distributions in the Universe would help to testify this assumption. The above reasoning suggests that EC, but not GR should be the base theory (of gravitation) for vacuum geometry-based unification.

Finally, there is one more fundamental question related to both GR and EC, i.e. quantization. Both these theories understand gravitation as a continuous (classical) field and hence do not involve quantization. Obviously, a unified theory involving particle interactions is impossible without this requirement. This brings a dilemma of how to achieve quantization without conversion of the base theory into a QFT. Ideally, the equations of particles' motion in a unified theory should have certain wave-like solutions, which describe spacetime deformations as curvature/torsion waves with integer wavelengths, i.e. quantized. This possibility is further discussed in §3.1.

Thus, it seems possible, at least in principle, to develop a philosophically consistent concept of interaction applicable to all types of forces and based solely on vacuum geometry. Below, we explain such a concept defining all types of interaction as geometrical deformations of spacetime with unseen extra dimensions. We assume that a complete unification theory can be developed in future by setting EC as a base theory (describing gravitation as 4D spacetime deformations) and extending spacetime with a number of undetectable extra dimensions, deformations of which define electromagnetism and the nuclear forces.

2. The General Principle of Interaction

Assuming direct involvement of spacetime in all types of interaction, one can formulate the General Principle of Interaction stating that any physical interaction is governed by certain alterations of spacetime geometry. Three types of interaction (gravitational, electromagnetic, and strong) occur in three separate "compartments" of spacetime. If spacetime contains extra spatial dimensions somehow separated from 4D ordinary spacetime (OST), each type of interacting field geometrically alters its own "compartment". Thus, electromagnetism and the nuclear forces should be understood as certain geometrical deformations originating in the extra spatial dimensions. Mass induces vacuum deformations in 4D OST, similarly, electric charges induce deformations in the fifth dimension, i.e. "electromagnetic space" (EMS), and "color" charges alter the geometry of "nuclear space" (NS), which consists of three additional dimensions. If this is so, the whole Universe contains nothing but "empty" vacuum geometrically altered in different ways, and all types of matter, i.e. all elementary particles are 4D manifestations of various deformations of 8D spacetime. The undetectable extra dimensions and the OST dimensions appear different in the observable Universe. However, at a very high energy, all the dimensions are likely to become equal, forming a symmetrical compactified manifold with no "compartmentalization" and one universal interaction. This concept of "compartmentalized" spacetime provides a simple philosophical basis for vacuum geometry-based unification of all forces.

According to GPI, any potential energy is a measure of spacetime deformation; it increases with any curvature or torsion and decreases with flatness or lowered torsion. Thus, all interactions are governed by various geometrical deformations of one of the three spacetime "compartments" (NS, EMS or OST) driven by the principle of minimum energy, i.e. minimal curvature and torsion. GPI can be consistently applied to all four types of interactions simplifying the basic descriptions of particle interactions (see §3).

GPI leads to a very general understanding of all types of physical fields as certain spacetime alterations. If all types of interaction can be described with various deformations of the 8D spacetime, all interacting fields are vacuum deformations defined by the spacetime geometry. Moreover, in case all types of these deformations are described as waves with integer wavelengths, interactions are always quantized. The number of fundamental fields consequently reduces to just three, i.e. gravitational, electromagnetic and strong fields defined as geometrical deformations of the three distinct "compartments" of 8D spacetime (OST, EMS, and NS, respectively). The weak field is just a type of electromagnetic field. The concept of spacetime deformation excludes all the gauge fields and gauge bosons. Thus, H, W and Z bosons can be avoided. Photon and gluon can be understood as "vacuum waves" participating in interactions, but not mediating them. Neutrino rejection also comes naturally (see §3.4).

3. GPI-based descriptions of particle interactions

3.1. GPI-based description of electromagnetism

3.1.1. The electromagnetic field as EMS deformations. According to GPI, electric charges induce deformations of the EMS “compartment” of spacetime. This requires the existence of at least one extra spatial dimension (EMS) in addition to the ordinary four dimensions (OST). In the simplest case, EMS can be described as a 1D-circle extension at each point of 4D OST exactly as suggested by Kaluza in 1921 [8]. Then, electric charge-induced deformations of the EMS should represent the electromagnetic field. However, the electromagnetic field has two interrelated, but distinct components - the electrostatic field and the magnetic field. In order to be distinguishable, these two fields should be identified with two different geometrical alterations of EMS. It is logical to assume that EMS curvature defines the electrostatic field, and EMS torsion defines the magnetic field. These two types of deformation differ, yet coexist in one dimension. An elementary electric charge deforms EMS vacuum inducing a standing wave (e.g. soliton) with curvature and torsional components: a curve (positive or negative) identified with its electrostatic field and a twist (left or right) identified with its magnetic field (Fig. 1). The curve is unchangeable due to the law of charge conservation; the twist also has a constant value, but variable direction. Thus, an elementary electric charge always has a magnetic moment and induces both electrostatic and magnetic fields.

Unlike gravitation, electromagnetic interaction involves two types of inducers: positive and negative charges. Assuming that positive and negative electric charges deform EMS in opposite ways (for simplicity, let us suggest that positive charges induce positive curvature, and negative charges induce negative curvature), an electrostatic interaction can be seen as a geometrical combination of EMS curvatures produced by interacting elementary charges (Fig. 1). The principle of minimum energy (maximal flatness in this case) explains the dual nature of this interaction. A positive and a negative charge attract because two opposite sign curves tend to cancel each other, and same sign charges repulse due to increased local EMS curvature.

Assuming that an elementary charge actually spins in the EMS dimension, the spin-induced torsional deformation presents an elementary magnetic field. Let us call this elementary torsion a twist (to avoid possible mixing with the quantum mechanical term of spin). EMS twist occurs in one dimension having one of two possible directions (left or right), which can change during interactions. Two electrons with opposite twists can share the same atomic orbital as these two torsional deformations cancel each other. This concept also explains the fact that a macroscopic electrostatic field can exist in the absence of a magnetic field (even if electrons in a substance are rearranged so they induce an electrostatic field, the electrons’ twists can cancel each other removing the magnetic field). A macroscopic magnetic field is also possible in the absence of an electrostatic field when electrons’ twists are in order (mostly left or mostly right). This concept also allows explaining electromagnetic induction with EMS geometry. (A magnetic field induces electric current when, for example, a magnetized body with co-oriented electron twists is moving about a metal rod. In such case, the rod's electron twists also become co-oriented but in an opposite direction. As the rod's electrons are now bound with the body's electrons via the magnetic field, the rod's electrons will follow the body's movement producing an electric current in the rod. An electric current induces a magnetic field if moving electrons tend to have their magnetic twists co-oriented with the direction of motion.)

3.1.2. EC extension in 5D spacetime. In order to describe electromagnetism and gravitation as two separate forces, spacetime should be seen as having two separate "compartments", 4D OST and 1D EMS (presumably embedded into a "base" dimension in order to "sense" their deformations). Assuming that any electromagnetic interaction occurs in the fifth dimension (EMS) only, it can always be "separated" from gravitation. This ensures that electromagnetism has a different action power and is distinguishable from gravitational forces. In the simplest case, the fifth dimension is circular and closed, and the combined 5D spacetime can presumably be described with an almost flat 4D anti-deSitter space (OST) and a highly curved 1D circle (EMS) separately embedded in a flat 6D canonical space. Although this description of spacetime has obvious similarities with known KK models [9-12], there are some notable differences. First, if as according to GPI, physics does depend on the extra coordinate, Kaluza's cylinder condition has to be rejected completely (the "anti-cylinder" condition). Secondly, assuming that electric charges induce deformations in the extra dimension, EMS cannot be compactified. For a compactified EMS, its geometrical alterations are limited to the microscopic size consequently having a very short range of action, which is not the case as both electric and magnetic fields are macroscopic. Thirdly, although both Klein [9, 10] and Einstein [6, 7] did consider the fifth dimension as an origin of electric charges, the electromagnetic field was never understood as deformations of the fifths dimension. Despite the core difference in their basic understanding of interaction (Einstein's KK models were built as classical background-independent theories and Klein's model relied on a gauge field description), both these approaches have understood electromagnetism as a 4D field, i.e. a property of 4D spacetime (OST) only. On the contrary, the GPI-based approach assumes that the electromagnetic field physically presents only in the fifth dimension (the "anti-cylinder" condition), and its 4D manifestations are the secondary effects. The electromagnetic field is observed in 4D OST only because charged particles always have mass and thus are physically present in 4D OST. Unfortunately, neither Einstein nor other theorists worked on KK models had not studied this possibility.

In order to describe electromagnetic field with geometrical deformations of the fifth dimension, one can possibly construct a minimal extension of EC with a 5D metric tensor and a 5D torsion tensor. The metric tensor will describe the electrostatic field as EMS curvatures and "main" gravitational field as OST curvatures (e.g. eq. (5) in [12]), and the torsion tensor will describe magnetic field as EMS torsion and "additional" gravitational field as OST torsion. In the case of 5D metric tensor, both the scalar and the 4-vector parts of the tensor describe the electrostatic field. The scalar describes electric charge-induced spacetime curvatures that occur in the fifth dimension (EMS), and the 4-vector describes a secondary effect of these deformations in OST, i.e. electrostatic field acting on charged 4D objects. (Notably, none of all known 5D metric tensors used in KK models [11, 12] matches this description, as the three parts of the tensor are always assumed to define three different fields.) As a result, in OST, one would have 5D geometry-based electrostatic interactions distinct from gravitation. Assuming that the EMS "background" vacuum curvature is much higher compared to OST (i.e. EMS vacuum has nonzero curvature even in the absence of interaction), it is possible to explain the present physical separation of OST and EMS together with the fact that the electrostatic field is much stronger than gravitation. Another secondary effect of electric charges in 4D will be 5D metric-derived "shadow" deformations of OST described by the gravitational parts of the metric tensor and interpreted as mass actually induced by the charge. This effect is similar to the "induced matter" phenomenon of noncompactified KK models [12]. Similarly, the 5D torsion tensor would describe electric charge-induced spacetime torsion that occurs in 1D EMS and manifests itself as the magnetic field in 4D OST. This EMS torsion also induces a "shadow" deformation of OST as an "additional" mass induced by the charge. This torsion-induced mass should be negligibly small compared to the curvature-induced mass.

3.1.3. Quantization of the electromagnetic field. Quantization of the electromagnetic field comes naturally if elementary electric charges, electron and positron, could be described as wave-like deformations of the EMS with integer wavelengths. If the EMS dimension is circular and closed (but not compactified), any elementary EMS deformation induced by an electric charge can be defined as a standing wave with an integer wavelength. Interestingly, in the noncompactified KK models [12], an equation of electron motion derived from the 5D metric tensor is mathematically equivalent to the Klein-Gordon equation allowing wave-like solutions. Thus, it is likely that the field equations derived from the 5D metric/torsion tensors will be a form of the Klein-Gordon equation, thereby describing electron (or positron) as a quantized wave-like EMS deformation.

3.1.4. Electron and photon as two types of EMS wave-like deformations. We speculate that there are two types of EMS waves: 1) the photon, a wave-like EMS deformation with zero peak-to-peak curvature amplitude and zero average torsion ("zero-wave"), and 2) the electron, a wave-like EMS deformation, possibly soliton ("nonzero-wave") with a negative curve (negative nonzero peak-to-peak curvature amplitude) identified with its charge and a twist (left or right) identified with its magnetic moment. The positron EMS wave is similar to the electron wave but has a positive EMS curve (Fig. 1). In OST, "nonzero-waves" have secondary 4D effects identified with the electromagnetic field and mass and defined by the metric and torsion tensors.

It is likely that the photon wave produces no overall EMS deformation with no secondary OST deformation because its positive curve/twist and negative curve/anti-twist wave elements cancel each other in time. Thus, it has no charge, no mass, but kinetic energy only. Being massless, the photon wave exists solely in the extra dimension, and the only way to register it in 4D OST is by absorption. Hence, the photon speed in the EMS cannot be measured in 4D OST, and therefore, it is not necessarily limited to the value measured in the OST.

The EMS curves and twists of electrons and positrons govern the particles' attraction or repulsion. For example, the Pauli Exclusion Principle can be explained with the assumption that two negative EMS curves cannot co-localize due to the resulting increase in local EMS deformation (principle of minimum energy); therefore, electrons occupy separate atomic orbitals. However, two electrons can share one orbital if they have opposite EMS twists canceling their magnetic repulsion (but not electrostatic repulsion). Photon waves induce no overall EMS deformation, therefore, they do not attract/repel either each other or "nonzero-waves"; hence they co-localize (superpose) together or with a curvature-inducing wave. An electron or a positron wave can superpose with a photon wave increasing the energy (absorption). A positron can annihilate an electron as their EMS deformations cancel each other; however, their associated photons remain. GPI and the minimum energy principle prohibit any spontaneous appearance of particle-antiparticle pairs that is generally allowed in QFTs. EMS vacuum cannot spontaneously change into a higher energy state represented by the two spacetime deformations with no cause.

3.1.5. Connecting spacetime geometry with quantum physics. At a first glance, it seems that the GPI-based approach completely rejects quantum physics and calls for a purely classical unified theory. This is not true. Although EC, the most probable base theory for a vacuum geometry-based unification is indeed a classical theory, the classical field description cannot work with EMS, as it does with OST. It is impossible to use a classical field theory to describe the EMS deformations because the EMS coordinate is unmeasurable in principle. Only the secondary effects of the EMS deformations (4D electromagnetic field characteristics and particles' masses) can be measured. If so, how do we describe these unmeasurable EMS waves? Surprisingly, the mathematical methods of quantum electrodynamics could be the answer. It seems very likely that the complex-valued wavefunction (or complex-valued operator-based mathematics in general) is indeed such a method that describes a function depending on an extra coordinate, which is always hidden. This would explain the uncertain nature of particles' behavior, as well as the wave-particle duality. As shown above, interacting elementary charges are primarily EMS waves; however, they can be approximated as point particles with masses in 4D OST. All the particles' main characteristics (energy, momentum, position) are primarily defined by the unmeasurable extra (EMS) coordinate. Thus, a GPI-based theory of electromagnetism has to operate with the methods of quantum, not classical physics and adopt complex-valued mathematics. In such case, the uncertainty and probabilistic nature of the "adopted" wavefunction are predetermined by the "undetectability" of the fifth dimension. In addition, the assumption that an electromagnetic interaction actually occurs in the fifth dimension (the "anti-cylinder" condition) allows preserving both locality and realism (local relativistic causality and observational determinism) of the interaction. Any "spooky action at a distance" questioned by the famous EPR paradox [20] remains "local" in case it actually happens in the extra dimension (EMS). By adopting quantum electrodynamics methodology, the GPI-based understanding of electromagnetism can build a bridge between spacetime geometry and quantum physics. An important difference, however, will always remain – background-independence with consequent rejection of gauge particles. This key difference allows avoidance of the renormalization problem (see §1.1). Another bonus of the GPI-based approach, an explanation of charged particles' masses, appears naturally as a secondary effect of the EMS deformations described by the metric and torsion tensors (see §3.1.2). This explanation avoids any requirement for a special (Higg's) mechanism.

The future 5D spacetime geometry-based theory is expected to bring the same mathematical descriptions of particles as quantum electrodynamics. It is encouraging that both quantization and wave dynamics have been shown previously in both compactified [9, 10] and noncompactified KK models [12, 21]. Although in a GPI-based theory, the metric tensor should be different from those models and additionally combined with a torsion tensor (see §3.1.2), the general similarity is likely to remain. For instance, it is very likely that the equation of electron motion derived in the 5D spacetime will be a form of the Klein-Gordon equation. This equation cannot describe electron motion in quantum electrodynamics, because it only applies to zero-spin particles and, hence, calculates the electron's energy levels in the atom incorrectly [22]. However, in a GPI-based theory, this issue is likely to be resolved, as the addition of a charge-induced EMS torsion will change the motion equations in a way equivalent to the introduction of electron spin in quantum electrodynamics.

3.2. GPI-based description of strong interactions

Strong interaction is governed by the three types of "color" charge ("R", "B" and "G"), has extremely short distance and high power of action. It is expected that by extending the 5D spacetime (see §3.1) with an additional "compartment" having three spatial dimensions that form 3D "nuclear space" (NS), it would be possible to describe strongly interacting objects together with the electromagnetic interactions. Thus, the combined 8D manifold needed for the unification of gravitation, electromagnetism, and strong forces should include 4D OST, 1D EMS and 3D NS separated by differences in their "background" vacuum curvatures reflecting the differences in their action powers.

Each type of "color" charge has its anti-charge; and each "color"-"anticolor" pair behaves like a pair of positive and negative electric charges. This similarity allows assuming that a "color" and an "anticolor" charge deform one of the NS dimensions in opposite ways inducing a positive and a negative curvature. Thus, the NS deformations also should include the two types: 1) "nonzero-waves" with positive or negative curvatures (curves) and certain torsional deformations (twists) induced by "color" charges, i.e. quarks (similar to the electron/positron waves in the EMS), 2) "zero-waves" with zero average curvature and torsion, i.e. gluons (similar to the photon waves in the EMS). Although the first type of NS waves has both curves and twists, these two types of deformation are likely indistinguishable due to a very short range of action. The two major types of strong interaction can be explained as followed. 1) Quark-antiquark pair (meson): a "color" and an "anticolor" charges induce two NS deformations that cancel each other. This interaction is similar to the electron-positron interaction in EMS. 2) "Tricolor" quark triplet (baryon): three different "colors" or three different "anti-colors" induce a symmetrical 3D NS deformation forming a compact 3D sphere or an inverted sphere. It is unlikely that the “tricolor” combination can compactify the EMS or OST dimensions, as baryons’ and leptons’ electromagnetic and gravitational fields act similarly. The “tricolor” combination can be composed only of charges with the same curve (either positive or negative), as that is the only possibility to form a 3D sphere (inverted sphere). As the sphere is geometrically closed, no internal NS deformation, i.e. no quark or gluon can escape it, which explains the confinement. This geometrical “compactness” can explain the physical stability of proton. A spontaneous proton decay is impossible unless the NS 3D sphere undergoes decompactification. The second type of strong interaction is also responsible for baryon-baryon interactions. If two nucleons (two NS spheres) are close enough, an additional “tricolor” charge combination forms an inverted NS sphere in between (a triplet with one quark from the first nucleon and two quarks from the second nucleon). Therefore, the six-quark combination representing two bound nucleons is geometrically more stable than two separated quark triplets.

Thus, it seems possible to describe the strong interaction with a minimal EC extension in the 8D spacetime with topology [R^4 x S^1 x C^3] embedded in a flat 9D canonical space. This requires an 8D metric tensor and an 8D torsion tensor. As with the 5D tensors describing electric charge-induced EMS deformations (see §3.1.2) the main components of the 8D metric and torsion tensors will be identified with the “color”-induced NS deformations. Other components of the 8D tensors will describe the secondary effects of “color” charges (EMS deformations and OST deformations). As a result, the extended theory will describe strongly interacting quarks with “induced” electric charges that in turn have “induced” masses. This concept correlates with physical reality, as a “color” charge always has both an electric charge and a mass. Quantization will be achieved similar to the GPI-based electrodynamics (see §3.1.3) by describing the “color” charge-induced NS deformations as waves with integer wavelengths. Notably, classical field description for these waves may not be possible due to the “unmeasurable” nature of the NS dimensions. Hence, the new theory will have to adopt (at least partially) quantum field methodology, however, not allowing for the gauge transformation principle. In overall, the concept of extended 8D spacetime sets a philosophically consistent framework for a future GPI-based background-independent theory of strong interactions.

3.3. GPI-based description of weak interactions

Historically, the weak nuclear force was introduced as a special type of nuclear interactions that explains neutron decay. However, there is no special charge identified with the weak interaction. For protons and electrons, the weak forces are calculated based on the electric charges. Hence, it is logical to assume that the weak interaction is actually a kind of electromagnetic interaction involving electric charges and “color” charges. In hadron-lepton interactions, “color” charges interact indirectly, via their “induced” electric charges (see §3.2). When a proton interacts with an electron inside hydrogen atom, the electron’s EMS deformation and the quark triplet’s “induced” EMS deformation are likely not completely co-localized as the electron cloud is “spread” around the nucleus, and hence, the two EMS deformations cannot cancel each other perfectly. The complete co-localization of these two EMS deformations is identified with a neutron, in which these EMS deformations are fully canceled. Thus, the neutron has a zero electric charge and no (or at least immeasurably low) electric dipole moment. Surprisingly, the neutron is less stable than the hydrogen atom. One of the two reasons can possibly explain this instability: 1) an increased kinetic energy of the "inner" electron or 2) an increased EMS torsional deformation induced by the neutron compared with the hydrogen atom. Obviously, the second explanation is dubious, because the atomic electron's magnetic moment is about 1,000 fold higher than that of the neutron or the proton. Thus, the electron's co-localization with the proton actually reduces EMS torsional deformation consequently increasing the neutron's stability. The only explanation left is an increased kinetic energy of the "inner" electron (experimentally seen as the mass difference between the neutron and the proton). When the neutron decays, the extra energy of the "compressed" electron is emitted as a photon mistakenly identified with a neutrino. A more detailed explanation should come with the future GPI-based theory of electrodynamics.

Although the GPI-based concept explains the weak interaction in a much simpler way than the SM, this comes with a price of rejecting W and Z bosons (as GPI allows no gauge bosons) and a neutrino. If the neutrino has neither electric nor "color" charge and is not a photon, it cannot induce any EMS deformation; and hence, it cannot interact with other particles, except via gravitation. Thus, the GPI-based approach does not allow neutrino to interact in the EMS. Notably, these rejections do not contradict any experiments as gauge bosons are always virtual, and no experiment can prove them directly. In bubble chambers and all other types of detectors, bosons make no visible track, and, therefore, cannot be distinguished from photons. Therefore, the neutrino concept requires careful re-evaluation. In 1930, a weakly interacting particle, the neutrino, was suggested by Wolfgang Pauli to explain the continuous energy spectrum of beta-rays in beta decay. As another possibility, this spectrum [23] can be explained by the bremsstrahlung radiation produced when the beta-rays are deflected by the neighbor atomic nuclei. This radiation was not completely ruled out in the early beta-ray experiments as the detectors were typically shielded from gamma-rays [23]. Moreover, all currently used types of neutrino detection are indirect; hence, the detected particles are indistinguishable from photons. For instance, the neutrino telescopes actually detect photons, which are presumably produced by the neutrinos. However, the counted rare events interpreted as neutrino detection can be possibly explained by the high-energy cosmic gamma radiation.

3.4. Reduction of the elementary particle set

The SM elementary particle set presently includes 61 components: 36 quarks (2 flavors x 3 generations x 3 "colors" x 2 quark-antiquark pairs), 12 leptons (2 types x 3 generations x 2 particle-antiparticle pairs) and 13 gauge bosons (8 gluon types, photon, W^+, W^-, Z, and H bosons, not including graviton). From philosophical grounds, some quarks and leptons are not truly elementary as they decay into other elementary particles or transform into each other. In addition, SM requires a number of *ad hoc* parameters and a special Higg's mechanism explaining masses of hadrons and leptons.

The GPI-based concept of particle interactions reduces the number of all interacting fields to three (see §2) and drastically simplifies the list of elementary interacting objects (Tables 1 - 3). The revised elementary set includes only two types of NS and EMS deformations: "nonzero-waves" induced by charges and "zero-waves" (Table 2). The six types of the elementary **u** quark (3 "colors" x 2 quark-antiquark pairs) are explained with the positive or negative average curvature deformations induced by the elementary "color charges" in the three NS dimensions. The two elementary leptons (electron and positron) are explained with the positive or negative curvature deformations induced by the elementary electric charges in the EMS. The NS "nonzero" deformations (quarks) always induce secondary deformations in the EMS (quarks' electric charges), and the latter in turn induce 4D OST deformations (quarks' masses). Thus, it is likely that any kind of mass is a secondary effect of electric charges. Gravitational waves induced by the electric charges can be derived from the 5D metric and torsion tensors for a given EMS deformation. All gauge bosons and virtual particles are avoided as all interactions are driven by the geometrical deformations of 8D spacetime. Thus, H, W, and Z bosons are not needed. Photons and gluons are not gauge bosons, but wave-like deformations with zero peak-to-peak curvature amplitudes and zero average torsion ("zero-waves") propagating in the EMS and the NS, respectively. Neutrinos are prohibited as uncharged particles, except photons, cannot interact with charged particles. As particles' masses come naturally as a secondary effect of the electric charges, no Higg's mechanism is needed.

All particles except listed in Table 3 are either composite or "excited" states of the elementary spacetime deformations listed there. An elementary **u** quark and its antiquark represent elementary "color" charges, i.e. NS "nonzero-waves" with a positive or a negative curve (elementary curvature deformation) and a twist (elementary torsional deformation). A **d** quark is understood as an **u** quark co-localized with an electron (see §3.3). Quarks and leptons of the second and the third generations are not elementary as they decay into the first-generation quarks and leptons. The higher quark generations can be explained by an increased energy (frequency) of gluons associated with the first-generation quark inside mesons and baryons. Increased total energies of the composite mesons and baryons containing such "excited" quarks (**c**, **s**, **t** and **b**) are presently interpreted as larger masses. The muon and tau leptons similarly represent "excited" states of electron combined with a higher energy photon. If there is no limit to the maximum energy of this associated photon, it is possible that more than three generations of leptons exist. Similarly, the number of quark generations can be greater as well, and future experiments will possibly justify these assumptions.

Table 1: Fundamental interactions

Interaction	Field origin	Primary elementary deformations
Gravitation	OST deformations	none (induced by EMS deformations)
Electromagnetic and weak	EMS deformations	electric charges (2 types) and photon
Strong	NS deformations	"color" charges (6 types) and gluon

Table 2: Three "compartments" of 8D spacetime

"Compartment"	Description	Deformation origin	Dimensions
OST	almost flat, closed, noncompactified	mass (induced)	3 spatial + 1 time
EMS	curved, closed, noncompactified	electric charge	1 spatial
NS	extremely curved, closed, compactified	"color" charge	3 spatial

Table 3: Elementary deformations of 8D spacetime

Elementary spacetime deformation	Description	Curve* (average)	Twist** (average)	Primary origin	Secondary effect(s)
Quark, antiquark	NS deformation, wave	nonzero	nonzero	"color" charge	electric charge, mass
Gluon	NS deformation, wave	zero	zero	unknown	none
Electron, positron	EMS deformation, wave	nonzero	nonzero	electric charge	mass
Photon	EMS deformation, wave	zero	zero	unknown	none

***** - Curvature part of the deformation (averaged in time)
****** - Torsional part of the deformation (averaged in time)

4. Conclusion

Despite all the great achievements of quantum physics, complete unification of the four fundamental interactions remains beyond its reach. The main theoretical effort is still concentrated on the development of a superstring unified QFT. Why the alternative unification approach based on vacuum geometry is ignored by present theorists? The vacuum geometry-based unification simply impossible until the concept of spacetime deformation is able to explain particle interactions. The General Principle of Interaction (GPI) presents such a concept extending Einstein's understanding of geometrically deformed vacuum (spacetime) and making it applicable to all types of interaction. The extended definition of spacetime includes three separate "compartments": 4D OST, 1D EMS and 3D NS, and each type of interaction is governed by certain geometrical alterations of one of these "compartments". Following this concept seems challenging, as even Einstein himself was unable to unify gravitation and electromagnetism by means of a 5D relativity theory [6, 7]. However, the assumption that all the particle interactions actually occur in the undetectable extra dimensions (the “anti-cylinder” condition) allows to resolve the two major problems of the vacuum geometry-based unification: 1) define clearly what kinds of spacetime deformations are responsible for each type of particle interactions (without mixing them with 4D deformations, which always are of gravitational nature), and 2) adopt the quantum physics methodology without relying on the gauge transformation principle (as the general uncertainty of particle interactions is pre-defined by the undetectable nature of the extra dimensions). The remaining difficulties of the GPI-based strategy are mainly technical, and a correct description of the multidimensional spacetime geometry will eventually bring the right theory.

In the early years of quantum physics, some scientists, including Einstein, rendered it incomplete for its incompatibility with the two philosophical principles of scientific observation, determinism and causality [20]. During that time, many have expected that a complete theory of particle interactions eventually reveal some hidden parameters missing in the QFTs. However, recent experiments [24] have proven in general the Bell’s theorem [25], which stated that although quantum mechanics violates both locality and realism, it is nevertheless the best possible theory describing particle interactions. Notably, the Bell’s theorem had been formulated for a 4D reality, but what if nature is a bit more complicated, and extra dimensions exist? Then, the question of the general incompleteness of the quantum field description will rise again, and the extra coordinates could present the additional parameters instead of “hidden” 4D parameters. The introduction of unseen extra dimensions seems irrational and unnatural. However, it may, in fact, build a bridge between spacetime geometry and quantum physics explaining the uncertain and dualistic nature of particle interactions by the “undetectability” of the extra coordinates. This explanation resolves the famous argument between Bohr and Einstein. If the extra dimensions exist, the both sides are right! According to the Copenhagen interpretation, particles cannot have definite properties, and this is true because the extra coordinates primarily defining particles’ interactions are “unmeasurable” in our 4D world. Yet, according to Einstein’s view, nature remains completely deterministic at all levels, however, our deterministic abilities may be limited by our four-dimensionality.

The vacuum geometry-based unification strategy holds a great promise to fulfill Einstein’s vision of reducing physics to the pure geometry of spacetime. The GPI unifies matter and spacetime at a very basic level. Philosophically speaking, unaltered spacetime (in the absence of curvature or torsional deformations) or true vacuum is the only one primary entity, a very basic “element” of the Universe, and all types of matter can be understood as its deformations (Table 3). The GPI-based descriptions of the four types of natural forces allow for a background-independent unified field theory describing all known types of interaction as geometrical deformations of the 8D spacetime. This future theory will be developed as an extension of EC (4D theory of gravitation) with the 5D metric and torsion tensors (for electromagnetism) and the 8D metric and torsion tensors (for strong nuclear forces). In order to operate with “unmeasurable” extra coordinates, the theory will adopt some QFT methodology, however, rejecting the gauge principle of interaction. This approach promises a number of advantages over the

SM and any other QFT-based unification (see §3.1 – §3.4): 1) fully deterministic understanding of all interactions; 2) background-independence and full compatibility with GR; 3) natural quantization with the description of elementary particles as wave-like deformations; 4) reduction of the elementary particle set and the number free parameters; 5) avoidance of the renormalization problem; 6) simple explanation of confinement; 7) avoidance of the Higg's mechanism. In addition, gravitational torsion described by EC is expected to explain the "dark matter" and the "dark energy" phenomena (see §1.2).

Overall, the concept of "compartmentalized" 8D-spacetime deformation, i.e. GPI provides a philosophically consistent basis for a future vacuum geometry-based background-independent unified theory expected to describe all four types of physical interactions. This GPI-based theory will naturally combine the Einsteinian understanding of interaction as deformation of spacetime with natural quantization by describing all elementary particles as wave-like deformations of unseen extra dimensions. The unified theory will adopt certain quantum field methodology without relying on the gauge transformation principle. Mathematical development of this theory remains an open question; possible modifications of the Kaluza-Klein approach for the GPI-based electrodynamics is discussed in §3.1. It is possible nevertheless to make a number of falsifiable predictions shown in §§3.1-3.4. Future physical and astronomical observations will be needed to validate these predictions.

5. References

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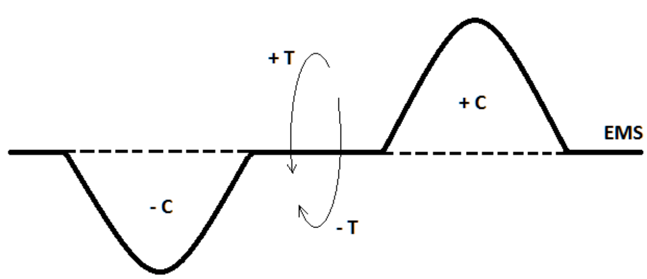

Figure 1: A simplified and averaged-in-time representation of the “nonzero” EMS waves (electron, on the left and proton, on the right) with the curvature and torsional components: a curve (C) and a twist (T), respectively. The horizontal line depicts a fragment of the fifth dimension (EMS), which is assumed as a 1D closed circle extending each point of 4D spacetime as suggested by T. Kaluza [8].