Gravitation ever Since and Forever

By Doron Kwiat

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The more mass created by these processes, the more is the distortion of the gravitation field and the more mutual attraction of masses to each other. This gradually leads to the accumulation of larger and larger masses.

Mass considerations, under general relativity, lead to Planck length. This in turn, brings to conclusion on quantization of space. Quantum fluctuations in space, lead us to the basic definition of time.

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I. Introduction

Gravitation was discovered by Sir Isaac Newton, as published in the third volume of the Principia[1]. Newton proved that his laws of motion, together with the law of universal gravitation, explained the laws of planetary motion.

In 1915, Einstein had modified the concept and showed that gravitation is a field that becomes distorted under the presence of mass. Hence the force of gravitation is due to bending of the field lines of the gravitation field as a result of a nearby massive object. General relativity, is the geometric theory of gravitation published by Albert Einstein and Marcel Grossman[2,3] in 1913. It is the basis for the description of gravitation in modern physics. General relativity describes gravity as a geometric property of four-dimensional spacetime. In particular, the curvature of spacetime is directly related to the energy and momentum of matter and radiation present.

In the search for quantization of the gravitational field, current assumption is that gravitation is mediated by quantum particles named gravitons, Gravitons are assumed to be the bosons which carry the gravitational force. Just like photons carry the electromagnetic force.

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They would be a microscopic phenomenon that will dominate quantum fluctuations at high intensity gravitation fields.

II. Mass

Mass as we know it is a collection of elementary particles (elementary particles may be massive or massless). Gravitation affects mainly cosmic objects because its effect falls off slowly with distance. Other forces (weak and strong) fall off rapidly with distance.

At short distances, the effects of the electromagnetic, weak, and strong forces shield off the effect of gravitation. Nevertheless, gravitational attraction affects both at small, as well as large distances. It affects stellar objects, as well as all elementary particles.

All elementary particles (see appendix) are either massive (with rest mass $m_0 > 0$), or massless (with rest mass $m_0 = 0$).

Massive elementary particles are fermions (Dirac particles).
Massless elementary particles are bosons.

An exception to these, is the massive weak bosons $W^\pm$, Z, and Higgs. But their half-lives are so short (of the order of 10^{-26} seconds), that their spatial existence is limited to distances of no cosmological effect. ($\sim 10^{-26}/3 \times 10^8 \approx 10^{-32}$cm, but still within the Planck distance).

Fermions are confined to 4 dimensions[12] and can never cross to an extension of our universe to higher dimensions.

All particles, including bosons, have to move, according to gravitational principles of general relativity, along with the gravitational geodesic 2-dimensional tensor $8^{\mu\nu}$:

$$ds^2 = dx_\mu dx_\nu \, 8^{\mu\nu}$$

Massless particles must, according to relativity, move at the speed of light c ($\approx 3 \times 10^8$ m/sec). c is a universal constant.

The reason is that the mass m of a particle moving at speed v, is given by

$$m = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} m_0$$

and unless $m_0 \to 0$ where $v \to c$, m becomes infinite.

According to the confinement assumption[13], the universe is made of two sub-universes. All particles in one sub-universe (for instance, our universe) can never reach the other sub-universe (a parallel universe). Each

of these sub-universes has 4 dimensions. One may point from one sub-universe, to the origin of the other (parallel) sub-universe, with the use of a 3-dimensional pointer which start point is at 3 coordinates of one sub-universe and its endpoint is at 3 coordinates of the second sub universe.

Therefore, the whole universe is an 11-dimensional universe (4+4+3).

The only common to both sub-universes is the gravitational field.

The universe is made of the so-called gravitation field.

a) What is Gravitation?

Since Newton, scientists believe that gravitation is caused by the presence of mass. Mass was considered to be the central source of the gravitational field. It is governed by a universal constant G (=6.6743x10^{-11} [Nm^2/Kg^2]), representing the magnitude of the force which falls off inversely proportional to the square of the distance from the mass center. It is also known[14] that this is only true for a distance greater than the radius of the mass and falls off linearly with the distance from outer radius of the mass to its center.

Attraction between masses is caused by gravitational forces.

Einstein has suggested that gravitational forces are the result of the distortion of gravitational field caused by the presence of mass.

Any particle moving in space, will simply follow the gravitational field lines along the geodesic.

Therefore, if field lines are bent, the object will behave as if a force is applied to it. Hence its trajectory in space appears to be that of a body under gravitational attraction.

Even moving massless elementary particles will be diverted from a free trajectory, and will appear to undergo such an attraction.

b) A new concept – gravitation is the source for everything

Our current concept says that mass is the source of gravitation and that the presence of mass creates distortion in the geodesic of space-time in our 4-dimensional universe.

One must ask. Is mass the source of gravitation? Is gravitation caused by the presence of mass? What if this assumption is wrong and one must change the concept?

One possibility is that gravitation has always been there. It is a field of 11 (and maybe more) dimensions, regardless of masses.

c) Assume, masses were introduced into the gravitational field after it was already there.

Once a mass is introduced somehow (by some mechanism that needs yet to be explained), it bends the gravitation field lines (see figure) and therefore creates the effect of attraction of other masses by gravitational field.
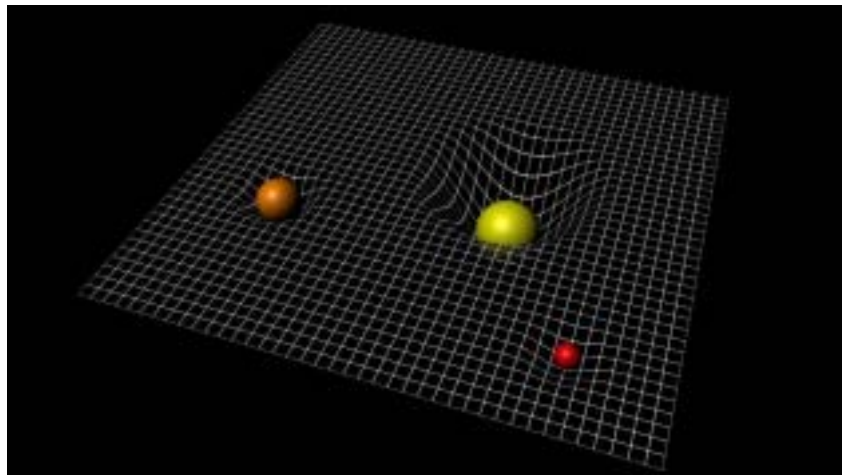

Figure 1: Spacetime curvature in the gravitation field caused by the presence of masses. ©European Space Agency

Once a mass is placed in this field, the field itself becomes curved (distorted) and any other object (massive or massless) passing in this distorted field is forced to move along this curved space field lines, as if being attracted by gravity.

Once the distorting mass is removed, the distortion disappears.

Notice that according to this concept, only inward distortion, negative curvatures ("valleys") are allowed. Otherwise, if by some mechanism (for instance, antigravitation) positive curvature ("hills") were allowed to occur, then we would have seen anti-gravity. Masses would then repel each other instead of attracting. If this was the case everywhere, our universe could never exist since all its mass would have eventually disappeared (dispersed) into infinity. Yet, a mixture of gravity and antigravity ("valleys" and "hills") is a possibility.

When studying elementary particles, we learn that particles have properties like charge and spin, while their antiparticles have the same properties but of opposite signs. However, all massive elementary particles without exception have positive mass.

If, for some reason, there would be elementary particles with negative mass, we would see them bending the gravitational field in the opposite direction. Thus, creating "hills" (positive curvatures) instead of "valleys" (negative curvatures).

So far we have never observed such a phenomenon.

III.   QUANTUM GRAVITY

The current theory of gravity is *general relativity*. Similarly, quantum mechanics explains matter, energy and causality. These two theories, one deterministic and the other probabilistic, both experimentally supported, have opened a major conceptual revolution in physics.

However, they appear to be incompatible: deterministic vs. probabilistic, large scale vs. microscopic scale.

The revolution opened by general relativity and quantum mechanics at the beginning of the 20th century is not concluded yet, and a new synthesis is required.

Quantum gravity, merging general relativity and quantum mechanics should be this new synthesis.

Contradictions in the known laws of nature require a theory that can resolve the clash between the laws of gravity and those of quantum mechanics.

Gravity and quantum mechanics have been developed and confirmed separately in countless experiments over the last century.

But when applied together they produce nonsense. Quantum mechanics is a probabilistic theory, whereas gravitation theory is deterministic, with no place for probabilities.

Quantum mechanics, though verified experimentally, relies on complex numbers representation and is unfortunately perceived by many as a magical, mysterious world of complex wave functions and Hermitian operators. It was shown[15], though that it is just a real-world representation, masked in complex representation. Though making the representation easier mathematically, it hides the true physics behind it. Instead of complex wave functions over a complex Hilbert space, and Hermitian operators, all can be represented by real wave functions in a real world and non-Hermitian operators.

Looking at the Schrodinger equation reveals that it is a description of two separate functions, coupled together.

This may give a clue to the real nature of elementary particles as being made of some form of coupled pairs of string-like fields.

Yet, classical gravitation, with general relativity, predicts a lower limit on space, below which classical mechanics fails. This lower limit as will later be proven is the so-called Planck distance.

A theory of quantum gravity would resolve these contradictions by applying the rules of quantum mechanics to effects below this lower limit of gravity. This willy endow the gravitational field with the randomness and uncertainty characteristic of quantization.

At first theorists thought there would be a simple fix: Just modify general relativity to allow the gravitational field to be in two places at once[4-9]. Physicists Richard Feynman[21] and Bryce DeWitt[22] developed such a theory in the 1960s, but they quickly realized that it worked only at small energies. In contrast, at high energies, when space-time becomes strongly curved, it produces infinite divergencies. This straight forward quantization, it turned out, is only an approximation to a more complete theory, one which should not suffer from the problem of infinities. It is this complete theory that physicists refer to as "quantum gravity."

These first attempts at quantization break down when the gravitational force becomes very strong. This happens when large amounts of energy are compressed into a small region of space-time. Without a full theory of quantum gravity, one cannot understand what happens in the early universe.

Blackhole information loss problem is another strong indication that we need a theory of quantum gravity. As Stephen Hawking[11] demonstrated in 1974, quantum fluctuations of matter fields close to a black hole's horizon lead to the production of particles, now called "Hawking radiation," that make the black hole lose mass and shrink until nothing is left. Once the universe has cooled down sufficiently, black holes will evaporate, leaving behind nothing but radiation and (as will be soon argued) gravitation.

It is claimed, that this radiation carries no information besides its temperature. Information about what fell into the black hole is irretrievably destroyed during the evaporation.

Information that crosses the horizon is gone for good, which conflicts with quantum mechanics, which demands that information must be conserved. The information loss problem is a deep conceptual issue about the soundness of our theories.

Some phenomena where quantum gravity plays a major role are the microscopic structure of spacetime, early cosmology, black holes and astrophysical effects.

In the following, a short description of different approaches to solving quantum gravity are given. But for the moment, none of these offers a *complete* theory of quantum gravity and none of these have any experimental support. These theories are tentative at present.

IV. STRING THEORY

String theory attempts to create a unified description of the physical world, where *all* physical entities are understood as manifestations of the energy states of a single object: a string.

Gravity emerges in this theory as one of the aspects of the dynamics of the string. String theory can be defined in terms of a perturbation expansion around a fixed spacetime. In this formulation certain infinities of perturbative quantum general relativity do not appear. However, when summed-up, the entire series appears to be divergent. A definition of string theory as a perturbation expansion is not sufficient for describing genuine quantum gravitational phenomena, which appear in the nonperturbative regime.

In this needed nonperturbative formulation, the characteristic features of quantum gravity become manifest: for instance, the lack of fixed background space and time and the resulting conceptual difficulties.

V. LOOP QUANTUM GRAVITY AND SPINFOAMS

Loop quantum gravity[26] is an attempt to find a quantum version of general relativity.

The theory is consistent with the other fundamental theories (such as the standard model). Still, it does *not* unify gravity as a manifestation of the dynamics of a single physical entity.

Loop quantum gravity is based on general relativity. It offers a precise mathematical description of quantum spacetime. The granular properties of space can be explicitly computed. The *area* and the *volume* of any physical surface of region turns out to be "quantized" just as the energy of a hydrogen atom. Corresponding discrete values that area and volume can take have been computed accordingly. The quantum states of physical space are described by labeled graphs called *spin networks*[25]. Each node of a spin network represents an elementary "quantum of space", and the links between these indicates who is next to who, building the spatial structure. The main incompleteness of the theory regards the relation between the Planck scale and macroscopic physics, and the consistency of its classical limit.

Related to loop quantum gravity is a covariant approach to quantum that goes under the name of *spinfoam formalism*[27]. This is sometimes presented as the path-integral, or, covariant (Lagrangian) version of the canonical (Hamiltonian) loop formalism[28].

VI. NONCOMMUTATIVE GEOMETRY

Einstein's discovery is that gravity, which is a dynamical field, is the geometry of spacetime. Quantum mechanics teaches us that dynamical quantities are noncommutative. It is therefore, natural, to suspect that the mathematics needed to describe quantum spacetime is a noncommutative version of geometry. A number of different formulations of such a noncommutative theory of geometry are under study[29].

VII. QUANTUM SPACE AND QUANTUM TIME

Quantum gravity is expected to force us to further modifications of the concepts of *space* and *time*, in order to make them compatible with quantum theory. Quantum gravity should be the theory of a probabilistic "quantum space" and "quantum time". Building the mathematical language and the conceptual structure for making sense of such notions of quantum space and quantum time is the challenge for a quantum theory of gravity.

VIII. THE PLANCK SCALE

Simple dimensional arguments show that the physical phenomena where quantum gravitational effects become relevant are characterized by the "Planck length" $\ell_p = \sqrt{\frac{\hbar G}{c^3}} = 1.616x10^{-35}\ m.$

Here $\hbar$ is the Planck constant that governs the scale of the quantum effects, G is the Newton constant that governs the strength of the gravitational force, and c is the speed of light, that governs the scale of the relativistic effects. All are assumed to be universal constants.

The Planck length is extremely small ($1.616x10^{-33}$). Current technology is not yet capable of observing physical effects at scales that are so small (although several recent suggestions of how it could be possible, have appeared[45].) However, until genuine quantum gravitational phenomena are directly or indirectly observed, we cannot confirm or falsify any of the current tentative theories.

Where did masses come from?

Mass is energy. Assuming a completely flat gravitational field with no masses at all, the only energy around is either that stored in the gravitational field, or, energy moving around in the form of super energetic electromagnetic radiation (photons).

These photons may annihilate and convert to massive particles. One important rule in these annihilation-creation processes is that energy, momentum, charge, and spins, must be conserved.

Once created, these elementary particles start collapse under mutual gravitational attraction.

But how can a photon undergo annihilation process in an empty space? Momentum conservation rules forbid such a process!

Yet, in the presence of a strong gravitation field, this becomes possible[37]. But where does a strong gravitational field come from, when the field is flat as

assumed to be the case in the early stage of the universe?

The answer may be in quantum fluctuations. If the field fluctuates, then the derivatives of the metric may be very high. This creates very strong local accelerations due to the local interactions between the passing energetic photons with the tremendous local distortions of the otherwise flat gravitational field. It is at this microscopic level that gravitons, the presumed carriers of the gravitation field come into action.

This phenomenon may allow for annihilation processes and the creation of massive particles.

IX. Photon-Gravitation Interaction

As described already[37-44], the interaction of a photon with gravitational field is possible. This

The following figure describes these processes:

interaction results in energy-momentum loss by the photon. The results are that annihilation process of an incoming photon into some massive pair production becomes possible. For instance, a photon graviton annihilation pair production process.

Since no charges nor spins have been yet introduced to this model of a universe, the most expected process to occur is the creation of Higgs bosons. The Higgs boson has mass (1.25 GeV/c^2) but neither spin nor charge. The Higgs boson's half-life is 1.56^{-22} sec. It decays into one of the following possible pairs: a Bottom-anti Bottom pair, a two W bosons, a two gluons, a Tau-antiTau pair, two Z bosons, two photons, Muon-antiMuon pair, or various other decays.
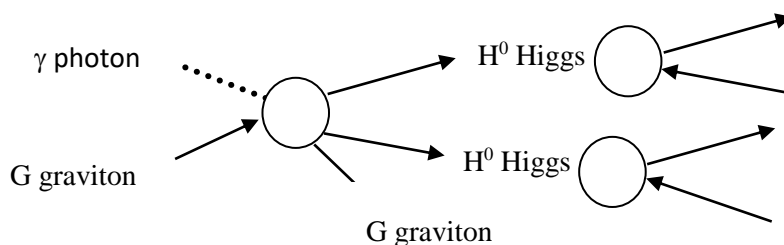

Figure 2: Photon annihilation Higgs pair production under graviton scattering

It will be therefore reasonable to presume that the earliest photon-gravity interactions were:

$$\gamma + grav.fluct. \rightarrow 2H^0 + G$$

Here, *grav.fluct.* stands for gravitational fluctuations of some kind. For instance, interaction of photon with graviton has been analyzed recently[40,41]. It brought out the various features of the interaction between photons and gravitons that can be used in astrophysical observations[40,41,42,43].

Since gravitons are spin-2 particles, one must, in order to preserve spin, have an outgoing graviton in this photon-graviton scattering process[44].

The effective action for photons, developed there, demonstrates possible interactions between photons and gravitons at the quantum level. Thus, allowing with an outcome of a Jet of Higgs bosons as a result of gamma-graviton interaction.

If the gravitational field has always been there much before the introduction of masses, then how do one settle this the Big Bang theory?

The explosion of the early universe is just a phenomenon that involves masses. It of course has an effect on the distortion of the gravitational field. The early "valley" is gradually changing towards a flat manifold. Masses become less and less attracting (expanding universe). At a certain point, the flat universe will stop gravitation attraction completely (end of expansion).

Will the universe continue into an anti-phase? This means the distortion converts from flat to negative curvature (a hill) ? This will create the opposite effect of attraction and masses will start repelling each other. This may continue indefinitely (an endless dispersed universe), or, the flattening process may reach an end and stop at zero curvature.

At the point of zero curvature, gravitational forces stop altogether. Therefore, there are no pendulums or other repetitive processes available to measure time. The unavoidable conclusion is that time stops at that point and there is no meaning to physical processes anymore. This will mean the end of the universe as we know it.

The question remains though, is this a stable situation? Has the universe reached a stable equilibrium state?

Remember, all masses still exist. They are so far away from each other, that there are practically no gravitational forces between them.

During the process of expansion (cool down) energy must be released in the form of photons. The total energy of the universe must be conserved. Therefore, the equilibrium that was reached at the flattened state is unstable. The huge photon energy will prevent a steady state. Once this happens, some masses will start absorbing enough energy to increase their mass and so attraction will soon begin again and the universe will start collapsing again.

Gravitation is an 11-dimensional field in which everything is embedded (massive and massless particles).

Gravitation and mass co-exist in our universe. But which came first?

Were masses created after gravitation?

Suppose the opposite is true:

Masses came first, without the presence of gravitation. Gravitation emerged later on due the presence the masses.

Take the first mass created (if there are several, then pick one of them).

How can it create gravitation around it? If gravitational attraction is caused by bending of the gravitational field lines, this means that the first mass could not have attracted other masses. It did not have any field lines to bend.

This argument leads us to conclude:

1. Gravitational field was there before any masses were created.
2. This Primordial Gravitation field is the spacetime itself.
3. The concept of Vacuum should be abandoned, gravitation is the vacuum.
4. In the beginning there was gravitation field alone.
5. Gravitation is our spacetime grid.

Need that early gravitation field be flat? Not necessarily.

But assuming symmetry of space and with assumption on minimal energy state, it is the most reasonable assumption to be made.

Thus:

6. The Primordial gravitational field (spacetime) was flat and endless.

X. SPACETIME QUANTIZATION

If one accepts the assumption that spacetime and gravitation field are the same, then quantization of gravity is quantization of spacetime.

This means that spacetime is an 11-dimensional grid, in which two 4-dimensional sub-universes co exist. Our universe and a parallel universe. Matter in one sub-universe is confined[9,10] in its 4-dimensional spacetime and can never reach the other sub-universe. However, the distortions in the gravitational grid are not confined. Hence, attraction of mass in our universe can result by distortion of the grid in the parallel universe.

We will not be able to measure the mass in the parallel universe causing the distortion, but we will be able to measure the gravitational effects.

We will refer to this phenomenon as "dark matter".

Why do we detect it only at very far galaxies? Probably, because the two sub-universes have departed already so much since their moment of creation, that their mutual effect expresses itself only at very far distances.

So where is, the long sought, quantization of spacetime?

One point which can be derived from general relativity and the constants of nature G, c, and h, is the quantum limit on mass density. This is dictated by dimensional analysis of the Planck's units and General Relativity. General relativity, therefore, leads to the quantization of gravity[11].

Simple dimensional analysis shows that quantum gravitational effects become relevant at the Planck length $\ell_p = \sqrt{\frac{\hbar G}{c^3}} = 1.616 x 10^{-35}$ m. Here $\hbar$ is the Planck constant that governs the scale of the quantum effects, G is the Newton constant that governs the strength of the gravitational force, and c is the speed of light, that governs the scale of the relativistic effects. The Planck length is many times smaller than what current technology is capable of observing. Because of this, we have no direct experimental guidance for building a quantum theory of gravity.

Suppose there exists a quantum minimum for distance. We call it the Planck length and denote it by ℓ_p.

It is given by $\ell_p = \sqrt{\frac{\hbar G}{c}} = 1.616 x 10^{-35}$ m.

Define in addition the Planck mass $m_p = \sqrt{\frac{\hbar c}{G}}$ $= 2.176 x 10^{-8}$ Kg.

If this assumption is true, then the minimal spherical volume possible is $V = \frac{4\pi \ell_p^3}{3}$

Let m denote the mass of this minimal volume. Its density will be given by $\rho P =$

Since by assumption ℓ_p is the minimal possible length in nature, then for any mass m the density ρ_P is the maximum possible.

For a classical spherically symmetric object of mass m and radius R, the general relativistic limit gives[14]

$$d\tau = dt \sqrt{\left(1 - \frac{4\pi\rho G}{c^2} R^2\right)}$$

Since the expression in brackets must be real, we arrive at the restriction:

$$\rho \leq \frac{c^2}{4\pi G R^2}$$

For an object of any given mass m and radius R we have $\rho = \frac{m}{V} = \frac{3m}{4\pi R^3}$

Since for any mass m of radius R one must have $\rho = \frac{3m}{4\pi R^3} \leq \frac{c^2}{4\pi G R^2}$

The result is that for any mass m, of radius R, one must have $m(R) \leq \frac{Rc^2}{G}$

Obviously, the smaller the radius R, the smaller the allowed mass m.

Recall now, (by Planck's dimensionality analysis) that $\ell_p = \sqrt{\frac{\hbar G}{c}}$ and $m_p = \sqrt{\frac{\hbar c}{G}}$

Therefore

$$m \leq \frac{\ell_p c^2}{G} = m_p$$

Hence, for any mass m, whose radius is ℓ_p

$$m \leq m_p$$

And since

$$\rho = \frac{m}{V} \leq \frac{m_p}{V} = \rho_P$$

We have the result that ρ_P is the maximal possible density, namely Planck density.

In other words, for any given radius R, the mass m(R) becomes smaller and smaller with R. Still when one reaches the smallest possible radius ℓ_p, the mass must be smaller than the Planck mass m_p, and so, the density will always be smaller than the Planck density ρ_P.

One can reduce the radius R. Still, the density will never exceed the Planck density.

$$\lim_{R \to \ell_p} \rho(R) = \left(\frac{\ell_p}{R}\right)^3 \rho_P$$

Assume next, that the sphere has density $\rho(r)$, which varies with distance r from its center. Assume the sphere is of minimal possible radius ℓ_p.

We need to calculate the radius R of a quantized particle by its average normalized density to obtain a reduced average radius.

By comparing the integrated variable density over the Planck radius, to a volume, with constant density ρ_0 one obtains:

$$4\pi \int_0^{\ell_p} r^2 \rho(r) dr = \frac{4\pi \rho_0 \ell_p{}^3}{3}$$

By definition, the average classical distance $\langle r^2 \rangle$ is given by the integral over the normalized density:

$$\langle r^2 \rangle \overset{\text{def}}{=} \frac{1}{\ell_p} \int_0^{\ell_p} r^2 \rho(r)/\rho_0 \, dr$$

Thus

$$4\pi \ell_p \rho_0 \langle r^2 \rangle = \frac{4\pi \rho_0 \ell_p{}^3}{3}$$

and so

$$\langle r \rangle = \sqrt{\langle r^2 \rangle} = \frac{1}{\sqrt{3}} \ell_p$$

Hence, the actual measured classical radius R is given by

$$R = \langle r \rangle = \frac{1}{\sqrt{3}} \ell_p$$

The above result shows how the lower limit of the classical gravitation theory by Einstein, is related to the Planck length, which is a quantum phenomenon posed by the dimensional analysis of the universal constants.

Therefore, classical relativity and the relationship between the universal constants leads to the quantization of space.

XI. Quantization of Time

So far, it was shown that general relativity leads to the conclusion about quantization of space. Notice however, that by quantization of space we mean that space is a grid, just like in loop gravity.

This does not mean yet that quantum effects must take place. The only quantum effect so far was in the assumption, that it is a must, for the plausibility of photon annihilation and pair production processes to take place, even in the event of a flat primordial gravitation field.

Still, there remains a question – is time quantized?

Time is something we have based on repetitions. Be it the motion of stellar objects in orbits, or the motion of the pendulum. These are the origins of our concept of time and its measurement.

In modern days, we measure time by using atomic clocks. The second is defined as the duration of 9,192,631,770 cycles of radiation due to the transition between two energy levels of the ground state of the Cesium-133 atom, at rest at a temperature of absolute zero.

One way to assign time to processes is by averaging. For instance, measuring decay time or half-life time. In other words, one can measure <t> and this gives time a quantization aspect. Irrespective of how accurate our "time" measurement is, we will never be able to be accurate enough and there will always be an uncertainty in such measurement,

Obviously, in the absence of gravitation, there would be neither stellar nor pendulum repetitions. Therefore, in the absence of gravitation, time becomes meaning less to us.

The atomic decay process would only be possible if atoms existed. But as we assumed. Gravitation was there, as flat as Denmark, with no elementary particles present. Therefore, time did not exist.

Once we allow for quantum fluctuation to exist, then any passing photon would start the process of elementary particles creation, followed by gravitational attraction (caused by space distortion) and then time started ticking with the creation of repetitions.

We may thus assume that time was created by gravity and quantum. Without the two, time has no meaning.

XII. CONCLUSION

Gravitation is spacetime. It is the grid where everything occurs. When primordial electromagnetic energy hovers in this grid, interactions with this empty grid gives rise to the production of massive elementary particles. These interactions are allowed, because of the quantization of space. This quantization allows for very strong distortions in the fabric of the gravitation field, which in turn allows for the annihilation and pair production processes to occur. Most reasonable, because of symmetry reasons, these were Higgs particles to be produced first.

Without those quantum fluctuations, the otherwise gravitation field would have remained flat and hence no pair production could have taken place because kinematics and momentum conservation would forbid it.

Once elementary particles are created, they bend the gravitational fabric and start attracting each other. This process of mass accumulation went on and on and the masses have become large enough to create the cosmos as we know it.

Finally, only the coexistence of gravitation and quantum fluctuations could give time meaning.

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12

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APPENDIX

a) Elementary particles

An elementary particle or a fundamental particle is a subatomic particle with no (currently known) substructure, i.e. it is not composed of other particles. Elementary particles include the fundamental fermions (quarks, leptons, antiquarks, and antileptons), which generally are "matter particles" and "antimatter particles", as well as the fundamental bosons (gauge bosons and the Higgs boson), which generally are "force particles" that mediate interactions among fermions. Ordinary matter is composed of atoms.

Subatomic constituents of the atom were first identified in the early 1930s; the electron and the proton, along with the photon, the particle of electromagnetic radiation.

Via quantum theory, protons and neutrons were found to contain quarks – up quarks and down quarks – now considered elementary particles.

b) Standard Model

The Standard Model includes members of several classes of elementary particles, which in turn can be distinguished by other characteristics, such as mass, electric charge, color charge, and spin.
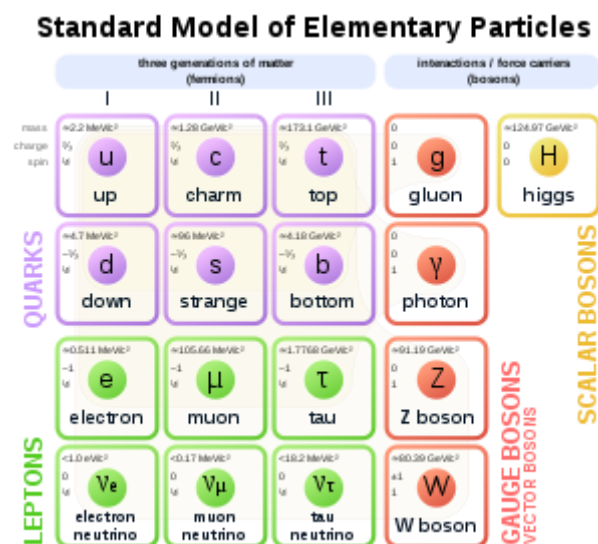All particles can be summarized as follows:

Standard Model of Elementary Particles
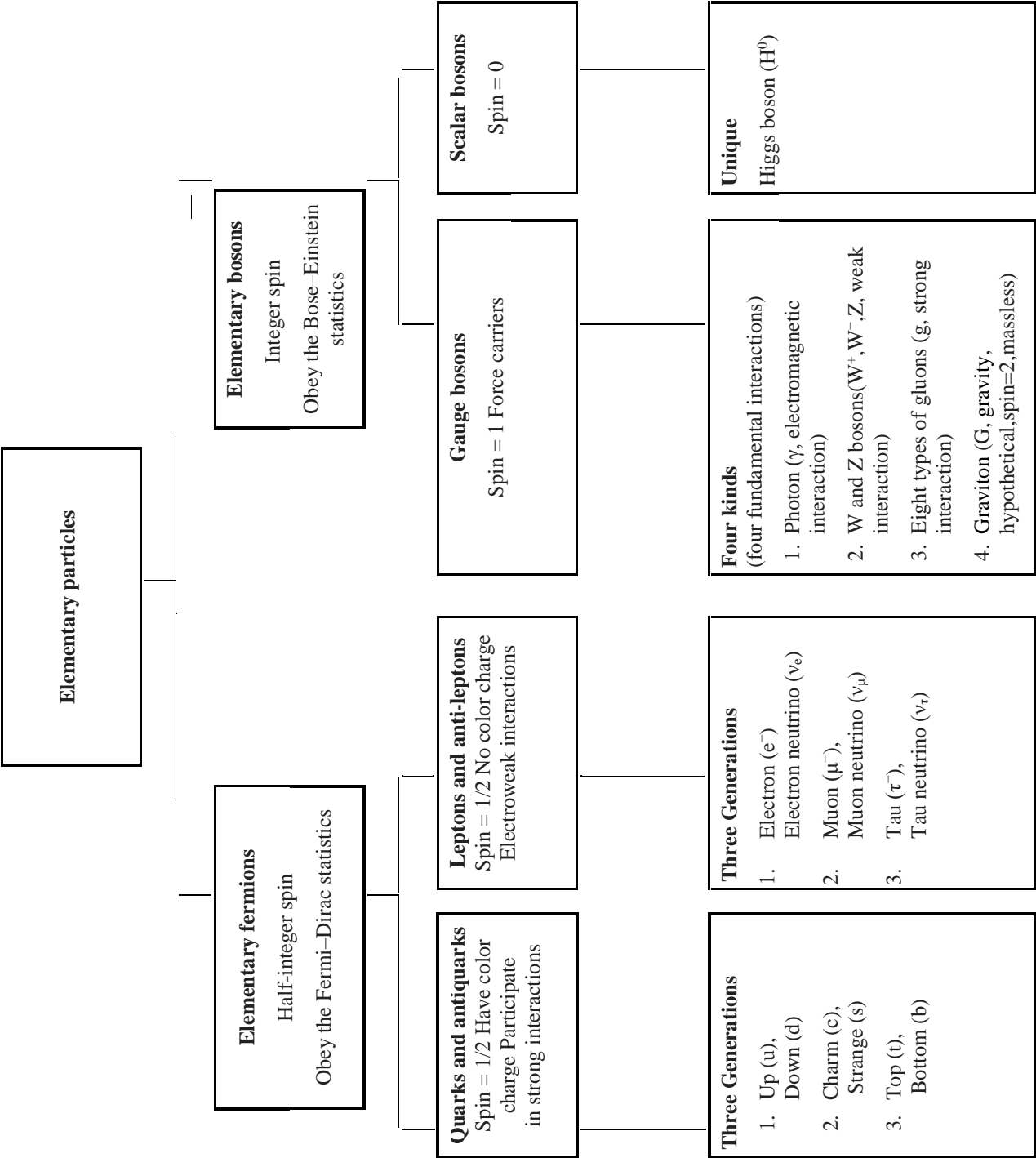
Figure 3: The Standard Model of elementary particles: Quarks in purple, Leptons in green and with the gauge bosons in the fourth column in red. Last in yellow is the Higgs boson

c) Gauge boson

Photons, W and Z bosons, gluons, and the hypothetical gravitons are gauge bosons. All known gauge bosons have a spin of 1; for comparison, the Higgs boson has spin zero. Therefore, all known gauge bosons are vector bosons.

Gauge bosons are different from the other kinds of bosons: first, fundamental scalar bosons (the Higgs boson); second, mesons, which are composite bosons, made of quarks; third, larger composite, non-force-carrying bosons, such as certain atoms.

In particle physics, a gauge boson is a bosonic elementary particle that mediates interactions among elementary fermions, and thus acts as a force carrier. Gauge bosons can carry any of the four fundamental interactions of nature.[1][2] Elementary particles, whose interactions are described by a gauge theory, interact with each other by the exchange of gauge bosons; usually as virtual particles.

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The Standard Model of particle physics recognizes four kinds of gauge bosons: photons, which carry the electromagnetic interaction; W and Z bosons, which carry the weak interaction; and gluons, which carry the strong interaction.

d) Multiplicity of gauge bosons

In a quantized gauge theory, gauge bosons are quanta of the gauge fields. Consequently, there are as many gauge bosons as there are generators of the gauge field. In quantum electrodynamics, the gauge group is $U(1)$; in this simple case, there is only one gauge boson, the photon. In quantum chromodynamics, the more complicated group $SU(3)$ has eight generators, corresponding to the eight gluons. The three W and Z bosons correspond (roughly) to the three generators of $SU(2)$ in electroweak theory.

e) Massive gauge bosons

Due to gauge invariance, gauge bosons are described mathematically by field equations for massless particles. Therefore, at a naïve theoretical level, all gauge bosons are required to be massless, and the forces that they describe are required to be long-ranged. The conflict between this idea and experimental evidence that the weak and strong interactions have a very short range, requires further theoretical insight.

According to the Standard Model, the W and Z bosons gain mass via the Higgs mechanism. In the Higgs mechanism, the four gauge bosons (of $SU(2){\times}U(1)$ symmetry) of the unified electroweak interaction couple to a Higgs field. This field undergoes spontaneous symmetry breaking due to the shape of its interaction potential. As a result, the universe fluctuates around nonzero Higgs vacuum expectation value (VEV). This VEV couples to three of the electroweak gauge bosons (the Ws and Z), giving them mass; the remaining gauge boson remains massless (the photon). This theory also predicts the existence of a scalar Higgs boson, which has been observed in experiments.

f)   Gravitons

The fourth fundamental interaction, gravity, may also be carried by a boson, called the graviton. In the absence of experimental evidence and a mathematically coherent theory of quantum gravity, it   is unknown whether this would be a gauge boson or not.