Quantum gravity: a solution for current problems in cosmology and particle physics

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Abstract

We propose a new phenomenological model for quantum gravity. This is based on a new interpretation in which quantum gravity is not an interaction, rather it is just responsible for generation of space-time-matter. Then we show this model is capable of solving the important problems of cosmology and particle physics.

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1 Introduction

The “problem of time” in General Relativity is of particular importance which means the theory is a completely time parametrized system in the sense that there is no natural notion of time due to the diffeomorphism invariance of the theory and therefore the canonical Hamiltonian as the generator of time reparametrizations vanishes which casts in the form of Hamiltonian constraint. Physical observables are functions of phase space which are reparametrization invariant, that is, they commute with all Dirac constraints and they do not evolve with respect to the canonical Hamiltonian. One important problem of time comes from cosmology and can be explained as follows: The Friedmann equations describe the physical time evolution which is actually observed for instance through red shift experiments. The puzzle here is that these observed quantities as functions of the phase space do not commute with the constraints, so they are not gauge invariant and therefore should not be observable, in sharp contradiction to observation. Moreover, the Friedmann equations are generated by a vanishing Hamiltonian constraint and must be interpreted as gauge transformations rather than evolution equations. Therefore, the phase space dependent quantities in these equations should not be observable, again in sharp contradiction to reality. The conclusion is: Either the constraint formalism which has been exactly tested by experiments in other gauge theories is inappropriate or we are missing some new physics in gravitation theory [1].

There is another important problem in the standard model called the “Hierarchy problem”. It is known that at least two fundamental energy scales exist in nature and they are extremely different: the Planck scale \( M_P \sim 10^{19} \) GeV and the electroweak scale \( M_{EW} \sim 10^3 \) GeV, with the ratio around \( M_P/M_{EW} \sim 10^{16} \). Over the past two or three decades there was a great interest to explain this large ratio which is known as the Hierarchy problem. One may translate this problem into the puzzle that why gravity is so weak compared to the other interactions, such as electroweak one. So, it seems the resolution of this problem will lead us to a better understanding of our Universe. Many proposals to solve this problem have been made so far. By his Large number hypothesis, Dirac first conjectured
that the Newton’s constant may be a time-dependent parameter $G \sim t^{-1}$ to solve the problem [2]. Recently, a great amount of interest has been concentrated on solving this problem based on the existence of extra dimensions in brane models. These proposals are based on the higher-dimensional unification in that the gravitational force in higher-dimension is supposed to be as strong as other forces, but a relatively large internal space of the order of TeV scale or a warp factor which is a rapidly changing function of an additional dimension makes the 4-dimensional gravitational force very weak [3]. Some attempts have also been done to solve this problem based on the non-commutativity in the space-time coordinates or even in the mini-superspace coordinates of specific quantum cosmological models [4]. Recently, an idea based on Mach principle has also been introduced to solve this problem with the price that one has to resort to weak form of equivalence principle and assume the inertial and gravitational masses of any object are not exactly the same [8].

The third problem is known as the so called cosmological constant problem. The problem arises in the following way

$$\Lambda_{\text{eff}} = \Lambda_0 + O(M_P)^4$$

(1)

where $\Lambda_{\text{eff}}$ is a combination of bare cosmological constant $\Lambda_0$ and quantum field theory contributions of the order of quantum gravity cut off $(M_P)^4$. Due to huge values of these contributions we face with the so-called cosmological constant problem, namely a large difference of the order $10^{120}$ between the observational bound and theoretical predictions on the value of cosmological constant.

To the authors opinion, such enigmatic problems which have resisted a long time against being solved by the most “advanced” theories and “sophisticated” technics imply that we may need to turn back and look for “simple” and “natural” solutions to these problems just in our “observed” four dimensional universe with space-time-matter elements. For example, instead of a model based on “complex” higher dimensional picture of the universe to solve the hierarchy and cosmological

\footnote{We point that the idea in [8] is a step forward to solve the hierarchy problem within our four dimensional universe. However, the idea which is introduced here is more fundamental and rich enough to solve the other problems of particle physics and cosmology as well as hierarchy problem, in a more fashionable form.}
constant problems we may suspect about some “complex” evaluations of different energy scales, without considering their four dimensional “length-time” scales which may lead to those unjustifiable large numbers. In this regard, it seems a correct interpretation of quantum gravity in which length, time and mass-energy scales are well defined may solve the important current problems in cosmology and particle physics.

In this paper we propose a new idea on the phenomenology of quantum gravity which is mainly based on the assumption that quantum gravity is not a framework to quantize the gravitational interaction as mediating a force, rather it is a mechanism by which quantum baby universes with length-time-mass scales as the building blocks of the whole universe are continuously generated. We will show how this model may solve the current problems of cosmology and particle physics.

2 Discrete space-Time

The notion of discrete space-time is not a new one. Some people have already proposed such a discrete notion of time or space-time [5]. However, no physical mechanism by which space-time can be discretized is ever introduced. It is important to note that any such mechanism must respect gravity. In fact, since general relativity as a gravitational theory very respects the important role of space-time, the quantum gravity is the only framework which is deeply involved with the space-time structure at small scales. The time problem, whose solution is not given by general relativity, is therefore strongly supposed to be solved within the context of quantum gravity.

In any constraint system with some gauge invariant quantities one may fix the gauge freedom. The important gauge freedom in general relativity is space-time reparametrization. So, one may arbitrarily fix the lapse and shift functions in the metric to fix the gauge. However, this kind of gauge fixing does not help to solve the time problem, in particular at the cosmological level, as explained above. A very important step in this direction may be the assumption that “space-time” is a discrete notion having a fundamental unit which is mainly fixed by quantum gravity. In other words, we will assume that quantum gravity is nothing but a phenomena by which these fundamental units are generated. This
self-gauge-fixing in a consistent way makes all the gravitational quantities to be naturally defined in terms of this fundamental unit of space-time (a fundamental gauge). A fundamental unit of space-time requires a fundamental parametrization in space-time, which is different from what is usually done by arbitrarily fixing, for example the shift or lapse functions.

There is only one space-time scale in nature which is uniquely fixed by gravitation, namely Planck length-time

\[
l_P = \sqrt{\frac{G\hbar}{c^3}}, \quad t_P = \sqrt{\frac{G\hbar}{c^5}},
\]

where \(G\) is the gravitational constant, \(\hbar\) is the planck constant and \(c\) is the constant velocity of light. We will call this set as our fundamental quantum unit of space-time which discretizes the space-time continuum. Note that \(G\) as an element of gravity fixes the length and time scales in a unique and fundamental way. At classical or even quantum mechanical level space-time is just a continuum, but at scales close to Planck length-time scales, it becomes fundamentally discrete and can not be arbitrarily reparametrized. In fact, the reason why general relativity is a reparametrization invariant theory is that space-time at the level of general relativity is a continuum made of huge numbers of quantum units of space-time and we can easily change the time parameter or shift the space coordinates by arbitrarily small values due to the additive properties of these quantum units. However, going down to the Planck scales, which are the characteristic features of quantum gravity regime, we can no longer reparametrize the space-time, simply because a fundamental gauge fixing is made by “quantum gravity” itself through the fundamental constants \(G, \hbar, \) and \(c\) in (2) and one can not breaks down the fundamental quantum unit of space-time. According to above discussion, we will assume that the “gravitational” universe has its specific language (gauge) based on Planck natural units, \(t_P, l_P,\) and \(M_P\). In other words, we will compare any time, length and mass scales in the gravitational universe just with Planck time, length and mass.
3 Quantum gravity, time problem and space-time-matter generation

At time scales close to $t_p$ and length scales close to $l_p$ “quantum gravity” is supposed to become important, just like “space” and “time” whose discrete natures become important at these scales. Suppose, instead of thinking about quantum gravity as a “complicate framework” of quantizing the background metric $g_{\mu\nu}$ with a quantum particle so called graviton mediating the gravitational force [6], we think about it as a “simple phenomena” by which fundamental quantum units of space-time with the Planck length-time scales, namely “quantum baby universes” are just generated. This is a very important step forward leaving behind all the technical and conceptual problems concerning the quantization of background metric $g_{\mu\nu}$\(^2\). In the present model: we suppose a “virtual” quantum baby universe of Planck length-time-mass is initially born, with no real characteristics, by a vacuum quantum gravitational fluctuation obeying uncertainty principle. Each single quantum baby universe generated possibly by successive vacuum quantum gravitational fluctuations is also supposed to be a virtual one. However, we assume once they (at least two virtual quantum baby universes) can correlate and interplay with each other by “Mach principle” they all get realized into a larger “mother” universe with real characteristics imposed by Mach principle. Therefore, by this assumption we certify that:

\(^2\)An idea was already developed as the “gravitational complementary principle” by the author [7] to show how we can absolutely separate the domains of quantum gravity from general relativity, not only in their energy scales but also in their essence. In fact, it was shown that general relativity is not the low energy limit of quantum gravity, rather it is absolutely “pure classical” gravitational theory which governs the scales larger enough than Planck length and there is no absolutely a quantum theory of gravity at large scales. For example, it was shown that gravitational waves as the metric perturbations may exist in the framework of general relativity but no (quantum) particle concept like graviton can be attributed to this wave behavior. In other words, no wave-particle duality is expected for gravitational radiation. In the present model, we almost follow the same picture and show that the pure classical features of gravity manifest as general relativity at large scales, and that quantum gravity is just responsible for continuous creation of the universe by Planck length-time scales quantum baby universes. Moreover, no Heisenberg uncertainty principle, namely wave-particle duality is expected for these quantum baby universes in an expanding universe.
our present *real* large scale four dimensional space-time whose origin is assumed to be a Planck scales

_virtual_ universe (created during a quantum gravitational fluctuation in the vacuum state) is nothing

but a huge reproduction of such virtual baby universes which have been steadily realized into the

mother universe, according to Mach principle\(^3\). Realization into mother universe of such single virtual

universes each of which created by uncertainty principle from the vacuum, is done by Mach principle.

Therefore, Mach principle in the case of quantum gravity plays a very important role to avoid these

newborn (through uncertainty principle) virtual quantum baby universes from annihilation to the

vacuum. If there was no Mach principle, the uncertainty principle would annihilate each virtual

quantum baby universe after its creation and would not let a large scale mother universe to be realized

by huge accumulation of these virtual quantum baby universes\(^4\). The interesting point is that once,

for example, two such virtual quantum baby universes get realized they share uncertainty principle

in a Machian way so that this Machian universe, namely mother universe as a whole, inherit the

uncertainty principle. In other words, uncertainty principle is just applied for the whole “real Machian

mother universe” and not for each quantum ingredient as “virtual single baby universe”, because

after realization into the mother universe they have no longer a definite and specific length-time-mass

characteristics for themselves\(^5\). Therefore, if for example the energy scale of the original quantum baby

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\(^3\)We may assume the spatial part of each quantum baby universe is a spherical shell (bubble) with the tickness of one Planck length. The internal radius of each bubble is always equal to the radius of the universe. So, at early universe the size of each quantum baby universe (bubble) is so smaller than that of at present universe. Of course, the relative size of quantum baby universe is irrelevant in our model, rather its absolute tickness does matter.

\(^4\)This phenomena is like to the pair production out of electromagnetic vacuum at the horizon of a black hole. The horizon lets the newborn virtual pair particles to be realized. If the horizon would not exist these virtual particles would annihilate again to the electromagnetic vacuum, by uncertainty principle.

\(^5\)We know that general relativity as a fully deterministic theory has a sharp conflict with uncertainty principle so that one can determine simultaneously the position and velocity of a particle locally in general relativity. If we assume that the large scale universe is constructed by huge numbers of quantum baby universes then locally it is like to a quantum baby universe. This is based on the large scale-small scale duality, connecting the large scale universe to the quantum baby universe, which is established by Mach-Heisenberg principle. Therefore, in order the locally deterministic behavior of general relativity is realized, each virtual quantum baby universe as a local universe should behave deterministically
universe is of the Planck mass $M_P$, the energy scale of the enlarged Machian mother universe should be reduced below the Planck mass due to Heisenberg uncertainty principle which is now applied for this enlarged mother universe. An important result is that if in a vacuum quantum gravitational fluctuation during which a unit of space-time of Planck length-time orders is realized into the mother universe, a corresponding energy scale could also be realized into this mother universe, its order of rather than obeying uncertainty principle, otherwise one can not localize a particle in the deterministic way that general relativity requires. In fact, due to the Machian correlations (socialization) between the virtual quantum baby universes (with single characters) we can no longer expect each virtual single quantum baby universe to keep its original single character and obey uncertainty principle after it is introduced into this Machian mother universe as a realized community constructed by accumulation of virtual single quantum baby universes. Therefore, one can only expect the Machian universe “as a whole”, no matter what size and age, to obey the uncertainty principle. There is no fundamental problem if we leave uncertainty principle for a single local quantum baby universe, namely the Planck scale unit of space-time, after its realization into the Machian universe. The situation is almost the same when we leave special relativity for the expansion of the universe. Expansion of the universe with velocities more than velocity of light does not contradict the special relativity to be applied to natural relative velocities. In the same way, a single quantum baby universe (included in the mother universe) which does not obey the uncertainty principle locally, does not contradict this principle to be applied globally to the mother universe, as a whole. The uncertainty principle applies just for the whole “real mother universe” not for its ingredients as “virtual quantum baby universes”. This follows exactly because of space-time expansion of the universe. The position-momentum and time-energy uncertainty relations are usually defined on a fixed space-time background. Therefore, it is reasonable to apply these relations on the three gauge interactions (weak, strong, electromagnetic) which are usually assumed to take place on a fixed background. However, in the case of general relativity we are dealing with expanding background (space-time), so we can no longer expect these relations to be valid locally for a quantum unit of space-time-matter. In an expanding universe, for example given by (3), the expansion of the space-time boundaries of the universe renormalizes every $\Delta x$ and $\Delta t$ corresponding to general relativity, by imposing decaying measures as $\tilde{\Delta}x = 10^{-60}\Delta x$ and $\tilde{\Delta}t = 10^{-60}\Delta t$ so that $\tilde{\Delta}x$ and $\tilde{\Delta}t$ are decreasing by expansion of the universe. One may then reduce simultaneously $\Delta p\tilde{\Delta}x$ or $\Delta E\tilde{\Delta}t$ to arbitrarily small values, for each quantum unit of space-time-matter. This certifies our conjecture that uncertainty principle looses gradually its local validity for each quantum baby universe because of the global expansion of the universe. In other words, in the case of general relativity the expansion of the universe kills the local validity of uncertainty principle for each quantum baby universe while keeping it valid globally for the mother universe. But, the global expansion of the universe is due to the gradual accumulation of quantum baby universes. It then appears that addition of one quantum baby universe to the
magnitude should be at most of the same energy scale of the mother universe, namely reduced Planck energy. In other words, once this enlarged universe is realized through Mach-Heisenberg principle, its energy scale is reduced below the Planck energy and just an energy scale at most of the order of reduced Planck energy can be borrowed from vacuum and then be realized as a real energy or mass into this mother Machian universe. This procedure may continue non stopping to enlarge more and more the Machian mother universe and reduce less and less its energy scale. So, this enlarging universe at each stage of its time evolution can borrow a decreased energy, corresponding to the energy scale of that stage, from vacuum to convert it to a real energy or mass. Due to the existence of fundamental quantum gravitational natural units of length-time-energy, namely the Planck scales it is very natural to expect that the enlargement of universe in space-time and the subsequent decay of its energy scale, is realized in terms of Planck units.

We assume that the enlargement or “time evolution of the universe” is nothing but “steadily realization of virtual quantum universes of Planck length-time generated by vacuum quantum gravitational fluctuations. In specific words, when “each” vacuum quantum gravitational fluctuation mother universe decreases globally the quantum importance of other quantum baby universes already existed in the mother universe and rises their classical importance. Therefore, as the universe expands the quantum local features of space-time, namely uncertainty principle or wave-particle duality, is lost in favor of pure classical features. For example, the “metric” in a large enough universe becomes almost a pure classical field with no probabilistic features. This solves the contradiction between deterministic features of general relativity and probabilistic features of uncertainty principle in favor of the former. The mechanism by which the uncertainty principle looses its local validity for a quantum baby universe in an expanding universe while it is being valid globally for the mother universe is very much like the formation of a community. In a one-person community the normalization factor (social value) of this person is one. In a two-persons community the normalization factor reduces to one-half. In a $10^{60}$-persons community the normalization factor reduces to $10^{-60}$ while the system of $10^{60}$-persons (mother universe) is still a “comm-unity” (uni-verse) having the same original one-person character (uncertainty principle). It is important to note that the realization of each new quantum baby universe is a global effect throughout the mother universe because this realization is “recognized” by the global Mach-Heisenberg principle which is imposed on the mother universe. Therefore, for example, the reduction of cosmological constant due to the realization of new quantum baby universes is a global effect (see below).
generates “one” virtual unit of space-time which is then realized as a quantum universe of Planck length-time scales, we say that the “age” of the mother universe gets older up to one Planck time and its “radius” gets larger up to one Planck length. Therefore, although at the level of general relativity we have an apparent continuous time reparametrization symmetry with no natural notion of time, but at ultrashort distances this symmetry is broken by the discrete structure of space-time and so a preferred time parameter is singled out as a natural one $t = N t_P$ where $N$ is an integer indicating the numbers of quantum universes or fundamental units of space-time generated dynamically so far by vacuum quantum gravitational fluctuations in the entire history of the universe. In this way, time evolution of the universe becomes a dynamical process controlled by vacuum quantum gravitational fluctuations so that cosmological quantities when interpreted in terms of these quantum fluctuations become meaningful. This solves the “problem of time” at the cosmological level by resorting to such a quantum gravity model.

We showed, according to the Mach-Heisenberg principles, that as the original quantum baby universe becomes large and larger, its energy scale in contact with the gravitational vacuum fluctuations becomes small and smaller. This situation may continue without any nontrivial effect until a space-time “continuum” is formed out of large enough numbers of discrete units of space-time so that a “manifold” can be effectively defined with an specific causal structure which is called the “metric”. In fact, since the uncertainty principle is ignored for virtual quantum baby universes, the causal deterministic structure can be formed out of these small universes after their realization into the mother universe. It means that at this stage of time evolution of the universe the rules of standard “quantum field theory” govern on this new geometric background. Suppose, by energy scale considerations, this stage of time evolution of the universe coincides with the government of the “electroweak” interactions. The immediate question then arises about the Higgs field which we believe gives mass to the standard model particles. In this model, the only candidate for the Higgs field at the phase transition from discrete to a continuous metric structure of space-time is the “scalar sector” of vacuum quantum gravitational fluctuations which determines the background energy scale of the universe at that stage.
In other words, once the universe becomes large enough that the “vacuum expectation value” of a quantum field can be defined over the resultant space-time manifold, the scalar sector of vacuum quantum gravitational fluctuations with an energy scale much below the Planck scale, namely the Higgs energy scale, may well effectively play the role of a Higgs field. The fact that universal vacuum quantum gravitational fluctuations may give mass to the particles is conceptually in complete agreement with the Mach principle which is included in this model\(^6\). If so, there is no a real Higgs particle because its associated field is just an emergent background field out of quantum gravitational vacuum fluctuations\(^7\).

We have already assumed that expansion of the universe in space-time is realized, step by step, by Planck length-time scales. We can assume the same behavior for the mass extension of the universe. Consider the following ratios

\[
\frac{T}{t_P} \sim 10^{60}, \quad \frac{R}{l_P} \sim 10^{60}, \quad \frac{M}{M_P} \sim 10^{60}
\]  

(3)

where \(T, R,\) and \(M\) are age, size, and observed mass of the universe, respectively. We realize that in the Planck language the amount of Planck masses in the universe is the same as the amount of space-time units. This coincidence means that a one to one correspondence exists between each Planck mass, each Planck length and each Planck time. Therefore, in our Machian viewpoint of time evolution of the universe during elapse of one Planck time the radius of universe becomes larger with one Planck length and its mass gets fatter with one Planck mass. There is no real problem with this mass or energy generation because the universe is borrowing this mass or energy from the vast gravitational vacuum sea to which it is always contacted.

We may first study the generation of mass at early universe. Since energy scale of the universe in contact with the vacuum gravitational fluctuations is reducing by expansion of the universe so the

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\(^6\)A similar idea is introduced in [8] where the universal background Higgs field may be replaced by the background gravitational potential of the universe.

\(^7\)The fact that mass of the Higgs particle is not predicted by the standard model may be a confirming evidence that it is not associated with a genuine field.
first mass generation had energy scale of the order of Planck scale. Later, when the universe expands and its energy scale decreases, mass generation of “reduced Planck” scale happens. For example, at the electroweak stage at which the energy scale of the universe is about Higgs energy scale, the standard model particles could be created.\(^8\)

Note that at each stage of the history of the universe during one Planck time the value of one Planck mass is generated. Let us, for example, study the mass generation at the present stage of Machian universe, namely with radius \( R = 10^{60} l_P \) and \( T = 10^{60} t_P \). First of all, we have to find out the energy scale of the present universe in contact with the gravitational vacuum. As explained before, to evaluate the energy scale of the present mother universe we have to use Heisenberg uncertainty principle. But, the very important point is that since the universe as a four dimensional object has both space and time extensions, we have to impose both momentum-position and energy-time uncertainty relations at once on the present universe and compare the result with that of imposed on the original Planck length-time scale quantum baby universe, as follows

\[
(M_P^{reduced})^2(R)(T) \simeq (M_P^{original})^2(l_P)(t_P),
\]

where the units \( \hbar = c = 1 \) are used. A simple calculation shows \( M_P^{reduced} \sim 10^{-60} M_P^{original} \) which implies that the present energy scale of the universe is vanishing compared to its initial value at the original stage of quantum baby universe. But how this infinitesimal energy scale can lead to “one” Planck mass generation at the present stage of Machian universe? Fortunately, there are \( 10^{60} \) quantum baby universes with temporal extension\(^9\) which have constructed the temporal extension of the present large scale universe and each of them can contribute the same energy \( 10^{-60} M_P^{original} \) into the present large universe. This gives the desired “one” Planck mass \( 10^{60} \times 10^{-60} M_P^{original} = M_P^{original} \) generated per each Planck time \( t_P \). Note that by a Planck mass generation we do not mean a Planck

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\(^8\)In the present model of mass generation the massive particles are created first and the light particle later. Therefore, the mass ratio of different particles depends on the time difference (in the Planck unit \( t_P \)) between the generation of those particles.

\(^9\)Note that according to (3) our large scale universe has temporal and spatial extensions each of which \( 10^{60} \) times larger than those of each quantum baby universe.
mass particle. In fact, generation of particles requires some particle physics rules and symmetries other than their space-time-mass characteristics. So, below the electroweak energy scale toward the present very small energy scale we may not expect the generation of stable standard model massive particles like electrons and protons. However, neutrinos as particles with no specific mass scale may be good candidates for the gradually mass generation after electroweak stage for a while. This may justify the present dark matter sector of the total mass $M$ of the universe. On the other hand, the vast majority of the Planck mass generation may be turned into the dark energy. In other words, after dark matter generation such as neutrinos is completed, the vacuum energy of the quantum gravitational fluctuations with “reducing Planck” scale could be realized continuously into the expanding universe as the dark energy.

The important results we obtained here are: 1) quantum gravity is not a framework to quantize the gravitational interaction (force); it is just a mechanism which continuously turns the “vacuum quantum gravitational fluctuations” into an expanding universe, 2) quantum gravity is fully Machian in that no space-time continuum exists in the absence of gravitating matter; it creates space-time and matter simultaneously, 3) each virtual single quantum baby universe after realization into the mother universe no longer admits the uncertainty principle, instead the mother universe does.

4 Hierarchy problem

It seems the energy scale of electroweak interaction is so below the quantum gravitational interaction and the question that why this happens is the mass hierarchy problem. In specific words, the strength of a gravitational interaction between two particles compared to their electroweak interaction is very small up to a ratio $10^{-16}$. According to the present model for quantum gravity one may justify such a large ratio by considering the very different space-time scales of the two interactions and ask about the hierarchy in their space-time scales. According to Heisenberg uncertainty relation the energy scale of electroweak interactions is $10^3 Gev$. What about quantum gravitational interactions? We have already reasoned that there is no such a real interaction and quantum gravity just provides us
with a space-time background so that other quantum field interactions together with classical general relativity can act on this background. So, how can we measure the energy scale of gravitation to compare with electroweak one? In fact, we do not need to measure the energy scale of a quantum gravitational interaction between two particles, which does not really exist. We just need to know the value of Newton’s gravitational constant which fortunately has already been fixed at early universe by the original quantum baby universe as \( \hbar = c = 1 \)

\[
G = \frac{1}{M_P^2},
\]

where \( M_P \sim 10^{19}\text{Gev} \). So, it seems we are comparing the parameters of “electroweak universe” with respect to that of the original “quantum baby universe”, as a reference. In other words, we suppose the electroweak universe has happened right after the appearance of quantum baby universe. The length-time scales for the original quantum baby universe are \( 10^{-34} m, 10^{-43} s \), respectively. On the other hand, we obtain the length-time scales \( 10^{-18} m, 10^{-27} s \) for electroweak interaction. Now, during one electroweak interaction in the “electroweak universe” the amount of \( \sim 10^{-18}/10^{-34} \times 10^{-27}/10^{-43} \sim 10^{32} \) space-time dimensional quantum baby universes contribute to the original space-time according to the previously explained Mach-Heisenberg principle. In fact, in order the electroweak interaction can take place during \( 10^{-27} \) seconds over a distance \( 10^{-18} m \), gravitational vacuum must deploy \( 10^{32} \) quantum baby universes as the units of space-time each of which with the Planck length-time scale \( 10^{-34} m - 10^{-43} s \) and the reduced Planck mass scale corresponding to the energy scale of that stage of the universe. However, the energy scale of the universe at this stage is assumed to be the electroweak energy scale. So, each quantum baby universe created at this stage has energy scale \( M_P^{\text{reduced}} \sim 10^{3}\text{Gev} \). It seems the gravitational \( G \) looses its strength against electroweak one because of the creation of a large amount \( \sim 10^{32} \) of space-time units to provide the length-time scale that electroweak interaction needs to take place! To support this idea we may provide the following relation

\[
(M_{\text{EW}})^2(L_{\text{EW}})(T_{\text{EW}}) \simeq (M_P)^2(l_P)(t_P),
\]
where Heisenberg’s position-momentum and time-energy uncertainty relations (in units of \( \hbar = c = 1 \)) have been used at once for the electroweak universe in the left, and for the original quantum baby universe, in the right. This relation leads to

\[
\frac{G}{G_{EW}} \simeq \frac{M_{EW}^2}{M_P^2} \simeq \frac{(l_P)(t_P)}{(L_{EW})(T_{EW})} \simeq 10^{-32},
\] (7)

which shows the strength of gravitational coupling is \( \sim 10^{-32} \) times weaker than electroweak one.

Note that up to now we have not really solved the hierarchy problem. We have just converted the mass hierarchy to the space-time hierarchy. So at this point the problem is why the space-time scales of electroweak universe is much larger than the quantum baby universe? We have now a reasonable justification for this hierarchy: we know the electroweak universe is a stage in which massive particles are to be realized, namely the energy scale of Higgs field is converted to massive particles. But, no particle concept can be realized without the concept of localization in space-time. So, we have to obtain a threshold localization criteria for massive particles. In the present model, the background vacuum gravitational fluctuations account for the Higgs field giving mass to the particles. At the same time these fluctuations are responsible for space-time realizations corresponding to that energy scale, namely Higgs energy scale. Therefore, the Higgs energy corresponding to a space-time scale can be converted to a typical massive particle localized on this space-time scale provided the Compton wavelength of the particle at least is of the order of its size\(^{10}\). The agreement of the Compton wavelength of the proton with its actual radius is a clue to solve the space-time hierarchy problem.

It seems proton is the only stable standard model particle which satisfies the localization criteria of a massive particle. In other words, protons are the first massive particle could be generated, since the birth of the first quantum baby universe, by the background vacuum gravitational fluctuations, namely the Higgs field\(^{11}\). Before this criteria for massive particle production could be realized,

\(^{10}\)If we consider the Higgs mechanism as an effective model of this quantum gravity, this criteria may play the role of order parameter which triggers the electroweak spontaneous symmetry breaking so that the particles become massive.

\(^{11}\)It is easy to show that a relation like to (7) exists to compare the Planck and proton energy scales as

\[
\frac{M_{P,r}^2}{M_P^2} \simeq \frac{(l_P)(t_P)}{(L_{P,r})(T_{P,r})} \simeq 10^{-39},
\]
the universe just was enlarging filled with energies pumped by vacuum gravitational fluctuations. Once this criteria is realized the universe was then enlarging filled with massive particles created by vacuum gravitational fluctuations. As the universe expands according to Mach-Heisenberg principle, its energy scale corresponding to the vacuum gravitational fluctuations, decreases and so particles with less mass such as electrons are realized whose Compton wavelengths are larger than their actual radiuses and so are more localized. In this way, all the standard model particles could be realized during the electroweak era when the electroweak universe was almost in contact with the vacuum gravitational fluctuations with the energy scale of the Higgs order\textsuperscript{12}. After all the fermionic particles with specific mass scales and bosons like photons as the $U(1)$ gauge particles are realized in the electroweak universe by spontaneous symmetry symmetry breakdown, the universe is filled with matter and radiation. The universe then continues its expansion getting less energy scale from gravitational vacuum by Mach-Heisenberg principle. At these later stages particles with variety of decreasing

\begin{align*}
M_P, L_P, \text{ and } T_P \text{ are the proton’s mass, radius and time light needs to pass the proton radius, respectively. The}
\end{align*}

large number $10^{-39}$ here has the same justification as explained for the electroweak case. In fact, one can write down the position-momentum and time-energy uncertainty relations in the following times sequence for the quantum baby universe, electroweak universe, proton universe and our large scale universe as

\begin{align*}
(M_P)^2(\ell_P)(T_P) \simeq (M_{EW})^2(L_{EW})(T_{EW}) \simeq (M_{Pr})^2(L_{Pr})(T_{Pr}) \simeq (M_{\text{reduced}})^2(R)(T).
\end{align*}

The last equality between the length-time-mass scales of a proton and our present universe shows that proton is the unique particle which can play the role of a small size universe. In other words, proton universe is a typical small size universe which have led to our present large scale universe. This sheds light on the puzzles which Dirac had introduced in his large numbers hypothesis [2].

\textsuperscript{12}The fact that the actual masses of the fermions are not predicted by Higgs-fermion couplings in the standard model is an evidence that these couplings have their origin in the dynamical coupling of the electroweak universe to the vacuum gravitational fluctuations. In other words, the unknown couplings in the standard model are related to the dynamical parameters of the evolving universe in contact with the dynamical evolving vacuum energy scale. The mass ratio of different particles will depend on the time difference (in the Planck unit $t_P$) between the stages of generation of these particles.
mass or energy scales are to be realized whose best candidates are neutrinos\textsuperscript{13} with unspecified mass scale which itself is a good candidate for “Dark matter”. Moreover, a large amount of energy with decreasing scales can be gradually pumped (realized) into this expanding universe by gravitational vacuum, which in turn may be interpreted as what we call “Dark energy”.

Now, we pay attention to the localization criteria and space-time hierarchy problem. We may conclude that the reason why gravity coupling $G$ is so weak against electroweak coupling $G_{EW}$ is that electroweak era has to be realized in a stage of the universe with such a large enough space-time scale on which the massive particle can be localized over a space-time continuum. In other words, the scale of causal and continuous structure of space-time at electroweak universe over which a massive particle can be realized should be very far enough (about $10^{32}$ order of scale) from the scale of discrete structure of space-time at the stage of quantum baby universe. This solves the space-time scales hierarchy and so the mass scales hierarchy problems. This is like to the vast desert between the continuous property of a light beam and its discrete feature at the scale of one photon. For the same reason that one can not realize a interference pattern by one or few photons, one can not realize a particle concept by one or few quantum baby universes (units of space-time). Rather, huge numbers of quantum baby universes as eigenkets of a Hilbert subspace are required so that a massive particle on a space-time continuum can be localized according to the superposition rules of quantum mechanics.

We assert that in this model there is no time independent unification of electroweak energy scale $M_{EW} \sim 10^{3} Gev$ and Planck energy scale $M_{P} \sim 10^{19} Gev$. The Higgs sector is the low energy limit of Planckian quantum gravity, namely quantum baby universe, which is attained just by elapse of time or expansion of the universe. In other words, at electroweak stage the energy scale of decaying vacuum gravitational fluctuations with the reduced Planck mass scale coincides with the Higgs energy

\textsuperscript{13}In fact, these later and cooled stages of the universe may coincide with matter-radiation decoupling and cosmic microwave background CMB after which only light particles such as neutrinos may survive leaving a background in neutrinos in thermal equilibrium.
scale $M_P^{reduced} \sim M_{EW} \sim 10^3 Gev$. Just in this regard, we may have a unification.

5 Cosmological constant problem

If this model is capable of solving the hierarchy problem, it has to be of the same capability to solve the cosmological constant problem. The main prescription to solve the Hierarchy problem is to consider carefully the space-time scales when we compare Higgs energy scale with the Planck energy scale. The story is almost the same when we wish to address the cosmological constant problem. Here also we face with a problem which arises due to a comparison between the current observed value of the vacuum (cosmological constant) energy density and the quantum gravity contributions of the order of $(M_P)^4$. The “4-th” order huge correction $(M_P)^4 \sim (10^{19})^4$ implies that something is wrong with the length-time scales (in a “4-d” space-time) which have been used to evaluate the cosmological constant today. So, we have to be very careful about the length-time scales in this problem. According to above prescription it seems these two energy scales are compared without considering their characteristic length-time scales. In fact, in the present era the characteristic length and time scales corresponding to the present energy scale of the universe, namely the observed cosmological constant, are the current size $\sim 10^{60}l_P$ and current age $\sim 10^{60}t_P$ of the universe, respectively. The characteristic length and time scales $l_P$ and $t_P$ do not belong the the present stage of the universe rather they belong to the early quantum baby universe. Fortunately, the Mach-Heisenberg uncertainty principle lets us to relate and compare the length-time-mass scales of one “unique” universe at these two hierarchial stages as

$$(M_P^{reduced})^2(R)(T) \simeq (M_P)^2(l_P)(t_P),$$

or

$$(\Lambda_c)(R)(T) \simeq (\Lambda_P)(l_P)(t_P),$$

where $\Lambda_c$ and $\Lambda_P$ account for the current observed cosmological constant and the corresponding one at early quantum baby universe, respectively. This relation asserts that each of the cosmological constants $\Lambda_c$ and $\Lambda_P$ have their own characteristic length-time scales belonging to two different stages.
of the universe. So, if according to the popular interpretation of quantum gravity we use scales $l_P$, $t_P$ and $M_P \sim 10^{19}\text{Gev}$ to evaluate the quantum gravity contributions to $\Lambda_c$ we will encounter with the well known cosmological constant problem, because we are using the scales belonging merely to the early universe and not present universe. If one is still interested in the popular interpretation of quantum gravity to evaluate $\Lambda_c$, he/she has to use the cosmological length-time scales $R, T$ leading to the reduced energy scale $M_{\text{reduced}}^p$. At the present universe, the energy scale of quantum gravity (vacuum gravitational fluctuations) is not the Planck scale $10^{19}\text{Gev}$, rather it is very reduced due to the large expansion of the present universe. Therefore, if one wishes to include the quantum gravity contributions to $\Lambda_c$ at present universe he/she finds that these contributions are of the same order of $\Lambda_c \sim M_{\text{reduced}}^p$ and concludes that the current cosmological constant is noting but the current “background” vacuum quantum gravitational fluctuations to which our present universe is in contact. This solves the cosmological constant problem.

Note that according to Mach-Heisenberg principle we assume that the energy scale of each virtual single quantum baby universe realized (socialized) in our present Machian universe is the same energy scale of this present universe. So, one may compare the length-time-mass scales of each virtual single quantum baby universe at present and the one at early universes as ($c = 1$)

$$
\begin{align*}
    t &\approx 10^{17}\text{s} \\
    l_P &\approx 10^{-34}\text{m} \\
    t_P &\approx 10^{-43}\text{s} \\
    M_{\text{reduced}}^p &\approx 10^{-60}M_P,
\end{align*}
$$

and

$$
\begin{align*}
    t &\approx 10^{-43}\text{s} \\
    l_P &\approx 10^{-34}\text{m} \\
    t_P &\approx 10^{-43}\text{s} \\
    M_P &\approx 10^{19}\text{Gev}.
\end{align*}
$$

This latter certifies that Heisenberg uncertainty relation does not work for a single quantum baby universe after realization (socialization), according to Mach-Heisenberg principle, into the mother universe. This is because as we probe the length-time scales close to the Planck scales $t_P, l_P$ in the present universe we get small energy scale $M_{\text{reduced}}^p$. 


The story of cosmological constant problem is almost the same as Big Bang problem: where did the Big Bang happen? The answer is: “everywhere” and “nowhere”! If we take any point in the present universe and trace back its history, it would start out at the explosion point, and in that sense the Big Bang happened everywhere in space. In another sense, the location of Big Bang is nowhere, because space itself is evolving and expanding, and it has changed since the Big Bang took place. Imagine the universe as an expanding sphere. The place where the “Bang” happened is at the center of the sphere, but that is no longer part of the space, the surface of the sphere, in which we live [9]. At present, we just observe its imprint as “CMB” radiation with a very reduced temperature of 3.2 K. In the same way, the original cosmological constant of the order of Plank mass squared has been very reduced due to the huge expansion of the universe. So, if we wish to compute the quantum gravitational corrections, namely the contributions of vacuum quantum gravitational fluctuations to the cosmological constant, it is so unreasonable to use the original Planck mass $10^{19} \text{Gev}$, because this large mass scale has happened at the stage of quantum baby universe and is no longer part of our present expanded universe, so the Planck mass $10^{19} \text{Gev}$ is “nowhere”. On the other hand, its imprint at present universe is “everywhere” as a very small mass scale $M^\text{reduced}_P \simeq (10)^{-60} M_P$ which we interpret its square as the observed cosmological constant $\Lambda^\text{reduced}_P \simeq (10)^{-120} \Lambda_P$.

6 Discussion

In this section we just speculate on the immediate impacts of this model on the popular interpretation of quantum gravity and cosmology. The result that a virtual single quantum baby universe embed in our present mother universe do not admit Heisenberg uncertainty relation is of particular importance in the study of renormalizability of quantum gravity as well as other quantum field theories. We know the quantum gravity is nonrenormalizable because its coupling has dimension $(\text{mass})^{-2}$ and the index of divergence is growing by the order of perturbation. However, the important point is that once we leave Heisenberg uncertainty relation for each virtual quantum baby universe in our expanding mother universe we realize that there are no large momentum-energy scales at ultrashort
Planck scales, rather we find that the energy or momentum scale is infinitesimally small (10). This means the degrees of freedom which are relevant to the Planck scales are no longer responsible for divergences. Therefore if one still insists to interpret quantum gravity as an effective quantum field theory he/she will find it free of ultraviolet divergences and a renormalizable theory which may describe the creation of the observed universe. For the same reason that uncertainty principle looses it validity at small scales in an expanding universe, we have no ultraviolet divergences corresponding to small scales in other quantum field theories. In other words, it seems all the divergences appearing in the standard quantum filed theories are due to the assumption of a fixed mathematical space-time background in which uncertainty principle is valid in this fixed background so that large momentums appear at short scales. The renormalization technics are then necessary to make these mathematical divergences finite. However, in reality expansion of the universe as a natural renormalization process makes all such quantum field theories to lead to the finite results. In other words, in a physical expanding space-time, rather than mathematical fixed space-time, in principle we do not expect any real ultraviolet divergences.

The cosmology of this model is of Dirac-steady state type in which mass or energy is continuously generated while the universe expands in space and time homogeneously (see (3) and the following discussion) obeying perfect cosmological principle and large number hypothesis. However, the present model has not the problems of the original model which made it to be abandoned in the literature.

The problem of continuous mass-energy generation is easily solved because our universe is assumed to be in contact with the vacuum state of quantum gravitational fluctuations and this vacuum sea loans its energy in a continuous “one-way” to the universe, from its original quantum baby state till its present large scale state, according to the uncertainty principle which is always applied to the whole Machian universe.

The problem of CMB is solved because in contrast to the original model where all radiation in the universe originate in stars and galaxies without thermalization to produce a perfect black body spectrum, in this model all radiation (as well as matter) originate from vacuum gravitational
fluctuations which themselves are assumed to be in a perfect thermalized state. Moreover, all radiation after realization in the mother universe are in perfect causal contact with each other because the rate of expansion of the universe in this cosmology is always the light velocity $\frac{R}{T} = c$, so the radius of universe always coincides with the horizon.

This model for quantum gravity, however, has major impacts on the currently accepted scenarios for time evolution of the universe such as inflation, Big Bang, and current acceleration of the universe. It is important to note that the ratios $\frac{T}{t_P} \sim 10^{60}, \frac{R}{t_P} \sim 10^{60}$ do not really mean a time evolution in the present interpretation of the creation of the universe, because space-time as a unique entity is generated dynamically. Rather, they just tell us that the space-time extension of the present universe is $10^{120}$ times larger than those of the original quantum baby universe, that is it. These ratios do not tell us anything about real time evolution. However, in this pure quantum gravitational interpretation of the universe based on the fundamental constants $c, G, \hbar$ we may interpret that the radius of the universe is evolving with the constant light velocity $c$ in terms of a pure quantum gravitational clock made of these constants as $t_P$. In other words, we may consider this as the “perfect uniform” quantum gravitational evolution of the universe with a fundamental time parametrization made by quantum gravity itself, namely Planck time. This is so reasonable because the vacuum sea of quantum gravitational fluctuations which give birth and extension to this universe is always in “perfect thermalized” state.

On the other hand, according to the present model there is a fundamental distinction between quantum gravity and general relativity. It turns out that quantum gravity is “just” responsible for the creation and perfectly uniform time evolution of the Machian universe with all its stuffs inside, without telling us how gravitational interactions take place between these stuffs inside the universe. Here, Einstein equation plays the role and “just” tells us that how a massive object may curve the surrounding space-time continuum and more importantly how this curved space-time continuum determines the local geodesics. The situation here is almost the same situation we have in the case of Newton’s laws of motion. We know the first law of Newton is “just” responsible for providing a
well defined coordinate system in a perfect uniform state of motion, namely inertial frame, so that the second law of Newton becomes meaningful to “just” govern the “local dynamics” on this inertial background. In the same way, it seems quantum gravity plays the role of first law of Newton to provide a uniform Machian frame (space-time pavement) so that Einstein equation (playing the role of second law of Newton) becomes meaningful to describe the “local dynamics” on this Machian background. Therefore, we arrive at the important conclusion that in the framework of the present model, quantum gravity and Einstein equation are different in essence\textsuperscript{14}, almost in the same manner that the first law of Newton is different from the second law of Newton\textsuperscript{15}. This distinction between quantum gravity and Einstein equation provides us with opportunities to solve the remaining problems in the present quantum gravitational interpretation of the cosmology.

To this end, we again resort to the Newton’s first and second laws. If we take the rest inertial frame as our reference frame and wish to describe the “local dynamics” of a particle with arbitrary motion on this background we have to apply the second law of Newton to obtain $\vec{r}(t)$. Now, suppose a particle is uniformly moving with constant velocity $\vec{v}$ in the rest inertial frame as $\vec{r}(t) = \vec{v}t$ and another observer in an arbitrarily rotating frame with time dependent frequency and rotational direction, observes the motion of this particle and wishes to describe its local dynamics $\vec{r}'(t)$. He/she will certainly find a complicate motion for that particle in this rotating reference frame and this is because the reference frame of the observer has been changed from inertial to a rotating frame. This complicate and nonuniform motion together with some terms with wrong signs in the Hamiltonian to support the observations in this rotating frame is the price the observer pays for the change of reference frame.

We now identify the first and second laws of Newton with the quantum gravity and Einstein equation, respectively. For the same reason that one can not, in principle, use the second law of

\textsuperscript{14}A same conclusion was already proposed by the author elsewhere [7].

\textsuperscript{15}The fact that just quantum gravity is Machian sheds light on the useless effort of Einstein to reconcile his local equation with Mach principle. In comparison, Einstein would try to establish the first law of Newton, namely inertial frames (Mach principle) by the “vanishing force” case of Newton’s second law (“vanishing energy momentum tensor” case of Einstein’s equation).
Newton to alter the definition of “uniform inertial frames” in the first law, here also one can not, in principle, use the local Einstein equation to alter the quantum gravitational fundamental definition of “uniform evolution of the universe”. In other words, locally one may use Einstein equation just to determine the local geodesics on the surrounding space-time. On the other hand, for the same reason that in the Newtonian dynamics the uniform motion of a particle in an inertial frame may become a complicate motion if it is observed in an arbitrarily rotating frame, the uniform expansion (in time) of the universe (scale factor playing the role of the particle) in the absolute Machian frame will appear as a nonuniform (in time) expansion, if it is observed by a general relativistic observer who uses Einstein equation to describe the “global” expansion of the universe. This is because the framework of general relativity in comparison to that of quantum gravity is almost like to the framework of a rotating frame in comparison to that of an inertial frame.

To summarize, if we use Einstein equation (Newton’s second law) in the framework of general relativity (rotating frame) with a time dependent “equation of state” (time dependent frequency) to describe the evolution (motion) of the scale factor $R$ (particle) having a uniform motion in the rest Machian frame (rest inertial frame) defined by quantum gravity (Newton’s first law), we obtain complicate evolutions (motions) of the scale factor $R$ (particle), such as inflation, Big Bang and current acceleration (acceleration, deceleration and again acceleration), together with some terms in the Hamiltonian with wrong signs in the kinetic term between gravitational and matter degrees of freedom, and even potential terms such as exotic matter or dark energy with “negative” pressure (frequency dependent terms with wrong signs)$^{16}$ and violation of strong energy conditions (non conservation of energy), to support the observations in the general relativistic universe (rotating coordinate system)!

The point is that the initial ($R = l_p, T = t_p$) and final ($R = 10^{60} l_p, T = 10^{60} t_p$) states of the universe are the same for both quantum gravitational (QG) and general relativistic (GR) observers,

$^{16}$Dark energy is also predicted to be realized in our quantum gravitational picture of the universe, but we do not need a negative pressure to accelerate the universe because in this picture the universe is uniformly expanding.
but the ways and dynamics starting from initial state toward ending at the final state are different.
In other words, both observers agree on a “cosmological time” which is set by quantum gravity and
in comparison to the Newtonian discussion made above we may call it as the “absolute time”. QG
observer realizes a perfect uniform evolution of the scale factor starting from initial and ending at
final state, according to this absolute clock. GR observer, however, realizes accelerating (inflation)-
decelerating (Big Bang)-accelerating (current) phases for the same universe with the same endpoints,
according to the same absolute clock. This means the appearance of nonuniform motions of the scale
factor in the GR frame is due to the nonuniform dynamic state of this frame with respect to the
QG rest absolute (vacuum) state frame. In fact, time evolution of the GR universe depends on a
dynamical state which is set by different phases of its matter content, whereas time evolution of the
QG universe depends on an absolute state which is set by perfectly thermalized vacuum quantum
gravitational fluctuations. In other words, the reason why GR observer experiences nonuniform
motions like inflation, Big Bang and current acceleration in the GR universe is the existence of a
“dynamical state” which makes GR frame to be in nonuniform motion states with respect to the QG
frame with uniform motion and “absolute state”. This behavior for the GR universe is inevitable
because unlike the QG absolute gravitational universe, the GR universe is governed by new physics
coming from other three interactions which make its state of matter-energy content to be dynamical
which is usually determined by the time dependent “equation of state”17.

There is still more to learn. Suppose exactly in the same way that local inertial forces manifest in
a local rotating coordinate system with respect to an “absolute” rest frame as Newton would demand,
universal inertial forces appear in the GR universe for a given GR observer due to the nonuniform (in
time) evolution of the GR universe with respect to the “absolute” Machian universe. However, since
this nonuniform evolution of the scale factor is spatially homogeneous and isotropic, the net effect of

17It is not so difficult to construct, for example, a model universe whose dynamics depends on the equation of state
in four dimension while it has a uniform constant dynamics independent of equation of state in higher dimension [7].
We may look for a similar pattern in the present model to realize the difference between QG and GR universes if we
interpret the former and latter as 5 and 4 dimensional universes (see the conclusion).
the universal inertial forces imposed spherically from all directions on the observer is zero and this observer is at rest. If this observer exerts a net force in order to accelerate a particle at rest, the local balance of universal inertial forces in the direction of acceleration will change by this exerted local force and the nonuniform (accelerating or decelerating) homogeneous and isotropic evolution of the universe will try to fix the balance again. Therefore, the GR observer will experience a restoring local force, imposed by nonuniform motion of the universe while the particle is being accelerated, and will interpret it as the “inertia” of the particle\textsuperscript{18}. This is like the “Mach force” introduced for the first time by E. Mach, but contrary to Mach’s idea its origin is not the gravitational effect of distant distribution of matter with action of distance problem, rather it is the nonuniform homogeneous and isotropic evolution of the universe which imposes this local inertial force with no action of distance problem, because like the local inertial forces which always appear simultaneously in the local rotating systems the universal inertial forces, as well, appear simultaneously throughout the entire universe as a coordinate system with nonuniform motion.

Finally we may comment on two important puzzles in general relativistic cosmology according to the present quantum gravitational interpretation of the universe. First, since the origins of matter and dark energy in the GR universe (according to the present interpretation of the creation of universe based on quantum gravity) are the same thermalized vacuum gravitational fluctuations, this model then predicts that their order of magnitudes should always be the same. It is easy to show that this

\textsuperscript{18} It is interesting that unlike Einstein original idea in considering an static universe to recover the Mach principle, in this model inertial properties of matter requires a universe with nonuniform motion no matter this motion is accelerating or decelerating. The rate of acceleration or deceleration does not change the gravitational configurations. This is because we believe in the Einstein equivalence between inertial and gravitational masses, so all possible variations in the “inertia” of an object due to the nonuniform (accelerating or decelerating) motion of the universe has no detectable dynamical effect because of this equivalence. However, different rates of acceleration or deceleration, for example, at inflationary phase, Big Bang or current accelerating phases of the universe leading to different values for the inertia of a particle, may affect the non gravitational configurations and lead to unexpected results.
prediction is really the case. The matter density at present universe is \((h = c = 1)\)

\[
\rho_M = \frac{M}{R^3} \sim 10^{-120} \frac{M_P}{L_P^3} \sim 10^{-120} M_P^4
\]

and that of dark energy (cosmological constant) at present is certainly the same

\[
\rho_{DE} = \frac{\Lambda c}{G} \sim \frac{10^{-120} \Lambda P}{M_P^{-2}} \sim 10^{-120} M_P^4.
\]

Therefore, the “coincidence problem” as an “apparent” problem in the general relativistic interpretation of the universe is solved by resorting to the quantum gravitational interpretation\(^\text{19}\). Moreover, the fact that the density of the total matter-energy content of the present universe is divided up amongst the dark energy, dark matter and baryonic matter as

\[
\rho_{DE} \gg \rho_{DM} > \rho_{BM},
\]

indicates that the ages corresponding to each content is set as

\[
\tau_{DE} \gg \tau_{DM} > \tau_{BM}.
\]

Therefore, the reason why the dark energy content has become dominant to trigger the current acceleration in the general relativistic interpretation of the universe is that according to the quantum gravitational interpretation this energy is pumped continuously into the universe so that at late time evolution of the universe it is mostly filled with dark energy naturally, as explained in section 4. Therefore the problem of “dark energy domination” at the present general relativistic universe is solved as well, by resorting again to the quantum gravitational interpretation.

\(^\text{19}\)In fact, this is really a problem in GR interpretation while it is a natural behavior in QG interpretation. By a change of reference frame from GR to QG this problem is easily solved, like a complicate and unjustified situation in a rotating frame which is easily solved when we change our frame to an inertial one.
Conclusion

In this paper, we have proposed a new idea that space-time is discrete and given a phenomenological model for quantum gravity which we hope to solve the well known current problems of cosmology and particle physics. In this interpretation, quantum gravity is not an interaction, like the other three ones, mediating gravity force at Planck scales. Rather, it is just responsible for continuously generation of the universe (space-time-matter) by a newly developed Mach-Heisenberg principle which lets virtual quantum baby universes to be realized from a sea of vacuum quantum gravitational fluctuations. The problem of time is solved due to the discrete structure of space-time at ultra-short distances and a fundamental time parametrization imposed by this quantum gravity. Hierarchy and cosmological constant problems as the two problems with the same origin are solved simultaneously by using Mach-Heisenberg principle which makes the energy scale of the universe to decrease as it expands, in this interpretation. It is shown that this quantum gravity provides us with a framework in which all interactions together with the vacuum quantum gravitational fluctuations may lead to finite results without ultraviolet divergences, in an expanding universe.

A very interesting prediction of this renormalizable quantum gravity is that if two ultra high energetic particles collide each other up to Planck energy scale they will be shattered into discrete units of space-time, namely quantum baby universes of the Planck energy scale. For simplicity suppose just one quantum baby universe is generated in this collision. In fact, the Planck energy of this quantum baby universe with Planck length-time scale is borrowed from the energy content of our universe during the collision, but this Planck energy per Planck time is provided in our universe by the vacuum fluctuations. In other words, this time the universe borrows one Planck energy per one Planck time from the vacuum, not for itself (the whole universe) but for the generation of one quantum baby universe with Planck energy. This new born quantum baby universe, unlike the others already existed virtually in the mother universe with reduced Planck mass, obeys naturally the uncertainty principle firstly because it has been generated in a “real collision” obeying uncertainty principle, and
secondly because the mother universe does not play the same game with this new quantum baby universe. In fact, since this new quantum baby universe, instead of generation by the vacuum, is generated inside the mother universe, the mother universe has to support the Planck length-time-energy scale of this quantum baby universe. In doing so, the mother universe consumes of its own length-time-energy scale to generate one Planck length-time-energy scale corresponding to the new quantum baby universe. In other words, the mother universe does not get old up to one Planck time, does not get large up to one Planck length and does not get fat up to one Planck mass to compensate for the generation of this quantum baby universe. In simple terms, the mother universe stops its evolution for one Planck time to compensate for the generation of this new quantum baby universe. Therefore, this quantum baby universe seems to be rejected by the mother universe back to the vacuum and so it plays the same role of the original quantum baby universe which had led to the present mother universe. In other words, this new born quantum baby universe with huge energy scale is no longer part of our mother universe with very small energy scale, rather it is rejected back to the vacuum so as to be possibly the seed of another universe which is to be expanded to another mother universe, causally disconnected with us, by a new Big Bang!

We have shown that quantum gravity is completely distinct from Einstein equation in that the former defines a uniform creation and evolution of a Machian universe just like the first law of Newton which defines just the rest inertial frames, whereas the latter defines a nonuniform evolution of the general relativistic observed universe just like the second law of Newton expressed in a non-inertial time dependent frame, which describes the nonuniform motion of a particle in this frame. It seems quantum gravity establishes an “absolute state of motion” as Newton would desire and general relativity establishes a “Machian framework” to describe the universe as Einstein would desire.

The cosmological implications of this quantum gravity, based on perfect cosmological principle and large number hypothesis, sheds light on the most important subjects in cosmology such as Dirac large number coincidences, time evolution of the universe like inflation, Big Bang, current acceleration of the universe, matter-energy content of the current universe and coincidence problem. This model
is free of singularity because a fundamental quantum unit of space-time exists which never lets the scale factor $R$ goes to zero. Moreover, horizon, flatness and fine-tuning problems are easily solved in the quantum gravitational interpretation of the universe. Since the quantum gravitational universe is interpreted to be expanded always with the light velocity we have not horizon and flatness problems. On the other hand, there is no fine-tuning problem because there are no free parameters in the quantum gravitational interpretation of the universe except the fundamental constants $\hbar, c, G$. In fact, the fine-tuning problem is specific to the general relativistic universe with few parameters like density and deceleration parameters. This model also gives a convincing justification for the origin of “inertia”.

Another interesting result is that the arrow of time in the observed GR universe is induced by the arrow of time in the Machian QG universe. Therefore, one may conclude that the reason why the observed cosmological time in GR universe is not reversible is that the arrow of time in the Machian QG universe is not reversible and this is because the “time” is generated continuously through the irreversible generation of quantum baby universes by Mach-Heisenber principle which abandons the annihilation of these baby universes after their realization into the causal Machian universe. However, as explained in the second paragraph of the conclusion a super-collision of the Planck energy scale may generate a few quantum baby universes which may stop and reverse the direction of cosmological time in our universe for a few Planck times. In other words, this super-colliding local apparatus plays the role of a time machine which may alter the cosmological arrow of time for a while\textsuperscript{20}. Each of these missed Planck times in our universe may become a beginning Planck time for other new universes!

If this phenomenological model works, one has to look for a dynamical mechanism by which the quantum baby universes are generated from vacuum gravitational fluctuations. A possible mechanism would be generation of Planck scale wormholes occurring all the time as virtual processes as conjectured by Baum, Coleman and Hawking [10]. On the other hand, since this model asserts that the Higgs field

\textsuperscript{20}Of course, it is not technically simple because in order to stop and reverse the arrow of time for “one second” a huge numbers of collisions of the order of $10^{43}$ is required!
as a genuine field does not really exist, it is of particular importance to study a model by which the Higgs type potential can effectively arise at ultrashort distances. One such a mechanism is already proposed by the author [7]. In this model, an scalar field is defined at ultrashort distances (which effectively may arise as the scalar sector of vacuum quantum gravitational fluctuations) and a Higgs type potential is effectively appeared. Non vanishing vacuum condensation of this Higgs field occurs once a signature transition from Euclidean to Lorentzian metrics is formed at ultrashort distances. It is therefore appealing to suppose that quantum baby universes had originally no demarcation between space and time. Once they have been realized in a mother universe, their quantum uncertainty features are faded in favor of a classical causal relation with each other. We may interpret this as a signature transition from Euclidean to the Lorentzian metric which could then lead to a large effective vacuum condensation, in the effective Higgs type potential, to trigger the inflationary era. This scenario is also in the spirit of the “no-boundary” proposal of Hartle-Hawking in quantum cosmology [12].

It is worth noting that since this quantum gravity is a model of space-time-matter generation, effectively it is in the spirit of 5D space-time-matter theory developed by Wesson et al [11]. The similarity may be realized roughly if one assumes the vacuum gravitational fluctuations as a 5D entity, whose 4D sector generates space-time and one remaining dimension as the scalar sector generates matter (energy-mass), and assume this vacuum state to play the role of 5D vacuum Ricci flat equation \( R_{AB} = 0 \) which reduces to the Einstein equation with matter in 4D universe almost like the realization of space-time-matter in our 4D universe, according to the present model of quantum gravity. The emergence of 4D Einstein equation with matter from 5D vacuum Ricci flat equation may imply that Einstein equation is emerged from Mach principle, just like the emergence of Newton’s second law from the first law. Just in this manner we may have consistency between Einstein equation and Mach principle. Note that, unlike brane higher dimensional theories in which the 5th dimension plays an specific ad hoc role to solve the cosmological or particle physics problems like hierarchy or cosmological constant, the 5th dimension in this model comes to play the natural role of matter. In this regard, we may claim that our solutions to the above problems are natural.
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