A Cosmological Model with Variable Constants (Functions of the Gravitational Potential)

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Abstract: Based on several assumptions to deduce a cosmological model with three fundamental constants along with the dimensionless electroweak coupling constant turned into functions of the gravitational potential. Initial research of this model has indicated solutions to avoid the singularity in both special relativity and general relativity, and to solve several long-standing cosmological puzzles.

Key words: Gravitational Waves, Black Hole, Quasar, Galaxy, Neutron Star, Cosmic Rays

1. Introduction

The quantum field theory of the standard model for particle physics is based on a flat space-time reference frame without considering gravitational fields, so it cannot explain the phenomena involved gravitational fields. A physical law expressed in a general covariant fashion takes the same mathematical form in all coordinate systems, so any dimensionless constant should take the same value in all coordinate systems as well, because the numerical values of dimensionless physical constants are independent of the units used. If the form of a physics law is changed with energy scale or temperature in microscopic scale because the value of the dimensionless electroweak constant is changed, then the general covariance breaks down in microscopic scale. Therefore, it is impossible to fit the quantum field theory into the framework of general relativity based on the principle of general covariance [10]. Hence, we try to modify the quantum theory in order to describe the phenomena inside a gravitational field at the microscopic scale. We assume that the speed of light in vacuum and Planck constant are functions of the gravitational potential, which are defined in a universal flat space-time reference frame sitting far away from any gravitational fields. People had made similar proposals before [1, 2], but none of them could reach completely self-consistent conclusions. Einstein first mentioned a variable speed of light in 1907; he reconsidered the idea more thoroughly in 1911. But Einstein gave up his VSL theory for unknown reasons; it might be because he could not successfully identify all those fundamental constants controlled by the gravitational potential. Our assumption on the active and passive gravitational mass in section 2 is critical in order to derive equation (3.1). We will design a thought experiment which is a photon traveling in a still gravitational field, and write down three equations to describe it based on several assumptions, and derive functions for those variable constants by solving these equations. We will investigate the physical significance of these functions in section 4 and eventually deduce a cosmological model in section 5 to solve several long-pending cosmological problems, such as the mechanism of the gravitational waves, the essence of the cosmic microwave background, and the origins of the cosmic rays. We will derive a new Hubble constant with totally new physical significance from the gravitational coupling constant in section 6.

2. Assumptions

The speed of light in vacuum is a function of the gravitational potential. A vacuum infinitely far away from any active gravitational rest mass is a flat space-time perfect vacuum; the speed of light in this perfect vacuum has a maximum speed. We assume that the inertial mass of particles is equivalent to the passive gravitational mass which is subjected to the gravitational force, and only the rest mass of fermions is equivalent to the active gravitational mass which can produce the gravitational potential, so the functions of the gravitational potential should be valid to the scale of fermions. Since a photon does not have a gravitational field associated with the active gravitational rest mass, a photon propagating in a gravitational field will not produce any gravitational waves; the change of the gravitational potential energy of a photon is absolutely equal to the change of the kinetic energy of the photon. These assumptions will yield equation (3.1) in section 3.

Based on the principle of general covariance, the fine structure constant, as a dimensionless coupling constant for the macroscopic electromagnetic force, should be invariant in the gravitational field. And because of the conservation of electric charge, we have to assume the Planck constant and the permeability of vacuum being functions of the gravitational potential [11] while keeping the elementary charge and the permittivity of vacuum as true constants. These assumptions will yield equation (3.2) in section 3.

Since the frequency of light will not change during its propagation through different mediums, we assume the frequency of a photon will not change when it travels in a gravitational field. This assumption will yield equation (3.3) in section 3. We have to assume all of our measurements are referring to a clock sitting in the universal flat space-time reference frame, which is sitting infinitely far away from any gravitational fields but still is full of Higgs field. In fact, it is the only valid inertial reference frame; if we talk about time dilation without referring to the preferred reference frame, then it can only lead to all kinds of paradoxes. It should be noted that general relativity curved space-time is incompatible with homogeneity of space, isotropy of space, and uniformity of time, and will violate the conservation laws associated with those symmetries [9].

3. Deriving Variable Constants as Functions of the Gravitational Potential

The speed of light in vacuum is a function of the gravitational potential showed as $c(u)$, where $c(0) = c$; c is the speed of light in perfect vacuum where the gravitational potential equals to zero. The Plank constant is a function of the gravitational potential showed as $h(u)$, where $h(0) = h$. The mass of a photon is a function of the gravitational potential showed as $m(u)$, where $m(0) = m$. Derive three equations (3.1), (3.2) and (3.3) according to the assumptions discussed in section 2.

$$m(u)c^2(u) + \int_0^u m(u)du = m \cdot c^2 \text{ ------ (3.1)}$$

This equation also can be written as: $m(u)c^2(u) - m \cdot c^2 = -\int_0^u m(u)du$ ------ (3.1.1)

The left hand part of this equation represents the change of the photon's kinetic energy; the right hand part represents the change of the photon's gravitational potential energy.

If we deal with a fermion with an active gravitational rest mass associated with its intrinsic magnetic field, then we have to add terms to represent the gravitational and electromagnetic radiation energy on the left hand part of equation (3.1.1), and a term to represent the change of the electromagnetic potential energy on the right hand part. In this case the equation can be written as:

$$[m(u)c^2(u) - m \cdot c^2] + E_{Radiation}^{Gravitational} + E_{Radiation}^{Eletromagnetic} = -\int_0^u m(u)du + \Delta E_{Potential}^{Electromagnetic} \text{ ------ (3.1.2)}$$

We notice $E_{Radiation}^{Gravitational} \to 0$ when $u \to 0$, this implies that fermions will not have gravitational radiation energy in perfect vacuum, and we will prove the essence of the gravitational radiation energy is thermal energy in section 4.4. So in this case equation (3.1.2) has changed into:

$$\Delta m \cdot c^2 + E_{Radiation}^{Electromagnetic} = \Delta E_{Potential}^{Electromagnetic} \text{ ------ (3.1.3)}$$

$\Delta m \cdot c^2$ is the kinetic energy of fermions in special relativity.

$$h(u)c(u) = h \cdot c \text{ ------ (3.2)}$$

This is based on the assumption that the fine structure constant is a true constant invariant in a gravitational field.

$$\frac{m(u)c^2(u)}{h(u)} = \frac{m \cdot c^2}{h} \text{ ------ (3.3)}$$

This is based on the assumption that the frequency of a photon defined by a universal clock sitting in the perfect vacuum is invariant during its propagation in a gravitational field.

Combine (3.2) and (3.3) to get

$m(u) = m \cdot c^3 / c^3(u)$ ------ (3.4)

Put (3.4) into (3.1) to get

$$\frac{1}{c(u)} + \int_0^u \frac{du}{c^3(u)} = \frac{1}{c} \text{ ------ (3.5)}$$

Differentiate both sides of equation (3.5) to get

$$\frac{-dc(u)}{c^2(u)du} + \frac{1}{c^3(u)} = 0 \text{ ------ (3.6)}$$

Derive from (3.6)

$c(u)dc(u) = du$ ------ (3.7)

Integrate both sides of equation (3.7) to get

$c^2(u)/2 = u + K$ ------ (3.8)

where K is a constant to be defined.

Since $c(0) = c$ ------ (3.9)

Combine (3.9) and (3.8) to get

$K = c^2/2$ ------ (3.10)

Substitute (3.10) into (3.8) to derive a function for variable speed of light in vacuum:

$c(u) = (1 + 2u/c^2)^{1/2} c$ ------ (3.11)

Substitute (3.11) into (3.2) to derive a function for variable Planck constant:

$h(u) = (1 + 2u/c^2)^{-1/2} h$ ------ (3.12)

Since $\mu_0 \varepsilon_0 = 1/c^2$ and $\mu_0(u) \cdot \varepsilon_0 = 1/c^2(u)$

where μ_0 the permeability of perfect vacuum and ε_0 is the permittivity of vacuum.

Combine this with (3.11) to derive a function for variable permeability of vacuum:

$\mu_0(u) = \left(1 + 2u/c^2\right)^{-1} \mu_0$ ------ (3.13)

The rest energy of a particle should be invariant in a gravitational field due to the conservation of energy. $E_0 = m_0(u)c^2(u) \equiv m_0 \cdot c^2$ ------ (3.14) where m_0 is the rest mass of a particle in perfect vacuum. Put (3.11) into (3.14) to derive a function for variable rest mass of a particle:

$m_0(u) = (1+2u/c^2)^{-1} m_0$ ------ (3.15)

Also based on the conservation of energy, the energy measuring unit such as Planck energy should be invariant in a gravitational field.

$E_P = [\hbar(u)c^5(u)/G(u)]^{1/2} \equiv (\hbar \cdot c^5/G)^{1/2}$ ------ (3.16)

where G is the gravitational constant in a perfect vacuum and $\hbar = h/2\pi$ is the reduced Planck constant in a perfect vacuum. Substitute (3.11) and (3.12) into (3.16) to derive a function for variable gravitational constant:

$G(u) = (1+2u/c^2)^2 G$ ------ (3.17)

Functions (3.11), (3.12), (3.13), (3.15), and (3.17) are five basic functions of the gravitational potential, and we will refer to these functions that describe variable constants as FGP from here after.

4. Investigating the Physical Significance of FGP

4.1. FGP as a Unified Microscopic Explanation to Time Dilations

Planck units are defined in terms of five fundamental physical constants; they are the speed of light in vacuum, reduced Planck constant, gravitational constant, Coulomb constant, and Boltzmann constant. Even though three out of five fundamental constants have turned into functions of the gravitational potential, Planck length, Planck charge and Planck temperature -- three out of five base Planck units -- remain invariant in a gravitational field. Only Planck time and Planck mass turn into functions of the gravitational potential:

$t_P(u) = (1+2u/c^2)^{-1/2} t_P$ ------ (4.18) where t_P is Planck time in perfect vacuum.

$m_P(u) = (1+2u/c^2)^{-1} m_P$ ------ (4.19) where m_P is Planck mass in perfect vacuum.

Function (4.18) and (3.11) indicate that time slowdown in the gravitational field exactly matches the slowdown of light in vacuum. FGP can deduce that all kinds of clocks should slow down to the same pace at the same background gravitational potential, no matter if they are atomic clocks or just simple pendulums, or even the mean lifetime of a decay particle. Hence if we locally measure the speed of light in vacuum using locally defined Planck units or SI units in a local reference frame, which has a close to a constant background gravitational potential, then we cannot actually detect any changes. Function (3.15) and (4.19) indicate that the gravitational coupling constant is a dimensionless true constant similar to the fine structure constant, so the principle of general covariance is confirmed to be valid at the macroscopic scale.

An inertial reference frame travels with a constant speed V in a perfect vacuum; the time measuring unit will be affected by the speed according to special relativity:

$$t(V) = (1 - V^2 / c^2)^{-1/2} t \text{ ------ (4.20)}$$

where t is any time measuring unit in perfect vacuum. Comparing (4.20) to (4.18), we can deduce a relationship between a constant speed V and a constant gravitational potential U as following: $V^2 = -2U$ ------ (4.21). This formula implies that these two reference frames are equivalent. Therefore, FGP can provide a unified microscopic explanation to special relativity time dilation and gravitational time dilation or gravitational redshift. So let's reconsider the thought experiment in a reference frame with a constant background gravitational potential U. In this scenario the equation (3.1) will be as below:

$$m(u+U)c^2(u+U) + \int_0^u m(u+U)du = m(U)c^2(U) \text{ ------ (4.22)}$$

Based on (3.4) and (3.11), equation (4.22) can be rewritten as below:

$$m(u+U)c^2(u+U) + \int_0^u m(u+U)du = m \cdot c^2 (1 + 2U / c^2)^{-1/2} \text{ ------ (4.23)}$$

Use the total gravitational potential $\bar{u} = u + U$ ------ (4.24) to do a substitution in (4.23)

$$m(\bar{u})c^2(\bar{u}) + \int_U^{\bar{u}} m(\bar{u})d\bar{u} = m \cdot c^2 (1 + 2U / c^2)^{-1/2} \text{ ------ (4.25)}$$

While the other two equations (3.2) and (3.3) can be rewritten as below:

$$h(\bar{u})c(\bar{u}) = h \cdot c \text{ ------ (4.26)}$$

$$\frac{m(\bar{u})c^2(\bar{u})}{h(\bar{u})} = \frac{m \cdot c^2}{h} \text{ ------ (4.27)}$$

Combine (4.26) and (4.27) to get

$$m(\bar{u}) = m \cdot c^3 / c^3(\bar{u}) \text{ ------ (4.28)}$$

Put (4.28) into (4.25) to get

$$\frac{1}{c(\bar{u})} + \int_U^{\bar{u}} \frac{d\bar{u}}{c^3(\bar{u})} = \frac{1}{(1 + 2U / c^2)^{1/2} c} \text{ ------ (4.29)}$$

Differentiate on both sides of equation (4.29) to get

$$\frac{-dc(\bar{u})}{c^2(\bar{u})d\bar{u}}+\frac{1}{c^3(\bar{u})}=0 \text{ ------ (4.30)}$$

Derive from (4.30)

$$c(\bar{u})dc(\bar{u})=d\bar{u} \text{ ------ (4.31)}$$

Integrate on both sides of equation (4.31) to get

$$c^2(\bar{u})/2=\bar{u}+K \text{ ------ (4.32)}$$

where K is a constant to be defined.

Since $c(0)=c$ ------ (4.33)

Combine (4.32) and (4.33) to get

$$K=c^2/2 \text{ ------ (4.34)}$$

Substitute (4.34) into (4.32) to derive a function for the variable speed of light in vacuum:

$$c(\bar{u})=(1+2\bar{u}/c^2)^{1/2}c \text{ ------ (4.35)}$$

Substitute (4.35) into (4.26) to derive a function for the variable Planck constant:

$$h(\bar{u})=(1+2\bar{u}/c^2)^{-1/2}h \text{ ------ (4.36)}$$

Comparing (4.35) to (3.11) and (4.36) to (3.12), we conclude that all functions will take the same forms for the total gravitational potential $\bar{u}$ as for the local gravitational potential u, so for convenience, from now on when we talk about the gravitational potential u, it will be the total gravitational potential by default. Let's consider another scenario, which is a gravitational field traveling with a constant speed V in a perfect vacuum. Based on formula (4.21), a constant speed in perfect vacuum is equivalent to a constant background gravitational potential, so the total background gravitational potential considering both scenario will be: $\overline{U}=U-V^2/2$ ------ (4.37)

4.2. The FGP Factor as an Explanation to muon g-Factor Deviation

The Bohr magneton is defined in SI units by $\mu_B=e\cdot\hbar/2m_e$ where e is the elementary charge, $\hbar$ is the reduced Planck constant, m_e is the rest mass of an electron. According to function (3.12) and (3.15) $\mu_B(u)=\left(1+2u/c^2\right)^{1/2}\mu_B$, the Bohr magneton as a measuring unit of the magnetic momentum becomes smaller in a gravitational field. So the muon g-factor experimental [3] value should be equal to the standard model theoretical value, which has not accounted for the effect of the gravitational field multiplied by a FGP factor $(1+2u/c^2)^{-1/2}$. After investigating the results from experiments measuring the g-factor of a muon, it was concluded that the FGP factor has a value of approximately 1.000000003, which will yield the total gravitational potential on the ground of the earth:

$\overline{U}_E = -2.7\times10^{8}(m/s)^2$ ------ (4.38)

Put the average ground gravitational potential associated with the rest mass of the earth $U_E = -6.24\times10^{7}(m/s)^2$ into formula (4.37) to get a constant speed: $V_E = 20376\ m/s$ which will be interpreted as the speed of a flux associated with the cosmic gravitational field in paragraph 5. If the gravitational potential describes some kind of flux in the vacuum, then V in formula (4.21) is the speed of the flux.

A fermion with half-integer spin has an intrinsic magnetic field with magnetic flux, and has a rest mass with an intrinsic gravitational field with some kind of flux as well. So we deduce that the magnetic flux not only describes the intrinsic magnetic field in one aspect but also describes the gravitational field in another aspect. The magnetic flux is neutrino flux with a speed defined by the gravitational potential. Fermions and anti-fermions have rest mass equivalent to active gravitational mass, while photons and gauge bosons, neutrinos and Higgs bosons only have inertial mass equivalent to passive gravitational mass. Even though some neutrinos or bosons may have rest mass, but only fermions can have active gravitational rest mass to produce gravitational potential. The gravitational force between fermions and anti-fermions is repulsive force, so their rest mass cancels each other after they annihilate into a pair of photons without rest mass. Anti-fermions will attract each other, just the same way as fermions will attract each other, while photons and Higgs bosons will be attracted by both fermions and anti-fermions. If the ALPHA experiment in CERN [12] can confirm the gravitational repulsive force between matter and anti-matter, then it will set the last nail on the coffin of the old dogmas, and set the cornerstone for the new theory of gravitation. When talking about gravitational mass, matter and anti-matter have opposite sign, just like the electric charge; you can define the electron as positive and positron as negative if you prefer that way. But when talking about inertial mass, then both matter and anti-matter have positive sign, because the momentum has the same definition for both matter and anti-matter.

4.3. The Electroweak Coupling Constant as a Function of the Gravitational Potential

Experiments have proven that the mean lifetime of a beta decay particle travelling at high speeds will become longer to match the slowdown of time, which is predicted by the special relativity. Formula (4.21) implies this should also happen when the time is slowed down in a gravitational field, since the mean lifetime of a muon decay τ_μ relates to the Fermi constant G_F in following formula: $192\pi^3\hbar/(Q_0^5\cdot\tau_\mu) = G_F^2/(\hbar\cdot c)^6$ ------ (4.39) [20, 21] where $Q_0 \approx m_\mu\cdot c^2$, m_μ is the rest mass of a muon. Based on functions (3.11), (3.12), (3.15) and (3.18) we can conclude that the

Fermi constant should be invariant in a gravitational field. The relation between G_F and α_W the coupling constant of the electroweak interaction is described by this formula:

$G_F/(\hbar \cdot c)^3 = \sqrt{2}\alpha_W{}^2/8m_W^2$ ------ (4.40) [20, 21] where m_W is the rest mass of a W boson. According to function (3.11), (3.12), (3.15), (4.39) and (4.40), we can derive the dimensionless coupling constant of the electroweak interaction as a function of the gravitational potential:

$\alpha_W(u) = (1+2u/c^2)^{-1}\alpha_W$ ------ (4.41)

Based on the electroweak coupling constant $\alpha_W \approx 10^{-7}$ and the electromagnetic coupling constant $\alpha \approx 1/137$, function (41) gives $u \approx (1.37\times10^{-5}-1)c^2/2$ when $\alpha_W(u) = \alpha$. According to the electroweak theory the electromagnetic force and weak force will merge into a single electroweak force when the temperature is high enough, so function (4.41) not only declares the principle of general covariance breaking down in microscopic scale, but also implies that a gravitational field should have temperature. Because a gravitational potential is related to the speed of a neutrino flux by formula (4.21), neutrino flux can carry thermal energy. So the energy change of a photon with a specific frequency in a gravitational field can represent the mean kinetic energy of the neutrinos which have a temperature of T, which can be described as below:

$[h(u)-h]f = k_B T$ ------ (4.42) where k_B is Boltzmann constant, f is the specific frequency of a photon. Since the cosmic microwave background has a thermal black-body spectrum at the temperature of $T = 2.72548K$ ------ (4.43), if we consider this as the temperature of the gravitational field on the earth, then we can put the FGP factor $(1+2u/c^2)^{-1/2} = 1.000000003$ calculated from the g-factor experiments, (4.36) and (4.43) into (4.42) to get the specific frequency: $f = 9.085\times10^8 k_B/h$, which corresponds to a photon of $78KeV$ in a perfect vacuum. Put f back into (42) to derive the temperature of a gravitational field:

$T = [(1+2u/c^2)^{-1/2}-1]9.085\times10^8 K$ ------ (4.44)

This yields a temperature of $T_U \approx 2.445\times10^{11}K$ when $\alpha_W(u) = \alpha$. Since the strong interaction coupling constant $\alpha_S \approx 1$, function (4.41) gives $u \approx (10^{-7}-1)c^2/2$, when $\alpha_W(u) = \alpha_S$. There for, the temperature of the gravitational field will reach about $2.872\times10^{12}K$ according to function (4.44). Function (4.41) defines an upper limit for the temperature and a lower limit for the gravitational potential, because the electroweak coupling constant should not be greater than one, otherwise the electroweak force will be stronger than the nuclear force. Formula (4.40) along with radiative corrections set an upper limit of rest mass for any gauge boson including photons and Higgs bosons at $125GeV$, and set a lower limit at $\alpha_W^2\times125GeV$ as well; the physical significance of the lower limit will be discussed in section 7. If Higgs bosons can carry a major portion of the vacuum zero-point energy, the vacuum catastrophe will disappear. The inertial mass density of bosons in space will be so high that it is comparable to Planck density, so we have to redefine the vacuum as a space with zero active gravitational rest mass density, and define the perfect vacuum as a pure Higgs field. Hence, fermions with active gravitational rest mass are similar to vortexes in the sea of Higgs bosons; the vacuum is similar to a sea without vortexes, while neutrinos are similar to fluxes, and photons are similar to waves. The perfect vacuum is similar to the quietest sea of Higgs bosons without vortexes, without fluxes, and even without waves. Because any black-body cavity with a hole can only be constructed by condensed matter, all black-body radiation experiments can only prove that Planck's law can be applied to condensed matter with a fixed emissivity. Since the sea of Higgs bosons is super fluid condensed matter, if a fermion is like a bubble in the center of a vortex in the sea of Higgs bosons, then the size of the bubble can be defined as the size of the fermion, and the vortex with neutrino flux can be defined as the gravitational field and the intrinsic magnetic field associated with the fermion, so it is possible for a fermion with gravitational rest mass to emit black-body radiations.

4.4. The Mechanism of Gravitational Waves is Black-Body Radiation

Function (4.42) indicates that the temperature of a gravitational field is proportional to variable Planck constant; the kinetic energy of a particle is stored in the intrinsic magnetic field associated with its spin defined by Planck constant. The fluctuation of the intrinsic magnetic fields will produce black-body radiations associated with the temperature fluctuation in the gravitational field; it will reduce the kinetic energy of a particle traveling in the gravitational field according to equation (3.1.2). Because the rest energy of a particle is stored in its intrinsic magnetic field as well, it is possible for a particle to lose its rest energy by the gravitational black-body radiation when the temperature is high enough. The essence of gravitational waves as black-body radiations seems to be consistent with the proposal of gravity as an entropic force [4] and gravitomagnetism [7].

The black-body radiation energy density: $E_d = 8\pi^5 k_B^4 T^4 / 15h^3c^3 = aT^4$ ------ (4.45) where a is the radiation density constant equal to $7.5657\times10^{-16} J/m^3K^4$, is a true constant invariant in a gravitational field. Put (4.44) into (4.45) to get the gravitational black-body radiation energy density:

$$E_d = [(1+2u/c^2)^{-1/2} - 1]^4 5.154\times10^{20} J/m^3 \text{ ------ (4.46)}$$

The gravitational black-body radiation energy plays a very important role to counterbalance the gravitational attraction. If the temperature reaches the upper limit of $T_H \approx 2.872\times10^{12} K$, then the gravitational radiation energy density reaches the maximum of $5.15\times10^{34} J/m^3$, which is 10^{16} times higher than the nuclear fission energy density of uranium; only annihilation can produce such high energy density. It can be concluded that the particle and anti-particle annihilation must be the energy source to power the gravitational black-body radiation near the black hole event horizon. Since Planck's law has turned into a function of the gravitational potential, the wavelengths of thermal radiations near the upper limit of temperature will be significantly shorter, so they will look like X-ray bursts or gamma ray bursts.

The vacuum fluctuation near the event horizon can be very large due to the Planck constant increasing sharply as it approaches the event horizon; there are a lot of virtual particle-antiparticle pairs that pop up from the vacuum and then cancel each other near the event horizon. Because the gravitational force works oppositely on particles and anti-particles, they are separated before they can cancel each other. The virtual anti-particle must either annihilate with a real particle or escape, so the black hole has to lose mass to ensure the conservation of energy. Because of the conservation of charge, only the virtual anti-particles without charges can be turned into real anti-particles. There for, only anti-neutrinos and anti-neutrons can be ejected from a black hole. Even though the conservation of baryon number appears to be broken, the number of anti-neutron being produced by a black hole should equal the number of neutron inside a black hole being converted into energy, so the process looks like a phase transition from neutron to anti-neutron. There for, if simultaneously a phase transition from anti-neutron to neutron can happen somewhere else in the universe, then the conservation of baryon number can be saved, and it can be the origin of cosmic rays when we establish our cosmological model. The phase transition from neutrino to anti-neutrino or from neutron to anti-neutron near the event horizon is similar to the so-called black hole evaporation [5], but it is much more intense because of the gravitational repulsive force towards the anti-particles and because the Planck constant and the temperature increase sharply according to function (4.36) and (4.44). Stellar objects that come near the event horizon will cause intense vacuum fluctuations that produce large amount of anti-neutrons, which will then annihilate and turn everything into thermal energy. Even though the black hole will lose mass due to the conservation of energy, the momentum and angular momentum of the falling particles are transferred to the black hole due to the conservation of momentum and angular momentum. Function (4.46) implies that the gravitational black-body radiations are extremely intense near the event horizon, so it is impossible to form such a black hole that sucks everything inside; the critical gravitational potential $u_c = -c^2/2$ to form a black hole cannot be reached. FGP have limits set by a lower limit gravitational potential at $u_L \approx (10^{-7} - 1)c^2/2$ when $\alpha_W(u) = \alpha_S$ according to function (4.41), otherwise photons will stop moving according to function (4.35), the Planck constant will become infinitely large according to function (4.36) and the temperature will become infinitely high according to function (4.44). Hence, the black holes that we known of should be truly called quasi-black holes. Quasi-black holes can be used to define the macro rest mass quanta formed by gravitation, so they provide important clues to establish a new cosmological model.

5. Deducing a Cosmological Model from FGP

5.1. The Cosmic Background Gravitational Potential and the Revised Hubble's Law

FGP is based on a universal flat space-time perfect vacuum reference frame, so I assume this should be the initial state of the universe, with an equal amount of hydrogen atoms and anti-hydrogen atoms along with photons and Higgs bosons spread evenly in the space, with an active gravitational rest mass density close to zero and a temperature close to absolute zero as well. After a long period of time, because the atoms and anti-atoms were subjected to the two types of gravitational forces, eventually hydrogen atoms separated from anti-hydrogen atoms and individually formed a huge sphere of hydrogen atoms and a huge sphere of anti-hydrogen atoms. These two spheres eventually sit still in a perfect vacuum far away from each other because the gravitational repulsive force is offset by their common gravitational attractive force towards the photons and Higgs bosons.

We have to use a function to describe the gravitational potential inside a sphere: $u(r) = -4\pi \times G \cdot \rho \cdot r^2 / 3$ ------ (5.47) where r is the distance from the center of mass, ρ is the average density of active gravitational rest mass within the sphere with a radius of r. Only the rest mass of fermions inside a sphere has contribution to the gravitational potential on the surface of the sphere, because the neutrino flux associated with the gravitational potential on the surface is an extension of the intrinsic magnetic fields associated with the rest mass of the fermions inside the sphere. So it is important to define the maximum size of a gravitational field by comparing its gravitational field strength with the nearby gravitational field strength. For example the earth has a maximum sphere radius of about $2.6 \times 10^8 m$ where the gravitational strength is about $0.006 N / kg$, equal to the sun's gravitational field strength. The moon is located outside the maximum sphere of the earth, so its maximum sphere radius is about $2.9 \times 10^7 m$ where the gravitational field strength is also equal to the sun's gravitational field strength. While the sun has a much bigger maximum sphere because the closest star to it known today is four light years away. We can use the mass of the earth or the moon to calculate the gravitation potential of the earth or the moon up to the maximum sphere only; outside the sphere we have to use the mass of the sun to calculate the gravitational potential of the sun. The gravitational potential has points of discontinuity on the maximum sphere, so the temperature and the radiation energy density of the gravitational field have points of discontinuity on the maximum sphere as well according to function (4.44) or (4.46). Even the speed of light in vacuum has points of discontinuity on the maximum sphere, and this will increase the gravitational lensing effect and lead to overestimation on the mass of stars. It is important to identify the boundary of a gravitational field for calculating or measuring the speed of light in vacuum. Theoretically only the perfect vacuum reference frame is an inertial reference frame, which is suitable for quantum theory and special relativity. But in practice, based on formula (4.21), we can apply those theories in a local reference frame with a very close to constant background gravitational potential, such as the ground of the earth reference frame. The boundary of a moving or spinning gravitational field will be squeezed and dragged along the moving direction, and will be flattened along the spinning axis to form the accretion disc. The alleged flyby anomaly could be related to the discontinuity of gravitational potential on the dynamic deforming boundary of the spinning gravitational field of the earth.

If we use function (5.47) to describe a cosmic sphere, then we can take the square root of both sides of this function to derive the revised Hubble's law: $v(r) = H_0 \cdot r$ ------ (5.48), since we consider the speed $v(r)$ as the speed of the neutrino flux associated with the cosmic gravitational field, so according to formula (4.21) we can combine (5.47) and (5.48) to get the density of the cosmic sphere: $\rho_c = 3H_0^2 / 8\pi \times G$ ------ (5.49), and use the Hubble constant $H_0 = 67.8(km/s)/Mpc$ to calculate the value of $\rho_c = 8.616 \times 10^{-27} kg/m^3$. This is exactly the critical density predicted by general relativity to form a stable universe. Put the critical gravitational potential $u_c = -c^2/2$ and the critical density ρ_c into function (5.47) to get the radius of the cosmic sphere: $R_C = c/H_0 \approx 1.367 \times 10^{26} m$ ------ (5.50) and this also is the radius of the so-called Hubble sphere; it is about 14.45 billion light years. If this was a cosmic black hole event horizon, then anything, including light, would be trapped inside. However, FGP has a lower limit gravitational potential $u_L \approx (10^{-7} - 1)c^2/2$, which means that the cosmic sphere cannot be a true black hole and it should still have interaction or particle exchange with the faraway anti-cosmic sphere. The Hubble constant and the cosmic density should have been much smaller in the past and eventually settled down to the current value after the cosmic sphere and the anti-cosmic sphere achieved a dynamic balance. A consequence of this scenario is that the heat death of an open universe will never happen, and there is no reason to break the dynamic balance to create the so-called Big Bang or Big Crunch scenario.

5.2. The Temperature is Proportional to the Gravitational Redshift

Function (5.47) along with the critical density in formula (5.49) suggests that a quasar will have a cosmic background gravitational potential of $-0.25c^2$ if it is $9.668 \times 10^{25} m$ away from the center of the cosmic sphere, which is about ten billion light years. The microwave background or the gravitational field temperature in that location is extremely high at $3.76 \times 10^8 K$ according to function (4.44); this could be an explanation for wide range ionization, which is currently unexplainable. Also, because the background gravitational potential is comparable to the critical gravitational potential, a quasi-black hole formed in this quasar takes only half amount the rest mass as one in the Milky Way galaxy. This quasar can easily output huge amounts of energy, because the gravitational black-body radiation energy density of the cosmic background gravitational potential itself reaches $1.52 \times 10^{19} J/m^3$ according to function (4.46), which is already ten times higher than the nuclear fission energy density of uranium. Lights from this quasar should have a gravitational redshift of $Z \geq 0.414$, because considering the cosmic background gravitational potential alone already yields a local Planck constant 1.414 times bigger than the one in a perfect vacuum according to function (4.36). A cosmic background gravitational redshift yields a distance significantly different from the distance given by considering the redshift as a Doppler shift. The redshift comes from a cosmic background gravitational potential: $Z = (1+2u/c^2)^{-1/2} - 1$; only the redshift of spectrums from interstellar plasma clouds, which is the smallest redshift from the same galaxy, is reliable for the estimation of distance. According to function (4.44), the temperature is proportional to the redshift: $T = Z \times 9.085 \times 10^8 K$, so a bigger redshift most likely implies higher temperature, but not necessarily relates to a larger distance. The temperature of the cosmic microwave background with the biggest redshift observed so far at $Z_{CMB} = 1089$ is $T_{CMB} = 9.89 \times 10^{11} K$, which is located near the edge of the cosmic sphere.

5.3. The Formation of Galaxies

Since a spiral galaxy is composed by billions of stars similar to the sun, and we assume they all evolved from a huge hydrogen gas ball, we use the solar mass $2 \times 10^{30} kg$ and the distant to the most faraway dwarf planet Eris (about $1.5 \times 10^{11} m$) as the radius of a hydrogen gas ball to estimate a density of $\rho_g = 1.4 \times 10^{-4} kg/m^3$. Substitute this into function (5.47) to get the radius to form a quasi-black hole of hydrogen gas $r_g = 1.07 \times 10^{15} m$ which will give a mass of $7.23 \times 10^{41} kg$; this is an estimated mass for a spiral galaxy. Since the mass of the cosmic sphere given by the critical density is about $9.22 \times 10^{52} kg$, the total number of spiral galaxy is about one hundred thirty billion. Because only about 60% of the galaxies are spiral galaxies, and other types of galaxies are generally smaller, the total number of galaxy may be over two hundred billion. Therefore, the average mass of a spiral galaxy should be $4.34 \times 10^{41} kg$ which is 40% less than the original estimation, and is about two hundred billion solar masses.

This huge hydrogen gas ball will shrink by gravitational attraction; the temperature and density keep rising in the core, and nuclear fusions start to form other abundant light elements. The galaxy at this stage is a giant quasi-star which is a huge hydrogen plasma ball shrinking without spinning. Because the core of a quasi-star is like a giant sun, I use the average density of the sun $\rho_S = 1408 kg/m^3$ to estimate the size of a super massive quasi-black hole with a radius $r_S = 3.38 \times 10^{11} m$ which will give a mass of $2.28 \times 10^{38} kg$, which is about 1.14×10^8 solar masses. It can be even bigger if its average density is smaller; the biggest one so far has about twenty one billion solar masses. Once the super massive quasi-black hole is formed in the center of a giant quasi-star, everything falling inside is turned into heat, so its angular momentum grows larger as the particles annihilate and their spin momentums transfer to the quasi-black hole. The spinning speed of the giant quasi-star will increase as the angular momentum being transferred from the super massive quasi-black hole. The high speed spinning will flatten the hydrogen plasma cloud into a big accretion disc; about 40% of the original estimated mass of a spiral galaxy has spun off to form the globular cluster or dwarf galaxies, and the spiral structure has formed at this stage. Because of the heat from the super massive quasi-black hole, the hydrogen plasma in the accretion disc starts the nuclear fusions to form other abundant light elements and shrinks locally by gravitation to form stars inside a spiral galaxy.

5.4. The Origins of Cosmic Rays

The plasma falling into a quasi-black hole is turned into thermal energy which gets carried away by high energy anti-neutrons and anti-neutrinos. All anti-neutrinos will escape easily, while most of the anti-neutrons lose their kinetic energy by knocking particles out of the surrounding plasma cloud, then annihilate to release intense gravitational heat radiation according to function (4.46). But a tiny fraction of anti-neutrons will not collide and will instead join with the particles being knocked out to form the so-called cosmic rays. The anti-cosmic sphere should be the final destination of those anti-particles in the cosmic rays, while most of the particles in the cosmic rays are from the anti-cosmic sphere event horizon. This not only can explain the origins of the cosmic rays, but also explains why the energy of the anti-protons and positrons from decayed anti-neutrons in the cosmic rays are significantly higher than the energy of the protons and electrons, and explains why they come so evenly from every direction. The particle exchange with the anti-cosmic sphere by cosmic rays is critical in achieving the dynamic balance of the universe. Because the quasi-black holes are converting huge amount of neutrons into energy and anti-neutrons at all times, the particle exchange with the anti-cosmic sphere is critical for saving the conservation of baryon number which seems to have been broken by the neutron phase transitions near the event horizon of quasi-black holes. Most of the protons and electrons in the cosmic rays are from the event horizon of the anti-cosmic sphere; they have been accelerated by the gravitational fields between the cosmic sphere and the anti-cosmic sphere to an average energy of $1GeV$. Hence, the estimated distance between these two cosmic centers should be larger than four times the radius of the cosmic sphere.

5.5. Neutron Stars and their Relationship with Stars and Planets

According to function (4.41) the electroweak coupling constant increases as the mass of a star increases, so the nuclear fusions to form heavy atomic nucleus will keep going as long as there is enough plasma to feed into it, until it turns into a quasi-black hole of neutron. Substituting the average nuclear density $\rho_n = 2.3\times10^{17} kg/m^3$ into function (5.47) will get the radius to form a quasi-black hole of neutron $r_N = 26463m$ and the required mass $m_N = 1.78\times10^{31} kg$, which is about nine solar masses. A star with more than nine solar masses will most likely end up as a supernova. Usually the explosion will be triggered by the collision of a fast moving outer shell with the lagging quasi-black hole inside it; the asymmetric explosion ejects its remains out of the supernova center to become a pulsar. In the case of a supernova is triggered by the collapse of a heavy outer shell, its remains stays in the center after a symmetric explosion due to large amount of matter being annihilated from every direction, which becomes a magnetar or a pulsar. If the outer shell is extremely heavy, then the quasi-black hole has to lose most of its mass in order to power a so-called hypernova explosion, and its remains will disappear after intense radioactive decays as a gamma ray burst. In the center of a super massive quasi-black hole, a hypernova explosion as a power source to withstand the gravitation attraction will happen from time to time. Older super massive quasi-black holes should have less mass and higher density than younger ones. The radioactive decays eventually will bring down the mass of a magnetar, it will turn into a pulsar, and then it will split into several small neutron stars, because the heavy nucleus is not stable without a strong gravitational field. The decayed small neutron star attracts and spins the surrounding hydrogen gas and supernova debris or smaller neutron stars into an accretion disc, and nuclear fusion starts again in the center with the highest temperature and density. Finally it becomes a newborn star with or without planets.

5.6. The Estimations Based on Zero Cosmic Background Gravitational Potential

The magnetic field of a star or a planet comes from a decayed small neutron star buried in its center, so let's study the magnetic field of a neutron star. Since $M = \chi_v \cdot H$ ------ (5.51) where M is the magnetic dipole moment per unit volume, H is the magnetic field strength, χ_v is the volume magnetic susceptibility of a neutron star, and the neutron star magnetic permeability $\mu = \mu_0(1+\chi_v)$, by comparing this to function (3.13) we notice that the vacuum in a gravitational field has a volume magnetic susceptibility $\chi(u) = (1+2u/c^2)^{-1} - 1$ ------ (5.52). It is very large near the event horizon, so it can be assumed that χ_v is very large as well, and this also implies that the magnetic dipole moment of most neutrons in a neutron star will take the same direction as that of the neutrino flux associated with the gravitational field. All of the neutrons will take the same spin direction, since the susceptibility becomes infinitely large when a neutron star becomes a quasi-black hole, so let's assume that the square of the mass ratio between a neutron star and a quasi-black hole is equal to the ratio of the neutrons taking the same spin direction, hence $M = (\rho_n / m_n) M_n [m_N(u)/m_N]^2$ ------ (5.53) where $\rho_n = 2.3\times10^{17} kg/m^3$ is the density of a neutron star, $m_n = 1.675\times10^{-27} kg$ is the mass of a neutron, $M_n = 9.66\times10^{-27} J/T$ is the magnetic dipole moment of a neutron, $m_N(u)$ is the rest mass of a neutron star with a surface gravitational potential of u, m_N is the rest mass of a quasi-black hole of neutron. According to function (5.47) we get $[m_N(u)/m_N]^2 = (-2u/c^2)^3$ ------ (5.54), put this into (5.53) and combine with (5.51) and (5.52) to get the magnetic field strength on the surface of a neutron star as below:

$H = 1.326\times10^{18}(-2u/c^2)^3/\chi_v \ A/m$ ------ (5.55)

Since $B = \mu_0(1+\chi_v)H$, where B is the magnetic flux density on the surface of a neutron star, and $\mu_0 = 4\pi\times10^{-7} T\cdot m/A$ is the perfect vacuum permeability, and $\chi_v \approx 1+\chi_v$ we can derive

$B \approx 1.666\times10^{12}(-2u/c^2)^3 \ T$ ------ (5.56)

The magnetic flux density reaches a maximum about $1.666\times10^{12}T$ on the surface of a quasi-black hole of neutron, and it has a minimum angular momentum of $5.6\times10^{23}J\cdot s$ from the spin of aligned neutrons.

Let us consider a neutron star as a solid sphere with even density to get the moment of inertia: $I_N = 2m_N(u)r_N^2(u)/5 = 8\pi\times\rho_n r_N^5(u)/15$ ------ (5.57) where $r_N(u)$ is the radius of a neutron star with a surface gravitational potential of u. From function (4.47) we get

$r_N(u) = (-3u/4\pi\times G\rho_n)^{1/2}$ ------ (5.58), and based on function (3.11) to get the theoretical maximum angular speed of a neutron star as below:

$$\omega_{\max} = c(u)/r_N(u) = 2c[\pi\times G\rho_n(1+2u/c^2)/(-3u)]^{1/2} = 2.4\times10^{12}(1+2u/c^2)^{1/2}/(-u)^{1/2}rad/s \quad (5.59)$$

Then derive the theoretical maximum angular momentum of a neutron star as below:

$$L_{\max} = I_N\omega_{\max} = (-3u)^2(1+2u/c^2)^{1/2}c/30\pi\times G^2\rho_n = 2.8\times10^{10}(-u)^2(1+2u/c^2)^{1/2}J\cdot s \text{ ------ } (5.60)$$

Put limit gravitational potential $u_L \approx (10^{-7}-1)c^2/2$ into function (5.59) and (5.60) to get the maximum angular momentum of a quasi-black hole of neutron as $1.79\times10^{40}J\cdot s$ with a spin frequency of $0.5698Hz$. A neutron star most likely will retain this angular momentum after a supernova explosion, so it is possible to estimate the actual upper limit of its spin frequency.

Let us estimate how long a $1.666\times10^{11}T$ magnetar will take to decay into a $1.666\times10^{8}T$ pulsar by the gravitational black-body radiation. According to functions (5.56) and (4.44) the magnetar has a temperature $T_m = 3.326\times10^8K$ and the pulsar has a temperature $T_p = 2.185\times10^7K$. According to functions (5.47), (5.56), (5.57) and (5.60) this magnetar may spin up to $3.88Hz$, has a radius of $r_m = 18029m$ and a mass of $m_m = 5.646\times10^{30}kg$; this pulsar may spin up to $1228Hz$, has a radius of $r_p = 5701m$ and a mass of $m_p = 1.785\times10^{29}kg$. According to Stefan-Boltzmann law, the black-body radiation power is $P = A\sigma T^4$, where the surface area of a black-body is A, and T is its temperature, and based on functions (3.11) and (3.12) the Stefan-Boltzmann constant σ is a function of the gravitational potential:

$$\sigma(u) = (1+2u/c^2)^{1/2}2\pi^5k_B^4/15h^3c^2 = (1+2u/c^2)^{1/2}5.67\times10^{-8}\ J/m^2sK^4 \text{ ------ } (5.61)$$

So the net radiation power is:

$$P_{net} = A_m\sigma_mT_m^4 - A_p\sigma_pT_p^4 = 7.125\times10^{-7}[r_m^2(1+2u_m/c^2)^{1/2}T_m^4 - r_p^2(1+2u_p/c^2)^{1/2}T_p^4]\ J/s \text{ ---- } (5.62)$$

where u_m is the gravitational potential on the surface of the magnetar and u_p is the one of the pulsar. From function (5.56) we get $2u_m/c^2 = \sqrt[3]{0.1}$ and $2u_p/c^2 = \sqrt[3]{0.0001}$; substitute the actual values into (5.62) to get $P_{net} = 2.075\times10^{36} J/s$ and determine

$t_{decay} = (m_m - m_p)c^2 / p_{net} = 2.372\times10^{11} s$ ------ (5.63)

Thus a magnetar with three solar masses takes about seven thousand five hundred years to decay into a pulsar with one tenth of a solar mass.

Now let us replace the magnetar with a quasi-black hole of neutron; this will be a scenario for an extremely intense hypernova explosion. Since we already know $r_N = 26463m$ and $m_N = 1.78\times10^{31} kg$, the highest temperature of a quasi-black hole at the limit gravitational potential is $T_H \approx 2.872\times10^{12} K$ at $u_L \approx (10^{-7} - 1)c^2/2$, so we can substitute the data of the magnetar with the data of a quasi-black hole of neutron in function (5.62) to get:

$$P_{net} = 7.125\times10^{-7}[r_N^2(1+2u_L/c^2)^{1/2}T_H^4 - r_p^2(1+2u_p/c^2)^{1/2}T_p^4]\ J/s = 1.074\times10^{49} J/s \text{ ------ (5.64)}$$

The time for the extremely intense hypernova explosion will be:

$t_{hyper} = (m_N - m_p)c^2 / p_{net} = 0.148s$ ------ (5.65)

A powerful hypernova can consume a typical super massive quasi-black hole with one hundred million solar masses in about eleven trillion years if it repeats every million years. Since the super massive quasi-black hole in the center of the Milky Way galaxy has only four million solar masses left now, this suggests that it is about eleven trillion years old.

Usually a supernova explosion happens when the temperature of a neutron star reaches the temperature $T_U \approx 2.445\times10^{11} K$ when $\alpha_W(u) = \alpha$ and $u \approx (1.37\times10^{-5} - 1)c^2/2$ according to function (4.41) and (4.44). In this scenario: $P_{net} = 6.6\times10^{45} J/s$ and $t_{super} = 240.3s$, so it takes about four minutes to power a supernova explosion.

All estimations above are based on the assumption that the cosmic background gravitational potential is close to zero, which is suitable for the galaxies in the Local Group. If the supernovae are far away from the center of the cosmic sphere, then the estimations will be different, hence to consider supernovae as standard candles will lead to wrong conclusions.

Knowing that the core temperature of the sun is about $1.57\times10^{7} K$, we assume that this is equal to the temperature of a decayed small neutron star in the core, and use functions (4.44) and (5.47) to get the radius of the decayed small neutron star to be about $4857m$. Hence its mass is about $1.1\times10^{29} kg$, which is about 5.5% solar mass, and this implies the standard solar model has to be revised [8]. According to function (5.56) the decayed neutron star in the center of the sun has a magnetic field of $6.37\times10^{7} T$.

Knowing that the core temperature of the earth is about $7000K$, we also can derive that a decayed small neutron star with a radius of $104m$ and a mass of $1.08\times10^{24}kg$ is buried in the center of the earth, which has 18% of the mass of the earth. The decayed neutron star in the center of the earth has a magnetic field of $6.1\times10^{-3}T$, and on the surface of the earth the measured average magnetic flux density still has $4.5\times10^{-5}T$, probably because the earth's inner core consists primarily of an iron-nickel alloy which has high permeability.

Substitute the nuclear density ρ_n in function (5.53) with the average density ρ of active gravitational rest mass in function (5.47), and then we can transform function (5.56) into a function that describes the magnetic field associated with a gravitational field described by function (5.47). The universal formula of magnetic flux is as below:

$$B \approx 1.666\times10^{12}(\rho/\rho_n)(-2u/c^2)^3\ T \text{ ------ (5.66)}$$

If we assume the emissivity of a condensed matter $\varepsilon \approx \rho/\rho_n$, then the quasi-black hole of neutron with the highest density of active gravitational rest mass ρ_n is a close to perfect black-body with $\varepsilon \approx 1$, while the cosmic sphere with the lowest density of active gravitational rest mass ρ_c is a close to perfect white-body with $\varepsilon \approx 0$, and all other condensed matters with $\rho_c < \rho < \rho_n$ are gray bodies with $0 < \varepsilon < 1$.

The Milky Way super massive quasi-black hole has a mass of about $8.2\times10^{36}kg$, and according to function (5.47) it has a radius of about $1.2\times10^{10}m$ and its density is about $1.1\times10^{6}kg/m^3$. And according to function (5.66) the magnetic flux density on the surface of a quasi-black hole is proportional to its density, so the magnetic flux density of this super massive quasi-black hole:

$B_{milky} \approx 7.97(-2u/c^2)^3\ T$ ------ (5.67) which is $8\ T$ on its surface and decreases to $8\times10^{-31}T$ at our location. The magnetic flux density falls off inversely with the cube of the distance from its center; this is a characteristic of a dipole field. This magnetic field plays a very important role in the formation of a spiral galaxy, and I suggest that the stars near the galaxy center have heavier decayed neutron star cores with stronger magnetic fields, and that they also have higher overall densities than the stars far away from the galaxy center. The decayed neutron stars hiding in the center of stars could be the so-called dark matter, and this can explain why the stars in the globular cluster show no evidence of dark matter. A neutron star core can have up to nine solar masses, which can explain why the typical mass to light ratios are up to ten times the mass to light ratio of the sun. Even though the magnetic field associated with the cosmic sphere is extremely weak, the so-called cosmic axis might be a result of it [6], and $f_C = H_0/2\pi$ should be the typical spin frequency of the neutrino fluxes associated with the gravitomagnetic field of the cosmic sphere.

5.7. The Total Gravitational Black-Body Radiation Energy of the Cosmic Sphere

According to functions (4.46) and (5.47), we can estimate the total gravitational black-body radiation energy inside and outside the cosmic sphere:

$$E_{Inside} = 3.777\times10^{20}G^{-3/2}\rho_c^{-3/2}\int_{u_L}^{0}(-u)^{1/2}[(1+2u/c^2)^{-1/2}-1]^4 d(u)\ \ J/m^3 \text{ ------ (5.68)}$$

$$E_{Outside} = 6.477\times10^{21}G^3 m_C^3\int_{u_L}^{0}(-u)^{-4}[(1+2u/c^2)^{-1/2}-1]^4 d(u)\ \ J/m^3 \text{ ------ (5.69)}$$

where m_C is the rest mass of the cosmic sphere and ρ_c is its density, $0 > u > u_L = (10^{-7}-1)c^2/2$

From formula (5.49), $\rho_c = 8.616\times10^{-27}kg/m^3$ and we can derive $E_{Inside} = 5.87\times10^{106}J$. According to function (5.47) the lower limit of the gravitational potential is $u_L = (10^{-7}-1)c^2/2$ which gives the rest mass of the cosmic sphere as $m_C = 9.22\times10^{52}kg$, which can be used to derive $E_{Outside} = 1.64\times10^{107}J$. The average radiation energy density inside the cosmic sphere is about $5.48\times10^{27}J/m^3$. The lowest density is zero in the center of the cosmic sphere and in the space infinitely far away from it; the highest density is $5.15\times10^{34}J/m^3$ at the edge of the cosmic sphere. The gravitational black-body radiation energy is the portion of the vacuum zero-point energy carried by the gravitomagnetic field, while the major portion of the vacuum zero-point energy is carried by Higgs field.

6. Conclusions

6.1. Summary

The cosmological model deduced from functions of the gravitational potential (FGP) has provided proper answers to several long pending cosmological problems, such as gravitational waves, microwave background radiations, cosmic rays, neutron stars and quasars. The universe is stable and cosmic evolution will continue forever, because a true black hole, the heat death of the open universe, and the Big Bang or Big Crunch scenario are ruled out by FGP.

6.2. Deriving the True Electroweak Coupling Constant from the Nuclear Density

The highest radiation energy density at the edge of the cosmic sphere is produced by the annihilation of neutrons and anti-neutrons from the neutron phase transitions near the event horizon, so it should equal the rest energy density of the neutron $2.07\times10^{34}J/m^3$, derived from the nuclear density $\rho_n = 2.3\times10^{17}kg/m^3$. From function (4.46) we derive the true lower limit of the gravitational potential $u_L = (1.577\times10^{-7}-1)c^2/2$ ------ (6.70); this also sets an upper limit for the speed of fermions with rest mass according to formula (4.21), which will be

$v_U = (1-1.577\times10^{-7})^{1/2}c$. From function (4.45) we get a true maximum temperature of $T_H = 2.287\times10^{12}K$ [14], which corresponds to the maximum thermal energy of a fermion at $197MeV$. It can be reached by $u \to u_L, v \to 0$, or by $u \to 0, v \to v_U$, or by $u - v^2/2 \to u_L$ according to formula (4.37). Approaching the maximum temperature might lead to the alleged CPT and Lorentz Violation [13], and cause symmetry breaking in the phase transition from particle to anti-particle, which we have discussed in section 4.4 [16]. CPT and Lorentz Violation along with the emergence of the gravitational repulsive force towards anti-fermions seems to be the only way to avoid the singularity in both special and general relativity [15].

From function (4.41) we derive the true electroweak interaction coupling constant in perfect vacuum $\alpha_W = 1.577\times10^{-7}$, and get the temperature $T_U = 1.945\times10^{11}K$ when $\alpha_W(u) = \alpha$. From function (4.45) we derive the corresponding radiation energy density $E_U = 1.083\times10^{30}J/m^3$. If it is produced by the annihilation of left-handed neutrinos and left-handed anti-neutrinos from the neutrino phase transition near the event horizon, then we can derive the corresponding density of neutrino as $1.2\times10^{13}kg/m^3$, and it will belong to a massive neutrino with an inertial mass of about α^2 times the rest mass of a neutron, which is about $50KeV$. Formula (4.40) also suggests the existence of a boson with a rest mass of about α^2 times the rest mass of a Higgs boson when $\alpha_W(u) = \alpha$, which is about $6.7MeV$. This suggests a possible one to one relationship between fermions and bosons.

6.3. Deriving a New Hubble Constant from the Gravitational Coupling Constant

Comparing the gravitational coupling constant $\alpha_G = (m_e/m_P)^2 = 1.7518\times10^{-45}$ to the square of the mass ratio between the quasi-black hole of neutron and the cosmic sphere $(m_N/m_C)^2 \approx 3.7\times10^{-44}$, it can be noted that they are quite close to each other. The electron is the smallest micro mass quanta, while the quasi-black hole of nucleus is the smallest macro mass quanta; Planck mass is the biggest micro mass quanta, while the cosmic sphere is the biggest macro mass quanta. The gravitational coupling constant should be the link between the micro and macro mass quanta, so their mass ratio should be equal to each other, which allow us to accurately derive a new Hubble constant. From formula (5.49) and (5.50) we derive $m_C = c^3/2G\cdot H_0$ ------ (6.71), from function (5.47) and the nuclear density $\rho_n = 2.3\times10^{17}kg/m^3$ we get $m_N = 1.78\times10^{31}kg$, and then derive Hubble constant as below:

$$H_0 = \alpha_G^{1/2}\cdot c^3/2G\cdot m_N = 4.759\times10^{-19}s^{-1} = 14.68(km/s)/Mpc \text{ ------ (6.72)}$$

Thus the critical rest mass density defined by the new Hubble constants should be $\rho_c = 3H_0^2/8\pi\times G = 4.053\times10^{-28}kg/m^3$. Since the newly derived Hubble constant is smaller than the current estimated value, the radius of the cosmic sphere is larger:

$R_C = c / H_0 = 6.3038 \times 10^{26} m$, which is about 66.63 billion light years. The rest mass of the cosmic sphere is larger as well $m_C = c^3 / 2G \cdot H_0 = 4.253 \times 10^{53} kg$. Note that $m_C / R_C = c^2 / 2G$. The gravitational constant in perfect vacuum is indeed interrelated with the properties of the cosmic sphere, which has actually proved Mach's principle: Local physical laws are determined by the large-scale structure of the universe, or in our words by functions of the gravitational potential. According to functions (6.68) and (6.69) the total radiation energy of the cosmic sphere depends on the critical density or the active gravitational rest mass, both are associated with the Hubble constant, and the total radiation energy is inversely proportional to the cube of the Hubble constant.

The g-factor experiments indicate the cosmic background gravitational potential on the earth is quite small at $-2.076 \times 10^8 (m/s)^2$, which has an equivalent neutrino flux speed of $20.376 \ km/s$ according to formula (4.21). Substitute this into (4.48) to get the distance from the earth to the center of the cosmic sphere, which is about one million light years based on the current estimated Hubble constant. However, it should actually be 4.5 million light years based on the newly derived smaller Hubble constant, and of course all distances estimated by gravitational redshift have to be adjusted accordingly. The irregular galaxy Sextans B is 4.44 million light years away from the earth, which might be the most distant member of the Local Group and the galaxy closest to the center of the cosmic sphere.

7. Discussion

Since we have proposed that the magnetic flux is essentially neutrino flux, and a photon contains magnetic flux, this implies every photon inside our cosmic sphere should be composed of one pair of left-handed neutrino and left-handed anti-neutrino, while every photon inside the anti-cosmic sphere should be composed of one pair of right-handed anti-neutrino and right-handed neutrino. The missing left-handed anti-neutrino is always hiding inside a photon in our cosmic sphere, because in the vacuum of our cosmic sphere is dominated by left-handed neutrinos; annihilation will lock the left-handed anti-neutrinos inside photons forever, while the missing right-handed neutrino is always hiding inside a photon in the anti-cosmic sphere for the same reason. Neutrino is a special kind of fermion without rest mass, so it does not have an intrinsic magnetic dipole field associated with its spin. But a pair of neutrinos can form a Cooper pair with integer spin magnetic flux quantum inside a superconductor, and the neutrino flux being composed of neutrino Cooper pairs should be superfluid. Neutrino Cooper pairs might even turn into fractionally charged quasi-particles which contain more than one pair of neutrinos when the temperature is cold enough; this might be able to explain the fractional quantum Hall effect. Because the symmetry between fermions and anti-fermions is broken by the gravitational force, the rest mass of gauge bosons inside a gravitational field cannot be exactly cancelled out; the lower limit of $0.003 eV$ has been given by formula (4.40) as $\alpha_W^2 \times 125 GeV$ in section 4.3. This conclusion seems to be consistent with the prediction of RTG [17], and the proposal of massive photons [18].

According to the Pauli Exclusion Principle, a pair of fermions must have opposite spins to exchange virtual gauge bosons; this not only can guarantee the conservation of angular momentum, but can also ensure their intrinsic magnetic momentums are anti-parallel. Hence the magnetic force between their intrinsic magnetic fields is always attraction. Meanwhile, a fermion anti-fermion pair must have opposite spins to ensure the conservation of angular momentum when they exchange virtual gauge bosons, but their magnetic momentums are parallel. Hence, the magnetic force between their intrinsic magnetic fields is always repulsion. The gravitational force might emerge as a long range quantum entanglement entropic force from the intrinsic magnetic field of fermions.

So only fermions with active gravitational rest mass can have the De Broglie matter waves, which is the gravitational black-body radiations surrounding a fermion. If the frequency of the electron zitterbewegung [19] $f_e = 2m_e c^2 / h$ predicted by the Dirac equation is the frequency of the electron De Broglie matter wave, then the total energy of the electron De Broglie matter wave is $2m_e c^2$, which is twice the rest energy of an electron. Note that the total black-body radiation energy outside the cosmic sphere calculated by formula (5.69) is exactly twice the total black-body radiation energy inside the cosmic sphere calculated by formula (5.68). Hence, the rest energy of a fermion should be the gravitational black-body radiations being trapped inside by a micro quasi-black hole, similar to the cosmic sphere.

The electron zitterbewegung energy or De Broglie matter wave energy is in fact the energy carried by the gravitomagnetic field of an electron, since the gravitational field along with the associated intrinsic magnetic field of an electron are actually two sides of one coin. In the case of a electron and anti-electron annihilation, the rest energy of the electron becomes the kinetic energy of a photon, while the gravitomagnetic field energy of the electron becomes the electromagnetic field energy of a photon. Hence, the electromagnetic field energy carried by the photon should be twice its kinetic energy, and all kinds of field energies associated with different kinds of particle obey their own conservation law (i.e. the conservation of field energy). The zero point energy of vacuum is composed by all kinds of field energies, which implies the total amount of zero point energy cannot be changed, and therefore it is impossible to tap into the huge amount of zero point energy as an energy resource by converting it into kinetic energy directly. That is to say, only potential energies created by all kinds of fields can be converted into kinetic energy. For example, the gravitational black-body radiation energy surrounding the cosmic sphere is the gravitomagnetic field energy associated with the gravitomagnetic field of the cosmic sphere. It is impossible to use this energy directly, but we can tap into the energy from cosmic rays, which are accelerated by the gravitomagnetic fields between the cosmic sphere and the anti-cosmic sphere.

Since a photon contains a neutrino and anti-neutrino pair, they spin along the axis defined by the photon's velocity vector, and are bound together by the gravitomagnetic force. They resemble a cosmic and anti-cosmic sphere pair on the microscopic scale; therefore, we propose that neutrinos are just microscopic cosmic spheres, which associated with a much faster microscopic speed of light than the speed of light in perfect vacuum associated with our cosmic sphere. If gravity is indeed a quantum entanglement entropic force, then this extremely high microscopic speed of light should be the speed of gravity.

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