A Cosmological Model with Variable Constants

Guoliang Liu

Independent Researcher

London, Ontario, Canada

December 24, 2013

Abstract: Based on several assumptions to deduce a cosmological model with three fundamental constants along with the dimensionless electroweak interaction coupling constant turned into functions of the gravitational potential. Initial research of this model has indicated solutions to several long-standing cosmological puzzles.

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

1. Introduction

The quantum theory is based on a flat space-time reference frame without considering the gravitational field, so it cannot explain the phenomena involved gravitational fields. The electroweak interaction coupling constant is a variable dimensionless constant, which implies that the principle of general covariance is breaking down in microscopic scale. So it is impossible to fit the quantum theory into the framework of general relativity based on the principle of general covariance. Hence I try to modify the quantum theory in order to describe the phenomena inside a gravitational field in microscopic scale. For example the gravitational lensing can be explained by the speed of photons in vacuum is slower in a gravitational field, and the gravitational redshift can be explained by a bigger Planck constant. So I assume that these two fundamental constants are functions of the gravitational potential defined in a universal flat space-time reference frame sitting far away from any gravitational fields. In paragraph 2 and 3, I 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. I will investigate the physical significance of the functions in paragraph 4 and eventually deduce a cosmological model in paragraph 5 to solve several long-pending cosmological problems, such as the source of the gravitational wave, the essence of the cosmic microwave background, and the origin of the cosmic rays. I will derive a more accurate value for the electroweak coupling constant and a more accurate Hubble constant in paragraph 6.

2. Assumptions

The speed of light in vacuum is a function of the gravitational potential. A vacuum infinitely far away from any rest mass is a flat space-time perfect vacuum; the speed of light in this perfect vacuum has a maximum speed. The inertial mass of a photon is equivalent to the passive gravitational mass which is subjected to the gravitational force, even though only the rest mass is equivalent to the active gravitational mass which produces the gravitational potential. Since a photon does not have a gravitational field associated with it, a photon propagating in a gravitational field will not produce any gravitational wave; the change of the gravitational potential energy of a photon is absolutely equal to the change of the energy of the photon. These assumptions will yield equation (1) in next paragraph.

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, I have to assume the Plank constant and the permeability of vacuum being functions of the gravitational potential, while keep the elementary charge and the permittivity of vacuum as true constants. These assumptions will yield equation (2) in next paragraph.

Since the frequency of light will not change during its propagation through different mediums, so I assume that the frequency of a photon will not change when it travels in a gravitational field, and of course I have to assume that 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. This assumption will yield equation (3) in next paragraph.

3. Derive the 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 the following three equations according to the assumptions discussed in the above paragraph:

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

$$h(u)c(u) = h \cdot c \text{ ------ (2)}$$

$$\frac{m(u)c^2(u)}{h(u)} = \frac{m \cdot c^2}{h} \text{ ------ (3)}$$

Combine (2) and (3) to get

$$m(u) = m \cdot c^3 / c^3(u) \text{ ------ (4)}$$

Put (4) into (1) to get

$$\frac{1}{c(u)} + \int_0^u \frac{du}{c^3(u)} = \frac{1}{c} \text{ ------ (5)}$$

Differentiate both sides of equation (5) to get

$$\frac{-dc(u)}{c^2(u)du} + \frac{1}{c^3(u)} = 0 \text{ ------ (6)}$$

Derive from (6)

$$c(u)dc(u) = du \text{ ------ (7)}$$

Integrate both sides of equation (7) to get

$$c^2(u)/2 = u + K \text{ ------ (8)}$$

where K is a constant to be defined.

Since $c(0) = c$ ------ (9)

Combine (9) and (8) to get

$$K = c^2/2 \text{ ------ (10)}$$

Substitute (10) into (8) to derive a function for the variable speed of light in vacuum:

$$c(u) = (1 + 2u/c^2)^{1/2} c \text{ ------ (11)}$$

Substitute (11) into (2) to derive a function for the variable Planck constant:

$$h(u) = (1 + 2u/c^2)^{-1/2} h \text{ ------ (12)}$$

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 (11) to derive a function for the variable permeability of vacuum:

$$\mu_0(u) = \left(1 + 2u/c^2\right)^{-1} \mu_0 \text{ ------ (13)}$$

The rest energy of a particle should be invariant in a gravitational field due to the conservation of energy. $E_0 = m_0(u) c^2(u) \equiv m_0 \cdot c^2$ ------ (14) where m_0 is the rest mass of a particle in perfect vacuum, put (11) into (14) to derive a function for the variable rest mass of a particle:

$m_0(u) = (1+2u/c^2)^{-1} m_0$ ------ (15)

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

$E_P = [\hbar(u) c^5(u)/G(u)]^{1/2} \equiv (\hbar \cdot c^5/G)^{1/2}$ ------ (16) where G is the gravitational constant in perfect vacuum, $\hbar = h/2\pi$ is the reduced Planck constant in perfect vacuum. Substitute (11) and (12) into (16) to derive a function for the variable gravitational constant:

$G(u) = (1+2u/c^2)^2 G$ ------ (17)

(11), (12), (13), (15), and (17) are five basic functions of the gravitational potential, and we will abbreviate these functions that describe the variable constants as FGP from here after.

4. Investigate the Physical Significance of FGP

Planck units are defined in terms of five fundamental physical constants; they are the speed of light in vacuum c, the reduced Planck constant $\hbar = h/2\pi$, the gravitational constant G, the Coulomb constant $k = (4\pi\varepsilon_0)^{-1}$, and the Boltzmann constant k_B. 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 are invariant in a gravitational field, only Planck time and Planck mass turn into functions of the gravitational potential:

$t_P(u) = (1+2u/c^2)^{-1/2} t_P$ ------ (18) where t_P is Planck time in perfect vacuum.

$m_P(u) = (1+2u/c^2)^{-1} m_P$ ------ (19) where m_P is Planck mass in perfect vacuum.

Function (18) and (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; no matter if they are atomic clocks or just simple pendulums or even the mean lifetime of a decay particle. FGP can also deduce that all length measuring units are invariant in the gravitational field, so if we locally measure the speed of light in vacuum, we actually cannot detect any change. Function (15) and (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 in 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:

$t(V) = (1-V^2/c^2)^{-1/2} t$ ------ (20) where t is the time measuring unit in perfect vacuum.

Compare (20) to (18), we can deduce a relation between a constant speed V and a constant gravitational potential U as following: $V^2 = -2U$ ------ (21), this formula implies that these two reference frames are equivalent. So let's reconsider the thought experiment in a reference frame with a constant background gravitational potential U, in this scenario the equation (1) will be as below:

$$m(u+U)c^2(u+U) + \int_0^u m(u+U)du = m(U)c^2(U) \text{ ------ (22)}$$

Based on (4) and (11), equation (22) can be rewritten as below:

$$m(u+U)c^2(u+U) + \int_0^u m(u+U)du = m \cdot c^2(1+2U/c^2)^{-1/2} \text{ ------ (23)}$$

Use the total gravitational potential $\bar{u} = u + U$ ------ (24) to do a substitution in (23)

$$m(\bar{u})c^2(\bar{u}) + \int_U^{\bar{u}} m(\bar{u})d\bar{u} = m \cdot c^2(1+2U/c^2)^{-1/2} \text{ ------ (25)}$$

While the other two equations (2) and (3) can be as below:

$$h(\bar{u})c(\bar{u}) = h \cdot c \text{ ------ (26)}$$

$$\frac{m(\bar{u})c^2(\bar{u})}{h(\bar{u})} = \frac{m \cdot c^2}{h} \text{ ------ (27)}$$

Combine (26) and (27) to get

$$m(\bar{u}) = m \cdot c^3 / c^3(\bar{u}) \text{ ------ (28)}$$

Put (28) into (25) to get

$$\frac{1}{c(\bar{u})} + \int_U^{\bar{u}} \frac{d\bar{u}}{c^3(\bar{u})} = \frac{1}{(1+2U/c^2)^{1/2}c} \text{ ------ (29)}$$

Differentiate on both sides of equation (29) to get

$$\frac{-dc(\bar{u})}{c^2(\bar{u})d\bar{u}} + \frac{1}{c^3(\bar{u})} = 0 \text{ ------ (30)}$$

Derive from (30)

$$c(\bar{u})dc(\bar{u}) = d\bar{u} \text{ ------ (31)}$$

Integrate on both sides of equation (31) to get

$$c^2(\bar{u})/2 = \bar{u} + K \text{ ------ (32)}$$

where K is a constant to be defined.

Since $c(0) = c$ ------ (33)

Combine (32) and (33) to get

$K = c^2/2$ ------ (34)

Substitute (34) into (32) to derive a function for the variable speed of light in vacuum:

$c(\overline{u}) = (1+2\overline{u}/c^2)^{1/2}c$ ------ (35)

Substitute (35) into (26) to derive a function for the variable Planck constant:

$h(\overline{u}) = (1+2\overline{u}/c^2)^{-1/2}h$ ------ (36)

Comparing (35) to (11) and (36) to (12), we conclude that all functions will take same forms for the total gravitational potential $\overline{u}$ 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 perfect vacuum. Based on formula (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: $\overline{U} = U - V^2/2$ ------ (37)

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 (12) and (15) $\mu_B(u) = (1+2u/c^2)^{1/2}\mu_B$, the Bohr magneton as a measuring unit of the magnetic momentum turns smaller in a gravitational field. So the g-factors experiment value should equal to the QED theoretical value which has not accounted the effect of the gravitational field multiplied by a FGP factor $(1+2u/c^2)^{-1/2}$. After investigating the results from five experiments measuring the g-factor of electron and muon, I conclude that the FGP factor has a value of approximately 1.000000003 to get the total gravitational potential on the earth:

$\overline{U}_E = -2.7\times10^8 (m/s)^2$ ------ (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 (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 (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 I deduce that the magnetic flux not only describe the intrinsic magnetic field in one aspect but also describe the gravitational field in another aspect. Fermions and anti-fermions have rest mass equivalent to active gravitational mass, while photons and neutrinos only have inertial mass equivalent to passive gravitational mass. 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. I propose that the magnetic flux is neutrino flux with a speed defined by the gravitational potential.

Experiments have proved 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 (21) implies that this should also happen when the time is slowdown in a gravitational field. Since the mean lifetime of a muon decay τ_μ relates to the Fermi constant G_F in following formula: $192\pi^3\hbar/(Q_0^5 \cdot \tau_\mu) = G_F^2/(\hbar \cdot c)^6$ ------ (39) where $Q_0 \approx m_\mu \cdot c^2$, m_μ is the rest mass of a muon. Based on function (11), (12), (15) and (18) to conclude 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:

$G_F/(\hbar \cdot c)^3 = \sqrt{2}\alpha_W{}^2/8m_W^2$ ------ (40) where m_W is the rest mass of a W boson. According to function (11), (12), (15), (39) and (40), we can derive the dimensionless coupling constant of the electroweak interaction as a function of the gravitational potential:

$\alpha_W(u) = (1 + 2u/c^2)^{-1}\alpha_W$ ------ (41)

Based on the fact that the electroweak interaction coupling constant $\alpha_W \approx 10^{-7}$ and the electromagnetic coupling constant $\alpha \approx 1/137$, function (41) gives $u \approx (1.37 \times 10^{-5} - 1)c^2/2$ when $\alpha_W(u) = \alpha$. According to the electroweak theory the electromagnetic force and weak interaction will merge into a single electroweak force when the temperature reaches approximately $10^{15}K$, so function (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 (21), the neutrinos in the flux may produce black body radiation from their kinetic 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:

$[h(u) - h]f = k_B T$ ------ (42) where k_B is the 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 $T = 2.72548K$ ------ (43), if we consider it 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, (36) and (43) into (42) to get the specific frequency: $f = 9.085\times10^8 k_B / h$. Put f back into (42) to derive the temperature of a gravitational field:

$$T = [(1+2u/c^2)^{-1/2} - 1]9.085\times10^8 K \text{ ------ (44)}$$

This yields a unified temperature of $T_U \approx 2.445\times10^{11}K$ when $\alpha_W(u) = \alpha$, significantly lower than $10^{15}K$ predicted by the electroweak theory. Since the strong interaction coupling constant $\alpha_S \approx 1$, function (41) gives $u \approx (10^{-7} - 1)c^2/2$, when $\alpha_W(u) = \alpha_S$ the electroweak interaction and strong interaction merge into a unified force, the temperature of the gravitational field will reach about $2.872\times10^{12}K$ according to function (44). So function (41) not only provides a clue to the so called grand unified theory, but also defines the limits to the temperature and the gravitational potential, because the electroweak interaction coupling constant or the grand unified interaction coupling constant should not be bigger than one, otherwise an electron could have a speed faster than the speed of light in vacuum.

Function (42) indicates that the temperature of a gravitational field is proportional to the variable Plank constant; the kinetic energy of a particle is stored in the intrinsic magnetic field associated with its spin defined by the 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. This should be the microscopic explanation of the gravitational wave predicted by general relativity. Because the rest energy of a particle is stored in the 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 black body radiation energy density: $E_d = 8\pi^5 k_B^4 T^4 / 15h^3c^3 = aT^4$ ------ (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 (44) into (45) to get the gravitational black body radiation energy density:

$$E_d = [(1+2u/c^2)^{-1/2} - 1]^4 5.154\times10^{20} J/m^3 \text{ ------ (46)}$$

The gravitational black body radiation energy plays a very important role to counterbalance the gravitational attraction; it could be the so called dark energy. If the temperature reaches the upper limit to $T_H \approx 2.872\times10^{12}K$ 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 the annihilation can produce such high energy density. So I conclude 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. The vacuum fluctuation near the event horizon can be very big due to the Planck constant turning bigger sharply; 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, so only anti-neutrinos and anti-neutrons can be ejected from a black hole. Even though the conservation of baryon number seems to be broken, but the number of anti-neutron being produced by a black hole should equal to 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. So if simultaneously a phase transition from anti-neutron to neutron can happen somewhere in the universe, then the conservation of baryon number can be saved, and it can be the origin of the cosmic rays when I establish my 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, but it is much more intense because the gravitational repulsive force towards the anti-particles and because the Planck constant and the temperature increase sharply according to function (36) and (44). Any 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 heat 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 (46) implies that the gravitational black body radiations are extremely intense near the event horizon, so a black hole which sucks everything inside is impossible to be formed. 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 $\alpha_W(u) = \alpha_S$ the electroweak interaction force merges with the strong interaction force according to function (41). Otherwise photons will stop moving according to function (35), the Planck constant will turn infinitely big according to function (36) and the temperature will be infinitely high according to function (44). Hence, a black hole should be called a quasi-black hole accurately. Because it can be used to define the macro mass quanta formed by gravitation, it becomes a clue for me to establish my cosmological model.

5. Deduce a Cosmological Model from FGP

FGP is based on a universal flat space-time perfect vacuum reference frame, so I assume that this should be the initial state of the universe with an equal amount of hydrogen atoms and anti-hydrogen atoms along with photons spread evenly in the space with a 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 faraway from each other because the gravitational repulsive force is offset by their common gravitational attractive force towards the photons inside these two cosmic spheres.

We have to use a function to describe the gravitational potential inside a sphere: $u(r) = -4\pi G \cdot \rho \cdot r^2 / 3$ ------ (47) where r is the distance from the center of mass, ρ is the average density of the rest mass within the sphere with a radius of r. Only the rest mass 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 the 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 $2.6\times10^8 m$ where the gravitational strength is about $0.006N/kg$ and equals the one of the sun. The moon is located outside the maximum sphere of the earth, so its maximum sphere radius is about $2.9\times10^7 m$ where the gravitational field strength also equals the one of the sun. 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 (44) or (46). Even the speed of light in vacuum has points of discontinuity on the maximum sphere as well, and this will make the gravitational lensing effect bigger 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. Even though theoretically only the universal flat space-time reference frame is suitable for quantum theory and special relativity, in practice, based on formula (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.

If we use function (47) to describe a cosmic sphere, then Hubble's law can be:

$v(r) = H_0 \cdot r$ ------ (48), since I consider the speed $v(r)$ as the speed of the neutrino flux associated with the cosmic gravitational field, so according to formula (21) we can combine (47) and (48) to get the density of the cosmic sphere: $\rho_c = 3H_0^2 / 8\pi G$ ------ (49), use the Hubble constant $H_0 = 67.8(km/s)/Mpc$ to calculate the value of $\rho_c = 8.616\times10^{-27} kg/m^3$. 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 (47) to get the radius of the cosmic sphere: $R_c = c/H_0 \approx 1.367\times10^{26} m$ ------ (50) and this also is the radius of the so called Hubble sphere; it is about 14.45 billion light years. If it is a cosmic black hole event horizon, then anything including lights is trapped inside, but FGP has a lower limit gravitational potential $u_L \approx (10^{-7} - 1)c^2 / 2$, so 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 settle down to today's value after the cosmic sphere and the anti-cosmic sphere achieved a dynamic balance. So the heat death of the open flat space-time universe will never happen in this scenario, and there is no reason to break the dynamic balance to create the so called Big Bang or Big Crunch scenario.

Function (47) along with the critical density in formula (49) indicated that a quasar may 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 (44); it can produce the wide range ionization which cannot be explained before. 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 than one in the Milky Way galaxy. This quasar can easily output huge amount of energy, because the gravitational black body radiation energy density counted on the cosmic background gravitational potential itself reaches $1.52 \times 10^{19} J / m^3$ according to function (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 just considering the cosmic background gravitational potential already yields a local Planck constant 1.414 times bigger than the one in a perfect vacuum according to function (36). A cosmic background gravitational redshift gives a distance significantly different from the distance given by considering the redshift as a Doppler shift. Since the redshift comes from a cosmic background gravitational potential: $Z = (1 + 2u / c^2)^{-1/2} - 1$, if $Z = 8.6$ which is the highest redshift confirmed from a faraway galaxy, then $u = -0.4946c^2$, and if this redshift was solely caused by the cosmic background gravitational potential, then it will give a distance of $1.36 \times 10^{26} m$ according to function (47) and formula (49), which is about 14.37 billion light years. It seems to be too close to the edge of the cosmic sphere, since only the redshift of spectrums from interstellar plasma clouds are reliable for the estimation of distance.

Since a spiral galaxy is composed by billions of stars similar to the sun, and I assume that they all evolved from a huge hydrogen gas ball, I 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 at $\rho_g = 1.4 \times 10^{-4} kg / m^3$, substitute this into function (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 $9.22\times10^{52}kg$, the total number of spiral galaxy is about one hundred thirty billion. Because only about 60% of the galaxies are spiral galaxies, other types of galaxies are smaller, so the total number of galaxy may be over two hundred billion. Therefore the average mass of a spiral galaxy should be $4.34\times10^{41}kg$ 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 $\rho_S = 1408kg/m^3$ to estimate the size of a super massive quasi-black hole with a radius $r_S = 3.38\times10^{11}m$ which will give a mass of $2.28\times10^{38}kg$, 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 continues to be transferred from the super massive quasi-black hole by its magnetic field. 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.

The plasmas falling into a quasi-black hole are turned into heat energy 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 (46). But a tiny fraction of anti-neutrons not hitting anything will 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 explain why the energy of the anti-protons and positrons which have been decayed from the anti-neutrons in the cosmic rays are significantly higher than the energy of the protons and electrons, and explain why they come so evenly from every direction. The particle exchange with the anti-cosmic sphere by cosmic rays is critical to achieve 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 anti-cosmic sphere is critical to save the conservation of baryon number which seems to have been broken by the neutron phase transitions near the event horizon of quasi-black holes.

According to function (41) the electroweak interaction 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 are enough plasmas to feed into it, until it turns into a quasi-black hole of neutron. Put the average nuclear density $\rho_n = 2.3\times10^{17} kg/m^3$ into function (47) will get the radius to form a quasi-black hole of neutron $r_N = 26463m$ and the mass is $m_N = 1.78\times10^{31} kg$ which is about nine solar masses. A star with more than nine solar masses most likely will end up with a supernova. Usually the explosion will be triggered by a fast moving outer shell smashed by a lagging quasi-black hole inside it; the asymmetric explosion ejects its remains out of the supernova center to become a pulsar. In case a supernova is triggered by the collapse of a heavy outer shell, then 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, the 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, the nuclear fusion starts again in the center with highest temperature and density. Finally it becomes a newborn star with or without planets.

I suggest that 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 $M = \chi_v \cdot H$ ----- (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 $\mu = \mu_0(1+\chi_v)$, comparing this to function (13) and we notice that the vacuum in a gravitational field has a volume magnetic susceptibility $\chi(u) = (1+2u/c^2)^{-1} - 1$ ------ (52). It is very big near the event horizon, so I assume that χ_v is very big as well, and this also implies that the magnetic dipole moment of most neutrons in a neutron star will take the same direction as the neutrino flux associated with a gravitational field. Hundred percent of the neutrons will take the same spin direction since the susceptibility becomes infinitely large as a neutron star becomes a quasi-black hole, so I simply assume that the square of the mass ratio between a neutron star and a quasi-black hole to equal the ratio of the neutrons taking the same spin direction, hence $M = (\rho_n / m_n) M_n [m_N(u)/m_N]^2$ ------ (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 (47) we get $[m_N(u)/m_N]^2 = (-2u/c^2)^3$ ------ (54), put this into (53) then combine with (51) and (52) to get the magnetic field strength on the surface of a neutron star as below:

$$H = 1.326\times10^{18}(-2u/c^2)^3/\chi_v \ A/m \text{ ------ (55)}$$

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

$$B \approx 1.666\times10^{12}(-2u/c^2)^3 \ T \text{ ------ (56)}$$

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.

Consider a neutron star as a solid sphere with even density to get the moment of inertia: $I_N = 2m_N(u)r_N^2(u)/5 = 8\pi\rho_n r_N^5(u)/15$ ------ (57) where $r_N(u)$ is the radius of a neutron star with a surface gravitational potential of u. From function (47) we get

$r_N(u) = (-3u/4\pi G\rho_n)^{1/2}$ ------ (58), and based on function (11) to get the theoretically maximum angular speed of a neutron star as below:

$$\omega_{\max} = c(u)/r_N(u) = 2c[\pi G\rho_n(1+2u/c^2)/(-3u)]^{1/2} = 2.4\times10^{12}(1+2u/c^2)^{1/2}/(-u)^{1/2} rad/s \text{ ---- (59)}$$

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

$$L_{\max} = I_N\omega_{\max} = (-3u)^2(1+2u/c^2)^{1/2}c/30\pi G^2\rho_n = 2.8\times10^{10}(-u)^2(1+2u/c^2)^{1/2} J\cdot s \text{ ------ (60)}$$

Put limit gravitational potential $u_L \approx (10^{-7}-1)c^2/2$ into function (59) and (60) to get the maximum angular momentum of a quasi-black hole of neutron is $1.79\times10^{40}J\cdot s$ with a spin frequency of $0.5698Hz$. A neutron star most likely will retain this angular momentum after a supernova explosion, so I can 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 function (56) and (44) the magnetar has a temperature $T_m = 3.326\times10^8 K$ and the pulsar the pulsar has a temperature $T_p = 2.185\times10^7 K$. According to functions (47), (56), (57) and (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 $P = A\sigma T^4$, where the surface area of a black body is A, and T is its temperature, and based on function (11) and (12) the Stefan-Boltzmann constant σ is a function of the gravitational potential:

$$\sigma(u) = (1+2u/c^2)^{1/2} 2\pi^5 k_B^4 / 15h^3c^2 = (1+2u/c^2)^{1/2} 5.67\times10^{-8}\ J/m^2sK^4 \text{ ------ (61)}$$

So the net radiation power:

$$P_{net} = A_m\sigma_m T_m^4 - A_p\sigma_p T_p^4 = 7.125*10^{-7}[r_m^2(1+2u_m/c^2)^{1/2}T_m^4 - r_p^2(1+2u_p/c^2)^{1/2}T_p^4]\ J/s \text{ ---- (62)}$$

where u_m is the gravitational potential on the surface of the magnetar and u_p is the one of the pulsar. From function (56) we get $2u_m/c^2 = \sqrt[3]{0.1}$ and $2u_p/c^2 = \sqrt[3]{0.0001}$; put all data into (62) to get $P_{net} = 2.075\times10^{36} J/s$ and determine that $t_{decay} = (m_m - m_p)c^2 / p_{net} = 2.372\times10^{11} s$ ------ (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 nucleus; 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 nucleus in function (62) to get:

$$P_{net} = 7.125\times10^{-7}[r_N^2(1+2u_L/c^2)^{1/2}T_H^4 - r_p^2(1+2u_p/c^2)^{1/2}T_p^4]\ J/s = 1.074\times10^{49} J/s \text{ ------ (64)}$$

The time for the extremely intense hypernova explosion will be:

$t_{hyper} = (m_N - m_p)c^2 / p_{net} = 0.148s$ ------ (65), the 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 unified temperature $T_U \approx 2.445\times10^{11}K$ when $\alpha_W(u) = \alpha$ and $u \approx (1.37\times10^{-5}-1)c^2/2$ the electromagnetic force merges with the weak interaction force according to function (41). In this scenario $P_{net} = 6.6\times10^{45} J/s$ and $t_{\text{super}} = 240.3s$, it takes about four minutes to power a supernova explosion.

Knowing the core temperature of the sun is about $1.57\times10^7 K$; we assume this to be the temperature of a decayed small neutron star in the core, and use function (44) and (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. According to function (56) the decayed neutron star in the center of the sun has a magnetic field of $6.37\times10^{7}T$.

Knowing 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 inner core consists primarily by an iron-nickel alloy which has high permeability.

Substitute the nuclear density in function (53) with the density of rest mass in function (47), then we can transform function (56) into a function to describe the magnetic field associated with a gravitational field described by function (47): $B \approx 1.666\times10^{12}(\rho/\rho_n)(-2u/c^2)^3\ T$ ------ (66)

The Milky Way super massive quasi-black hole has a mass of about $8.2\times10^{36}kg$, according to function (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 (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:

$B_{milky} \approx 7.97(-2u/c^2)^3\ T$ ------ (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 those 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 for dark matter. A neutron star core can have up to nine solar masses, which can explain the typical mass to light ratios up to ten times the mass to light ratio of the sun.

According to function (46) and (47) we can estimate the total gravitational black body radiation energy inside and outside the cosmic sphere:

$$E_{Inside} = 3.777\times10^{20}G^{-3/2}\rho_c^{-3/2}\int_{u_L}^{0}(-u)^{1/2}[(1+2u/c^2)^{-1/2}-1]^4 d(u)\ \ J/m^3 \text{ ------ (68)}$$

$$E_{Outside} = 6.477\times10^{21}G^3 m_C^3\int_{u_L}^{0}(-u)^{-4}[(1+2u/c^2)^{-1/2}-1]^4 d(u)\ \ J/m^3 \text{ ------ (69)}$$

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 (49) $\rho_c = 8.616\times10^{-27} kg/m^3$, we derive $E_{Inside} = 5.87\times10^{106} J$. According to function (47) the lower limit of the gravitational potential $u_L = (10^{-7} - 1)c^2/2$ which gives the rest mass of the cosmic sphere $m_C = 9.22\times10^{52} kg$ to derive $E_{Outside} = 1.65\times10^{107} J$. 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.

6. Conclusions

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

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 (46) we get the more accurate lower limit of the gravitational potential: $u_L = (1.577\times10^{-7} - 1)c^2/2$ ------ (70). From function (44) or (45) we get the more accurate maximum temperature $T_H = 2.287\times10^{12} K$. Then from function (41) we get the more accurate electroweak interaction coupling constant in perfect vacuum: $\alpha_W = 1.577\times10^{-7}$, and get the more accurate unified temperature $T_U = 1.945\times10^{11} K$ when the weak interaction merges with the electromagnetic force. From function (45) we get the unified 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 $1.2\times10^{13} kg/m^3$ in the gravitational field at the unified temperature, and that will be the most massive neutrino with an inertial mass of up to 1/19167 the rest mass of a neutron.

I suggest that every photon inside our cosmic sphere is composed by one pair of left-handed neutrino and left-handed anti-neutrino, while every photon inside the anti-cosmic sphere is composed by one pair of right-handed anti-neutrino and right-handed neutrino, so the temperature of a gravitational field is associated with the energy density of neutrinos in the vacuum described by function (44) and (46). 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 a rest mass, so it does not have an intrinsic magnetic field associated with its spin. According to Pauli Exclusion Principle, a pair of fermions must have opposite spins to exchange virtual photons, this not only can guarantee the conservation of angular momentum, but also can ensure their intrinsic magnetic momentums are anti-parallel, hence the magnetic force between their intrinsic magnetic field is always attraction; while a fermion-antifermion pair must have opposite spins to ensure the conservation of angular momentum when they exchange virtual photons, but their magnetic momentum are parallel, hence the magnetic force between their intrinsic magnetic field is always repulsion. So I suggest that the gravitational force might be the long range effect from the intrinsic magnetic field of fermions, while the electroweak and strong interactions might be its short range effects.

Comparing the gravitational coupling constant: $\alpha_G = (m_e / m_P)^2 = 1.7518 \times 10^{-45}$ to the square of the mass ratio between the quasi-black hole of neutron and the cosmic sphere: $(m_N / m_C)^2 \approx 3.7 \times 10^{-44}$, 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. And the gravitational coupling constant should be the link between the micro and macro mass quanta, so I deduce that their mass ratio should be equal to each other, and then we can calculate the Hubble constant and the critical rest mass density accurately. From formula (49) and (50) we derive $m_C = c^3 / 2G \cdot H_0$, from function (47) and the nuclear density $\rho_n = 2.3 \times 10^{17} kg / m^3$ we get $m_N = 1.78 \times 10^{31} kg$, and then derive the Hubble constant as below:

$$H_0 = \alpha_G^{1/2} \cdot c^3 / 2G \cdot m_N = 4.759 \times 10^{-19} s^{-1} = 14.68 (km/s) / Mpc \text{ ------ (71)}$$

And then the critical rest mass density defined by the derived Hubble constants should be $\rho_c = 3H_0^2 / 8\pi G = 4.053 \times 10^{-28} kg / m^3$. Since the newly derived Hubble constant is smaller than the current estimated value, the radius of the cosmic sphere is larger: $R_c = c / H_0 = 6.3038 \times 10^{26} m$; the rest mass of the cosmic sphere is higher as well: $m_C = c^3 / 2G \cdot H_0 = 4.253 \times 10^{53} kg$. According to function (68) and (69) the total radiation energy of the cosmic sphere depends on the critical density or the rest mass associated with the Hubble constant, and the total radiation energy is inversely proportional to the cube of the Hubble constant.

The g-factor experiments showing that 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 (21), put this into (48) to get the distant from the earth to the center of the cosmic sphere about one million light years based on the current estimated Hubble constant. But it should be 4.5 million light years based on the newly derived Hubble constant, and 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, thus may be the most distant member of the Local Group, and could be located near the center of the cosmic sphere.

References

1. Feynman, Richard Phillips (1988). QED: The Strange Theory of Light and Matter. Published by Princeton University Press.
2. Weinberg, Steven. Dreams of a final theory. Publish in the United States by Pantheon Books, a division of Random House, Inc., New York, and simultaneously in Canada by Random House of Canada Limited, Toronto.