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ORIGINAL ARTICLE

Variation of the gravitational constant with time in the framework of the large number and creation of matter hypothesizes

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Abstract We present the status of the idea that the gravitational constant may vary with time, explaining the basic theories and hypothesis. We predicted that the gravitational constant may vary with time. Different kinds of tests, experiments, and measurements were involved to verify the variation of the gravitational constant with time.

1. Introduction

The fundamental constants of physics, such as speed of light (c), Plank's constant (h), the charge (e) and mass of the electron (m_e) provide us with a set of absolute units for measurements of distance, time and mass. It had been noted by Diarc, 1937 that most physical and astrophysical dimensionless constants are of the order of magnitude of integral power of the number 10^{40}. For example, given e the charge of the electron, the constant of gravitation (G), the electron mass (m_e) and the proton mass (m_p), one can construct dimensionless constant, i.e. a constant with no units

$$\frac{e^2}{Gm_em_p} \approx 10^{40} \tag{1}$$

This constant gives the ratio of the electrical Force $F_e = k\frac{e^2}{r^2}$ to the gravitational force $F_g = \frac{Gm_em_p}{r^2}$ between the electron and the proton within distance of r. However, this constant does not depend on the units used. Dirac considered another dimensionless number, the ratio of the length scale of the universe $\frac{c}{H_0}$ where H_0 is Hubble constant and the length scale of the electron $\frac{e^2}{m_ec^2}$, or in another word the time for the photon to cross the universe $T_0 \approx 10^{17}$ s to the time for photon to cross an electron $t_e = 10^{-23}$ s, this ratio is:

$$\frac{m_ec^3}{e^2H_0} = \frac{T_0}{t_e} \approx 10^{40} \tag{2}$$

We note that we have another large dimensionless number in Eq. (2) and it is of the same order as Eq. (1).

We can also construct another dimensionless large number by estimating the number of particles (N) in a sphere of radius (c/H), assuming the mass of each particle being (m_p), the mass of single proton, within closed universe with the critical density equal to

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$$\rho_0 = \frac{3H_0^2}{8\pi G},$$
$$N = \frac{4\pi}{3m_p}\left(\frac{c}{H_0}\right)^3 \rho_0 = \frac{4\pi}{3m_p}\left(\frac{c}{H_0}\right)^3 \frac{3H_0^2}{8\pi G} = \frac{c^3}{2m_p G H_0} \approx 10^{80} = (10^{40})^2. \quad (3)$$

We note that N in (3) is an order of power 2 of the dimensionless number in (2), while the ratio between the two forces F_e and F_g in (1) is of power one of the dimensionless number in (2). The relationships (2) and (3) contain the Hubble constant H_0 which is vary inversely with the present epoch, hence with the epoch t.

Dirac pointed out the following:

First, the large numbers in Eqs. (1)–(3) are to be regarded not as a constant but as a simple function of the present time. Second, any large number at the present epoch is of the order $\left(\frac{T_0}{t_e}\right)^k$, where k is of order of unity, varies with the epoch t as $\left(\frac{t}{t_e}\right)^k$, which implies that the ratio in (1) vary as $\left(\frac{t}{t_e}\right)^k$, is called the Large Number Hypothesis (LNH).

2. The Large Number Hypothesis (LNH)

Assuming that the atomic constants are not changing, and considering (1) and (2) this leads to that the large number in (1) vary with the epoch,

$$\frac{e^2}{G m_e m_p} \approx 10^{40} \approx \frac{T_0}{t_e} \quad (4)$$

While the large number in (3) varies with the square of the epoch as:

$$N = \left(\frac{T_0}{t_e}\right)^2. \quad (5)$$

3. The creation of matter hypothesis (CMH)

Dirac LNH implies a creation of particles. The number of particles N in the universe is increasing with the time as $N \propto t^2$, where t is equal to T_0 according to relation (5) which implies that matter is being continuously created. The creation of matter can occur by two possible ways, additive creation in which particles are uniformly created throughout the universe, or multiplicative creation in which new particles are created predominantly where matter already exist.

4. Jordan's theory

Jordan, 1949 provided basis for Dirac's Large Number Hypothesis. He developed his theory by singled out six fundamental quantities, which are the velocity of light (c), the spatial curvature parameter ($k = 8\pi G/c^2$), the age of the universe (t), the mean mass density of the universe (ρ), Hubble's constant (H) and the radius of the universe $R = c/H$.

He constructed from these quantities dimensionless numbers which are of order of unity

Table 1 Summarized the LNH for multiplicative and uniformly creation.

Uniformly creation, $M = const$	Multiplicative creation $M \propto t^2$
$G \propto 1/t$	$G \propto 1/t$
$H \propto 1/t$	$H \propto 1/t$
$\rho_0 = const$	$\rho_0 \propto t^2$
$\rho = \rho_0/t^3 \propto 1/t^3$	$\rho = \rho_0/t^3 \propto 1/t$
$R \propto 1/t$	$R \propto t$

$$Ht \approx 1$$
$$R/ct \approx 1 \quad (6)$$
$$k\rho c^2 t^2 \approx 1$$

The mass of the universe M is given by:

$$M = \rho R^3 \quad (7)$$

By substituting ρ and t in (6) using (7) we obtain $k(M/R^3)c^2(R^2/c^2) = 1$, or

$$kM = R \quad (8)$$

From the definition of k we write (8) as:

$$MG = (c^2/8\pi)R \quad (9)$$

And by substituting for ρ and R from (6) into (7) using the definition of k, we get:

$$M = (1/8\pi G t^2)x(ct)^3 \quad (10)$$

If we consider multiplicative creation of matter where $M \approx t^2$ one get immediately that $G \propto 1/t$. Jordan's theory is important in providing a theoretical basis for Dirac's hypothesis.

5. Limit of the changing of G

Applying the LNH to Eq. (1) we will have;

$$\frac{e^2}{G m_e m_p} = \left(\frac{t}{t_e}\right)^k \quad (11)$$

If we distinguish between e, m_e, m_p, and t_e on one side and G on the other side assuming e, m_e, m_p, and t_e are constant in 4, and use the above argument, will forward get $G \propto \left(\frac{1}{t}\right)^k$.

Narlikar and Kembhavi, 1980 calculated the limit of the changing of G during the age of the universe in Dirac's cosmology at the present epoch, by differentiation $G \propto \left(\frac{1}{t}\right)^k$ with time and we get $\dot{G} \propto -k\left(\frac{1}{t}\right)^{k-1}$, and hence $\frac{\dot{G}}{G} = -7 \times 10^{-11}\ \text{yr}^{-1}$ with t equal to the present epoch $T_0 = 1.5 \times 10^{10}\ \text{yr}^{-1}$, and $k = -1$. This means that if the G is changing with time according to the Large Number Hypothesis it will change as a fraction of $-7 \times 10^{-11}\ \text{yr}^{-1}$ (see Table 1).

6. Testing the LNH

6.1. *Temperature of celestial body*

If the (LNH) and the (CMH) are valid in our solar system, the earth will recede from the sun, therefore the temperature of the earth will decrease, (Roxburgh, 1976).

From steelar structure the luminosity of the Sun can be given by $L \propto G^7 M^5$, substituting $G \propto 1/t$ (from LNH) and $M \propto t^2$ (from multiplicative creation matter MCM) in the luminosity relation we get $L \propto t^3$. Surface temperature of the earth T_E affected by the Sun luminosity and can be given from Boltzmann Stefan's relation $L \propto R^2 T_E^4$ or $T_E = \left(\frac{L}{R^2}\right)^{\frac{1}{4}}$ by combining previous equation and taking $R \propto t$ (MCM) we get $T_E \propto t^{\frac{5}{4}}$. The rate of the changing of T due to the changing of the epoch is given as $\frac{dT_E}{T_E} = 5/4 \frac{dt}{t}$. The temperature of the Earth would have increased from 209 K to 245 K ($t = 3 \times 10^9$ years) to 300 K $t = 5 \times 10^9$ years, therefore $t = 3 \times 10^9$ years the Earth's temperature would be cooler than the present temperature by 55 K. Uniform creation would leave the masses of the Sun and Earth effectively constant so that with get $T_E \propto t^{\frac{9}{4}}$ and the temperature would be 412 K in this case which is too hot for life to develop.

6.2. Neutron stars

Qadir and Mufti, 1980 tested the LNH and MCM on Neutron stars by using the following assumption: MCM requires an increase of the mass proportional to the mass and square of the time, one can express the mass of the Neutron stars m_t at time t in terms at the present time m_p as $m_t = m_p\left(t^2/t_p^2\right)$ and the change of the mass of Neutron star with time at t_p can be given as $\left(\frac{dm_t}{dt}\right)_{t=t_p} = \left(\frac{2m_p}{t_p}\right)_{t=t_p}$.

Putting the MCM into the picture Qadir and Mufti found that the total energy loss $\frac{dE_T}{dt}$ is given by $\frac{dE_T}{dt} = -dE_{\rm rad}/dt + 2mc^2/t_p$ where $\frac{dE_{\rm rad}}{dt}$ is the total energy radiated and given by $\frac{dE_{\rm rad}}{dt} = dE_{\rm rot}/dt + \Delta E/dt$, where $\frac{dE_{\rm rot}}{dt} = I\dot{w}w$, where I is the moment of inertia of the neutron star, w its frequency and $\dot{w}$ is the rate of decrease of the frequency and $\Delta E/dt$ is the non-rotational energy that could be radiated. For the observed slowing down of Neutron star the left hand side must be negative therefore we have $\left|\frac{dE_{\rm rad}}{dt}\right| \geqslant 2mc^2/t_p$, to be consistent with $m = t_p(dE_{\rm rad}/dt)2c^2$ for a given amount of radiation energy. The studies of the radiation flux of 20 Neutron stars found 18 of them are incompatible with MCM as the last equation required them to have a mass less than $10^{-5}M_0$.

6.3. Laboratory methods

Laboratory methods proposed to measure $\frac{\dot{G}}{G}$ are of various sorts. Two ways have been suggested measuring $\frac{\dot{G}}{G}$ to an accuracy of about 1×10^{-11} yr^{-1}. One involves a pendulum experiment and other involves the use of spring loaded gravimeter. The object being to obtain $\frac{\dot{G}}{G}$ via intermediate step of estimating secular changes in the value of the local acceleration due to gravity g_E at the earth's surface (Roxburgh, 1976). A continuous creation experiment of Ritter et al. (1978) being carried out at the University of Virginia. Two cylinders of temperature-stable ceramic rotate concentrically in an evacuated region inside an acoustic and magnetic shield. The inner cylinder is magnetically suspended from the outer one which rotates with precise angular velocity $\acute{w}$, mass created in the inner cylinder tends to slow it down. Feedback system employing laser pulse sensing and photon driving keeps the inner cylinder velocity very near to ω. the forward/backward asymmetry needed in these feed back-driving pulse to keep $\acute{w} = \omega$ constitutes the signal. With the two cylinders running synchronously, viscous, magnetic hysteresis and other damping effects are kept near zero (Wesson, 1980).

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التغير في ثابت الجذب العام مع الزمن في إطار فَرَضِيَتِيْ الأرقام الكبيرة وخلق المادة

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ملخص البحث. نقدم في البحث حالة فكرة تغير ثابت الجذب العام مع الزمن، شارحون النظريات والفرضيات الأساسية، والتي تتنبأ بإمكانية تغير ثابت الجذب العام مع الزمن. نقدم عرضاً لاختبارات عدة تجريبية وقياسات متعلقة للتحقق من أن ثابت الجذب العام يتغير مع الزمن.