Cosmic mass and the electromagnetic & strong interactions

U. V. S. Seshavatharam, Honorary faculty
I-SERVE, Alakapuri, Hyderabad-35, AP, India.
E-mail: seshavatharam.uvs@gmail.com

Prof. S. Lakshminarayana
Dept. of Nuclear Physics, Andhra University
Visakhapatnam-03, India
e-mail: insrirama@yahoo.com

Abstract: It seems that quanta of the angular momentum and the strong interaction range - both are connected with the large scale structure of the universe. In the expanding universe ‘quanta’ increases with increasing mass of the universe. By any chance if the noticed empirical relation is found to be true and valid, ‘rate of decrease in fine structure ratio’ is a measure of cosmic rate of expansion. Considering the integral nature of number of protons (of any nucleus), integral nature of ‘hbar’ can be understood.

Keywords: Hubble’s constant; present universe mass, electron rest mass; proton rest mass; reduced planck’s constant; classical force limit; strong interaction range;

1 Introduction

Considering and comparing the ratio of characteristic size of the universe and classical radius of electron with the electromagnetic and gravitational force ratio of electron and proton, Dirac in his large number hypothesis [1,2] suggested that, magnitude of the gravitational constant $G$ inversely varies with the cosmic time. In supporting of this till today no such data is reported [3]. Considering the characteristic mass of the universe, in this paper an attempt is made to understand the mystery of the origin of the integral quantum constant and the strong interaction range.

1.1 Hubble’s law

Hubble’s law is the name for the astronomical observation in physical cosmology that:

1. All objects observed in deep space (interstellar space) are found to have a doppler shift observable relative velocity to Earth, and to each other; and

2. That this doppler-shift-measured velocity, of various galaxies receding from the Earth, is proportional to their distance from the Earth and all other interstellar bodies.

In effect, the space-time volume of the observable universe is expanding and Hubble’s law is the direct physical
The law is often expressed by the equation accurate value for the constant that now bears his name. However, it was first derived from the General Relativity equations by Georges Lemaître and confirmed the existence of that law and determined a more accurate value for the constant that now bears his name. Two years later Edwin Hubble confirmed the existence of that law and determined a more accurate value for the constant that now bears his name. The law is often expressed by the equation

\[ v = H_0 D, \]

with \( H_0 \) the constant of proportionality (the Hubble constant), \( D \) is the galaxy distance and \( v \) is the recession velocity of the galaxy. The SI unit of \( H_0 \) is \( \text{sec}^{-1} \) but it is most frequently quoted in \( \text{Km/s/Mpc} \).

### 1.2 Magnitude of the Hubble’s constant

The value of the Hubble constant \( H_0 \) is estimated by measuring the redshift of distant galaxies [9] and then determining the distances to the same galaxies (by some other method than Hubble’s law). Uncertainties in the physical assumptions used to determine these distances have caused varying estimates of the Hubble constant. For most of the first half of the 20th century the value of \( H_0 \) was estimated to be between 50 and 90 \( \text{Km/s/Mpc} \). The Hubble Key Project [10] used the Hubble Space Telescope to establish the most precise optical determination in May 2001 of \( 72 \pm 8 \text{ Kms}^{-1} \text{Mpc}^{-1} \), consistent with a measurement of \( H_0 \) based upon Sunyaev-Zel’’dovich effect observations of many galaxy clusters having a similar accuracy. The most precise cosmic microwave background radiation determinations were \( 71 \pm 4 \text{ Kms}^{-1} \text{Mpc}^{-1} \), by WMAP in 2003, and \( 70.4^{+1.5}_{-1.4} \text{ Kms}^{-1} \text{Mpc}^{-1} \), for measurements up to 2006. The five year release from WMAP in 2008 found \( 71.0^{+2.6}_{-2.7} \text{ Kms}^{-1} \text{Mpc}^{-1} \), using WMAP-only data and \( 70.1 \pm 1.3 \text{ Kms}^{-1} \text{Mpc}^{-1} \) when data from other studies were incorporated, while the seven year release in 2010 found \( 71.0 \pm 2.5 \text{ Kms}^{-1} \text{Mpc}^{-1} \) using WMAP-only data and \( 70.4^{+1.3}_{-1.4} \text{ Kms}^{-1} \text{Mpc}^{-1} \) when data from other studies were incorporated [11]. Thus in this paper it is taken as \( H_0 \approx 70.4 \text{ Kms}^{-1} \text{Mpc}^{-1} \).

### 1.3 Physical constants and their fundamental ratios

Characteristic size of the universe is

\[ R_0 \approx \frac{c}{H_0} \approx 1.314147 \times 10^{26} \text{ m} \]

Classical radius of electron of mass \( m_e \) is

\[ R_e \approx \frac{e^2}{4\pi\varepsilon_0 G m_e c^2} \approx 2.8794 \times 10^{-15} \text{ m} \]

Ratios of \( R_0 \) and \( R_e \) is

\[ X_1 \approx \frac{R_0}{R_e} \approx \frac{4\pi\varepsilon_0 G m_e c^3}{e^2 H_0} \approx 4.6635 \times 10^{40} \]

Electromagnetic and gravitational force ratio of electron of mass \( m_e \) and proton of mass \( m_p \) is

\[ X_2 \approx \frac{e^2}{4\pi\varepsilon_0 G m_p m_e} \approx 2.26867 \times 10^{39} \]

Ratio of \( X_1 \) and \( X_2 \) is

\[ \frac{X_1}{X_2} \approx \frac{4.6635 \times 10^{40}}{2.26867 \times 10^{39}} \approx 20.5561 \]

### 1.4 Characteristic mass of the present universe

Let the cosmic closure density is,

\[ \rho_0 \approx \frac{3 H_0^2}{8\pi G} \]

Volume of the universe in a Euclidean sphere of radius \( \left( \frac{c}{H_0} \right) \) is equal to

\[ v_0 \approx \frac{4\pi}{3} \left( \frac{c}{H_0} \right)^3 \]

Mass of the universe in a Euclidean sphere is

\[ M_0 \approx \rho_0 \cdot v_0 \approx \frac{c^3}{2 G H_0} \approx 8.84811 \times 10^{52} \text{ Kg} \]

If \( m_n \) is the mass of nucleon, number of nucleons in a Euclidean volume of size \( \left( \frac{c}{H_0} \right) \) is

\[ X_3 \approx \frac{M_0}{m_n} \approx \frac{c^3}{2 G H_0 m_n} \approx 5.286322 \times 10^{79} \]

From these ratios it is noticed that,

\[ X_1 \approx \sqrt{X_3} \approx X_2 \]

J. V. Narlikar says [12]: Reactions among physicists have varied as to the significance of all these numbers. Some dismiss it as a coincidence with the rejoinder ‘So what’? Others have read deep significance into these relations. The later class includes such distinguished physicists as A. S. Eddington and P. A. M. Dirac.

Dirac pointed out in 1937 that the relationships (3) to (11) contain the Hubble constant \( H_0 \) and therefore
the magnitudes computed in these formulae vary with the epoch in the standard Friedmann model. Finally Dirac made a distinction between $c$, $m_e$, and $m_p$ on one side and $G$ on the other in the sense that the former are atomic quantities where as $G$ has macroscopic significance. In the Machian cosmologies, $G$ is in fact related to the large scale structure of the universe. Dirac therefore assumed that, if we use ‘atomic units’ that always maintain fixed values for atomic quantities, then $G$ varies with cosmic time $t$ as $G \propto t^{-1}$.

2 The reduced Planck’s constant - strange coincidence

David Gross [13] says: After sometime in the late 1920s Einstein became more and more isolated from the mainstream of fundamental physics. To a large extent this was due to his attitude towards quantum mechanics, the field to which he had made so many revolutionary contributions. Einstein, who understood better than most the implications of the emerging interpretations of quantum mechanics, could never accept it as a final theory of physics. He had no doubt that it worked, that it was a successful interim theory of physics, but he was convinced that it would be eventually replaced by a deeper, deterministic theory. His main hope in this regard seems to have been the hope that by demanding singularity free solutions of the nonlinear equations of general relativity one would get an overdetermined system of equations that would lead to quantization conditions. These words clearly suggest that, at fundamental level there exists some interconnection in between quantum mechanics and gravity [14]. Empirically it is noticed that

$$h \cong \frac{Gm_p \sqrt{M_0m_e}}{c} \cong 1.057185 \times 10^{-34} \text{ joule.sec}$$

(12)

where $M_0$ is the characteristic mass of the present universe. This is a striking, astounding and accurate coincidence! This is a multi-purpose expression also. Any value of the atomic constant can be estimated with this expression. Writing this in a ratio form,

$$X_4 \cong \frac{hc}{Gm_p \sqrt{M_0m_e}} \cong 1$$

(13)

How to interpret this ratio? Compared to the above ratios $X_1, X_2$, and $X_3$ this ratio is close to unity. Giving a primary significance to the existence of $m_e, m_p$, & $c$, and considering the Machian concept of the distance cosmic back ground [15,16], $h$ can be considered as the compound physical constant. From the atomic structure point of view also this idea can be strengthened. If electron is revolving round the nucleus, naturally $m_p$ and $m_e$ both are the characteristic physical inputs. If so in the expanding universe ‘quanta’ increases with increasing mass of the universe. Any how this is a very sensitive problem.

Considering the ‘integral nature’ of number of protons (of any nucleus), integral nature of $n \cdot h$ can be understood. Considering any two successive integers $n$ and $n + 1$, their geometric state can be expressed as $\sqrt{n(n + 1)} \cdot h$. If this logic is true, it can be suggested that $h$ is a compound physical constant and is connected with the large scale structure of the universe. The cosmological fine structure ratio can be given as

$$\alpha \cong \frac{e^2}{4\pi \varepsilon_0 Gm_p \sqrt{m_em_p} M_0}$$

(14)

It is the strength of electromagnetic interaction and is an intrinsic property of nature. Several different types of astrophysical observations [17,18], have established the evidence that the expansion of the universe entered a phase of acceleration. Cosmic acceleration and dark energy constitute one of the most important and challenging of current problems in cosmology and other areas of physics. By any chance if the noticed empirical relation (12) is found to be true and valid, and if universe is really accelerating and its mass is increasing, then ‘rate of increase in $h$’ or ‘rate of decrease in $\alpha$’ will be a measure of cosmic rate of expansion[19,20]. With reference to relation (12), magnitude of the Hubble’s constant can be fitted as

$$H_0 \cong \frac{Gm_p^2m_em_e}{2\hbar^2} \cong 70.74955 \text{ Km/sec/Mpc}$$

(15)

In hydrogen atom, potential energy of electron in Bohr radius [21,22] can be expressed as

$$E_p = - \frac{e^2}{4\pi \varepsilon_0 Gm_p M_0} \times \frac{e^2 c^2}{4\pi \varepsilon_0 Gm_p}$$

(16)

Total energy of electron in Bohr radius can be expressed as

$$E_p = - \frac{e^2}{4\pi \varepsilon_0 Gm_p M_0} \times \frac{e^2 c^2}{8\pi \varepsilon_0 Gm_p}$$

(17)

Considering the integral nature of number of protons (of any nucleus), above relation can be expressed as

$$E_T = - \frac{e^2}{4\pi \varepsilon_0 G(n \cdot m_p) M_0} \times \frac{e^2 c^2}{8\pi \varepsilon_0 G(n \cdot m_p)}$$

(18)

where $n = 1, 2, 3, ..$. Thus in a discrete form this relation can be expressed as

$$E_T = - \frac{1}{n^2} \frac{e^2}{4\pi \varepsilon_0 Gm_p M_0} \times \frac{e^2 c^2}{8\pi \varepsilon_0 Gm_p}$$

(19)

To move further and to know the mystery of origin of $h$, in this paper an attempt is made to search for the other such coincidences.
2.1 Alternative to the Planck scale

If $\hbar$ is a cosmic variable, then what about the validity of ‘Planck mass’ and ‘Planck scale’? Answer is very simple. $\sqrt{\frac{\hbar}{2\pi}}$ can be replaced with $\sqrt{\frac{\hbar}{2\times4\pi\varepsilon_0G}}$. It can be called as ‘Coulomb mass’. Its corresponding rest energy is $\sqrt{\frac{e^2c^4}{4\pi\varepsilon_0G}}$. It can be called as the ‘Coulomb energy’. Planck energy can be replaced with the ‘Coulomb energy’.

$$M_C \cong \sqrt{\frac{e^2}{4\pi\varepsilon_0G}} \cong 1.859211 \times 10^{-9} \text{ Kg} \quad (20)$$

$$M_Cc^2 \cong \sqrt{\frac{e^2c^4}{4\pi\varepsilon_0G}} \cong 1.042941 \times 10^{18} \text{ GeV} \quad (21)$$

Coulomb size can be expressed as

$$R_C \cong \sqrt{\frac{e^2G}{4\pi\varepsilon_0c^3}} \cong 1.38068 \times 10^{-36} \text{ m} \quad (22)$$

Clearly speaking $e$, $c$ and $G$ play a vital role in fundamental physics. With these 3 constants space-time curvature concepts at a charged particle surface can be studied.

3 Classical limits of force and power

Special theory of relativity says that light speed is the maximum speed that a material particle can move with. It is the natural speed with which photon or electromagnetic signal travels in free space. Till today there is no explanation for this characteristic speed limit. Throughout the cosmic evolution whether the speed limit is constant or changing? is also an answer-less question. It is an accepted and universal idea that ‘gravity’ and ‘gravitational radiation’ also propagates with speed of light.

Here it is very important to note that physics works on physical constants and runs on mathematical equations. The combination of the observed and well believed physical constants play a vital role in understanding many physical phenomena. Their combination generates some special and strange constants which are natural, unbelievable and unmeasurable. The formation of black holes, coulomb mass etc can be understood with those fundamental and compound physical constants.

3.1 Expressions for the fundamental force and power

One such fundamental and unbelievable compound physical constant is $\frac{e^4}{c^7}$ where $c$ is the speed of light and $G$ is the gravitational constant. The more surprising and strange thing is that its dimensions are identical to the dimensions of ‘force’. Its magnitude is $1.21 \times 10^{44}$ newton. This is a very big magnitude and can not be measured in laboratory experiments. The most unfortunate thing is that it appears in general theory of relativity in inverse form as $\frac{G\varepsilon_0}{c^7}$. It connects the gravitational and non-gravitational forces. Whether to consider it or discard it - it depends only on our personal and scientific interest. It represents the maximum ‘gravitational force of attraction’ and maximum ‘electromagnetic force’. It can be considered as the maximum ‘string tension’.

Another fundamental and unbelievable compound physical constant is $\frac{e^4}{c^7}$. The more surprising and strange thing is that its dimensions are identical to the dimensions of ‘power’. Its magnitude is $3.63 \times 10^{42}$ joule/sec. This is also a very big magnitude and can not be measured in laboratory experiments. Whether to consider it or discard it - it depends only on our personal and scientific interest. Combining them with some of the classical and quantum laws of physics, some miracles can be done.

3.2 Deduction of the fundamental force $\frac{e^4}{G}$

In Sun-Planet system, from Newton’s law of gravitation,

$$F_g = \frac{GM_Sm_P}{r^2} \quad (23)$$

Here, $M_S =$ mass of sun, $m_P =$mass of planet and $r =$ distance between them. Centripetal force on planet is,

$$F_c = \frac{m_Pv^2}{r} \quad (24)$$

where, $v =$ orbiting velocity of planet. Eliminating $r$ from equation (23), force of attraction between sun-planet can be given as,

$$F = \left( \frac{m_P}{M_S} \right) \left( \frac{v^4}{G} \right) \quad (25)$$

It is very clear that, since $(m_P/M_S)$ is a ratio, $(v^4/G)$ must have the dimensions of ‘force’. Following the ‘constancy of speed of light’, a force of the form, $(e^4/G)$ can be constructed. This can be considered as the upper limit or magnitude of any force. Nature of the force may be mechanical or electromagnetic or gravitational. Note that in GTR this force appears in an inverse form [12] as

$$\frac{1}{F} = 8\pi G \frac{c^4}{e^4} \quad (26)$$

Considering this magnitude as the upper limit of gravitational force of attraction, minimum distance between any 2 massive bodies can be obtained as follows. Let,

$$\frac{Gm_1m_2}{r^2} \leq \frac{e^4}{G} \quad (27)$$
Here, \( m_1 \) and \( m_2 \) are any 2 massive bodies and \( r \) is distance between them. Then minimum distance between the 2 bodies can be obtained as

\[
r_{\text{min}} = \frac{Gm_1m_2}{c^2} \quad (28)
\]

This is a simple and very strange expression. By any chance if mass of the 2 bodies is equal then

\[
r_{\text{min}} = \frac{Gm}{c^2} \quad (29)
\]

Without going deep into general theory of relativity and combining Newton’s law of gravitation and Special theory of relativity, results of GTR can be obtained. This idea can be applied to elementary particles also. Magnitude of force of attraction or repulsion between any 2 elementary particles having charges \( e_1 \) and \( e_2 \) can be expressed as

\[
F = \frac{e_1e_2}{4\pi\varepsilon_0r^2} \leq \frac{e^4}{G} \quad (30)
\]

Minimum distance between \( e_1 \) and \( e_2 \) can be obtained as

\[
r_{\text{min}} = \sqrt{\frac{e_1e_2}{4\pi\varepsilon_0} \left( \frac{G}{c^4} \right)} = \sqrt{\frac{e^2}{4\pi\varepsilon_0} \left( \frac{G}{c^4} \right)} \quad (31)
\]

where \( e_1 = e_2 = e \).

Charged particle’s space-time curvature can be understood from this expression. With this idea GTR can be applied to charged elementary particles easily. Not only that this method simply and directly leads to Coulomb scale and grand unification or TOE. With a suitable proportionality ratio or scaling factor quark confinement can be understood as a charged space-time curvature. Characteristic potential energy near to a charge \( e \) corresponding to \( r_{\text{min}} \) can be expressed as

\[
E_p \approx \frac{e^2}{4\pi\varepsilon_0r_{\text{min}}} \approx \sqrt{\frac{e^2}{4\pi\varepsilon_0} \left( \frac{e^4}{G} \right)} \quad (32)
\]

3.3 The strong interaction range

From equation (28), considering the electron and the universe as the two point particles, their minimum distance can be expressed as

\[
d_e = \frac{G\sqrt{m_em_0}}{c^2} \approx 0.2108 \text{ fm} \quad (33)
\]

Considering the proton and the universe as the two point particles, their minimum distance can be expressed as

\[
d_p = \frac{G\sqrt{m_pm_0}}{c^2} \approx 9.034 \text{ fm} \quad (34)
\]

Surprisingly it is noticed that, geometric mean of \( d_e \) and \( d_p \) is close to the strong interaction range 1.4 fm [22,23,24].

\[
R_s \approx \sqrt{d_ed_p} \approx \frac{G\sqrt{M_0\sqrt{m_pm_e}}}{c^2} \approx 1.38 \text{ fm} \quad (35)
\]

where \( R_s \) is the strong interaction range. In a ratio form it can be expressed as

\[
X_5 \approx \frac{\sqrt{d_ed_p}}{R_s} \approx \frac{G\sqrt{M_0\sqrt{m_pm_e}}}{c^2R_s} \approx 1 \quad (36)
\]

Qualitatively and quantitatively it is clear that \( \frac{GM}{c^2} \) represents the characteristic radius of a black hole where gravity is very strong. Relation (36) is having a peculiar meaning and seems to connected with the large scale structure of the universe. This is another significance of the characteristic mass of the universe. This idea may be given a chance.

4 Conclusion

Large dimensionless constants and compound physical constants reflects an intrinsic property of nature. Whether to consider them or discard them depends on physical interpretations, experiments and observations. By any chance if the noticed empirical relation (12) is found to be true and valid, and if universe is really accelerating and its mass is increasing, then ‘rate of increase in \( h \)’ or ‘rate of decrease in \( \alpha \)’ will be a measure of cosmic rate of expansion. The mystery can be resolved with further research and analysis.

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