

Quantum gravitational applications of nuclear, atomic and astrophysical phenomena

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Abstract

By following the old concept of “gravity is having a strong coupling at nuclear scale” and considering the ‘reduced Planck’s constant’ as a characteristic quantum gravitational constant, in this letter we suggest that: 1) There exists a gravitational constant associated with strong interaction, $G_s \sim 3.328 \times 10^{28} \text{ m}^3/\text{kg}/\text{sec}^2$. 2) There also exists a gravitational constant associated with electromagnetic interaction, $G_e \sim 2.376 \times 10^{37} \text{ m}^3/\text{kg}/\text{sec}^2$. Based on these two assumptions, in a quantum gravitational approach, an attempt is made to understand the basics of final unification with various semi empirical applications like melting points of elementary particles, strong coupling constant, proton-electron mass ratio, proton-neutron stability, nuclear binding energy, neutron star’s mass and radius, Newtonian gravitational constant, Avogadro number and molar mass unit. With further research and investigation, a practical model of ‘quantum gravitational string theory’ can be developed.

Keywords: Quantum Gravity; Strong Interaction; Electromagnetic Interaction; Newtonian Gravitational Constant, Schwarzschild Interaction Strength, Neutron Star, Avogadro number and Molar Mass Unit.

1. Introduction

Even though ‘String theory’ and ‘Quantum gravity’ models [1], [2] are having a strong mathematical back ground and sound physical basis, both the models are failing in understanding the role of the Newtonian gravitational constant [3-8] in atomic and nuclear physics and thus seem to fail in developing a ‘workable’ model of final unification.

According to W. Lerche: “The most dramatic extension of the Standard Model of particle physics that has been proposed so far is string theory. However, as we will discuss in more detail below, string theory too does not provide very concrete answers to the questions posed above. But what string theory does is to provide a resolution of conceptual problems that are on a far deeper level than these “practical” problems. One of the most important problems in modern theoretical physics is the apparent mutual incompatibility of quantum mechanics and general relativity (the theory of gravity) – one theory describing well the world at very short, the other at long distances. Certainly a truly satisfying unified theory should incorporate the gravitational interaction as well, even though traditionally it is not considered as belonging to particle physics”.

According to Juan M. Maldacena: “We now have a theory, called string theory (or M-theory), which has been able already to provide a solution to the first two challenges. Unfortunately, we do not know yet how to solve the third challenge. May be string theory is the solution and we just have to understand it better or maybe we have to modify it in some way. String theory is a theory under construction. We know several limits and aspects of the theory, but we still do not know the fundamental axioms of the theory that

would enable us to approach the third challenge” (To Explain the Big Bang and the parameters of the Standard Model).

According to Roberto Onofrio [9], [10], weak interactions are peculiar manifestations of quantum gravity at the Fermi scale, and that the Fermi coupling constant is related to the Newtonian constant of gravitation. In his opinion, at atto-meter scale, Newtonian gravitational constant seems to reach a magnitude of $8.205 \times 10^{22} \text{ m}^3/\text{kg}^{-1}\text{sec}^{-2}$. In this context; one can see plenty of papers on ‘strong gravity’ in physics literature [12-28]. It may be noted that, till date, ‘strong gravity’ is a non-mainstream theoretical approach to Color confinement/particle confinement having both a cosmological scale and a particle scale gravity. In between ~ (1960 to 2000), it was taken up as an alternative to the then young QCD theory by several theorists, including Abdus Salam. Very interesting point to be noted is that, Abdus Salam showed that the ‘particle level gravity approach’ can produce confinement and asymptotic freedom while not requiring a force behavior differing from an inverse-square law, as does QCD.

In pursuit of bridging the gap in between ‘General theory of relativity’ and ‘Quantum field theory’ - in the earlier publications [29-37], the authors proposed three basic assumptions. The authors strongly encourage the readers to go through the above cited references. It may be noted that, in the earlier publications, the authors suggested and validated the role of two gravitational constants associated with strong and electromagnetic interactions. In an integrated approach the authors also showed that, ‘quantum of angular momentum’ is a characteristic result of the combined effects of gravitational constants associated with proton and electron. In this letter the authors compiled important characteristic relations for good understanding, better accuracy and best present-

tation. Each relation seems to have its own characteristic inner meaning.

2. Two basic assumptions of final unification

In the earlier publications [29-37] the authors proposed and established the following two assumptions. For detailed information readers are strongly encouraged to see the references.

Assumption-1: Magnitude of the gravitational constant associated with the electromagnetic interaction is,

$$G_e \approx 2.376 \times 10^{37} \text{ m}^3 \text{kg}^{-1} \text{sec}^{-2}.$$

Assumption-2: Magnitude of the gravitational constant associated with the strong interaction is,

$$G_s \approx 3.328 \times 10^{28} \text{ m}^3 \text{kg}^{-1} \text{sec}^{-2}.$$

Note: It may be noted that, with reference to the operating force magnitudes, protons and electrons cannot be considered as 'black holes'. But electrons and protons can be assumed to follow the relations that black holes generally believed to follow. Clearly speaking, in the study of black holes, Newtonian gravitational constant G_N plays a major role, whereas in the study of elementary particles, G_s and G_e play the key role. For detailed information, see the following sub section.

2.1. Key points to be noted

- 1) If it is true that c and G_N are fundamental physical constants, then (c^4/G_N) can be considered as a fundamental compound constant related to a characteristic limiting force [38-41].
- 2) Black holes are the ultimate state of matter's geometric structure.
- 3) Magnitude of the operating force at the black hole surface is of the order of (c^4/G_N) .
- 4) Gravitational interaction taking place at black holes can be called as 'Schwarzschild interaction'.
- 5) Strength of 'Schwarzschild interaction' can be assumed to be unity.
- 6) Strength of any other interaction can be defined as the ratio of operating force magnitude and the classical or astrophysical force magnitude (c^4/G_N) .
- 7) If one is willing to represent the magnitude of the operating force as a fraction of (c^4/G_N) i.e. X times of (c^4/G_N) , where $X \ll 1$, then

$$\frac{X \text{ times of } (c^4/G_N)}{(c^4/G_N)} \cong X \rightarrow \text{Effective } G \Rightarrow \frac{G_N}{X} \quad (1)$$

If X is very small, $\frac{1}{X}$ becomes very large. In this way, X can be called as the strength of interaction. Clearly speaking, strength of any interaction is $\frac{1}{X}$ times less than the 'Schwarzschild interaction' and effective G becomes $\frac{G}{X}$.

- 8) With reference to Schwarzschild interaction, for electromagnetic interaction, $X \approx 2.811 \times 10^{-48}$ and for strong interaction, $X \cong 2.0 \times 10^{-39}$.
- 9) Characteristic operating force corresponding to electromagnetic interaction is $(c^4/G_e) \approx 3.4 \times 10^{-4} \text{ N}$ and characteristic operating force corresponding to strong interaction is $(c^4/G_s) \approx 242600 \text{ N}$.
- 10) Characteristic operating power corresponding to electromagnetic interaction is $(c^5/G_e) \approx 101920 \text{ J/sec}$ and characteristic operating power corresponding to strong interaction is $(c^5/G_s) \approx 7.27 \times 10^{13} \text{ J/sec}$.
- 11) Based on these concepts, it is possible to assume that,

$$\frac{(m_e c^2)^{\frac{3}{2}} (m_p c^2)^{\frac{1}{2}}}{\sqrt{(c^4/G_e)(c^4/G_s)}} \cong \hbar c \quad (2)$$

$$\frac{(m_e c^2)^{\frac{3}{2}} (m_p c^2)^{\frac{1}{2}}}{\sqrt{(c^5/G_e)(c^5/G_s)}} \cong \hbar \quad (3)$$

- 12) As $\left[(c^4/G_e), (c^4/G_s) \right] \ll (c^4/G_N)$ and $\left[(c^5/G_e), (c^5/G_s) \right] \ll (c^5/G_N)$, protons and electrons cannot be considered as 'black holes', but may be assumed to follow similar relations that black holes generally believed to follow.
- 13) According to S.W. Hawking [42], temperature of black hole takes the following expression.

$$T_B \cong \frac{\hbar c^3}{8\pi G_N k_B M_B} \quad (4)$$

Where M_B and T_B represent the mass and temperature of a black hole respectively.

According to Abhas Mithra [43], [44], currently believed 'black holes' are kind of "Eternally Collapsing Objects". The so-called massive Black Hole Candidates (BHCs) must be quasi-black holes rather than exact black holes and during preceding gravitational collapse, entire mass energy and angular momentum of the collapsing objects must be radiated away before formation of exact mathematical black holes. Abhas Mitra's peer reviewed papers describe why continued physical gravitational collapse should lead to formation of ECOs rather than true black holes, and the mathematical "black hole" states can be achieved only asymptotically. An ECO is essentially a quasi-stable ultra-compact ball of fire (plasma) which is so hot due to preceding gravitational contraction that its outward radiation pressure balances its inward pull of gravity. Some astrophysicists claimed to have verified this prediction that astrophysical Black Hole Candidates are actually ECOs rather than true mathematical black holes. One can find relevant information at http://www.cv.nrao.edu/tuna/past/2006/NEW_QSO_STRUCTURE_FOUND.pdf. By considering these two views and by considering the proposed views, melting temperature of elementary particles can be estimated very easily.

3. Role of the Newtonian gravitational constant in nuclear physics

a) To understand the Proton rest mass

$$m_p \cong \left(\frac{G_N}{G_e} \right)^{\frac{1}{6}} \sqrt{M_{pl} m_e} \quad (5)$$

$$\text{where, } M_{pl} \cong \sqrt{\frac{\hbar c}{G_N}}$$

b) To understand the excited levels of proton

$$m_x \cong \left(\frac{G_N}{G_e} \right)^{\frac{1}{6}} \left(\frac{(n\hbar)cm_e^2}{G_N} \right)^{\frac{1}{4}} \cong (n)^{\frac{1}{4}} \times m_p \quad (6)$$

where, $n = 1, 2, 3, \dots$

$$\text{For, } n = 1, m_x \cong 938.3 \text{ MeV}/c^2$$

$$\text{For, } n = 2, m_x \cong 1115.8 \text{ MeV}/c^2$$

$$\text{For, } n = 3, m_x \cong 1234.8 \text{ MeV}/c^2$$

$$\text{For, } n = 4, m_x \cong 1326.8 \text{ MeV}/c^2$$

$$\text{For, } n = 5, m_x \cong 1403.3 \text{ MeV}/c^2$$

$$\text{For, } n = 6, m_x \cong 1468.5 \text{ MeV}/c^2$$

$$\text{For, } n = 7, m_x \cong 1526.1 \text{ MeV}/c^2$$

$$\text{For, } n = 8, m_x \cong 1578.0 \text{ MeV}/c^2$$

$$\text{For, } n = 9, m_x \cong 1625.2 \text{ MeV}/c^2$$

$$\text{For, } n = 10, m_x \cong 1668.6 \text{ MeV}/c^2$$

These estimated levels assumed to be associated with proton can be compared with currently believed nucleon resonances up to some extent [45]. Extending this idea, other baryonic masses can also be estimated and the authors are working on this.

Based on relation (6), G_N can be estimated with the following relation.

$$G_N \cong \left\{ \left(\frac{m_e}{m_p} \right)^{12} \left(\frac{G_s m_p^2}{\hbar c} \right) \right\} G_s \quad (7)$$

c) To understand the strong coupling constant

$$\alpha_s \cong \left(\frac{G_e}{G_N} \right)^{\frac{1}{6}} \left(\frac{G_s}{G_e} \right) \cong \frac{G_s}{G_N^{1/6} G_e^{5/6}} \quad (8)$$

4. To estimate the gravitational constant assumed to be connected with proton

Nuclear unit charge radius: It can be understood as follows [46], [47]

$$R_0 \cong \frac{2G_s m_p}{c^2} \quad (9)$$

Based on relation (9), G_s can be estimated with the following relation.

$$G_s \cong \frac{c^2 R_0}{2m_p} \quad (10)$$

5. To estimate the gravitational constant assumed to be connected with electron

Ratio of rest mass of proton and electron: It can be understood as follows.

$$\left(\frac{m_p}{m_e} \right) \cong \left(\frac{G_e m_e^2}{\hbar c} \right) \left(\frac{G_s m_p^2}{\hbar c} \right) \quad (11)$$

Thus, based on relation (11), G_e can be estimated with the following relation.

$$G_e \cong \left(\frac{\hbar^2 c^2}{G_s m_e^3 m_p} \right) G_s \cong \frac{2\hbar^2}{m_e^3 R_0} \quad (12)$$

6. To estimate the magnitudes of $(G_s, G_e, G_N, \alpha_s)$

Based on the reference [45]

Let,

$$\left\{ \begin{array}{l} e \cong 1.602 \ 176 \ 565(35) \times 10^{-19} \text{ C,} \\ \epsilon_0 \cong 8.854187817 \times 10^{-19} \text{ F/m} \\ m_n \cong 1.674 \ 927 \ 471(21) \times 10^{-27} \text{ kg,} \\ m_p \cong 1.672 \ 621 \ 777(74) \times 10^{-27} \text{ kg} \\ m_e \cong 9.109 \ 382 \ 91(40) \times 10^{-31} \text{ kg,} \\ \hbar \cong 1.054 \ 571 \ 726(47) \times 10^{-34} \text{ J.sec} \end{array} \right.$$

If $R_0 \cong (1.2384 \text{ to } 1.2388) \text{ fm,}$

$$\left. \begin{array}{l} G_s \cong (3.327167052 \text{ to } 3.328241718) \times 10^{28} \text{ m}^3 \text{kg}^{-1} \text{sec}^{-2} \\ G_e \cong (2.375276497 \text{ to } 2.376043705) \times 10^{37} \text{ m}^3 \text{kg}^{-1} \text{sec}^{-2} \\ G_N \cong (6.670254668 \text{ to } 6.67456314) \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{sec}^{-2} \\ \alpha_s \cong (0.1179231391 \text{ to } 0.117929483) \cong 0.1185 \pm 0.0006 \end{array} \right\}$$

7. Characteristic atomic and nuclear applications

a) Fermi's weak coupling constant: It can be understood as follows [45].

$$F_W \equiv \left(\frac{m_e}{m_p} \right)^2 \hbar c R_0^2 \equiv \frac{4G_s^2 m_e^2 \hbar}{c^3} \quad (13)$$

- b) Root mean square radius of proton: It can be understood as follows [45], [48], [49], and [50].

$$R_p \equiv \frac{\sqrt{2} G_s m_p}{c^2} \quad (14)$$

- c) Bohr radius of electron: It can be understood as follows.

$$a_0 \equiv \left(\frac{4\pi\epsilon_0 G_e m_e^2}{e_e^2} \right) \left(\frac{G_s m_p}{c^2} \right) \quad (15)$$

- d) Proton-neutron beta stability line: It can be understood as follows [51].

$$\left\{ \begin{array}{l} \text{Let,} \\ k \equiv \left(\frac{G_s m_p m_e}{\hbar c} \right) \equiv \left(\frac{\hbar c}{G_e m_e^2} \right) \equiv 1.6 \times 10^{-3} \end{array} \right.$$

$$A_s \equiv 2Z + k (2Z)^2 \quad (16)$$

- e) Nuclear binding energy at stable atomic nuclides: It can be understood as follows [51], [52]

For ($Z \geq 5$),

$$BE \equiv - \left(Z - 2 + \sqrt{\frac{Z}{30}} \right) \sqrt{\left(\frac{3}{5} \frac{e^2}{4\pi\epsilon R} \right) \left(\frac{3}{5} \frac{G_s m^2}{R} \right)} \quad (17)$$

$$\equiv - \left(Z - 2 + \sqrt{\frac{Z}{30}} \right) \times 19.8 \text{ MeV}$$

8. Characteristic sub-nuclear applications

RHIC have tentatively claimed to have created a quark–gluon plasma with an approximate temperature of 4 trillion degree Kelvin [53-56]. A new record breaking temperature was set by ALICE at CERN on August, 2012 in the ranges of 5.5 trillion degree Kelvin. In June 2015, an international team of physicists have produced quark-gluon plasma at the Large Hadron Collider by colliding protons with lead nuclei at high energy inside the super-collider's Compact Muon Solenoid detector at a temperature of 4 trillion degree Kelvin. With reference to the recommended up, down and strange quark masses, estimated geometric mean melting point is 14 trillion degree K and can be compared with the experimental results.

- a) Melting point of proton: It can be understood as follows.

$$T_{proton} \equiv \frac{\hbar c^3}{8\pi k_B (G_s m_p)} \equiv 0.147 \text{ Trillion K} \quad (18)$$

- b) Melting point of electron: It can be understood as follows.

$$T_{electron} \equiv \frac{\hbar c^3}{8\pi k_B (G_e m_e)} \equiv 0.3786 \text{ Million K} \quad (19)$$

These two melting points are for experimental verification.

9. Characteristic astrophysical applications

- a) Mass of neutron star: It can be understood as follows [57-61].

$$\frac{G_N M_N m_n}{\hbar c} \equiv \sqrt{\frac{G_s}{G_N}} \text{ and}$$

$$M_N \equiv \sqrt{\frac{G_s}{G_N}} \left(\frac{\hbar c}{G_N m_n} \right) \quad (20)$$

$$\equiv 3.17 \times \text{Solar mass}$$

where (M_N, m_n) represent masses of neutron star and neutron respectively.

- b) Radius of neutron star: It can be understood as follows.

- c) Let (R_N, R_n) represent the radii of neutron star [62] and neutron [63] respectively.

$$\frac{R_N}{(R_0/2)} \equiv \sqrt{\frac{G_s}{G_N}}$$

$$\rightarrow R_N \equiv \sqrt{\frac{G_s}{G_N}} \left(\frac{R_0}{2} \right) \equiv \sqrt{\frac{G_s}{G_N}} \left(\frac{G_s m_n}{c^2} \right) \equiv 13.8 \text{ km} \quad (21)$$

$$\text{where } R_n \equiv \frac{G_s m_n}{c^2} \equiv 0.62 \text{ fm}$$

10. 'System of units' independent Avogadro number and Molar mass unit

It is noticed that,

$$\sqrt{\frac{G_e}{G_N}} \approx 5.96 \times 10^{23} \quad (22)$$

In this context the authors could publish interesting contributions in Indian DAE-BRNS conference proceedings and International Intradisciplinary Conference on the Frontiers of Crystallography [36]. Even though, this is a semi empirical procedure, Avogadro number seems to be strongly connected with crystal structures as well as unification of fundamental forces. With this unified semi empirical procedure, it is possible to increase the scope and applicability of Avogadro number and with further research, independent of the 'gram mole' concept, absolute procedure for estimating the value of the Avogadro number can be developed. Proceeding further, the currently believed 'gram mole' or 'molar mass unit' [64-67] can be understood in the following way.

If 'atom as a whole' is believed to exhibit electromagnetic behavior, then

$$G_e (m_{atom})^2 \equiv G_N (M_{mole})^2 \quad (23)$$

Where m_{atom} is the unified atomic mass unit and M_{mole} is the molar mass unit or gram mole.

Thus it is very clear to say that, directly and indirectly 'gravity' plays a key role in understanding the molar mass unit.

$$\frac{M_{mole}}{m_{atom}} \equiv \sqrt{\frac{G_e}{G_N}} \approx N_A \quad (24)$$

$$\rightarrow M_{mole} \equiv \sqrt{\frac{G_e}{G_N}} \times m_{atom}$$

Independent of system of units, from this relation it may be possible to explore the physical meaning of the famous ‘Gram mole’ in a unified approach.

11. Discussion

It may be noted that,

- 1) Relations (5), (6), (7) and (22) clearly suggest the possible role of (G_N, G_e) in nuclear and atomic physics.
- 2) Relations (9), (13), (14), (17) and (18) clearly suggest the possible role of G_s in nuclear physics.
- 3) Relations (11) and (15) clearly suggest the combined role of (G_s, G_e) in nuclear and atomic physics.
- 4) Relations (16) clearly suggest the possible role of (G_s, G_e) in understanding the proton-neutron stability.
- 5) Relations (20) and (21) clearly suggest the possible combined role of (G_s, G_N) in astrophysics.
- 6) Relations (19) clearly suggests the possible role of G_e in sub-nuclear physics.
- 7) Relations (22) to (24) clearly suggest the possible role of (G_e, G_N) in understanding atomic mass and molar mass unit in a unified approach independent of system of and units.

The authors would like to stress the fact that, with currently believed unified (main stream) physics models it is impossible to discover/fit/derive such relations. If one is willing to consider this fact as a real inadequacy of current unified physics models, the proposed two gravitational constants can be recommended for in-depth study at fundamental level. From unification point of view, one can find many critical reviews on the foundations, predictions, current status and success of string theory in physics literature [68-71].

Reiner Hedrich says [71]: “String theory is at the moment the only advanced approach to a unification of all interactions, including gravity. But, in spite of the more than thirty years of its existence, it does not make any empirically testable predictions, and it is completely unknown which physically interpretable principles could form the basis of string theory. At the moment, “string theory” is no theory at all, but rather a labyrinthic structure of mathematical procedures and intuitions. The only motivations for string theory consist in the mutual incompatibility of the standard model of quantum field theory and of general relativity as well as in the metaphysics of the unification program of physics, aimed at a final unified theory of all interactions, including gravity”.

Edward Witten says [72]: “Even though we do not really understand it, quantum gravity is supposed to be some sort of theory in which, at least from a macroscopic point of view, we average, in a quantum mechanical sense, over all possible space-time geometries. (We do not know to what extent this description is valid microscopically).”

In this context, it is very clear to say that, when a well believed theoretical model is failing in addressing the basic and practical problems connected with unification of general theory of relativity and quantum mechanics, first of all, it must be reviewed at fundamental level to have a well defined set of physical quantities and physical constants to proceed further for testable predictions at observable energy scales associated with elementary particles physics and astrophysics.

12. Conclusion

Proposed relations (5 to 24) clearly demonstrate the role of proposed gravitational constants assumed to be associated with proton and electron. At first sight, their physical existence appears to be ad-hoc, but by seeing the applications one may be forced to say that, there is ‘some new physics’ behind their assumed ‘presence’.

Along with the proposed assumptions, key points and semi empirical relations, if one is willing to recall the old concepts which broadly falls in the category of ‘strong gravity’ as suggested by Abdus Salam, C.Civaram, K.P.Sinha, E.Recami, K. Tennakone, Usha Raut, V. De Sabbatta and Roberto Onofrio, everyone will be forced to consider the above relations for in-depth analysis at fundamental level.

Proceeding further, if one is willing to explore the possibility of incorporating the proposed assumptions either in String theory models or in Quantum gravity models, certainly, back ground physics assumed to be connected with proposed semi empirical relations can be understood and a ‘practical’ model of “everything” can be developed.

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