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To Understand the Four Cosmological Interactions

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Abstract Within the expanding cosmic Hubble volume, Hubble length can be considered as the gravitational or electromagnetic interaction range. Product of 'Hubble volume' and 'cosmic critical density' can be called as the "Hubble mass". The three key assumptions are: 1) within the Hubble volume, each and every point in free space is influenced by the Hubble mass, 2) 'molar electron mass' can be considered as the rest mass of a new heavy charged elementary particle and 3) atomic gravitational constant seems to be Avogadro number times the classical gravitational constant. This is a new approach and may be given a chance in understanding the four fundamental cosmological interactions.

Keywords Hubble Volume, Critical Density, Hubble Mass, Coulomb Mass, Molar Electron Mass, Atomic Gravitational Constant and the CMBR Temperature

1. Introduction

"Hubble volume" can be considered as a key tool in cosmology and unification. In this paper an attempt is made to understand the basic unified concepts of the four fundamental cosmological interactions. This is a new approach and particle physics and cosmology can be studied in a cohesive mode.

1.1. Basic Assumptions in Particle Cosmology

With reference to the Mach's principle[1-6] and the Hubble volume, if "Hubble mass" is the product of cosmic critical density and the Hubble volume[7-9], then it can be assumed that,

1) Within the Hubble volume, each and every point in free space is influenced by the Hubble mass.

2) Within the Hubble volume, the Hubble mass plays a vital role in understanding the properties of electromagnetic and nuclear interactions.

3) Within the Hubble volume, Hubble mass plays a key role in understanding the geometry of the universe.

With reference to the Avogadro number[10] and from unification point of view, the utmost fundamental question is: How to understand the origin of "mass" of elementary particles? In this connection it can be assumed that,

1) "Molar electron mass" can be considered as the rest mass of a new heavy charged elementary particle.

2) Atomic gravitational constant is Avogadro number times the classical gravitational constant.

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2. Key Concepts in Particle Cosmology

Concept-1: In atomic and nuclear physics, atomic gravitational constant (G_A) is Avogadro number times the classical gravitational constant (G_C).

$$G_A \cong NG_C \tag{1}$$

This idea may come under the subject classification of "strong gravity" and is not in the main stream physics. K.P. Sinha, C. Sivaram, Abdus Salam, E. Recami and colleagues developed the subject in a unified gravitational approach [11-15]. It is reasonable to say that - since the atomic gravitational constant is N times the classical gravitational constant, atoms are themselves arranged in a systematic manner and generate the "gram mole".

Concept -2: The key conceptual link that connects the gravitational and non-gravitational forces is - the classical force limit

$$F_C \cong \left(\frac{c^4}{G_C}\right) \cong 1.21026\times 10^{44} \text{ newton} \tag{2}$$

It can be considered as the upper limit of the string tension. In its inverse form it appears in Einstein's theory of gravitation[6] as $\frac{8\pi G_C}{c^4}$. It has multiple applications in Black hole physics and Planck scale physics[16]. It has to be measured either from the experiments or from the cosmic and astronomical observations.

Concept -3: Ratio of 'classical force limit (F_C)' and 'weak force magnitude (F_W)' is N^2 where N is a large number close to the Avogadro number.

$$\frac{F_C}{F_W} \cong N^2 \cong \frac{\text{Upper limit of classical force}}{\text{nuclear weak force magnitude}} \tag{3}$$

Thus the proposed weak force magnitude is $F_W \cong \frac{c^4}{N^2 G_C} \cong 3.33715\times10^{-4}$ newton. Considering this F_W, Higgs fermion and boson masses can be fitted. In this connection please see our earlier published papers[17-21] and application-9 of this paper.

Concept-4: In the expanding cosmic Hubble volume, $R_0 \cong (c/H_0)$, can be considered as the gravitational or electromagnetic interaction range.

Concept-5: In the expanding cosmic Hubble volume, characteristic cosmic Hubble mass is the product of the cosmic critical density and the Hubble volume. If the critical density is $\rho_c \cong (3H_0^2/8\pi G)$ and characteristic Hubble radius is $R_0 \cong (c/H_0)$, mass of the cosmic Hubble volume is

$$M_0 \cong \frac{c^3}{2GH_0} \tag{4}$$

Concept-6: There exists a charged heavy massive elementary particle M_X in such a way that, inverse of the fine structure ratio is equal to the natural logarithm of the sum of number of positively and negatively charged M_X in the Hubble volume. If the number of positively charged particles is $\left(\frac{M_0}{M_X}\right)$ and the number of negatively charged particles is also $\left(\frac{M_0}{M_X}\right)$ then

$$\frac{1}{\alpha} \cong \ln\left(\frac{M_0}{M_X}+\frac{M_0}{M_X}\right) \cong \ln\left(\frac{2M_0}{M_X}\right) \tag{5}$$

From experiments $1/\alpha \cong 137.0359997$ and from the current observations[22,23,24], magnitude of the Hubble constant is, $H_0 \cong 70.4^{+1.3}_{-1.4}$ Km/sec/Mpc. Thus

$$M_X \cong e^{-\frac{1}{\alpha}}\left(\frac{c^3}{GH_0}\right) \cong e^{-\frac{1}{\alpha}}\cdot 2M_0 \tag{6}$$

$$\cong (5.32 \text{ to } 5.53)\times10^{-7} \text{ Kg}$$

If $N \cong 6.022141793\times10^{23}$ is the Avogadro number and m_e is the rest mass of electron, surprisingly it is noticed that, $N.m_e \cong 5.485799098\times10^{-7}$ Kg and this is close to the above estimation of M_X. Thus it can be suggested that,

$$\frac{M_X}{m_e} \cong N \tag{7}$$

In this way, Avogadro number can be coupled with the cosmic, atomic and particle physics. Then with reference to $(N.m_e)$, the obtained cosmic Hubble mass is $M_0 \cong 8.957532458\times10^{52}$ Kg and thus the obtained Hubble's constant is $H_0 \cong \frac{c^3}{2GM_0} \cong 69.54$ Km/sec/Mpc. Note that large dimensionless constants and compound physical constants reflect an intrinsic property of nature [25,26]. Whether to consider them or discard them depends on the physical interpretations, logics, experiments, observations and our choice of scientific interest. In most of the critical cases, 'time' only will decide the issue. The mystery can be resolved only with further research, analysis, discussions and encouragement.

Concept -7: For any observable charged particle, there exist two kinds of masses and their mass ratio is 295.0606339. Let this number be γ. First kind of mass seems to be the 'gravitational or observed' mass and the second kind of mass seems to be the 'electromagnetic' mass. This idea can be applied to proton and electron.

This number is obtained in the following way. In the Planck scale, similar to the Planck mass, with reference to the elementary charge, a new mass unit can be constructed in the following way.

$$M_C \cong \sqrt{\frac{e^2}{4\pi\varepsilon_0 G}} \cong 1.859210775\times10^{-9} \text{ Kg} \tag{8}$$

$$M_C c^2 \cong \sqrt{\frac{e^2 c^4}{4\pi\varepsilon_0 G}} \cong 1.042941\times10^{18} \text{ GeV} \tag{9}$$

Here e is the elementary charge. How to interpret this mass unit? Is it a primordial massive charged particle? If two such oppositely charged particles annihilate, a large amount of energy can be released. This may be the root cause of cosmic energy reservoir. Such pairs may be the chief constituents of black holes. In certain time interval with a well defined quantum rules they annihilate and release a large amount of energy in the form of γ photons. In the Hubble volume, with its pair annihilation, "origin of the CMBR" can be understood. Clearly speaking, gravitational and electromagnetic force ratio of M_X is γ^2.

$$\frac{M_X}{M_C} \cong \sqrt{\frac{4\pi\varepsilon_0 G M_X^2}{e^2}} \cong 295.0606338 = \gamma \tag{10}$$

It can be interpreted that, if 5.486×10^{-7} Kg is the observable or gravitational mass of M_X, then M_C is the electromagnetic mass of M_X. With reference to the electron rest mass,

$$\left(\frac{M_X}{m_e}\right)^2 \cong \gamma^2 \cdot \frac{e^2}{4\pi\varepsilon_0 G m_e^2} \cong N^2 \tag{11}$$

Concept-8: If $\hbar$ is the quantum of the gravitational angular momentum, then the electromagnetic quantum can be expressed as $\left(\frac{\hbar}{\gamma}\right)$. Thus the ratio,

$$\left(\frac{\hbar}{\gamma}\right) \div \left(\frac{e^2}{4\pi\varepsilon_0 c}\right) \cong (X_E\alpha)^{-1} \cong \sin\theta_W$$

$$\cong 0.464433353 \tag{12}$$

where $\sin\theta_W$ is very close to the weak mixing angle

Concept-9: In modified quark SUSY[17,18], if Q_f is the mass of quark fermion and Q_b is the mass of quark boson, then

$$\frac{Q_f}{Q_b} \cong \Psi \cong 2.2627062 \tag{13}$$

and $\left(1-\frac{1}{\Psi}\right)Q_f$ represents the effective quark fermion mass. The number Ψ can be fitted with the following empirical relation

$$\Psi^2 \ln\left(1+\sin^2\theta_W\right) \cong 1 \tag{14}$$

With this idea super symmetry can be observed in the low and high energy strong interactions and can also be observed in the electroweak interactions[17,18].

3. To Fit the Rest Masses of Electron, Proton and Neutron

If m_e is the light charged elementary particle and M_X is the heavy charged elementary particle to be detected or observed, it is possible to represent the relation in the following form.

$$\sqrt{m_e M_X} \cong \gamma\sqrt{\frac{e^2}{4\pi\varepsilon_0 G_A}} \tag{15}$$

$$\text{let, } \sqrt{\frac{e^2}{4\pi\varepsilon_0 G_A}} \cong m_c \tag{16}$$

$$m_e \cong \frac{\left(\gamma m_c\right)^2}{M_X} \tag{17}$$

In this way the origin of the electron rest mass can be understood. It is noticed that,

$$\left(m_e^2.\gamma m_c\right)^{\frac{1}{3}} c^2 \cong 4695.8239 \text{ MeV} \tag{18}$$

and is roughly 5 times greater than the nucleon rest energy. If $k = \frac{G_A M_X m_e}{\hbar c} \cong 635.3132$, $k^{\frac{1}{4}} \cong 5.0205$.

An attempt is made to fit the rest masses of proton and neutron in the following way.

$$m_p c^2 \cong \left(\frac{1}{k}\right)^{\frac{1}{4}}\left(m_e^2.\gamma m_c\right)^{\frac{1}{3}} c^2 + \ln\left(\frac{k}{2}\right) m_e c^2$$

$$\cong 938.2738 \text{ MeV} \tag{19}$$

$$m_n c^2 \cong \left(\frac{1}{k}\right)^{\frac{1}{4}}\left(m_e^2.\gamma m_c\right)^{\frac{1}{3}} c^2 + \ln\left(2\pi k\right) m_e c^2$$

$$\cong 939.56713 \text{ MeV} \tag{20}$$

$$\left(m_n - m_p\right)c^2 \cong \left[\ln\left(2\pi k\right) - \ln\left(\frac{k}{2}\right)\right] m_e c^2$$

$$\cong 1.29335 \text{ MeV} \tag{21}$$

In support of these relations an attempt is made to implement the number k in fitting the nuclear binding energy constants and other areas of physics like strong interaction range, potential energy of electron in hydrogen atom, electroweak physics etc.

3.1. To Fit the Nuclear Binding Energy Constants

The semi-empirical mass formula (SEMF) is used to approximate the mass and various other properties of an atomic nucleus[27,28,29]. As the name suggests, it is based partly on theory and partly on empirical measurements. Based on the 'least squares fit', volume energy coefficient is $a_v = 15.78$ MeV, surface energy coefficient is $a_s = 18.34$ MeV, coulombic energy coefficient is $a_c = 0.71$ MeV, asymmetric energy coefficient is a_a = 23.21 MeV and pairing energy coefficient is $a_p = 12$ MeV. The semi empirical mass formula is

$$BE \cong Aa_v - A^{\frac{2}{3}} a_s - \frac{Z(Z-1)}{A^{\frac{1}{3}}} a_c - \frac{(A-2Z)^2}{A} a_a \pm \frac{1}{\sqrt{A}} a_p \tag{22}$$

It is noticed that,

$$a_v + a_s \cong a_a + a_p \cong \frac{3}{2} a_a \cong \frac{m_p c^2}{1+\sqrt{k}} \cong 35.8045 \text{ MeV} \tag{23}$$

Asymmetric energy constant be

$$a_a \cong \frac{2}{3}.\frac{m_p c^2}{1+\sqrt{k}} \cong 23.870 \text{ MeV} \tag{24}$$

Pairing energy constant be

$$a_p \cong \frac{a_a}{2} \cong \frac{1}{3}.\frac{m_p c^2}{1+\sqrt{k}} \cong 11.935 \text{ MeV} \tag{25}$$

Let the maximum nuclear binding energy per nucleon be

$$\left(B_A\right)_{\max} \cong \frac{1}{4}.\frac{m_p c^2}{1+\sqrt{k}} \cong 8.9511 \text{ MeV} \tag{26}$$

Coulombic energy constant be

$$a_c \cong \sqrt{\alpha}.\left(B_A\right)_{\max} \cong 0.7647 \text{ MeV} \tag{27}$$

Table 1. SEMF binding energy with the proposed energy coefficients

Z	A	$(BE)_{cal}$ in MeV	$(BE)_{meas}$ in MeV
26	56	492.18	492.254
28	62	546.67	545.259
34	84	727.78	727.341
50	118	1007.80	1004.950
60	142	1184.55	1185.145
79	197	1556.72	1559.40
82	208	1627.20	1636.44
92	238	1805.71	1801.693

Surface energy constant be

$$a_s \cong 2\left(B_A\right)_{\max}\left(1+\sqrt{\frac{a_c}{a_a}}\right) \cong 19.504 \text{ MeV} \tag{28}$$

Volume energy constant be

$$a_v \cong 2\left(B_A\right)_{\max}\left(1-\sqrt{\frac{a_c}{a_a}}\right) \cong 16.30 \text{ MeV} \tag{29}$$

In table-1 within the range of $(Z=26; A=56)$ to $(Z=92; A=238)$ nuclear binding energy is calculated and compared with the measured binding energy[30]. Column-3 represents the calculated binding energy and column-4 represents the measured binding energy.

3.2. Proton-nucleon Stability Relation

It is noticed that

$$\frac{A_s}{2Z} \cong 1+2Z\left(\frac{a_c}{a_s}\right)^2 \tag{31}$$

where A_s is the stable mass number of Z. This is a direct relation. Assuming the proton number Z, in general, for all atoms, lower stability can be fitted directly with the following relation[27].

$$A_s \cong 2Z\left[1+2Z\left(\frac{a_c}{a_s}\right)^2\right] \cong 2Z+Z^2 * 0.00615 \tag{32}$$

if $Z=21$, $A_s \cong 44.71$; if $Z=29$, $A_s \cong 63.17$; if $Z=47$, $A_s \cong 107.58$; if $Z=53$, $A_s \cong 123.27$ if $Z=60$, $A_s \cong 142.13$; if $Z=79$, $A_s \cong 196.37$; if $Z=83$, $A_s \cong 208.35$; if $Z=92$, $A_s \cong 236.03$;

Stable super heavy elements can be predicted with this relation. In between $Z=30$ to $Z=60$ obtained A_s is lower compared to the actual A_s. It is noticed that, upper stability in light and medium atoms up to $Z \approx 56$ can be fitted with the following relation.

$$A_s \cong 2Z\left[1+2Z\left(\left(\frac{a_c}{a_s}\right)^2+\left(\frac{a_c}{4(B_A)_{\max}}\right)^2\right)\right] \cong 2Z+Z^2 * 0.0080 \tag{33}$$

From this relation for $Z=56$, obtained upper $A_s \cong 137.1$. Note that, for $Z=56$, actual stable $A_s \cong 137 \cong \frac{1}{\alpha}$ where α is the fine structure ratio. This seems to be a nice and interesting coincidence. In between 0.00615 and 0.0080, for light and medium atoms up to $Z \approx 56$ or $A_s \approx 137$, mean stability can be fitted with the following relation.

$$A_s \cong 2Z+Z^2 * 0.00706 \tag{34}$$

Surprisingly it is noticed that, in this relation, $0.0071 \approx \alpha$. Thus up to $Z \cong 56$ or $A_s \approx 137$, mean stability can be expressed as

$$A_s \approx 2Z+\left(Z^2\alpha\right) \tag{35}$$

4. To Fit the Rms Radius of Proton

Let R_p be the rms radius of proton. Define two radii R_1 and R_2 as follows.

$$R_1 \cong \left(\frac{\hbar c}{G_A m_p^2}\right)^2 \frac{2G_C m_p}{c^2} \cong 1.9637\times 10^{-25} \text{ m} \tag{36}$$

$$R_2 \cong \left(\frac{\hbar c}{G_A m_p^2}\right)^3 \frac{2G_C m_p}{c^2} \cong 5.521\times 10^{-11} \text{ m} \tag{37}$$

It is noticed that,

$$R_p \cong \left(R_1 R_2^2\right)^{\frac{1}{3}} \cong 8.4278\times 10^{-16} \text{ m} \tag{38}$$

Thus,

$$R_p \cong \left(\frac{\hbar c}{G_A m_p^2}\right)^{8/3} \frac{2G_C m_p}{c^2} \tag{39}$$

This can be compared with the 2010 CODATA recommended rms radius of proton $0.8775(51)$ fm. Recent work on the spectrum of muonic hydrogen (an exotic atom consisting of a proton and a negative muon) indicates a significantly lower value for the proton charge radius, $R_p \cong 0.84184(67)$ fm and the reason for this discrepancy is not clear. This is 10 times more precise than all the previous determinations[31,32]. Thus from proton rest mass and rms radius,

$$G_A \cong \left(\frac{2G_C m_p}{R_p c^2}\right)^{\frac{3}{8}} \left(\frac{\hbar c}{m_p^2}\right) \tag{40}$$

$$N \cong \left(\frac{2G_C m_p}{R_p c^2}\right)^{\frac{3}{8}} \left(\frac{\hbar c}{G_C m_p^2}\right) \tag{41}$$

Here the most interesting thing is that, R_2 is very close to the Bohr radius of Hydrogen atom. It is very interesting to note that, with R_2 ionic radii of atoms can be fitted very easily as

$$(R)_A \cong A^{1/3}\cdot\left(\frac{R_2}{\sqrt{2}}\right) \cong A^{1/3}\times 3.904\times 10^{-11} \text{ m} \tag{42}$$

where $(R)_A$ is the ionic radius of mass number A. If $A=7, (R)_A \cong 0.0747$ nm, if $A=23, (R)_A \cong 0.111$ nm and if $A=39, (R)_A \cong 0.132$ nm. Their corresponding recommended radii are 0.076 nm, 0.102 nm and 0.138 nm respectively[31,32].

5. To Fit the Characteristic Potential Radius of Nucleus 1.4 fm

It is noticed that, gram mole is a black hole where the operating gravitational constant is (G_A) but not (G_C). That means for the simplest case of gram mole of electrons or gram mole of protons, there exist N number of electrons or N number of protons. Let it follows the concept of Schwarzschild radius. It can be expressed in the following way. Let us define two radii R_3 and R_4 as follows.

$$R_3 \cong \frac{2G_A\left(Nm_e\right)}{c^2} \cong 4.9066\times10^{-10}\text{ m} \tag{43}$$

$$R_4 \cong \frac{2G_A\left(Nm_p\right)}{c^2} \cong 9.009\times10^{-7}\text{ m} \tag{44}$$

$$V_3 \cong \frac{4\pi}{3}R_3^3 \tag{45}$$

$$V_4 \cong \frac{4\pi}{3}R_4^3 \tag{46}$$

For the above two cases, the characteristic mean distance (λ) in between N electrons or in between N protons, can be obtained as

$$\lambda_3 \cong \left(\frac{V_3}{N}\right)^{\frac{1}{3}} \tag{47}$$

$$\lambda_4 \cong \left(\frac{V_4}{N}\right)^{\frac{1}{3}} \tag{48}$$

It is noticed that,

$$\lambda_{34} \cong \left(\lambda_3\lambda_4^2\right)^{\frac{1}{3}} \cong 1.4\times10^{-15}\text{ m} \tag{49}$$

This can be compared with the characteristic alpha scattering experimental radius [31] of nucleus ≈ 1.4 fm. Based on the Yukawa's Pion exchange model nuclear interaction range is 1.4 fm. Thus if $m_\pi^{\pm}$ is the charged pion rest mass,

$$N \cong \left(\frac{3}{32\pi}\right)^{\frac{1}{5}}\left(\frac{\hbar c}{G_C\left(m_p^2m_e\right)^{1/3}m_\pi^{\pm}}\right)^{3/5} \tag{50}$$

6. Applications of the Proposed Assumptions and Concepts

6.1. PART-1: Applications in Particle and Nuclear Physics

6.1.1. Application-1: The Characteristic Nuclear Charge Radius

If $H_0 \cong 69.54$ Km/sec/Mpc, R_s is the characteristic radius of nucleus, it is noticed that,

$$R_s \cong \left(\frac{m_p}{M_X}\right)^2\frac{c}{H_0} \cong 1.2368\times10^{-15}\text{ m} \tag{51}$$

where m_p is the proton rest mass. This can be compared with the characteristic charge radius of the nucleus and the strong interaction range.

6.1.2. Application-2: Scattering Distance between Electron and the Nucleus

If $R_s \cong 1.21$ to 1.22 fm is the minimum scattering distance between electron and the nucleus, it is noticed that,

$$R_s \cong \left(\frac{\hbar c}{G_Am_e^2}\right)^2\cdot\frac{2G_Cm_e}{c^2} \cong 1.21565\times10^{-15}\text{ m} \tag{52}$$

Here M_X is the molar electron mass. Here it is very interesting to consider the role of the Schwarzschild radius of the 'electron mass'.

6.1.3. Aplication-3: To Fit the Charged Lepton Rest Masses

Muon and tau rest masses can be fitted in the following way[33]. Let R_s be the characteristic nuclear unit size. The key relation seems to be

$$\left(\frac{\hbar c}{G_Am_e^2}\right)^2 \cong \frac{R_sc^2}{2G_Cm_e} \tag{53}$$

Considering the ratio of the volumes $\frac{4\pi}{3}R_s^3$ and $\frac{4\pi}{3}\left(\frac{2G_Cm_e}{c^2}\right)^3$, let

$$\ln\left(\frac{R_sc^2}{2G_Cm_e}\right)^3 \cong 289.805 \approx \gamma \tag{54}$$

Now muon and tau masses can be fitted with the following relation[17,18].

$$\left(m_lc^2\right)_x \cong \left[\gamma^3+\left(x^2\gamma\right)^x\sqrt{N}\right]^{\frac{1}{3}}\cdot\frac{m_ec^2}{\gamma} \tag{55}$$

where x = 0,1 and 2. At x = 0, $\left(m_lc^2\right)_0 \cong m_ec^2$. At x = 1, $\left(m_lc^2\right)_1 \cong 105.9$ MeV and can be compared with the rest mass of muon (105.66 MeV). At x = 2, $\left(m_lc^2\right)_2 \cong 1777.4$ MeV and can be compared with the rest mass of tau (1777.0 MeV). x = 0,1 and 2 can be considered as the 3 characteristic vibrating modes.

6.1.4. Aplication-4: Electromagnetic and Strong Interaction Ranges

For electron, starting from $\left(c/H_0\right)$, its characteristic interaction ending range can be expressed as

$$r_{ee} \cong \frac{e^2}{4\pi\varepsilon_0\left(m_e/\gamma\right)c^2} \cong \gamma\frac{e^2}{4\pi\varepsilon_0m_ec^2} \cong 8.315\times10^{-13}\text{ m} \tag{56}$$

Similarly, for proton, its characteristic interaction starting range can be expressed as

$$r_{ss} \cong \frac{e^2}{4\pi\varepsilon_0\left(m_p/\gamma\right)c^2} \cong \gamma\frac{e^2}{4\pi\varepsilon_0m_pc^2} \cong 4.53\times10^{-16}\text{ m} \tag{57}$$

6.1.5. Application-5: Ratio of Electromagnetic and Strong Interaction Ending Range

Ratio of electromagnetic ending interaction range and strong interaction ending range can be expressed as

$$\frac{r_{ee}}{r_{se}} \cong \frac{G_A M_X m_e}{\hbar c} \cong k \cong 635.3131866 \tag{58}$$

Thus if $r_{ee} \cong 8.315\times10^{-13}$ m, $r_{se} \cong 1.309\times10^{-15}$ m,

$$\left(\frac{r_{ee}}{r_{se}}\right)^2 \cong \left(\frac{G_A M_X m_e}{\hbar c}\right)^2 \cong k^2 \tag{59}$$

Interesting observation is

$$\frac{r_{ss}+r_{se}}{2} \cong 0.881\times10^{-15} \text{ m} \tag{60}$$

This can be considered as the mean strong interaction range and is close to the proton rms radius!

6.1.6. Application-6

For any elementary particle of charge e, electromagnetic mass (m/γ) and characteristic radius R, it can be assumed as

$$\frac{e^2}{4\pi\varepsilon_0 R} \cong \frac{1}{2}\left(\frac{m}{\gamma}\right)c^2 \tag{61}$$

This idea can be applied to proton as well as electron. Electron's characteristic radius is

$$R_e \cong 2\gamma \frac{e^2}{4\pi\varepsilon_0 m_e c^2} \cong 1.663\times10^{-12} \text{ m} \tag{62}$$

Similarly proton's characteristic radius is

$$R_p \cong 2\gamma \frac{e^2}{4\pi\varepsilon_0 m_p c^2} \cong 0.906\times10^{-15} \text{ m} \tag{63}$$

6.1.7. Application-7: Potential Energy of Electron in Hydrogen Atom

Let E_p be the potential energy of electron in the Hydrogen atom. It is noticed that,

$$E_p \cong \frac{e^2}{4\pi\varepsilon_0 a_0} \cong \left(\frac{\hbar c}{G_A M_X m_e}\right)\frac{(\hbar/\gamma)c}{\sqrt{R_e R_p}} \cong 27.12493044 \text{ eV} \tag{64}$$

where a_0 is the Bohr radius[34,35]. With 99.6822% this is matching with $\alpha^2 m_e c^2 \cong 27.21138388$ eV. After simplification it takes the following form.

$$E_p \cong \left(\frac{\hbar c}{G_A M_X m_e}\right)^2 \frac{\sqrt{m_p m_e}\,c^2}{2} \cong \alpha^2 m_e c^2 \tag{65}$$

Thus the Bohr radius can be expressed as

$$a_0 \cong \left(\frac{G_A M_X m_e}{\hbar c}\right)^2 \frac{2e^2}{4\pi\varepsilon_0 \sqrt{m_p m_e}\,c^2} \tag{66}$$

Electron's n^{th} orbit radii can be expressed as

$$a_n \cong \left(\frac{G_A M_X m_e}{\hbar c}\right)^2 \frac{2(ne)^2}{4\pi\varepsilon_0 \sqrt{m_p m_e}\,c^2} \cong n^2 \cdot a_0 \tag{67}$$

where a_n is the radius of n^{th} orbit and $n = 1,2,3,..$ Thus in Hydrogen atom, potential energy of electron in n^{th} orbit can be expressed as

$$\frac{e^2}{4\pi\varepsilon_0 a_n} \cong \left(\frac{\hbar c}{G_A M_X m_e}\right)^2 \frac{\sqrt{m_p m_e}\,c^2}{2n^2} \tag{68}$$

Note that, from the atomic theory it is well established that, total number of electrons in a shell of principal quantum number n is $2n^2$. Thus on comparison, it can suggested that, $\left(\frac{\hbar c}{G_A M_X m_e}\right)^2 \sqrt{m_p m_e}\,c^2$ is the potential energy of $2n^2$ electrons and potential energy of one electron is equal to $\left(\frac{\hbar c}{G_A M_X m_e}\right)^2 \frac{\sqrt{m_p m_e}\,c^2}{2n^2}$.

6.1.8. Application-8: Magnetic Moments of the Nucleon

If $(\alpha X_E)^{-1} \cong \sin\theta_W$, magnetic moment of electron can be expressed as[36,37]

$$\mu_e \cong \frac{1}{2}\sin\theta_W \cdot ec \cdot r_{ee} \cong 9.274\times10^{-24} \text{ J/tesla} \tag{69}$$

It can be suggested that electron's magnetic moment is due to the electromagnetic interaction range. Similarly magnetic moment of proton is due to the strong interaction ending range.

$$\mu_p \cong \frac{1}{2}\sin\theta_W \cdot ec \cdot r_{se} \cong 1.46\times10^{-26} \text{ J/tesla} \tag{70}$$

If proton and neutron are the two quantum states of the nucleon, by considering the mean strong interaction range $\left(\frac{r_{ss}+r_{se}}{2}\right)$, magnetic moment of neutron can be fitted as

$$\mu_n \cong \frac{1}{2}\sin\theta_W \cdot ec \cdot \left(\frac{r_{ss}+r_{se}}{2}\right) \cong 9.82\times10^{-27} \text{ J/tesla} \tag{71}$$

6.1.9. Application-9: To Correlate the Charged Higgs Fermion Mass and the Electron Mass

If M_{Hf} is the charged Higgs fermion, it is noticed that,

$$\frac{M_{Hf}}{m_e} \cong \frac{m_e c^2}{F_W R_s} \tag{72}$$

Thus,

$$m_e c^2 \cong \sqrt{M_{Hf} c^2 \cdot F_W R_s} \tag{73}$$

From relation (52),

$$M_{Hf} c^2 \cong \frac{1}{2}\left(\frac{G_A M_X m_e}{\hbar c}\right)^2 m_e c^2 \cong 103125.417 \text{ MeV} \tag{74}$$

If Higgs fermion and Higgs boson mass ratio is 2.2627, then obtained Higgs boson mass is 45576.27 MeV and the most surprising thing is that, Higgs boson pair generates the neutral Z boson of rest energy 91152.53 MeV. Estimated top quark rest energy[17,18] is 182160 MeV and its corresponding boson is 80505.6 MeV. Thus the surprising thing is that, susy boson of the top quark seems to be the electroweak W boson. Another interesting idea is that W boson and Higgs boson generate a neutral boson of mass 126 GeV. It can be suggested that, W boson pair generates a neutral boson of rest energy 161 GeV.

6.2. PART-2 : Applications in Cosmology

6.2.1. Application-10: To fit the Hubble's Constant

Combining the relations (51) and (52) and if $H_0 \cong 69.54$ Km/sec/Mpc, it is noticed that,

$$\frac{\hbar c}{G m_p \sqrt{M_0 m_e}} \cong 0.991415 \tag{75}$$

Surprisingly this ratio is close to unity! How to interpret this ratio? From this relation it can be suggested that, along with the cosmic variable, H_0, in the presently believed atomic and nuclear physical constants, on the cosmological time scale, there exists one variable physical quantity. 'Rate of change' in its magnitude may be a measure of the present cosmic acceleration. Thus independent of the cosmic red shift and CMBR observations, from the atomic and nuclear physics, cosmic acceleration can be verified. Based on the above coincidence, magnitude of the present Hubble's constant can be expressed as

$$H_0 \cong \frac{G m_p^2 m_e c}{2\hbar^2} \cong 70.75 \text{ Km/sec/Mpc} \tag{76}$$

6.2.2. Application-11: Pair Creation of M_c within the Hubble Volume and the CMBR Temperature

Pair particles creation and annihilation is a characteristic phenomena in `free space', and is the basic idea of quantum fluctuations of the vacuum. In the expanding universe, from relation (8) by considering the proposed charged M_C and its pair annihilation as characteristic cosmic phenomena, origin of the isotropic CMB radiation can be addressed. At any time t, it can be suggested that

$$k_B T_t \cong \sqrt{\frac{M_C}{M_t}} \cdot 2 M_C c^2 \tag{77}$$

where M_t is the cosmic mass at time t. Please note that, at present

$$T_t \cong \sqrt{\frac{M_C}{M_0}} \cdot \frac{2M_C c^2}{k_B} \cong 3.52 \ {}^0\text{K} \tag{78}$$

Qualitatively and quantitatively this can be compared with the present CMBR temperature $2.725\ {}^0\text{K}$. But it has to be discussed in depth. It seems to be a direct consequence of the Mach's principle.

6.2.3. Application-12: A Quantitative Approach to Understand the CMBR Radiation

It is noticed that, there exists a very simple relation in between the cosmic critical density, matter density and the thermal energy density. It can be expressed in the following way. At any time t,

$$\left(\frac{\rho_c}{\rho_m}\right)_t \cong \left(\frac{\rho_m}{\rho_T}\right)_t \cong 1 + \ln\left(\frac{M_t}{M_C}\right) \tag{79}$$

where $\rho_c \cong M_t \left[\frac{4\pi}{3}\left(\frac{c}{H_t}\right)^3\right]^{-1} \cong \frac{3H_t^2}{8\pi G}$, ρ_m is the matter density and ρ_T is the thermal energy density expressed in gram/cm^3 or Kg/m^3. Considering the Planck - Coulomb scale, at the beginning if $M_t \cong M_C$

$$\left(\frac{\rho_c}{\rho_m}\right)_C \cong \left(\frac{\rho_m}{\rho_T}\right)_C \cong 1 \tag{80}$$

$$(\rho_c)_C \cong (\rho_m)_C \cong (\rho_T)_C \tag{81}$$

Thus at any time t,

$$\rho_m \cong \sqrt{\rho_c \cdot \rho_T} \tag{82}$$

$$\rho_m \cong \left[1 + \ln\left(\frac{M_t}{M_C}\right)\right]^{-1} \rho_c \tag{83}$$

$$\rho_T \cong \left[1 + \ln\left(\frac{M_t}{M_C}\right)\right]^{-2} \rho_c \cong \left[1 + \ln\left(\frac{M_t}{M_C}\right)\right]^{-1} \rho_m \tag{84}$$

In this way, observed matter density and the thermal energy density can be studied in a unified manner. The observed CMB anisotropy can be related with the inter galactic matter density fluctuations.

6.3. Present Matter Density of the Universe

From (76) at present if $H_0 \cong 70.75$ Km/sec/Mpc,

$$(\rho_m)_0 \cong \left[1 + \ln\left(\frac{M_0}{M_C}\right)\right]^{-1} (\rho_c)_0 \tag{85}$$

$\cong 6.573 \times 10^{-32}$ gram/cm^3 where $(\rho_c)_0 \cong 9.4 \times 10^{-30}$ gram/cm^3 and $\left[1 + \ln\left(\frac{M_0}{M_C}\right)\right] \cong 143.013$. Based on the average mass-to-light ratio for any galaxy[6]

$$(\rho_m)_0 \cong 1.5 \times 10^{-32} \eta h_0 \text{ gram/cm}^3 \tag{86}$$

where for any galaxy, $\left\langle\frac{M_G}{L_G}\right\rangle \cong \eta\left(\frac{M_\odot}{L_\odot}\right)$ and the number $h_0 \cong \frac{H_0}{100 \text{ Km/sec/Mpc}} \cong \frac{70.75}{100} \cong 0.7075$.

Note that elliptical galaxies probably comprise about 60% of the galaxies in the universe and spiral galaxies thought to make up about 20% percent of the galaxies in the universe. Almost 80% of the galaxies are in the form of elliptical and spiral galaxies. For spiral galaxies, $\eta h_0^{-1} \cong 9 \pm 1$ and for elliptical galaxies, $\eta h_0^{-1} \cong 10 \pm 2$. For our galaxy inner part, $\eta h_0^{-1} \cong 6 \pm 2$. Thus the average ηh_0^{-1} is very close to 8 to 9 and its corresponding matter density is close to $(6.0 \text{ to } 6.76) \times 10^{-32}$ gram/cm^3 and can be compared with the above proposed magnitude of 6.573×10^{-32} gram/cm^3.

6.4. Present Thermal Energy Density of the Universe

At present if $H_0 \cong 70.75$ Km/sec/Mpc,

$$\left(\rho_T\right)_0 \cong \left[1+\ln\left(\frac{M_0}{M_C}\right)\right]^{-2}\left(\rho_c\right)_0 \cong 4.6\times10^{-34} \text{ gram/cm}^3 \quad (87)$$

and thus

$$\left(\rho_T c^2\right)_0 \cong \left[1+\ln\left(\frac{M_0}{M_C}\right)\right]^{-2}\left(\rho_c c^2\right)_0 \cong 4.131\times10^{-14} \text{ J/m}^3 \quad (88)$$

At present if

$$\left(\rho_T c^2\right)_0 \cong aT_0^4 \quad (89)$$

where $a \cong 7.56576\times10^{-16}$ $\text{J/m}^3\text{K}^4$ is the radiation energy density constant, then obtained CMBR temperature is, $T_0 \cong 2.718$ ^{0}Kelvin. This is accurately fitting with the observed CMBR temperature[24] , $T_0 \cong 2.725$ ^{0}Kelvin. Thus in this way, the present value of the Hubble's constant and the present CMBR temperature can be co-related with the following trial-error relation.

$$\left[1+\ln\left(\frac{c^3}{2GH_0M_C}\right)\right]^{-1} H_0 \cong \sqrt{\frac{8\pi GaT_0^4}{3c^2}} \quad (90)$$

7. Discussion & Conclusions

String theory or QCD is not in a position to address the basics of cosmic structure[38]. In understanding the basic concepts of unification or theory of every thing, role of dark energy and dark matter is insignificant. Even though string theory was introduced for understanding the basics of strong interaction, its success seems to be a dilemma because of its higher dimensions and the non-coupling of the nuclear and Planck scale. Based on the proposed relations and applications, Hubble volume or Hubble mass, can be considered as a key tool in unification as well as cosmology. From relations (51,52,75), if it is possible to identify the atomic cosmological physical variable, then by observing the rate of change in its magnitude (on the cosmological time scale), the "future" cosmic acceleration can be verified and thus the cosmic geometry can be confirmed from atomic and nuclear physics! Without the advancement of nano-technology or fermi-technology this may not be possible. Not only that, independent of the cosmic red shift and CMBR observations "future" cosmic acceleration can be checked in this new direction.

Considering the proposed relations and concepts it is possible to say that there exists a strong relation between cosmic Hubble mass, Avogadro number and unification..

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