Understanding nuclear binding energy with nucleon mass difference via strong coupling constant and strong nuclear gravity

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Abstract: With reference to electromagnetic interaction and Abdus Salam’s strong (nuclear) gravity, 1) Square root of ‘reciprocal’ of the strong coupling constant can be considered as the strength of nuclear elementary charge. 2) ‘Reciprocal’ of the strong coupling constant can be considered as the maximum strength of nuclear binding energy. 3) In deuteron, strength of nuclear binding energy is around unity and there exists no strong interaction in between neutron and proton. \( G \approx 3.3293665 \times 10^{-28} \text{ m}^2 \text{kg}^3 \text{sec}^{-2} \) being the gravitational constant, nuclear charge radius can be shown to be, \( R_0 \approx 2Gm_p/c^2 \approx 1.2392185 \text{ fm} \). Based on the physical constants. One sample relation is, 

\[
e \approx \left( G m^2 / \hbar c \right) e \approx 4.7203105 \times 10^{-10} \text{ C being the nuclear elementary charge, proton magnetic moment can be shown to be, } \\
\mu_p \approx e \hbar / 2 m_p \approx eG m_p / 2c \approx 1.488055 \times 10^{-26} \text{ J.T}^{-1}.
\]

\[\alpha \approx (\hbar \frac{m_p}{G m^2}) \approx 0.1152072 \text{ being the strong coupling constant, strong interaction range can be shown to be proportional to } \exp(1/\alpha).
\]

Interesting points to be noted are: An increase in the value of \( \alpha \) helps in decreasing the interaction range indicating a more strongly bound nuclear system. A decrease in the value of \( \alpha \) helps in increasing the interaction range indicating a more weakly bound nuclear system. One interesting approximation is \( (m_p/m_e)^{10} \approx \exp(1/\alpha).\) From \( Z \approx 30 \) onwards, close to stable mass numbers, nuclear binding energy can be addressed with, 

\[(B)_{A} \approx Z \times \left[ \frac{1}{(1/\alpha_\pi)} + 1 \right] \left( m_n - m_p \right) c^2 \approx Z \times 19.6 \text{ MeV}.
\]

To improve the accuracy, we tried to understand nuclear binding with two simple terms having a single energy coefficient of \[
\left[ e^2 / 8 \pi \alpha_\pi \left( G m^2 / c^2 \right) \right] \approx 10.06 \text{ MeV}.
\]

With further study, magnitude of the Newtonian gravitational constant can be estimated with nuclear elementary physical constants. One sample relation is, \( (G_e / G) \approx (m_e/m_p)^{10} \left( G m^2 / \hbar c \right) \) where \( G_e \) represents the Newtonian gravitational constant. Electroweak gravitational constant can be expressed as, \( G_e \approx (m_e/m_p)^{10} G_s \). \( G_s \) being the Fermi’s weak coupling constant, we noticed that, \( 2G m_e/c^2 \approx \sqrt{G_e/\hbar c} \) and \( G_e \approx 4G_s \hbar^2/c^2 \). Based on the estimated and recommended values of \( G_s \), estimated average value of \( G_s \approx 6.6147224 \times 10^{-11} \text{ m} \text{kg} \text{sec}^{-2} \). Finally, it is possible to show that, \( R_e \approx (m_e/m_p)^{10} 4G_e \hbar /c^2 \) and \( G_e \approx \sqrt{(G_s)(\hbar/cm^2)} \).

Keywords: strong (nuclear) gravity, nuclear elementary charge, strong coupling constant, nuclear charge radius, beta stability line, nuclear binding energy, nucleon mass difference, Fermi’s weak coupling constant, Newtonian gravitational constant, deuteron, interaction range, super heavy elements.

1. Introduction

Low energy nuclear scientists assume ‘strong interaction’ as a binding neutron interaction associated with binding of protons and neutrons. High-energy nuclear scientists consider nucleons as composite states of quarks and try to understand the nature and strength of strong interaction [1] at sub nuclear level. Very unfortunate thing is that, strong interaction is mostly hidden at low energy scales in the form of ‘residual nuclear force’. At this juncture, one important question to be answered and reviewed at the basic level is: How to understand nuclear...
interactions in terms of sub nuclear interactions? Unfortunately, the famous nuclear models like, Liquid drop model and Fermi's gas model [2-5] are lagging in answering this question. To find a way, we would like to suggest that, by considering ‘square root’ of reciprocal of the strong coupling constant \( a_s \approx 0.1186 \), as an index of strength of nuclear elementary charge, nuclear binding energy and nuclear stability can be understood. In this direction, we have developed interesting concepts and produced many semi empirical relations [6-12]. Even though it is in its budding stage, our model seems to be simple and realistic compared to the new integrated model proposed by N. Ghahramany et al [13,14]. It needs further study at a fundamental level.

2. About Strong (nuclear) gravity

Microscopic physics point of view, one very interesting concept is that- elementary particles can be considered as ‘micro black holes’. ‘Strong (nuclear) gravity’ concept proposed by Abdus Salam, C. Sivaram, K.P. Sinha, K. Tennakone, Roberto Onofrio, O. F. Akinto and Farida Tahir [15-20], seems to be very attractive. The main object of unification is to understand the origin of elementary particles mass, (Dirac) magnetic moments and their forces. Right now and till today ‘string theory’ with 10 dimensions is not in a position to explain the unification of gravitational and non-gravitational forces. More clearly speaking it is not in a position to bring down the Planck scale to the nuclear size. The most desirable cases of any unified description are:

a) To implement gravity in microscopic physics and to estimate the magnitude of the Newtonian gravitational constant \( (G_N) \).

b) To develop a model of microscopic quantum gravity.

c) To simplify the complicated issues of known physics.

d) To predict new effects, arising from a combination of the fields inherent in the unified description.

3. About quantum chromo dynamics (QCD)

The modern theory of strong interaction is quantum chromo dynamics (QCD) [21]. It explores baryons and mesons in broad view with 6 quarks and 8 gluons. According to QCD, the four important properties of strong interaction are: 1) color charge; 2) confinement; 3) asymptotic freedom [22]; 4) short-range nature (<10^{-15} m). Color charge is assumed to be responsible for the strong force to act on quarks via the force carrying agent, gluon. Experimentally it is well established that, strength of strong force depends on the energy through the interaction or the distance between particles. At lower energies or longer distances: a) color charge strength increases; b) strong force becomes ‘stronger’; c) nucleons can be considered as fundamental nuclear particles and quarks seem to be strongly bound within the nucleons leading to ‘Quark confinement’. At high energies or short distances: a) color charge strength decreases; b) strong force gets ‘weaker’; 3) colliding protons generate ‘scattered free quarks leading to ‘Quark Confinement’. Based on these points, low energy nuclear scientists assume ‘strong interaction’ as a strange nuclear interaction associated with binding of nucleons. High-energy nuclear scientists consider nucleons as composite states of quarks and try to understand the nature and strength of strong interaction at sub nuclear level.

4. About the semi empirical mass formula

Let \( A \) be the total number of nucleons, \( Z \) the number of protons and \( N \) the number of neutrons.

According to the semi-empirical mass formula [2,3,4], nuclear binding energy:

\[
B = a_v A - a_s A^{2/3} - a_{v} \left( \frac{Z(Z-1)}{A^{4/3}} \right) - a_{s} \left( \frac{A-2Z}{A} \right) \pm a_{s} \sqrt{A} \tag{1}
\]

Here \( a_v \approx 15.78 \text{ MeV} \) = volume energy coefficient,

\( a_s \approx 18.34 \text{ MeV} \) = surface energy coefficient,

\( a_v \approx 0.71 \text{ MeV} \) = coulomb energy coefficient,

\( a_s \approx 23.21 \text{ MeV} \) = asymmetry energy coefficient

and \( a_{s} \approx 12.0 \text{ MeV} \) = pairing energy coefficient. If we consider the sum of the volume energy, surface energy, coulomb energy, asymmetry energy and pairing energy, then the picture of a nucleus as a drop of incompressible liquid roughly accounts for the observed variation of binding energy of the nucleus.

By maximizing \( B(A,Z) \) with respect to \( Z \), one can find the number of protons \( Z \) of the stable nucleus of atomic weight \( A \) as,
\[ Z \approx \frac{A}{2 + (a_s/2a_s)A^{2/3}} \quad \text{and} \quad A - 2Z \approx \frac{0.4A^2}{A + 200} \quad (2) \]

By substituting the above value of \( Z \) back into \( B \) one obtains the binding energy as a function of the atomic weight, \( B(A) \). Maximizing \( B(A)/A \) with respect to \( A \) gives the nucleus which is most strongly bound or most stable.

5. Three simple assumptions

With reference to our recent paper publications and conference proceedings [6-12], [23-33], we propose the following three assumptions.

1) Nuclear gravitational constant is very large in such a way that,
\[ R_0 \approx \frac{2G_m}{c^2} \quad (3) \]

2) Strong coupling constant can be expressed with,
\[ \alpha_s \approx \left( \frac{\hbar c}{G_m} \right)^2 \quad (4) \]

3) There exists a strong elementary charge in such a way that,
\[ e_s \approx \left( \frac{G_m}{\hbar c} \right) e \approx \frac{e}{\sqrt{\alpha_s}} \quad (5) \]

Note: Considering the relativistic mass of proton, it is possible to show that, \( \alpha_s \approx \left( \frac{1}{m_p} \right)^4 \left[ 1 - \frac{v^2}{c^2} \right] \) where \( v \) can be considered as the speed of proton. Qualitatively, at higher energies, strength of strong interaction seems to decrease with speed of proton.

6. To fix the magnitudes of \((G_s, \alpha_s \text{ and } e_s)\)

Considering neutron, proton and electron rest masses, and based on relation (6), proposed nuclear gravitational constant can be estimated. Based on that, other values can be estimated.

\[ \left\{ \begin{array}{l}
G_s \approx 3.3293665 \times 10^{28} \, \text{m}^3 \text{kg}^{-1} \text{sec}^{-2} \\
R_0 \approx \frac{2G_m}{c^2} \approx 1.2392185 \, \text{fm} \\
\alpha_s \approx 0.1152072 \\
e_s \approx 4.7203105 \times 10^{-19} \, \text{C}
\end{array} \right\} \]

7. New concepts and semi empirical relations

We would like to suggest that,

1) Fine structure ratio can be addressed with,
\[ \alpha \approx \left( \frac{e^2}{4\pi\varepsilon_0 G_m m_p^2} \right) \left( \frac{\hbar c}{G_m m_p^2} \right) \approx 7.29735233 \times 10^{-3} \]

2) Proton magnetic moment can be addressed with,
\[ \mu_p \approx \frac{e^2}{2m_p} \left( \frac{G_m}{m_p^2} \right) \approx 1.488055 \times 10^{-6} \, \text{J.T} \cdot \text{m}^{-1} \]

3) Neutron magnetic moment can be addressed with,
\[ \mu_n \approx \frac{(e - e)\hbar}{2m_e} \approx 9.816235 \times 10^{-9} \, \text{J.T} \cdot \text{m}^{-1} \]

4) Nuclear unit radius can be expressed as,
\[ R_0 \approx \left( \frac{2G_m}{c^2} \right) \left( \frac{e}{e} \right) \left( \frac{\hbar}{m_e c} + \frac{\hbar}{m_e c} \right) \]

5) Root mean square nuclear charge radii \([33]\) can be addressed with,
\[ R(Z,A) \approx \left\{ 1 - 0.349 \left( \frac{N - Z}{N} \right) \right\} \left( Z^{1/3} \right) \times 1.262 \, \text{fm} \]
\[ \approx \left\{ Z^{1/3} + \sqrt{Z(A-Z)} \right\} \left( \frac{G_m}{c^2} \right) \]

6) Nuclear potential energy can be understood with,
\[ \approx \frac{e^2}{4\pi\varepsilon_0 G_m m_e / c^4} \approx 20.17225 \, \text{MeV} \]

7) Close to stable mass numbers, nuclear binding energy can be understood with a single energy coefficient \([30,31]\),
\[ e^2 G_m \approx \frac{e^2}{8\pi\varepsilon_0 \left( m_e / c^4 \right)} \approx 10.086124 \, \text{MeV} \]

8) With reference to \((\hbar / 2)\), a useful quantum energy constant can be expressed with,
\[ E(\hbar / 2) \approx \left( \frac{e^2 G_m}{2\pi\varepsilon_0 (\hbar / 2)^2} \right) \approx 80.6889925 \, \text{MeV} \]

9) Close to magic and semi magic proton numbers \([31]\), nuclear binding energy seems to approach
\[
\left[ 2.531 \left( \frac{n + \frac{1}{2}}{2} \right) \right]^2 \times 10.09 \text{ MeV}
\]
where
\[ n = 0, 1, 2, 3, \ldots \text{ and } \left( m_e - m_p \right) = 2.531. \]

10) Characteristic melting temperature associated with proton can be expressed with,

\[
T_{\text{proton}} = \frac{\hbar c^3}{8\pi k_B G_s m_p} \approx 0.15 \times 10^{12} \text{ K}
\]

11) Characteristic nuclear neutral mass unit \([32]\) can be addressed with,

\[
\frac{\hbar c}{G_s} \approx 546.6365 \text{ MeV/c}^2.
\]

8. To fit neutron-proton mass difference

Neutron-proton mass difference can be understood with:

\[
\left( m_e c^2 - m_p c^2 \right) \approx \ln \frac{E_{(2/3)}}{m_e c^2} \approx \ln \sqrt{\frac{4e^2 G_s m_p^4}{4\pi e_0 \hbar^2 m_e c^2}}
\]

9. To fit neutron life time

Neutron life time \( t_n \) can be understood with the following relation:

\[
t_n \approx \exp \left( \frac{E_{(2/3)}}{m_n - m_p} \right) \times \left( \frac{h}{m_n c^2} \right) \approx 871.62 \text{ sec}
\]

This can be compared with recommended value \([1]\) of the neutron life time, \((880.2 \pm 1.0)\) sec

10. Understanding beta stability line with respect to proton and electron specific charge ratios

Nuclear beta stability line can be addressed with a relation of the form \([4]\),

\[
A_s \approx 2Z + s(2Z)^2 \approx 2Z + (4s)Z^2
\]

\[ \approx 2Z + 0.0064Z^2 \approx Z (2 + kZ) \quad (8)\]

where,

\[
S \equiv \left[ \left( \frac{e}{m_p} \right) + \left( \frac{e}{m_e} \right) \right] \left( \frac{G_e m_p m_e}{\hbar c} \right) \approx 0.00160454
\]

Based on relation (8), let, \( 4s = k = 0.0064182 \)

11. Nuclear binding energy at stable mass numbers

Interesting points to be noted are:

1. With reference to electromagnetic interaction, and based on proton number, \((1/\alpha_e) \approx 8.68\) can be considered as the maximum strength of nuclear binding energy.

2. \( Z \approx 30 \) seems to represent a characteristic reference number in understanding nuclear binding of light and heavy atomic nuclides.

Based on these points, at stable mass numbers of \( Z \), nuclear binding energy can be expressed by the following simple empirical relation.

\[
\left( B \right) \alpha_s \approx \gamma \times Z \times (m_n - m_p) c^2 \quad (10)
\]

If \( Z < 30 \), coefficient, \( \gamma \approx \left[ \frac{1}{\alpha_s} + 1 \right] + \sqrt{Z} \)

If \( Z \geq 30 \), \( \gamma \approx \left[ \frac{1}{\alpha_s} + 1 \right] + \sqrt{30} \) \( \approx 15.157 \)

and \( 15.157 \times 1.29333 \text{ MeV} \approx 19.6033 \text{ MeV} \)

Thus, for, \( Z \geq 30 \)

\[
\left( B \right) \alpha_s \approx Z \times 19.6033 \text{ MeV} \quad (11)
\]

See table 1. Close to the stable mass numbers, binding energy is estimated with relations (8) and (10) and compared with Semi empirical mass formula (SEMF). It needs further study with respect to its surprising results against a single energy coefficient.

In this context, we tried to understand nuclear binding with two simple terms. See section -14.
Above and below the stable mass number, binding energy can be approximately estimated with the following relation.

\[
(B)_A \approx (B)_{A*} - \ln \left( \frac{A_*}{kZ} \right) \left( \frac{A_* - A}{A} \right) \left( m_n - m_p \right) c^2
\]  
(12)

It needs further study with reference to unstable nuclides. See table 2 for Z=50.

12. Very simple approach for understanding nuclear stability starting form Z=21 to 118

With this simple method, super heavy elements lower stable mass numbers can be estimated. With even-odd corrections, accuracy can be improved. For \( Z \geq 11 \),

\[
A_* = \left[ Z + \left( \frac{e}{e_0} \right)^{1.2} \right] \approx \left[ Z + \left( \frac{1}{\sqrt{\alpha_z}} \right) \right]^{1.2} \approx \left( Z + 2.9462 \right)^{1.2}
\]  
(13)

where, \( \left( \frac{1}{\alpha_z} \right)^{0.6} \approx \left( \frac{e}{e_0} \right)^{0.6} \approx 1.19732 \pm 1.2 \)

13. Understanding nuclear binding energy of Deuteron

If it is assumed that, there exists no strong interaction in between proton and neutron, nuclear binding of deuteron can be expressed as,

\[
BE \text{ of } ^2H \approx 2 \times (m_n - m_p) c^2 \approx 2.59 \text{ MeV} 
\]  
(14)

where, \( \left( \frac{1}{\alpha_z} + 1 \right) \approx 1 \)

\[
\left( \frac{1}{\alpha_z} \rightarrow \left( \frac{e}{e_0} \right)^2 \rightarrow 0 \right) \Rightarrow e_z \rightarrow 0
\]

This can be compared with the experimental value of 2.225 MeV.

14. Understanding nuclear binding energy with two terms (close to stable mass numbers)

Based on the new integrated model proposed by N. Ghahramany et al [13,14],

\[
B(Z,N) = \left\{ A - \left( \frac{(N^3 - Z^3)}{3Z} + \delta (N - Z) + 3 \right) \right\} m_c^2 \gamma
\]  
(15)

where, \( \gamma \) = Adjusting coefficient \( \approx (90 \text{ to } 100) \).

If \( N \neq Z \), \( \delta (N - Z) = 0 \) and if \( N = Z \), \( \delta (N - Z) = 1 \).

Readers are encouraged to see references there in [13,14] for derivation part. Point to be noted is that, close to the beta stability line, \( \left[ \frac{N^3 - Z^3}{3Z} \right] \) takes care of the combined effects of coulombic and asymmetric effects. In this context, we would like suggest that,

\[
\frac{m_c^2}{\gamma} \approx \frac{m_c^2}{(90 \text{ to } 100)} \approx \text{Constant} \approx \frac{e^2}{8\pi\varepsilon_0 \left( G m_c^2 / c^2 \right)} \approx 10.09 \text{ MeV}
\]  
(16)

Proceeding further, with reference to relation (8), it is also possible to show that, for \( Z \approx 40 \text{ to } 83 \), close to the beta stability line,

\[
\left[ \frac{N^3 - Z^3}{3Z} \right] \approx kA Z
\]  
(17)

\[
\left[ \frac{N^3 - Z^3}{3Z} \right] \approx kA Z
\]  
(18)

Based on the above relations and close to the stable mass numbers of \( Z \approx 5 \text{ to } 118 \), with a common energy coefficient of 10.06 MeV, we would like to suggest two terms for fitting and understanding nuclear binding energy.

First term helps in increasing the binding energy and can be considered as,

\[
\text{Term}_1 = A_i \times 10.06 \text{ MeV}
\]  
(19)

Second term helps in decreasing the binding energy and can be considered as,

\[
\text{Term}_2 = \left( \frac{kA Z}{2.531} + 3.531 \right) \times 10.06 \text{ MeV}
\]  
(20)
where \( \left( \frac{m_e - m_p}{m_e c^2} \right) \approx \ln \left( \frac{1}{\sqrt{k}} \right) \approx 2.531 \). Thus, binding energy can be fitted with,

\[
B_A \approx \left( A_e - \left( \frac{kA_e Z}{2.531} + 3.531 \right) \right) \times 10.06 \text{ MeV}
\]  

(21)

See the following figure 1. Dotted red curve plotted with relations (8) and (21) can be compared with the green curve plotted with the standard semi empirical mass formula (SEMF).

15. To fix the magnitude of Fermi’s weak coupling constant

With trial-error we noticed that,

\[
R_e \equiv \frac{2G_e m_p}{c^3} \approx \left( \frac{m_e}{m_p} \right) \frac{G_e}{\sqrt{\hbar c}}
\]

(22)

where \( G_e \) is the Fermi’s weak coupling constant \([1,19]\) and \( \sqrt{\frac{G_e}{\hbar c}} \approx \) Characteristic electroweak length.

Based on this relation,

\[
\alpha_G \approx \frac{4\hbar \alpha^2}{m_e c^2}
\]

(23)

\[
G_e \equiv \left( \frac{1}{\alpha_{\text{em}}} \right) \frac{4\hbar \alpha^2}{m_e c^2} \approx \frac{4G_e m_i^2 h}{c^4}
\]

(24)

Recommended value of \( G_e \approx 1.43586 \times 10^{-2} \text{ J.m}^3 \). It may be noted that, relations (23) and (24) seem to play a key role in understanding the basics of final unification and needs further study.

16. To fix the magnitude of Newtonian Gravitational constant

With reference to Planck scale and considering the following semi empirical relation, magnitude of the Newtonian gravitational constant \( (N^G) \) can be fitted \([23, 34]\).

\[
\left( \frac{G_e}{N^G} \right) \approx \sqrt{\alpha} \left( \frac{m_e}{m_i} \right)^{12} \left( \frac{G_e}{\sqrt{\hbar c}} \right) \left( \frac{m_i}{m_e} \right)^{12}
\]

(25)

Based on relations (22) to (25),

\[
\left( \frac{G_e}{N^G} \right) \approx \left( \frac{1}{2} m_e \right) \left[ \frac{G_e}{\sqrt{\hbar c}} \left( \frac{m_i}{m_e} \right) \right]^{12}
\]

(26)

\[
\left( \frac{G_e}{N^G} \right) \approx \left( \frac{m_e}{m_i} \right)^{12} \left( \frac{G_e}{\sqrt{\hbar c}} \right)^{12} \left( \frac{m_i}{m_e} \right)^{12}
\]

(27)

where \( \frac{\hbar}{m_e c} \approx \) Compton wavelength of electron. Based on the recommended and estimated values of \( G_e \),

\[
G_e \approx 6.66937197 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ sec}^{-1}
\]

where \( G_e \approx 1.43586 \times 10^{-2} \text{ J.m}^3 \)

\[
G_e \approx 6.679076 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ sec}^{-1}
\]

where \( G_e \approx 1.440414 \times 10^{-2} \text{ J.m}^3 \)
Average value of \( G_s \approx 6.674224 \times 10^{-11} \text{ m}^3\text{kg}^{-1}\text{sec}^{-2} \).

In terms of nuclear charge radius,

\[
G_s \approx \left( \frac{m_e}{m_r} \right)^{11} \sqrt{\frac{c^4 G_s R^2}{\hbar}}
\]

(28)

Accuracy of \( G_s \) seems to depend on \( (G_s, R_s, \alpha_s, G_r) \).

17. To fix the magnitude of electroweak gravitational constant

According to Roberto Onofrio [19], electroweak scale gravitational constant is roughly \( 10^{33} \) times the Newtonian gravitational constant. In this context, we would like suggest that,

\[
G_e \approx \left( \frac{m_e}{m_r} \right)^{11} \sqrt{\frac{c^4 G_e R^2}{\hbar}}
\]

(29)

where \( G_e \approx 2.90723 \times 10^{15} \text{ m}^3\text{kg}^{-1}\text{sec}^{-2} \) can be considered as the electroweak gravitational constant. Based on this idea,

\[
R_s \approx \left( \frac{m_e}{m_r} \right) \sqrt{\frac{4 G_e \hbar}{c^3}} = \left( \frac{m_e}{m_r} \right)^{11} \sqrt{\frac{4 G_e \hbar}{c^3}}
\]

(30)

where \( \sqrt{4 G_e \hbar/c^3} \) can be called as the electroweak Planck length.

\[
G_e \approx \hbar c \left( \frac{4 G_e \hbar}{c^3} \right) = 4 G_e \hbar^3 / c^3
\]

(31)

Based on relation (27),

\[
G_e \approx \left( \frac{m_e}{m_r} \right)^{11} \sqrt{G_e \hbar c^3 / m_r} \equiv \left( \frac{G_e}{m_r} \right) \left( \frac{\hbar c}{m_r} \right)
\]

(32)

Characteristic electroweak mass and its Schwarzschild radius can be expressed as,

\[
M_e \approx \sqrt{\frac{\hbar c}{G_e}} \approx 584.983 \text{ GeV}/c^3
\]

(33)

\[
\frac{2 G_e M_e}{c^2} \approx \sqrt{\frac{4 G_e \hbar}{c^3}} \approx 6.74642 \times 10^{-6} \text{ m}
\]

(34)

\[
\frac{M}{m_r} \approx \frac{\hbar c}{G_e m_r} \approx \frac{\hbar c}{G_e m_r}
\]

(35)

\[
\frac{M}{m_r} \approx \frac{G}{G_e}
\]

(36)

18. To understand the range of strong interaction

One strange approximation is,

\[
\left( \frac{m_s}{m_r} \right)^{10} \approx \exp \left( \frac{1}{\alpha_s} \right)
\]

(37)

Based on above relations, strong interaction range can be understood with the following relation.

\[
R_s \approx \exp \left( \frac{1}{\alpha_s} \right) \left( \frac{m_s}{m_r} \right) \left( \frac{4 G_e \hbar}{c^3} \right) \sqrt{\frac{\hbar c}{G_e}}
\]

(38)

It seems interesting to infer that,

a) \( \left( \frac{1}{\alpha_s} \right) \) and \( \exp \left( \frac{1}{\alpha_s} \right) \) play a crucial role in deciding the strong interaction range.

b) An increase in the value of \( \alpha_s \) helps in decreasing the interaction range. This may be an indication of more strongly bound nuclear system.

c) A decrease in the value of \( \alpha_s \) helps in increasing the interaction range. This may be an indication of more weakly bound nuclear system.

d) Proportionality constant being \( \exp \left( \frac{1}{\alpha_s} \right) \),

\[
R_s \propto \left( \frac{m_s}{m_r} \right) \left( \frac{4 G_e \hbar}{c^3} \right) \sqrt{\frac{\hbar c}{G_e}}
\]

(39)

19. Conclusion
Even though our approach to nuclear physics seems to be speculative, proposed assumptions show a wide range of applications embedded with in-depth physical meaning connected with low energy nuclear physics and high energy nuclear physics. With reference to the famous semi empirical mass formula having 5 different energy terms and 5 different energy coefficients, qualitatively and quantitatively, our proposed relations (8), (10) and (21) are very simple to follow and a special study seems to be required for understanding the binding energy of isotopes above and below the stability line. We are working in this direction.

With further research, current nuclear models and strong interaction concepts can be studied in a unified manner with respect to strong nuclear gravity. Finally, value of the Newtonian gravitational constant can be estimated with nuclear elementary physical constants.

Acknowledgements

Author Seshavatharam is indebted to professors shri M. NagaphaniSarma, Chairman, shri K.V. Krishna Murthy, founder Chairman, Institute of Scientific Research in Vedas (I-SERVE), Hyderabad, India and Shri K.V.R.S. Murthy, former scientist IICT (CSIR), Govt. of India, Director, Research and Development, I-SERVE, for their valuable guidance and great support in developing this subject.

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Table 1: Estimated nuclear binding close to stable mass numbers

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