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Analytical Procedure for Estimating the Gravitational Constant with Nuclear Binding Energy of Stable Atomic Nuclides and Squared Avogadro Number

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Abstract By considering the strength of Schwarzschild interaction as 'unity' and by considering squared Avogadro number as a suitable scaling factor, in the previously published papers the authors made an attempt to understand the basics of nuclear physics and strong interaction. In this paper an attempt is made fit the magnitude of the gravitational constant with nuclear binding energy data of naturally occurring stable atomic nuclides starting from Z=30 to 92. Characteristic binding potential can be taken as $B_0 \cong (19.5 \text{ to } 19.7)$ MeV . Stable atomic nuclides can be selected in such a way that, ratio of binding energy of the nuclide and characteristic binding potential is close to the proton number of that nuclide. Accuracy of the gravitational constant mainly depends on the selected number of stable atomic nuclides which in turn depends on the accuracy of the assumed binding potential. Very interesting observation is that, $B_0 \cong -\left[1+(\alpha_s/\alpha)\right]\left(e^2/4\pi\varepsilon_0 R_0\right)$ where α_s is the strong coupling constant, α is the fine structure ratio and R_0 is the characteristic nuclear size (1.20 to 1.25) fm. If $B_0 \cong 19.6$ MeV, $G \cong 6.68541E-11 \text{ m}^3.\text{kg}^{-1}.\text{sec}^{-2}$ and if $B_0 \cong 19.5$ MeV, $G \cong 6.64761E-11 \text{ m}^3.\text{kg}^{-1}.\text{sec}^{-2}$.

Keywords: *Schwarzschild's interaction, squared avogadro number, gravitational constant, nuclear binding energy, naturally occurring stable atomic nuclides, nuclear charge radius, strong coupling constant*

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1. Introduction

From gravity point of view, so far no model [1-8] succeeded in understanding the link between strongly interacting nucleons and massive celestial objects. By interconnecting the strong coupling constant and gravitational constant via the Schwarzschild interaction and squared Avogadro number, in the previously published papers, the authors reviewed the basics of nuclear structure with reference to up and down quark masses, proton-neutron beta stability, root mean square radius of proton, nuclear binding energy and magic numbers. In this context, readers are strongly encouraged to see the authors published papers [9-17]. In this paper an attempt is made to fit the gravitational constant based on the binding energy of conditionally identified stable atomic nuclides starting from Z=30 to 92. Important point to be noted is that, 19.5 to 19.7 MeV can be considered as the characteristic unified binding energy potential.

2. Understanding the Strength of Any Interaction

From the above relations it is reasonable to say that,

1. If it is true that c and G are fundamental physical constants, then $\left(c^4/G\right)$ can be considered as a fundamental compound constant related to a characteristic limiting force.
2. Black holes are the ultimate state of matter's geometric structure [18,19].
3. Magnitude of the operating force at the black hole surface is the order of $\left(c^4/G\right)$.
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 $\left(c^4/G\right)$.
7. If one is willing to represent the magnitude of the operating force as a fraction of $\left(c^4/G\right)$ i.e. X times of $\left(c^4/G\right)$, where $X \ll 1$, then

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

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 $\frac{G}{X}$.

3. Basic Concepts and Relations of Unification Connected with Nuclear Structure

The following concepts and relations can be given a chance in final unification program.

1. Avogadro number is an absolute number [20,21,22,23] and it is having no units like 'per mole'. Atomic interaction strength is N_A^2 times less than the Schwarzschild interaction and hence atomic gravitational constant can be expressed as:

$$\left.\begin{array}{l} G_A \cong N_A^2 G \quad \text{and} \quad G_A m_A^2 \cong G m_M^2 \\ \rightarrow m_M \cong \sqrt{\frac{G_A}{G}} \cdot m_A \cong N_A m_A \end{array}\right\} \quad (2)$$

Here, m_A is the unified atomic mass unit, $m_M \cong 0.001$ kg is the molar mass unit expressed as 'one gram' and hence it is possible to think that, m_M constitutes N_A number of atoms which in turn constitutes N_A number of protons.

2. Similar to the classical force limit $\left(c^4/G\right)$, in atomic and nuclear system there exists a characteristic force of magnitude:

$$\left.\begin{array}{l} F_X \cong \left(1/N_A^2\right)\left(c^4/G\right) \cong \left(c^4/N_A^2 G\right) \\ \approx 3.34\times10^{-4} \text{ N} \end{array}\right\} \quad (3)$$

3. In various 'forms, $\left(\frac{\hbar c}{G_A m_e^2}\right)^x$ where $x = 1/3, 1/2, 1, 3/2, 2, ..$ seems to play a crucial role in nuclear and atomic physics [10].

4. Naturally occurring stable mass number connected with proton number can be expressed as follows [24,25,26].

$$A_s \cong 2Z + \left\{\left(\frac{\hbar c}{G_A m_e^2}\right)(2Z)^2\right\} \cong 2Z + \left[\left(\frac{4\hbar c}{G_A m_e^2}\right)(Z)^2\right] \quad (4)$$

5. For Z>=30, at the stable mass numbers, nuclear binding energy can be expressed as follows.

$$B_{A_s} \cong -Z\left\{\left(\frac{G_A m_e^2}{\hbar c}\right)^{3/2} \sqrt{\frac{e^2}{8\pi\varepsilon_0}\left(\frac{c^4}{G_A}\right)}\right\} \cong -Z * B_0 \quad (5)$$

where B_0 can be considered as the characteristic binding energy potential and can be represented as,

$$B_0 \cong \left(\frac{G_A m_e^2}{\hbar c}\right)^{3/2} \sqrt{\frac{e^2}{8\pi\varepsilon_0}\left(\frac{c^4}{G_A}\right)} \quad (6)$$
$$\approx -19.5 \text{ to } 19.7 \text{ MeV}$$

Note that, by considering the semi empirical mass formula [24,25], at the estimated stable mass numbers of Z>=30, it is possible to show that, ratio of nuclear binding energy and proton number is close to B_0. It is an observed fact.

4. To Fit the Gravitational Constant with Nuclear Data

G. Rosi et al say [27]: "There is no definitive relationship between ***G*** and the other fundamental constants, and there is no theoretical prediction for its value, against which to test experimental results. Improving the precision with which we know ***G*** has not only a pure metrological interest, but is also important because of the key role that ***G*** has in theories of gravitation, cosmology, particle physics and astrophysics and in geophysical models".

In this context, in the previously published papers [12,13] the authors proposed interesting procedures for estimating the gravitational constant.

From above relations it is possible to show that,

$$\left.\begin{array}{l} G_A \cong \left(\frac{B_{A_s}}{Z}\right)\frac{\hbar^{3/2}}{m_e^3 c^{1/2}}\left(\frac{8\pi\varepsilon_0}{e^2}\right)^{1/2} \\ \cong \frac{B_{A_s}\hbar^{3/2}}{Z m_e^3 c^{1/2}}\left(\frac{8\pi\varepsilon_0}{e^2}\right)^{1/2} \cong \frac{\sqrt{2}B_{A_s}\hbar}{\sqrt{\alpha} Z m_e^3 c} \end{array}\right\} \quad (7)$$

$$\left.\begin{array}{l} \Rightarrow G \cong \left(\frac{B_{A_s}}{Z}\right)\frac{\hbar^{3/2}}{N_A^2 m_e^3 c^{1/2}}\left(\frac{8\pi\varepsilon_0}{e^2}\right)^{1/2} \\ \cong \frac{B_{A_s}\hbar^{3/2}}{Z N_A^2 m_e^3 c^{1/2}}\left(\frac{8\pi\varepsilon_0}{e^2}\right)^{1/2} \cong \frac{\sqrt{2}B_{A_s}\hbar}{\sqrt{\alpha} Z N_A^2 m_e^3 c} \\ \cong 21.24315376\left(\frac{B_{A_s}}{Z}\right) \end{array}\right\} \quad (8)$$

With this simple formula and considering the actual binding energy [24,25,26] of naturally occurring stable atomic nuclides starting from Z=30 to Z=92 the mean value of the gravitational constant [27-33] and its standard deviation can be estimated. The important point to be noted is that, to fit the gravitational constant, the authors have chosen the following condition.

$$\text{After rounding off,}\left(\frac{B_{A_s} \text{in MeV}}{(19.5 \text{ to } 19.7) \text{ MeV}}\right) \cong Z \quad (9)$$

where $B_0 \cong (19.5 \text{ to } 19.7)$ MeV is the characteristic binding energy potential that lies close to the value obtained from relation (6). The authors try to fit this energy constant as given below.

Step-1: In a unified approach, it is noticed that,

$$\left.\begin{array}{l} R_0 \cong \left(\frac{\hbar c}{G_A m_e^2}\right)^2 \left(\frac{2G_A m_e}{c^2}\right) \cong 1.215 \text{ fm} \\ \rightarrow \left(\frac{G_A m_e^2}{\hbar c}\right) \cong \sqrt{\frac{2G_A m_e}{c^2 R_0}} \end{array}\right. \quad (10)$$

Step-2: Substituting this result in relation (6) it is noticed that,

$$B_0 \cong -\sqrt{2\alpha}\left(\frac{\hbar c}{R_0}\right) \cong -\sqrt{\frac{2}{\alpha}}\left(\frac{e^2}{4\pi\varepsilon_0 R_0}\right) \quad (11)$$

Step-3: From relation (11) it is further noticed that,

$$\sqrt{2\alpha} \cong 0.12080855 \cong \alpha_s \quad (12)$$

where α_s represents the currently believed strong coupling constant [20,23]. Hence relation (11) can be expressed as,

$$\left.\begin{array}{l} B_0 \cong -\left(1+\frac{\alpha_s}{\alpha}\right)\left(\frac{e^2}{4\pi\varepsilon_0 R_0}\right) \\ \rightarrow \alpha_s \approx \frac{B_0 R_0}{\hbar c} \end{array}\right\} \quad (13)$$

If

$$\left\{\begin{array}{l} \alpha_s \cong (0.116 \text{ to } 0.12); \\ \alpha \cong 7.297352533\text{e-}3; \\ \text{and } R_0 \cong (1.2 \text{ to } 1.25) \text{ fm}; \end{array}\right.$$

By adjusting the value of strong coupling constant in between 0.116 and 0.12 and fixing the characteristic nuclear size with (1.20 to 1.25) fm, value of B_0 can be shown to lie in between 19.5 MeV and 19.7 MeV. For calculation purpose, in this paper, the authors consider two values of B_0 i.e. $B_0 \cong 19.6$ MeV and $B_0 \cong 19.5$ MeV.

Now, by considering the above conditional relation (9), starting from Z=30 to 92, number of stable atomic nuclides can be minimized to 42 for $B_0 \cong 19.5$ MeV and 47 for $B_0 \cong 19.6$ MeV. After that, by considering relation (8) and by considering the actual binding energies of the conditionally identified stable atomic nuclides, gravitational constant can be estimated for each of the of the atomic nuclide. Average value can be compared with the recommended and other experimental values of the gravitational constant [20,27-33].

5. Discussion

From Table 1 it is noticed that, out of 213 stable atomic nuclides [26], by considering 19.6 MeV as a characteristic binding energy potential, 47 stable atomic nuclides can be identified for fitting gravitational constant. The minimum value of the estimated ***G*** is 6.62792E-11 $m^3.kg^{-1}.sec^{-2}$ and maximum value of the estimated ***G*** is 6.75292E-11 $m^3.kg^{-1}.sec^{-2}$ Mean of the estimated ***G*** for 48 stable atomic nuclides is 6.68541E-11 $m^3.kg^{-1}.sec^{-2}$ and standard deviation is 2.9872E-13 $m^3.kg^{-1}.sec^{-2}$. See Figure 1 and Table 1.

Note that, by considering 19.5 MeV as a characteristic binding energy potential, 42 stable atomic nuclides can be identified for fitting gravitational constant. The minimum value of the estimated ***G*** is 6.559016E-11 $m^3.kg^{-1}.sec^{-2}$ and maximum value of the estimated ***G*** is 6.73036E-11 $m^3.kg^{-1}.sec^{-2}$ Mean of the estimated ***G*** for 42 stable atomic nuclides is 6.64761-11 $m^3.kg^{-1}.sec^{-2}$ and standard deviation is 3.90471E-13 $m^3.kg^{-1}.sec^{-2}$. See Figure 2 and Table 2.

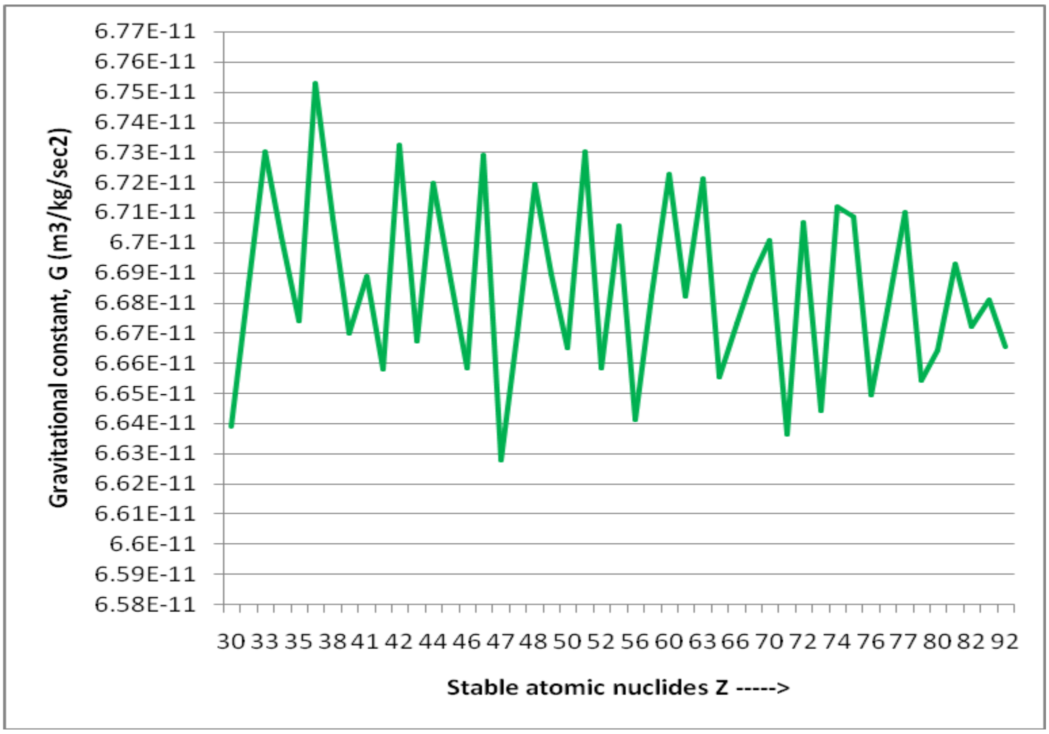

Figure 1. Estimation of the Gravitational constant with stable atomic nuclides of Z=30 to 92 with 19.6 MeV

Table 1. To fit the gravitational constant with stable atomic nuclides with 19.6 MeV

S.No	Z	A_s	Experimental BE in MeV [26]	BE/19.6MeV	Rounding off (BE/19.6 MeV)	Gravitational constant
1	30	67	585.189	29.9	30	6.639E-11
2	32	72	628.686	32.1	32	6.687E-11
3	33	75	652.564	33.3	33	6.73E-11
4	34	77	669.492	34.2	34	6.702E-11
5	35	79	686.321	35.0	35	6.674E-11
6	36	82	714.274	36.4	36	6.753E-11
7	38	86	748.928	38.2	38	6.708E-11
8	40	90	783.893	40.0	40	6.67E-11
9	41	93	805.765	41.1	41	6.689E-11
10	42	95	821.625	41.9	42	6.658E-11
11	42	96	830.779	42.4	42	6.732E-11
12	44	100	861.928	44.0	44	6.667E-11
13	44	101	868.73	44.3	44	6.72E-11
14	45	103	884.163	45.1	45	6.687E-11
15	46	105	899.914	45.9	46	6.658E-11
16	46	106	909.474	46.4	46	6.729E-11
17	47	107	915.263	46.7	47	6.628E-11
18	48	110	940.646	48.0	48	6.67E-11
19	48	111	947.622	48.3	48	6.719E-11
20	49	113	963.094	49.1	49	6.69E-11
21	50	115	979.121	50.0	50	6.665E-11
22	50	116	988.684	50.4	50	6.73E-11
23	52	120	1017.282	51.9	52	6.658E-11
24	54	126	1063.909	54.3	54	6.70564E-11
25	56	130	1092.722	55.8	56	6.641E-11
26	58	136	1138.792	58.1	58	6.683E-11
27	60	142	1185.142	60.5	60	6.723E-11
28	62	147	1217.251	62.1	62	6.682E-11
29	63	151	1244.141	63.5	63	6.721E-11
30	64	152	1251.485	63.9	64	6.655E-11
31	66	158	1294.046	66.0	66	6.673E-11
32	68	164	1336.447	68.2	68	6.689E-11
33	70	170	1378.13	70.3	70	6.701E-11
34	72	174	1403.928	71.6	72	6.637E-11
35	72	176	1418.801	72.4	72	6.707E-11
36	74	180	1444.588	73.7	74	6.644E-11
37	74	182	1459.335	74.5	74	6.712E-11
38	75	185	1478.341	75.4	75	6.709E-11
39	76	186	1484.807	75.8	76	6.649E-11
40	76	187	1491.097	76.1	76	6.678E-11
41	77	191	1518.088	77.5	77	6.71E-11
42	78	192	1524.964	77.8	78	6.654E-11
43	80	198	1566.489	79.9	80	6.664E-11
44	80	199	1573.153	80.3	80	6.693E-11
45	82	204	1607.507	82.0	82	6.672E-11
46	90	232	1766.687	90.1	90	6.681E-11
47	92	238	1801.69	91.9	92	6.665E-11

Table 2. To fit the gravitational constant with stable atomic nuclides with 19.5 MeV

S.No	Z	A_s	Experimental BE in MeV [26]	BE/19.5MeV	Rounding off (BE/19.5 MeV)	Gravitational constant
1	30	66	578.136	29.6	30	6.55901E-11
2	30	67	585.189	30.0	30	6.63902E-11
3	31	69	601.996	30.9	31	6.60939E-11
4	32	72	628.686	32.2	32	6.68672E-11
5	33	75	652.564	33.5	33	6.73036E-11
6	34	76	662.073	34.0	34	6.6276E-11
7	34	77	669.492	34.3	34	6.70187E-11
8	36	80	695.434	35.7	36	6.5748E-11
9	38	86	748.928	38.4	38	6.70789E-11
10	40	90	783.893	40.2	40	6.67E-11
11	41	93	805.765	41.3	41	6.68889E-11
12	42	94	814.256	41.8	42	6.59844E-11
13	42	95	821.625	42.1	42	6.65815E-11
14	44	99	852.255	43.7	44	6.59244E-11
15	44	100	861.928	44.2	44	6.66726E-11
16	45	103	884.163	45.3	45	6.68727E-11
17	46	104	892.82	45.8	46	6.60595E-11
18	46	105	899.914	46.1	46	6.65844E-11
19	47	107	915.263	46.9	47	6.62792E-11
20	48	110	940.646	48.2	48	6.66982E-11
21	49	113	963.094	49.4	49	6.68963E-11
22	50	114	971.574	49.8	50	6.61356E-11
23	50	115	979.121	50.2	50	6.66493E-11
24	52	120	1017.282	52.2	52	6.65836E-11
25	54	124	1046.257	53.7	54	6.59438E-11
26	56	130	1092.722	56.0	56	6.64127E-11
27	58	136	1138.792	58.4	58	6.6826E-11
28	62	147	1217.251	62.4	62	6.68217E-11
29	64	152	1251.485	64.2	64	6.65541E-11
30	66	158	1294.046	66.4	66	6.67322E-11
31	68	162	1320.698	67.7	68	6.61034E-11
32	70	168	1362.793	69.9	70	6.62615E-11
33	72	174	1403.928	72.0	72	6.63654E-11
34	74	180	1444.588	74.1	74	6.64418E-11
35	76	184	1469.921	75.4	75	6.58279E-11
36	76	186	1484.807	76.1	76	6.64945E-11
37	76	187	1491.097	76.5	76	6.67762E-11
38	78	192	1524.964	78.2	78	6.65418E-11
39	80	196	1551.218	79.5	80	6.59952E-11
40	80	198	1566.489	80.3	80	6.66449E-11
41	82	204	1607.507	82.4	82	6.67219E-11
42	92	238	1801.69	92.4	92	6.66533E-11

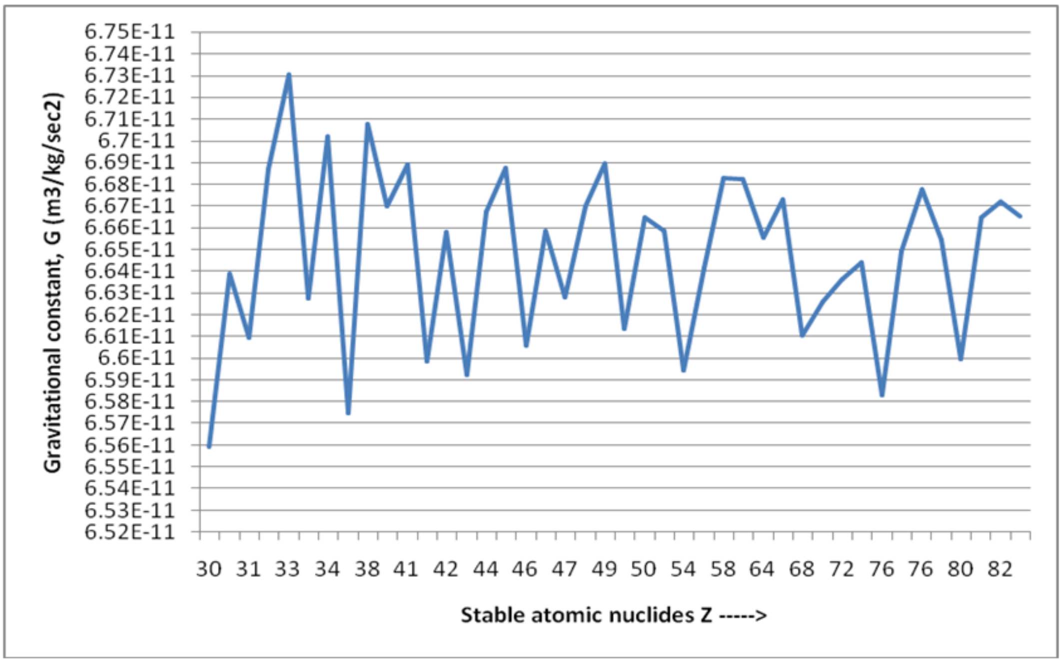

Figure 2. Estimation of the Gravitational constant with stable atomic nuclides of Z=30 to 92 with 19.5 MeV

With further research and analysis and by developing the proposed procedure from Z=2 to Z=92, in a suitable manner, accurate value of the gravitational constant can be estimated.

6. Conclusion

In general, 'Unification' means: a) Understanding the origin of the rest mass of atomic elementary particles. b) Finding and understanding the critical compositeness of the elementary physical constants. c) Minimizing the number of elementary physical constants. d) Merging different branches of physics with possible and suitable physical concepts. In this context, from final unification point of view [9-17], qualitatively and quantitatively, proposed method of estimating the gravitational constant can be recommended for further research and analysis.

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