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Gravitational Constant at Subnuclear Scale

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Abstract: The notion of weak interaction as a unique expression of quantum gravity leads us to add a new term to the semi-empirical mass formula (SEMF). This term considers the gravitational forces among nucleons and incorporates the required adjustments in the nucleus's binding energy. This additional term is consequently used to determine the intensity of gravitational attraction at subnuclear levels, producing acceptable outcomes.

Keywords: Liquid drop, binding energy, *odd-A* nuclei, gravitation, weak interaction.

Introduction:

Factors such as volume, surface tension, electrical repulsion, along with pairing energy, asymmetry and newly added terms are considered to contribute to the nucleus' energy in the ensuing liquid-drop model [1],[2]. Numerous properties of nuclei, such as the overall trend of binding energy and mass defect, can be well captured by the model [1], [3], [4], [5], [6], [7]. Two significant characteristics shared by all nuclei give birth to the theoretical portion: The overall binding energies are roughly proportionate to the masses, and the internal mass densities are roughly equal. In general, the binding energy [8], [9], [10], [11], [12], [13] can be expressed as follows:

$$BE(A,Z) = a_v A - a_s A^{\frac{2}{3}} - a_c \frac{Z(Z-1)}{A^{\frac{1}{3}}} - a_a \frac{(A-2Z)^2}{A} \pm a_p A^{\lambda} \qquad (1)$$

where a_i denoting the constants of the equation, respectively, referred to: volume, surface, coulomb, a symmetry, and pairing. The values of a_p is assigned positive for *e-e* nuclei, negative for *o-o* nuclei, and zero for *odd-A* nuclei. The value of $\lambda = -1/2$ has been determined by recent evaluations [14], [15], [16].

In this study, we will concentrate on calculating the gravitational constant at subnuclear level by adding a new term to SEMF that may account for the gravitational interactions between nucleons. In addition, the algorithm's tolerance in our earlier work [17] is now modified.

The approach and ansatz

Most significant interaction between objects at the macroscopic scale is gravity, which also has an impact at the microscopic scale [18]. Gravitational energy E_g associated with two identical spherical masses of homogeneous density is given by conventional equation [19], [20]:

$$E_g \propto -\frac{G\,M^2}{R} \qquad (2)$$

where G is the universal gravitational constant, M is the mass of the sphere, and R its radius. Eq. (2) is not necessarily true for subnuclear particles [21], it can be logically expressed in terms of coulomb energy, attaining the expression:

$$E_g = -a_g \frac{A(A-1)}{A^{1/3}} \qquad (3)$$

where the empirical radius $R = r_0 A^{1/3}$ and the mass of the sphere $M^2 = A(A-1)$ are used to replace the masses, emphasizing that gravitatio nal attraction only occurs in the presence of numerous particles.

It is necessary to use fitting to determine the prop ortionality constant, a_g. Eq. (1) is used to calculate the binding energy of *odd-A* nuclei, this automatically turns the pairing term to vanish. As a result, the semi-empirical mass formula now takes the following form:

$$BE(A,Z) = a_v A - a_s A^{\frac{2}{3}} - a_c \frac{Z(Z-1)}{A^{\frac{1}{3}}} - a_a \frac{(A-2Z)^2}{A} - a_g \frac{A(A-1)}{A^{1/3}} \qquad (4)$$

This is our basic expression, Eq. (4), and will be utilized in all of our computations.

Results and Comparison

Different earlier sets of calculations and estimated coefficients are given in references [22], [23], [24], [25] for the purpose of comparison. We present, in Table 1, a convenience sample of our calculations.

Table 1. Samples of our calculations for *odd-A* nuclei

a_v	a_s	a_c	a_a	a_g	Data ref.
15.52	17.48	0.67	24.70	4.23×10^{-4}	[25]

in the units of [MeV].

The renormalized gravitation constant [26], which is associated with subnuclear interactions, is also determined using our acquired gravitational constant a_g. Equations (2) and (3) allow us to write

$$a_g = \Gamma \frac{m_N^2}{r_0} \qquad (5)$$

where m_N is the nucleon's mass and Γ is the sub nuclear gravitational constant, which absorbing Newton gravitational constant G and falls within the realm of weak interaction, as mentioned by Onofrio [27], [28], giving

$$\Gamma = 4.36 \times 10^{34}\ G$$
$$= 2.90 \times 10^{22}\ m^3\ \mathrm{kg}^{-1}\ \mathrm{s}^{-2}$$

This value is in good agreement with Seshavatharam and Lakshminarayana's findings [29].

Conclusion

It is known that research on gravitational effects at the subnuclear scale is ongoing. In order to account for potential variations in binding energy caused by gravitational interactions between subnuclear particles, we were inspired to add a new term to the semi-empirical mass formula. A new parameter representing the gravitational constant at the subnuclear level is derived employing an extra term. In this work, we present a substantial analysis of what we perceive to be a significant high energy consequence of Newtonian gravitational constant, which is increasingly conspicuous at tiny distances, leading to a direct understanding of weak interaction.

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