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A SOLUTION TO THE 80 YEARS OLD PROBLEM OF THE NUCLEAR FORCE

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Abstract:

Nuclear structure theory has recently undergone a renaissance, attributed to isotopic anomalies in chemical systems at energies well below the expected ~10 MeV nuclear level and surprising ab initio super-computer calculations of nuclear properties, under the assumption that nucleons have well-defined intranuclear positions ($x \leqq 2$ fm). Considering a magnetic structure of nucleons consistent with classical physics, using the Biot-Savart law with carriers "in phase", we have made connected lattice calculations of nuclear binding energies and magnetic moments, obtaining results comparable with other Copenhagen-style nuclear models.

Key Words: Classical Physics, Low-Energy Nuclear Reactions, Transmutations, Biot-Savart Law, Magnetic Attraction & Nuclear Binding Energies

1. Introduction:

Since 1989, many experimental findings have indicated isotopic anomalies in "chemical" systems at energies well below the expected ~10 MeV nuclear level. In addition to this, since 2007 remarkable *ab initio* super-computer calculations of nuclear properties have been made under the assumption that nucleons have well-defined intranuclear positions in a nucleon lattice ($x \leqq 2$ fm).

Such theoretical work is the so-called "Nuclear Lattice Effective Field Theory" (NLEFT). Assuming the localization of nucleons to rather small intranuclear volumes ($x < 2.0$ fm), the Copenhagen interpretation implies a very low uncertainty in position associated with high uncertainty in angular momentum, with restrictions on what properties the particles themselves might have. As a consequence, non-Copenhagen theoretical "unconventional" assumptions are now routinely made as a computational necessity in NLEFT.

We made unconventional lattice calculations of nuclear binding energies and magnetic moments, finding good results that compare favorably with more complex theoretical results from nuclear models that are consistent with the Copenhagen interpretation of quantum mechanics.

We have calculated the nuclear binding energies of all stable/near-stable isotopes, and the magnetic moments of all stable odd-even, even-odd, and odd-odd isotopes whose magnetic moments have been experimentally measured. By specifying the positions of nucleons within a close-packed nucleon lattice, every nucleon is assigned a set of quantum numbers (*n, l, j, m, i, s,* and parity) based *solely* on its Cartesian coordinates [1-4]. This description of nucleons in the lattice is isomorphic with the symmetries known from the independent-particle model (IPM, ~shell model) of conventional nuclear structure theory.

Then we showed that LENR transmutation data on Lithium, Nickel, and Palladium isotopes can be simulated using the nuclear lattice and the magnetic nuclear force, because of the identity between the gaseous-phase IPM and the fcc lattice [5,6].

We and others have, in fact, developed the fcc lattice of nucleons as a model of nuclear structure and shown that its numerical results concerning nuclear size, shape, density, etc. well compare with the 30+ other models of nuclear structure developed throughout the 20th century [5].

2. Technical Details:

The Biot-Savart law allows one to calculate the magnetic field generated by electric currents, obtaining the mutual force between coils as due to the contribution of infinitesimal length elements, and ignoring any phase relation between the currents. If phase relations are brought into consideration, the situation radically changes, bringing to a modified potential energy.

We considered two circular coils (1) and (2), in which circulate the currents i_1 and i_2, respectively. Let R be the common radius of the coils, placed within a canonical orthogonal Cartesian coordinate system (xyz). The simplest configurations are: (i) the coils in two parallel planes; (ii) the coils in the same plane.

(i) Coil 1 lies in the plane (xz), while coil 2 is in a parallel plane at a distance y (Figure 1).

Using Biot-Savart and Laplace laws, the force perceived at coil 2 under the action of the field generated from coil 1 is given by:

$$\vec{F}_{12} = \frac{\mu_0 \, i_1 \, i_2}{4\pi} \int_{C_2} d\vec{l}_2 \times \int_{C_1} \frac{d\vec{l}_1 \times \vec{r}_{12}}{r_{12}^3} \quad . \quad (1)$$

Let $P_1=(x_1, 0, z_1)$ be a generic point of the coil 1 and $P_2=(x_2, y, z_2)$ a generic point of the coil 2, Eq. (1) can be rewritten in the form:

$$\vec{F}_{12} = \frac{\mu_0\, i_1\, i_2}{4\,\pi} \int_{C_1}\int_{C_2} \frac{d\vec{l}_2 \cdot \vec{r}_{12}}{r_{12}^3}\, d\vec{l}_1 - \frac{d\vec{l}_2 \cdot d\vec{l}_1}{r_{12}^3}\, \vec{r}_{12} \qquad (2)$$

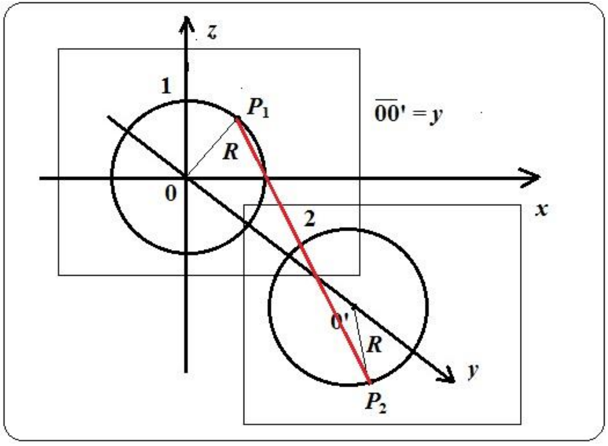

Figure 1: The case of coils in parallel planes

and its first part is zero, being the integral of a gradient extended to a closed line. With further algebra, considering cylindrical coordinates and the binomial series of the denominator, up to the first order, Eq. (2) becomes:

$$\vec{F}_{12} = -\frac{\mu_0\, i_1\, i_2}{4\,\pi}\,\frac{6\,\pi^2\, R^4}{y^4}\,\vec{j} \qquad (3)$$

with intensity:

$$\left|\vec{F}_{12}\right| = \frac{3}{2}\,\frac{\mu_0\, i_1\, i_2\, \pi\, R^4}{y^4} \;. \qquad (4)$$

In the hypothesis that the two currents are in phase, Eq. (2) gives:

$$\vec{F}_{12\,ph} = -\frac{\mu_0\, i_1\, i_2\, \pi\, R^2}{y^2}\,\vec{j} \;, \qquad (5)$$

$$\left|\vec{F}_{12\,ph}\right| = \frac{\mu_0\, i_1\, i_2\, \pi\, R^2}{y^2} \;, \qquad (6)$$

implying:

$$\left|\vec{F}_{12\,ph}\right| = \frac{2}{3}\left(\frac{y}{R}\right)^2 \left|\vec{F}_{12}\right| \;. \qquad (7)$$

(ii) The two coils are placed in the same plane, for example (*xz*) (Figure 2).

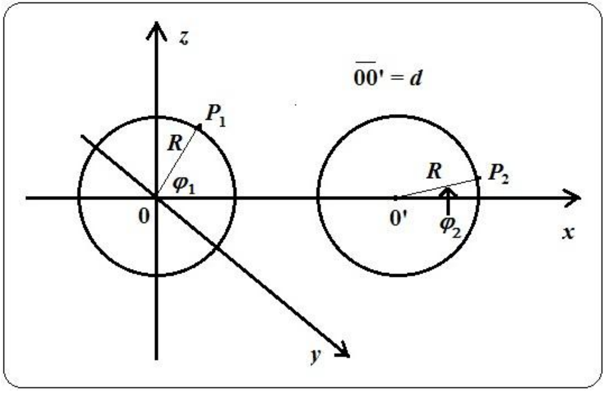

Figure 2: The case of coils in the same plane

If P_1 is the generic point of coil 1, P_2 that of coil 2, and d is the distance between the two centers, using the same procedure as the previous one, we get:

$$\left|\vec{F}_{12}\right| = \frac{3\,\mu_0\, i_1\, i_2\, \pi\, R^4}{d^4} \;, \qquad (8)$$

$$\left|\vec{F}_{12\,ph}\right| = \frac{\mu_0\, i_1\, i_2\, \pi\, R^2}{d^2} \;, \qquad (9)$$

$$\left|\vec{F}_{12\,ph}\right| = \frac{1}{3}\left(\frac{d}{R}\right)^2 \left|\vec{F}_{12}\right| \quad . \quad (10)$$

The corresponding energies are respectively:
(i)

$$E = \frac{\mu_0\ \mu_1\ \mu_2}{2\ \pi\ y^3} \quad , \quad (11)$$

$$E_{ph} = \frac{\mu_0\ \mu_1\ \mu_2}{\pi\ R^2\ y} \quad , \quad (12)$$

(ii)

$$E = \frac{\mu_0\ \mu_1\ \mu_2}{\pi\ x^3} \quad , \quad (13)$$

$$E_{ph} = \frac{\mu_0\ \mu_1\ \mu_2}{\pi\ R^2\ x} \quad , \quad (14)$$

with in evidence the magnetic moments [4].

3. Results:

As an example, considering the case of two nucleons placed at a distance y = 2 fm and the nucleon radius R = 0.5 fm, energies (11, 12) are respectively: E = 3.97 KeV; E_{ph} = 0.127 MeV.

It is possible also to introduce an appropriate exponential phase factor, of the form “exp(-λr)”; Eqs (12,14) can be rewritten as:

$$E_{ph}(r) = \frac{\mu_0\ \mu_1\ \mu_2}{\pi\ r^2\ y}\, e^{-\lambda r} \quad , \quad (15)$$

$$E_{ph}(r) = \frac{\mu_0\ \mu_1\ \mu_2}{\pi\ r^2\ x}\, e^{-\lambda r} \quad . \quad (16)$$

In Table 1 we have summarized the values of E_{ph} for different combinations of values of x, y and R.

Case (i)			Case (ii)		
y (fm)	R (fm)	E_{ph} (MeV)	x (fm)	R (fm)	E_{ph} (MeV)
0.5	0.2	3.18	2	0.1	3.19
1	0.2	1.59	2	0.2	0.80
1.5	0.2	1.06	2	0.3	0.35

Table 1: Values of E_{ph} corresponding to different R of coils and distances x and y.

We have calculated the tuning factor values for fixed R, binding energies and distance among coils in the case (i) (Table 2).

Case (i)			
y (fm)	R (fm)	*Binding energy* (MeV)	*Tuning factor* (m^{-1})
1.0	0.2	3.0	$3.18 \cdot 10^{15}$
1.0	0.4	2.0	$4.04 \cdot 10^{15}$
1.0	0.6	1.0	$2.89 \cdot 10^{15}$
1.0	0.8	0.5	$2.02 \cdot 10^{15}$

Table 2: Tuning factor values for fixed R, binding energies and distance among coils.

An attractive magnetic energy obtained from the classical Biot-Savart interaction without consideration of the phase relationship (4 keV) would be only a small contribution to nuclear binding energies, but 0.136 MeV between nearest neighbors is already a significant percentage of the mean nuclear binding in either the context of the LDM or the fcc lattice. Specifically, default structures for ^{90}Zr, ^{200}Hg, and ^{238}U lattice nuclei have, respectively, 370, 865, and 1036 nearest-neighbor interactions, corresponding to mean energies of 2.1, 1.8, and 1.7 MeV (per nearest-neighbor “bond”).

Considering now the case (i) (analogous calculations can be made for case (ii)), making the assumption about the nucleon dipole:

$$R = y = 0.2336\ \text{fm},$$

It follows that the magnetic interaction between two protons, two neutrons, or one proton and one neutron is 5 MeV; the short-range nuclear force with various spin and isospin combinations can explain the basic trend in nuclear binding energies.

With the adjustement above, we can conclude that the magnetic nuclear force is sufficient to explain nuclear binding. Binding effects (5MeV) among neighboring nucleons are enough to achieve binding for 273 isotopes built in the fcc software, implying that a magnetic nuclear force is consistent with the lattice model [6].

4. Conclusions:

Funding of LENR research should focus on the basic experimental science of isotopic transmutation effects, regardless of their possible technological utility. Once the empirical data are unambiguous, *ab initio* computational simulations should become possible.

We have developed the fcc lattice of nucleons as a model of nuclear structure, showing that its numerical results concerning nuclear size, shape, density, etc. compare well with the 30+ other models of nuclear structure developed throughout the 20th century [5].

To date, nuclear “modeling” contributes little or nothing to the fundamental unresolved issue of the nature of the nuclear force holding nuclei together. In the present work, we addressed the question of the nuclear force acting between nucleons in a close-packed nuclear lattice.

The validity of results depends crucially on the three variables R, x, y. A center-to-center internucleon distance of approximately 2.0 fm gives a core nuclear density of 0.17 nucleons/fm^3 [5], nuclear core density normally cited in the textbooks since the electron-scattering experiments of Hofstadter in the 1950s (somewhat larger values (0.13~0.16) for the “mean” density (core plus skin region) are also cited in the literature).

Similarly, the nucleon RMS radius for both protons and neutrons is known experimentally to be ~0.88 fm [7,8]. Nevertheless, the nuclear dipole that results in the magnetic moments of +2.79 and -1.91μ, respectively, might have dimensions somewhat different from the matter distribution within the nucleon, so that calculations of magnetic force effects over a broad range of dipole sizes are relevant.

The followed way, with the novelty of the “particular use” of the Biot-Savart law, is therefore a possible solution to the 80 years old problem of the nuclear force.

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