Critique of Electromagnetic Models of the Nucleus, re Older Theory

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Abstract

Early 1950s models of nuclei considered that they were made up solely of protons and neutrons having approximately equal sizes. A large nucleus was an approximately spherical ensemble made up of these packed entities. Nuclear reactions were treated using Quantum Mechanics, by solving the Schrödinger wave equation for wave amplitudes inside and outside a nucleus and relating these to cross sections.

Beginning in the 1990s, new Classical Electromagnetic models of nuclei were developed. These are quite totally different from those in the theoretical Standard Model which uses quarks and gluons, etc. Electrons and protons were considered to be spinning charged fibers, and a neutron was considered to be a paired combination of an electron and a proton. With these new nucleon models, nuclei were crudely modeled as concentric shells of these particles placed in a 3D spatial configuration by a geometrical mapping theory called Combinatorial Geometry. This theory was able to correctly predict the "Magic Numbers" as combinations of shells filling and emptying as nucleons were added. An improved Semi-Empirical Binding Energy Formula was developed, which accurately predicts the binding energies of stable and radioactive isotopes, and also correctly predicts their spins. The Electromagnetic model was improved by making detailed spatial and directional force balances using a variational minimization technique, which predicts decay energies for various reactions.

In 2004, a new Electromagnetic model of all types of particles was developed based upon a three-level scheme of wrapping fractionally charged fibers. This new fiber model has yet to be used to redo the nucleus calculations. However, Electromagnetic models have the potential to describe nuclear reactions in terms of unstable vibrations whose equations are analogs to the Schrödinger equation. The purpose of this paper is to discuss all of these models, and to predict where the research should go next.

1. 1950s Theory and Experiment

Robley Evans wrote The Atomic Nucleus [1] in 1955. Evans cites a 1951 paper, saying that Robson [2] measured the ~14 minute half life decay of slow neutrons using two magnetic lens spectrometers and coincidence measurements to get the beta end-point energy and confirm the neutron-proton mass difference measured by Li from various threshold reactions. Those were the days of vacuum tube circuits and single channel analyzers, so Robson did about all that could be done with his equipment. In fact, all these citations are from this experimental era.

There is a citation for Hofstadter which concerns probing the nucleus with 125-150 Mev electrons [3]. Using the idea of a roughly uniform distribution of charge in a nucleus, and a wave mechanical interpretation, all of the charged particle experiments correspond to a basic nucleon radius R_0 of about 1.1E-13 cm, and, among other experiments, this size came from isotope shifts over a range of A and Z.

The fast neutron scattering experiments were consistent with a radius of about 1.5E-13 cm. The ratio of these is about 1.4, so that seems to be the upper limit of size uncertainty. Hofstadter's results, for protons and neutrons, are shown in Figure 1, where the charge density times $4\pi r^2$ is plotted against the radius of the nucleon. Note that, on a relative scale, this strongly reduces the amplitude in the center of this plot compared to the outside. Since these data are the result of random orientations of the nucleons, any polar asymmetries would be averaged out. Nonetheless, the data support the fact that the neutron and proton are about the same size and each has an internal charge distribution.

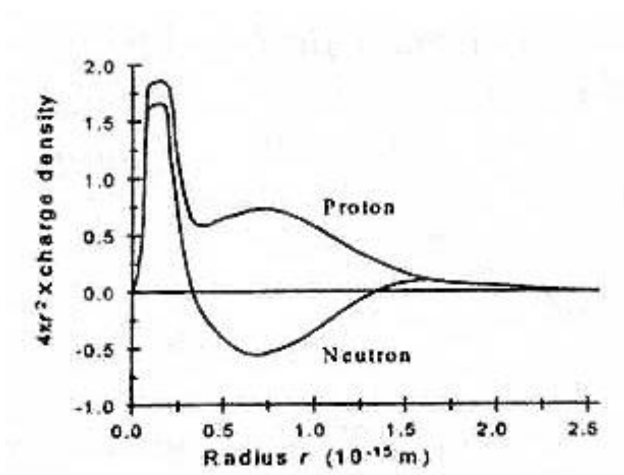

Figure 1. Neutron and Proton Size and Charge Density [3]

In Chapter 4 of Evans there is a discussion of anomalous magnetic moments of free nucleons. The proton has a larger than expected magnetic moment of +2.79 nmag, and the neutron has a large negative magnetic moment of -1.91 nmag. Evans states that no theory at that time was in agreement with either of these values by a long shot, but concludes that the neutron had to have a significant internal charge distribution in order to have a magnetic moment. Hofstadter's results for the broad peaks give approximately the correct ratio of moments. The results are not inconsistent with the Standard Model of protons and neutrons being made up of fractionally charged and spatially distributed -1/3e and +2/3e quarks.

Chapter 2 of Evans contains a short history, "It is worth noting that the early efforts to interpret anomalous scattering results, in terms of collisions which could be described by Classical mechanics, led to the introduction of a number of ad hoc, if not bizarre, models of the inner structure of atomic nuclei. Some of these models had to stay in vogue for over a decade because no more acceptable model could then be found. These included Chadwick's "plate-like alpha particle" and Rutherford's "core-and neutral-satellite" nucleus which contained a small positively charged core, surrounded by other nuclear matter in the form of heavy but uncharged satellites moving in quantized orbits, under a central 1/r-5th law of attraction which was attributed to polarization of the neutral satellites. The early speculations on the idea of neutrons are visible in this model. The gradual development of the Wave Mechanics, in the latter 1920s, provided the first basis for scrapping many of these Classical ad hoc models of the structure of nuclei. A wide variety of nuclear phenomena can now be interpreted on a basic of Wave Mechanics, as it is applied to a few newer nuclear models which are reasonably self-consistent. Much progress has been made, but much remains to be done."

In Chapter 8 it is stated, "A variety of experimental evidence now is consistent with the concept that nuclei are composed of only protons and neutrons and that these two forms of the "nucleon," or heavy nuclear particle, are bound together by very strong short-range forces." Immediately following is a section on Nonexistence of Nuclear Electrons. This contains a discussion of what nuclear electrons would do to change the statistics of odd N nuclei, especially N-14, and a discussion that positron emission also contradicts this idea. Fermi theory about pair production also says that electrons were not originally inside the nucleus. The next section is on Acceptability of Neutrons and Protons as Sub-nuclear Particles. He concludes that models containing electrons and neutrinos fail.

Evans says, "The shape of the nucleus is taken as being substantially spherical, because for a given volume this shape possesses the least surface area and will therefore provide maximum effectiveness for the short-range binding forces between the nucleons in the nucleus. The existing experimental evidence also supports the view that within the nucleus the spatial distribution of positive charge tends to be substantially uniform; thus the protons are not appreciably concentrated at the center, the surface, the poles, or the equator of the nucleus. Small asymmetries of the distribution of positive charge are present in some nuclei, as is known from the fact that, many nuclei have measurable electric quadrupole moments." These charge asymmetries are discussed in Chapter 4; "Here we note that, if the positive charge in a nucleus is regarded as uniformly distributed within an ellipsoid of revolution, then the largest known nuclear quadrupole moment (of Lu-76) corresponds to a major axis which is only 20 per cent greater than the minor axis of the assumed ellipsoid. In most nuclei the corresponding ellipticity is only of the order of 1 per cent. Therefore we may regard most nuclei as having nearly uniform and spherical internal distributions of positive charge."

Evans continues, "In the succeeding sections of this chapter we shall discuss nine varied types of experimental evidence, which lead to the conclusion that the nuclear volume is substantially proportional to the number of nucleons in a given nucleus. This means that nuclear matter is essentially incompressible and has a constant density for all nuclei. The variations from constant density, due to nuclear compressibility, appear to be only of the order of 10 per cent." Note that the property of compression resistance implies the existence of some sort of force that resists compression.

2. Electromagnetic Models of the Nucleus

There are two different Electromagnetic Models for fundamental particles. One is based on spinning rings of unit ±e charge, and the other is based upon wrapped groupings of fractional ±1/3e charges.

2.1 Spinning Charge Rings

Bergman has adapted a particle model originally proposed by Arthur H. Compton [4 - 6] (Compton Effect), which was later extended by one of Compton's last graduate students, Winston Bostick. Bostick worked on experimental plasma physics, and created something called a plasmoid, or a stable blob of charged particles. Based on Hofstadter's [3] experimental work on neutrons and protons, Bostick [7] proposed that an electron behaved as if it were composed of a charged fiber toroidal loop that had both electric and magnetic properties.

Bergman and Wesley [8] considered an electron to be a single spinning charged ring of negative unit charge -e, and adjusted its size to give it correct physical properties. Bergman [9] made a similar model of a proton as a single spinning charged ring of charge +e with a different size. Bergman [10] finally made a model of a neutron as a coplanar proton ring inside an electron ring, with sizes adjusted to match experiment, as shown in Figure 2.

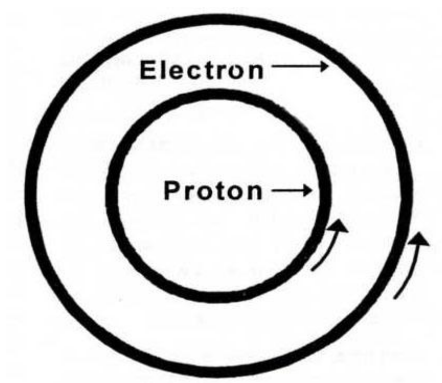

Figure 2. Bergman's Neutron Model

Some of the controversy about these models concerns the assertion by the authors that the sizes of the rings vary according to external electromagnetic fields, and that the free neutron has a considerably different size than the bound neutron, as does the free electron compared to the bound electron. The problem is that the Classical radius of an electron is bigger than the measured size of a proton or a neutron. However, the definition of the Classical radius of the electron is obtained by setting the potential energy of gathering the charge –e equal to the rest mass equivalent energy, m_0c^2. If a similar definition were made for a proton, its size would not agree with the measured size.

A second difficulty is that the spin and statistics of nuclei made up of these particles have to be rationalized away by assuming that the neutron combination acts as a single particle. While this might work for beta decay, it doesn't explain the neutrino, and the model cannot be used to explain positron decay. Despite these apparent difficulties, if the particle models are treated as black boxes having the right external properties, then useful results that agree with experiment do result.

2.2 Crude Nucleus Model

Lucas [11] essentially used Bergman's charged fiber models of neutrons and protons, and set about ordering them in space to make nuclei. Lucas says, "In the new physical geometrical packing model, the nucleons do not orbit about the center of the nucleus. Ampere's law and Faraday's law in electrodynamics require that charged nucleons radiate energy continuously if they orbit in the nucleus. This radiation would cause the nucleus to collapse and never be stable. In the geometrical packing model the balance of electric and magnetic forces on the finite-size charged neutron and proton rings in the nucleus causes them to come to a balanced equilibrium position some distance from the center of the nucleus without having to orbit the center of the nucleus."

"In order to complete the shell structure for all the nuclides that have been observed, the balance of electric and magnetic forces in the shells must be taken into account. The mathematics for handling large numbers of toroidal rings spatially distributed and allowed to deform is very complicated, so this was done systematically in a crude way through a series of assumed rules obtained by inspection of nuclide data. This pattern is shown for Pb-208 in Figure 3 [12]." The protons occupy the two outermost shells, getting away from each other as far as possible. The neutrons polarize with their positive ends turned in towards the center and, by separating as far as possible from one another, leave empty shells in the center. Additional protons and neutrons would occupy the inner shells for heavier nuclides.

Using the notion that smaller shells may come apart and rearrange themselves into larger more stable shell configurations, Lucas predicted the entire pattern of the Magic Numbers of closed shells of neutrons and protons, as shown in Table 1. One sees that the notion of shells rearranging into larger more stable shells due to the lack of an attractive nuclear center seems capable of explaining the magic number shell-like features of the nuclides. Specifically, 2 and 8 form the inner shells and each is a Magic Number. The next two shells can each have 18 nucleons, but the magic number 20 is made up of the two shells, 2 and 18. The magic number 28 is made up of 3 shells, 2, 8 and 18. The next shell has 32 nucleons, and the magic number 50 can be made using 18 and 32. The next shell contains 50 nucleons, so it is magic by itself, but the magic number 82 comes from 32 and 50. Finally, the magic number 126 comes from the shells 50, 32, 18, 18 and 8, as seen in Lead-208.

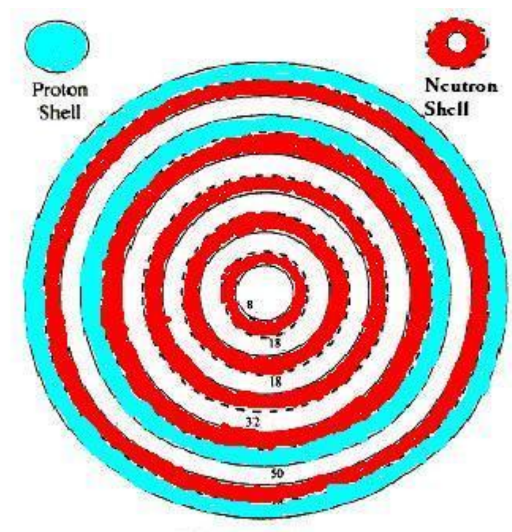

Figure 3. Lucas' Shell Structure for Lead-208

TABLE 1
NUCLEAR SHELL MAGIC NUMBERS

Magic # Nucleons	===== COMBINATORIAL GEOMETRY SHELLS =====									
0	2	2	8	8	18	18	32	32	50	50
2	2									
8			8							
20	2				18					
28	2		8		18					
50					18		32			
82							32		50	
126			8		18	18	32		50	

Lucas says, "What about the nuclides in between the magic number shells? The nuclides between the magic number nuclides have a number of physical properties which the physical geometrical packing model should explain. One of these properties is the spin or magnetic moment of the nuclides. Magic number nuclides have no spin or magnetic moment, because they consist of only completed (full) shells which are spherically symmetric. Nuclides with an even number of neutrons and protons also have no spin." Lucas correctly predicted the isotopic spins of all particles, while the regular shell model gets about half of the non-zero spins wrong. He says he can calculate the magnetic moments too, but this work is still in progress.

Lucas then decided to model all 3000 nuclei in the Chart of the Nuclides, and fit his own Semi-Empirical Mass Formula to the binding energy per nucleon versus mass number A. His new fit predicts the entire structure of the data, including the peaks, to accuracy within the measurement errors of the isotope masses. This fit is shown in Figure 4. It should be noted that the lead term is proportional to the nuclear volume or the number of nucleons present, A. In the shell model, unoccupied inner shells must not take up much space or this term would be wrong. So the shells are somewhat more mathematical than real.

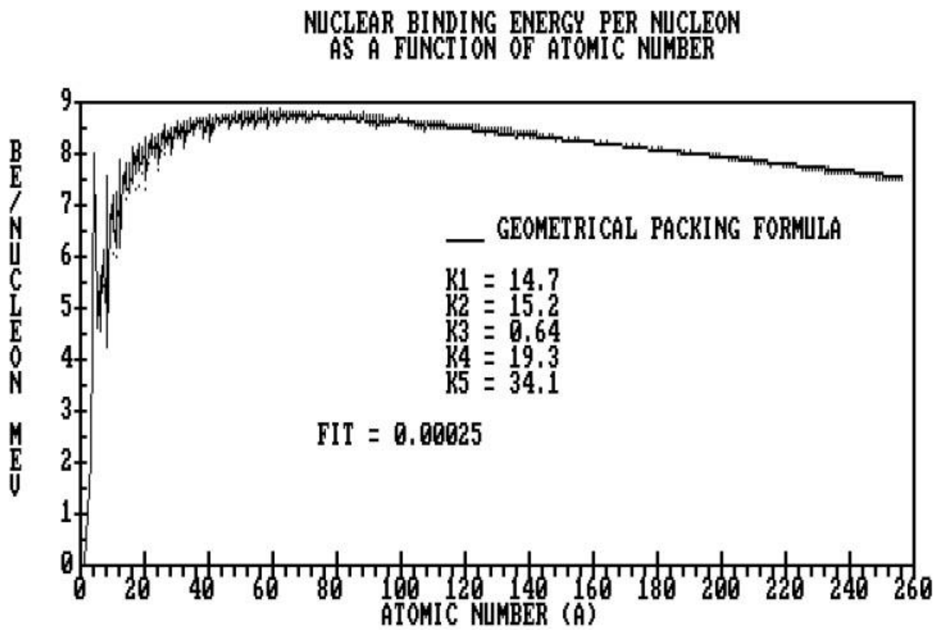

Figure 4. Lucas' Semi-Empirical Mass Formula Fit

Lucas says, "In the new geometrical packing model, a somewhat different formula is used for the binding energy per nucleon (W/A) than in the old model. The terms represent similar effects, but the new terms are dependent on the physical shell structures as shown below and are not ill-conditioned."

W/A = K_1	**(Volume)**
- K_2 (#Neutrons + #Protons in outermost shell)/A	**- (Surface)**
- K_3 $Z(Z-1)A^{-4/3}$	**- (Coulomb)**
- K_4 (#paired Neutrons - #paired Protons)^2 /A	**- (Asymmetry, Magic)**
- K_5 (#unpaired Protons + #unpaired Neutrons)/A	**- (Pairing)**

The above fit shown in Figure 4 can be compared to the experimental data for stable isotopes only, shown by Evans [1] in 1955 (Figure 5). The peak values in Figure 4 are only slightly different, and the rest of the curve is shown in considerably more detail. The old Semi-Empirical Mass Formula only fit well above A = 20.

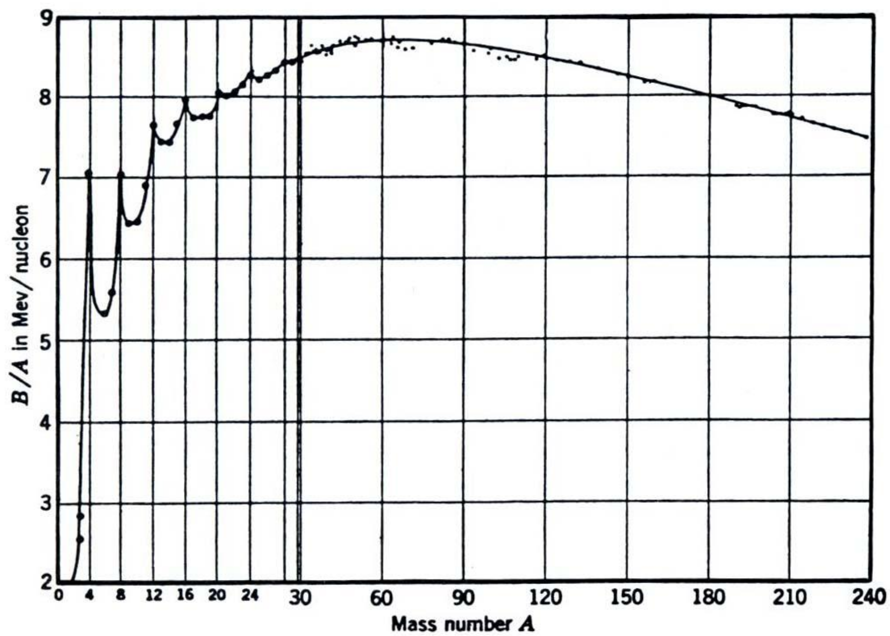

Figure 5. Evans' Semi-Empirical Mass Data
From R. D. Evans, **The Atomic Nucleus**, Chapter 2, McGraw Hill, 1955.

2.3 Detailed Nucleus Model with Decay

Boudreaux and Baxter [13] have adapted Bergman's model of a proton, and a neutron made up of an associated proton/electron, to make nuclear models based on detailed electromagnetic force balances between particles. Again, the nucleon sizes had to be adjusted to make the model work. The nucleons are allowed to separate and rotate to reach positions of minimum energy using a variational technique. When selected nuclei are approximately positioned according to Lucas' selection rules, the final positions converge quickly to the same pattern. By separately clustering particles, they tested several cases for decay, including Be-8, Na-24 and K-40, obtaining approximately correct decay energies.

K-40 proved to be a most interesting case. K-40 decays by beta emission, electron capture and by positron (β^+) emission. The beta-minus decay process produces Ca-40 as the stable daughter product and accounts for the major portion of the decay mechanism. The electron capture/positron-emission decay process produces the noble gas Ar-40 as its daughter and is the one employed in the radiometric dating of rocks. These calculations have provided two spin states for K-40, which are not at the same energy. These appear as two minima in the binding energy profile for K-40, and they appear to account for the branching effect.

2.4 Advanced Nuclear Model

Lucas [14] has now extended the three-level charged fiber particle model to all of the elementary particles and their decay products treated by the Standard Model. Neutrons and protons consist of parallel primary fibers made up of intertwined secondary and tertiary fibers. The configurations are similar to the particle definitions in terms of quarks, but the decay of a neutron requires extra fibers to support the definitions of the reaction products and conserve fibers. Depending on spatial orientation of the fibers, these models have the ability to match Hofstadter's [3] experimental data which showed that each nucleon has an internal charge distribution. The result may be a neutron that can polarize to produce an even more accurate nucleus model.

Again there is a controversy about the apparent sizes of the particles under different conditions. "In my paper on elementary particles the neutron consists of the same number of negatively and positively charged fibers as the electron and proton together. However, in the free neutron the charge fibers rearrange into an equilibrium configuration of one particle with the primary charge fibers in parallel on the surface of the toroid. Inside the nucleus this configuration can rearrange again and change size due to its elasticity." I don't know how to interpret this comment, or what experimental evidence supports it. Surely the free neutron has to contain the fibers needed to make an electron and a proton, and also a neutrino, but why should it change significantly when bound? To me, the major effect would be fiber compression by the combined forces from the other nucleons. The distortion would seem to be contained by the other factors cited above to be 10 to 20%. And the overall nucleus size would be slightly enlarged by having some empty inner shells.

2.5 Comments on EM Nuclear Models

It would be much better to treat the neutrons and protons as black boxes that have the correct EM properties which match outside experiments. The hang up is when you try to picture what is inside the boxes with a simple model of a fixed ring (or rings) of radius R that spins at c. The inside may be more complicated than that, like having wrapped fibers that may have different fractional charges, widths and sizes. I would like to see the internal charge distribution in a neutron show up as a charged dipole that might cause the neutron to twist. I would like to say that the magnetic force is like the strong force, and distortion of the rings due to compression resistance is like the weak force, and Coulomb effects come from both protons and neutrons, which may be more accurate than from just protons. Such a compression resistance is absolutely necessary for the light isotopes such as deuterium and tritium, which have only attractive nuclear forces and no Coulomb repulsion between nucleons. Without compression resistance, the attractive forces would cause the nucleons to merge!

With these modifications, all the spatial distribution of nuclear shells can be constructed from the force and energy balances of a group of these entities in space, as Lucas has done in a crude fashion, and which Boudreaux has done more accurately, by making detailed spatial and directional force balances. Neither has thus far included neutron polarization, or compression resistance, so there are small absolute errors left in the calculated examples. The decay schemes and energies seem to come out of this type of modeling. If the new Lucas model can be reworked into Boudreaux' computations, perhaps these inaccuracies would disappear.

2.6 Nuclear Vibration Model

It is precisely the interplay between plus and minus forces that allows the nucleus to vibrate, and vibrations can become unstable leading to a configuration change which we call decay. Rydin [15] has conceptually modeled the strong force (electromagnetic attraction), the weak force (charged fiber compression) and the Coulomb force as linear springs. By essentially writing Newton's law, F = ma, the resulting balance equation is of the same form as Schrödinger's Wave Equation. Hence, the wave solutions are similar to vibrations, and the nuclear excited states are similar to vibration eigenstates. The old liquid drop model of fission is precisely a vibration problem that leads to an unstable configuration whose pieces come apart. The fact that there are many possible outcomes in fission means that there are many degrees of freedom that can reach a vibration-caused instability.

This work enforces Bergman's, Lucas' and Boudreaux' contention that Quantum Mechanics is unnecessary to explain nuclear reactions, and that these reactions can instead be explained Classically using electromagnetic theory.

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