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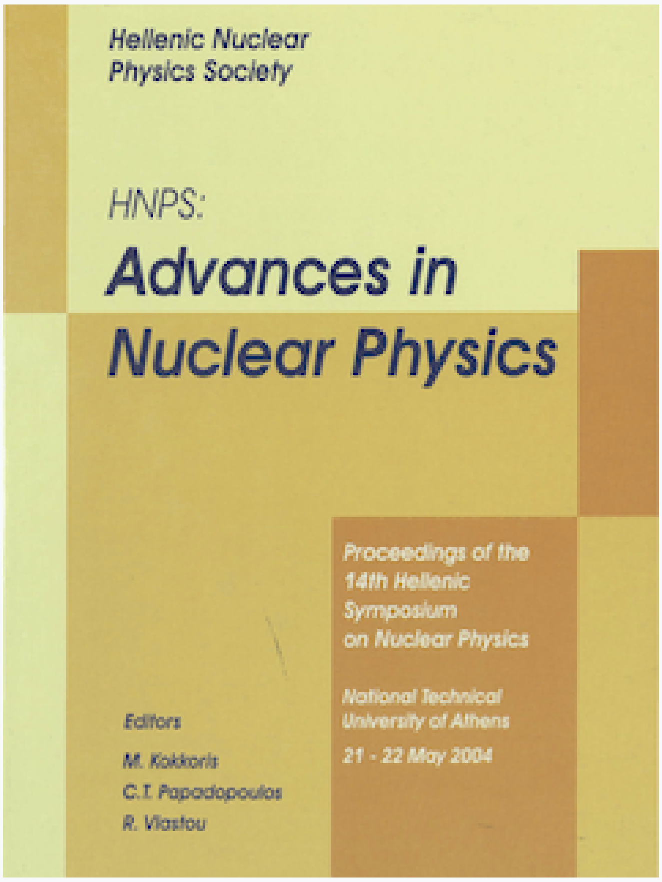


## Charge Distributions in Nucleons Able to Create the Nuclear Structure

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# Charge Distributions in Nucleons Able to Create the Nuclear Structure

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**Abstract**

Considerable charge distributions in nucleons as multiples of the fractional charges 2e/3 and −e/3 are determined after a careful analysis of the magnetic moments and the results of the deep inelastic scattering. In fact nucleons have fairly large magnetic moments which imply charge distributions of 8e/3 and −8e/3 along the peripheries of proton and neutron respectively. According to the deep inelastic scattering the corresponding charges of −5e/3 and 8e/3 are limited at the centers of the above nucleons. Basic equations derived from such distributed charges lead to the orientation of spins of nucleons and give strong and short ranged forces like the dipole-dipole interactions leading also to the well known binding energy of the deuteron which operates in radial direction with S=1. This operation due to the basic electromagnetic interaction of the opposite charges along the peripheries is in contrast to the Pauli principle. According to these fundamental interactions, p-p and n-n systems repel and only the p-n bonds form rectangles and closely packed parallelepipeds for the structure of nuclei providing an excellent description of nuclear properties.

## 1 Introduction

Unfortunately the discovery of neutron[1] along with the enormous strength and very short range of the nuclear force led to the abandonment of the fundamental electromagnetic laws in favor of qualitative approaches for the study of the nuclear structure, since both the proton and the neutron have fairly large magnetic moments which imply considerable charge distributions, able to create the nuclear structure by giving strong p-n bonds and repelling forces of identical nucleons under quantitative measurements of short ranged dipole-dipole interactions.

Nevertheless, after the failure of Heisenberg's theory[2] and without detailed knowledge about the charged substructure of nucleons, Yukawa's meson theory[3] seemed to be valid under the discovery of several mesons[4] . However, many attempts to fit them into a consistent scheme of nuclear forces did not succeed in reproducing quantitatively the known nuclear phenomena. Another serious problem had to do with the p-p scattering at high energies which is quite different from the p-n scattering, showing that the charge independence hypothesis[5] cannot be applied to the scattering data. Moreover, such hypothetical attractive forces of p-p and n-n systems cannot lead to the saturation[6] and the decay of light and massive nuclei.

Thus, in the absence of a realistic force the most important structure models like the liquid drop[7], the Fermi gas[8] , the nuclear shell[9] , and the collective picture[10] , lead to complications. H.Ohanian emphasizes that such models are caricatures of the real world[11] . On the other hand, the analysis of the deuteron, alone, based on a hypothetical square- well potential did not give the desired information about the p-n force[12]. The same difficulties will be observed, also, in the alternative approach, the theory of nuclear matter[13] . Of course the aspect of the quantum chromodynamics that the nuclear force is due to the residual strong interaction between the hypothetical color-charged constituents of nucleons[14] cannot provide any framework for quantitative measurements. Moreover, the quark picture[15] could not explain the same phenomena that are treated by the predominant meson theory, since nature works in only one way.

Note that the experimental values of the g-factors of the proton[16] and neutron[17] indicated charge distributions in nucleons confirmed by bombarding them with high-energy electrons[14] . Moreover a systematic analysis of the experimental data gives fractional charges as -5e/3 and 8e/3 or 8e/3 and -8e/3 distributed in the centers and along the peripheries of p and n respectively.

In our research[27] we found that the distributed charges favor a coupling of the simple p-n system along the radial direction with S=1 because in this area the motional emf is weaker than that in axial direction. Furthermore, quantitative measurements of electromagnetic forces at the shortest separation $2r_p$ for the observed value $r_p = 0.813 \pm 0.008$ fm of the proton radius[18] give a p-n bond, whose the binding energy equals the experimental value[5] $B(^2H) = -2.2246$ MeV .

The simple p-p and n-n systems operate also in radial direction but they give spins of S=0 with repulsive forces. Similarly the electron-electron system operates in radial direction giving S=0 but at a separation r ¡578.5 fm appears an attraction able to explain the Pauli principle.

Under such contrary forces, a close packing of nucleons tends to increase the binding energy by bringing the unlike nucleons (p-n bonds) closer together with oriented spins which form rectangles and closely packed parallelepipeds, while the p-p and n-n systems of repulsion favor a stable structure ,when they are arranged at greater distances (diagonals) with non oriented spins.

We have found [27] that two deuterons are coupled along the spin axis with S=0 (the motional emf is negligible) involving stronger p-n bonds in axial direction than those in radial one. They form $^4$He with S=0 which is a two-dimensional rectangle with a coordination number of 2. Despite this small number, $^4$He is extremely stable since the identical nucleons exert weak repulsions as a result of the non oriented spins and the greater separations (diagonals).

Two-dimensional shapes are formed, also, in other light nuclei. However their binding energies are smaller than that of $^4$He due to repulsive forces of additional oriented p-p and n-n systems. On the other hand, $^3$H and $^3$He have some disorder introduced by a missing nucleon, while in other nuclei, like in $^{14}$C additional neutrons outside closely packed systems make single p-n bonds of weak binding energy often leading to the decay because of the electromagnetic repulsive forces of identical nucleons.

Also, at the beginning of the three-dimensional structure there is a great difficulty for the two rectangles of $^4$He to form a simple parallelepiped belonging to the extremely unstable $^8$Be. According to our research[27] this is due to the parallel spin of identical nucleons, repelling with electric and magnetic forces along the diagonals of the squares, so as to reduce significantly the weak radial p-n bonds in a symmetrical shape with a coordination number of 3.

However, for the structure of the heavier $\alpha$ particle nuclei, for A=12,16,20 and 24, proper combinations of rectangles form symmetrical shapes with an increasing coordination number from 3 to 4 or 5 in inner rectangles or squares. This dynamic situation, which implies decrease of the so-called surface tension[7] , is able to overcome the repulsions of the oriented p-p and n-n systems to make stable arrangements. It is understandable by using the figures of our research[27].

Such contrary forces invalidate the charge independence and charge symmetry, as well as the models of the orbital shell and the Fermi gas. Unlike the electronic binding energy per electron, which increases as $Z^{3/4}$, they lead to the saturation properties and to unstable nuclei.

The two kinds of p-n bonds, which imply anisotropy, often lead to elongated shapes of vibrational and rotational modes of excitation described in terms of quanta. High symmetry together with the values of spins[19] and the known binding energies of nuclei[20] are the basic tools for understanding the structure of stable light nuclei, when Z=N, since for a fixed A any change from Z=N to N>Z or N<Z reduces the number of p-n bonds.

As the nuclei become heavier suitable geometric shapes like tetragonal or orthorhombic systems (cores) are surrounded by outer p-n composite bonds (non single bonds) by increasing the coordination number to the maximum number of 6. This situation implies a significant decrease of the surface tension leading to non elongated shapes with a minimum nuclear surface area. Under such a dynamics the outer p-n bonds appear with equal number of p and n and behave like unfilled shells because they form " empty" positions as many as possible between two or three protons able to receive extra neutrons, which make extra p-n composite bonds in order to overcome the repulsive energies of the dominant long ranged p-p repulsions. In magic nuclei for N>Z such shells are occupied completely as shown in the figures of our research[27].

## 2 Charge distributions in nucleons

Quarks, gluons, and a sea of quark-antiquark pairs in the quantum chromodynamics[21] cannot give any information about the charge distributions in nucleons. Note that the problem became more complicated after the so-called spin crisis[15]. Also the treatment of a nucleon as a core surrounded by a meson cloud[15] , suffers from peculiar complications . On the other hand, Dirac's theory[22] failed to give a sensible explanation of the nucleon structure[18].

Under these difficulties, an analysis of the $g_p$=2.79278 and $g_n$= -1.91315 and the results of the deep inelastic scattering gives detailed charge distributions showing also that the (uud) and (udd) schemes[23] are insufficient in describing the complicated quark structure.

In a simple discussion, the picture of the proton could be as a rather oblate spheroid associated with its spin[24] and the magnetic moment $\mu_p$. Examining the relation

$$\frac{\mu_p}{S} = g_p \frac{e}{m_p} = 2.79278 \frac{e}{m_p} \tag{1}$$

one may find that $g_p$¡2.79278, when the charges Q=2u=4e/3 and q=d=-e/3 of the (uud) scheme are distributed uniformly. Even, in the extreme case in which Q=4e/3 is along the periphery and q=-e/3 is limited at the center, the distribution gives again $g_p$¡2.79278 .

These puzzles are resolved under a reasonable assumption that Q=8e/3 and q= -5e/3. Note that the limitation of q=-5e/3 at the center is supported by the deep inelastic scattering experiments, since the deflections suffered by the electrons indicated the presence of a point like charged region in the deep interior of the proton[25]. Of course, the electrons must penetrate easily the rarely distributed positive charges along the periphery. Moreover, the uncharged mass which amounts to about 93 % of the total mass[11] , justifies this extreme case of a charge distribution. The contribution of Q =8e/3 to $\mu_p$ as a circular current with an angular velocity $\omega_p$ is

$$\mu_p = Q\frac{\omega_p}{2\pi}\pi r_p^2 = \frac{8e}{3}\frac{\omega_p}{2}r_p^2 \tag{2}$$

whereas the spin S is given by

$$S = (3/4)^{1/2} = t_p m_p \omega_p r_p^2 \tag{3}$$

where 0.5>$t_p$ >0.4 which characterizes the shape of p between a disk (S = $0.5m_p\omega_p r_p^2$) and a sphere ( S = $0.4m_p\omega_p r_p^2$). Now dividing (2) by (3) leads exactly to (1) when $t_p$ = 0.47742 .

The fractional charge Q = 8e/3 along the periphery, which is twice greater than the postulated charged quarks 2u = 4e/3 , can be justified also by the fact that the moment of proton is about twice greater[21] than that given by the simple (uud) scheme.

Similarly, to describe the structure of the neutron with a mass $m_n \approx m_p$ we see that

$$\frac{\mu_n}{S} = g_n\frac{e}{m_p} = -1.91315\frac{e}{m_p} \tag{4}$$

leads to the same complications under the (udd) scheme. So, taking into account the symmetry properties of nucleons that the current distributions within n and p are quite similar[18] a structure of n analogous to p is obtained by assuming that a negative charge Q=- 8e/3 is along the periphery while the opposite charge q=8e/3 is limited at the center. Hence, for $r_n$=$r_p$the current of Q with an angular velocity $\omega_n$ generates $\mu_n$ as

$$\mu_n = \frac{8e}{3}\frac{\omega_n}{2}r_p^2 \tag{5}$$

while the spin S of n may be given by

$$S = (3/4)^{1/2} = t_n m_p \omega_n r_p^2 \tag{6}$$

Dividing (5) by (6) leads exactly to (4) when $t_n$ = 0.69693. That is, 1>$t_n$ > 0.5 characterizing a shape between a disk and a ring. This value is not surprising for an oblate spheroid of n, since the mass of the negative charge along the periphery corresponding to the d quarks is expected to be greater than the mass of the positive one[11] . Such a distribution of charges is supported also by the earliest electron scattering experiments[26].

Note that these charge distributions of p and n satisfy the conservation of charge in the beta decay of n. That is, n(8e/3 - 8e/3) = p(8e/3 - 5e/3) + (-e). While the simple quark model leads to complications and suffers from deficiencies[11] .

## 3 Electromagnetic interaction of the simple p-n system

It should be stressed that the parallel spin of the simple p-n system can be misleading because this situation is forbidden by the Pauli principle[18] . This difficulty was avoided in our research[27] by treating the nucleons as two interacting dipoles. From the $g_d$= 0.85741of the deuteron[15] which is almost equal to the algebraic sum of $g_p$ and $g_n$ , it is concluded that the two nucleons are coupled in radial direction leading to S=1. Such a coupling is understood by using the magnetic field due to the current of Q, which exerts a torque on the current of the negative charge Q and vice versa. Also a large number of equations in our research[27]for the interacting charge distributions of the two nucleons lead to the following binding energy

$$B(^2H) = -1.2436\frac{ke}{r_p} \tag{7}$$

Substituting the values of constants and using the value $r_p$=0.805 fm, which is in the range of $r_p$=0.813 ± 0.008 fm one gets the experimental value $B(^2H)$ = -2.2246 MeV. Moreover two deuterons are coupled in axial direction to form $^4He$ with very strong p-n bonds of S=0.

## 4 Interaction of identical particles

The simple p-p and n-n systems operate in radial direction with S=0 because of the like charges along the peripheries. Such systems give repulsive forces.

Nevertheless, two electrons with S=0 at the radial direction r<578.5 fm exert on each other attractive electromagnetic forces. Before formulating this, notice that the relation

$$\frac{\mu_e}{S} = -1.00116\frac{e}{m_e} \tag{8}$$

in the theoretical precision of the Schwinger theory[14] cannot give any information about the charge distribution. So it is necessary to re-examine the simple idea of the electron spin introduced by Uhlenbeck and Goudsmit that the electron is a charged particle spinning with an angular velocity $\omega$. Then (8) is justified when the electron is treated as a rather spinning disk with $t_e$=0.49942 having the charge-e along the periphery. It is demonstrated by

$$\frac{\mu_e}{S} = -\frac{e(\omega/2)re^2}{t_e m_e \omega^r e^2} = -1.00116\frac{e}{m_e} \tag{9}$$

Note that the electromagnetic force $F_{em}$ of two interacting electrons is given by the formula[27]

$$F_{em} = F_e - F_m = \frac{ke^2}{r^2} - \frac{ke^2}{r^4} \tag{10}$$

Of course for $F_e = F_m$ one finds the equilibrium separation ,r = 578.5 fm. That is, for r<578.5 fm the electrons exert an attractive force ($F_m > F_e$). Moreover, the zero magnetic field of the two electrons with S=0 cannot exert any attractive magnetic force on a third electron approaching the system. (Pauli principle). In the p-n systems such a situation cannot occur since both $F_e$and $F_m$ always attract. While the simple p-p and n-n systems always repel because $F_e > F_m$. Note that the p-n systems form also a rectangle of $^4$He and other parallelepipeds with strong binding energy because the p-p and n-n systems are usually non oriented and exert weak repulsion.

## 5 Conclusions

The distributed fractional charges in the spinning nucleons explain not only the spin S=1 of the simplest structure of $^2$H, but also give exactly the radial binding energy of -2.2246 MeV. According to the electromagnetic laws the negligible motional emf in the coupling of two deuterons is responsible for the strong p-n bonds in $^4$He with S=0 along the spin axis. Of course the radial energy and the strong axial energy imply a great anisotropy which explains the rapidly increase of the binding energy from the odd-odd nucleus $^2$H, to the even-even nucleus $^4$He, while the asymmetric shape of $^3$He (odd A) gives an intermediate energy.

Such structures show also that the Pauli principle of the electronic configurations is inapplicable in nuclei, since the p-p and n-n systems repel and often are not oriented. For this reason, no bound state is observed for the simple p-p and n-n systems and only in neutron stars the long ranged gravitational energy can hold the repelling neutrons together. Moreover, such repelling forces are responsible for the saturation and the decay of nuclei.

According to our research[27] the symmetrical shape of $^4$He contains non-oriented spins of like nucleons for very stable arrangements, while most of light nuclei contain additional oriented spins of like nucleons reducing the total binding energy. This peculiarity explains the magic number of 2 and the non smooth curve of B(Z,N)/A for light nuclei.

From the structure of $^4$He, it became clear that only the geometry of positions and the orientation of spins of p-n bonds are responsible for holding back the protons. Consequently, the two concepts of charge symmetry and charge independence did much to retard the progress of nuclear physics. Unfortunately the known p-p repulsion seemed to become an attractive force at very short separations, and so far, in vain, nuclear physics aims at the exploration of new natural laws or an unification of different field theories.

In the heavier $\alpha$ particle nuclides for A=12, 16, 20 and 24, the closely packed parallelepipeds explain the peaks of B(Z,N)/A very well since the packing of these shapes increases the coordination number from 3 to 4 or 5. This fact implies a decrease of the surface tension for stable arrangements. The reasons Z=N and S=0 imply high symmetry with a maximum number of p-n bonds, since for a constant A any change from Z=N to N>Z or N<Z not only reduces the number of p-n bonds but also leads to asymmetric shapes.

According to our research[27] the magic numbers 2, 8, 20, 28, 50, 82 and 126 are related to the special shapes of very stable arrangements in widely different groups. For example, $^4$He belongs to the group of a two-dimensional structure, while $^{16}$O belongs to the group of parallelepipeds. In the shell structure of the tetragonal system we observe the magic nuclei $^{40}$Ca, $^{48}$Ca and $^{64}$Ni , while the magic nuclei $^{88}$Sr and $^{208}$Pb belong to another group of orthorhombic systems.

Now, it is easy to understand, why in the shell model the use of the hypothetical harmonic oscillator or the spherical-well potential could not reproduce all the data and why the additional postulation of the strong spin-orbit interaction is accompanied with adjustable parameters for reproducing the available data[9] . Furthermore the shell model cannot explain how in odd-odd nuclei protons and neutrons should couple.

Here, a type of shell structure which differs fundamentally from the orbital shells in atoms, favors stable structures after increasing the ratio N/Z with increasing A. This is due to the increasing surface area, able to receive a considerable number of outer p-n bonds for making blank positions as many as possible. More excess neutrons than those of blank positions lead to single bonds (saturated bonds). Therefore, the stability region cannot depart significantly from the line Z=N in the Segre plot[19].

The elongation along the spin axis, involving a number of nuclei between the magic nuclei, is explained here by the strong p-n bonds along the spin axis leading to a great anisotropy. However, as the elongation increases very much, a considerable surface tension energy favors the increase of the lattice points with the maximum coordination number of 6 by constructing non elongated shapes with completed shells belonging to heavier magic nuclei.

This real explanation, based on the electromagnetic interaction of nucleons, is very different from the collective model, which presents a great dilemma by using fundamentally different concepts from the nuclear shell and the liquid drop model. Actually, the p-n bonds of oriented spins in the nuclear structure cannot be related to the isotropic material of a liquid drop structure, which gives always spherical shapes neglecting the spins of nucleons.

Nevertheless, after the compound nucleus model and our first understanding of the dynamics of nuclear fission it is emphasized that the p-n bonds along with the repulsions of p-p and n-n arrangements have some affinities with the liquid drop structure due to the polar covalent bonds of $H_2O$ including $H^+$-$O^{--}$bonds and repulsions of $H^+$-$H^+$ and $O^{--}$-$O^{--}$.

In fact, a nucleus is divided into components relating to the intrinsic motion of the nucleons, described in the quantum mechanics, and to vibration and rotation of the nucleus as a whole. On this basis, the $\alpha$- decay can be explained by assuming a dynamic equilibrium at the surface where the nucleons of $^4$He receive an impulse which will raise the kinetic energy enough to break the weak radial p-n bonds. Whereas in the $\beta^-$ decay the single p-n bonds become very stable rectangles as in the case of the radioactive $^{14}$C which becomes a stable $^{14}$N.

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