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About Anomalous Magnetic Moment and Structure of Nucleon.

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The exotic electric dipole moment of neutron was suggested in [1] without an explanation what could be the mechanism responsible for its origin. This paper is the attempt to provide the qualitative explanation of this phenomena relying only on the true facts observed experimentally. The model similar to the one proposed by Ida and Kobayashi [2] is used here and the fact that neutron and proton are different members of one isospin multiplet. The magnetic moments of neutron and proton are measured now with the exceptionally high accuracy [3]:

$\mathbf{m_n}$ = -1.9130428± 0.0000005 $\mathbf{m_N}$, $\mathbf{m_p}$ = 2.79284739± 0.00000006 $\mathbf{m_N}$.

The magnetic moment of a nucleon can be expressed as:

$$\mathbf{m} = g(eh/4pMc)\mathbf{J} \qquad (1)$$

here g- factor of Lande, e - charge of a nucleon, M - mass of a proton,

J - spin of a nucleon, the term eh/4pMc - is a nuclear magneton $\mathbf{m_N}$. The measured magnetic moments $\mathbf{m_n}$ and $\mathbf{m_p}$ are in a striking contradiction with the ones expected from the expression (1) and this is the case of anomaly. We take here the model of Ida and Kobayashi in the sense that nucleon is composed of quark and diquark (one can find very detailed review about diquarks in [4]) and modify the expression (1) to:

$$\mathbf{m} = \mathbf{m}_N . \mathbf{S} e_i g_i \mathbf{J}_i \qquad (2)$$

here: e_i, g_i and $\mathbf{J}_i$ are the charge, factor of Lande and moment of a constituent quark (diquark). Then we take into account that diquark can exist as a pair of like quarks and as a pair of different quarks. Lets write the corresponding system of two equations for both cases taking into consideration that neutron and proton are members of one isospin multiplet:

Case I: n = u + dd, p = d + uu

$$2/3 \cdot g_1 J_1 - 2/3 \cdot g_2 J_2 = -1.913$$

$$-1/3 \cdot g_1 J_1 + 4/3 \cdot g_2 J_2 = 2.793$$

From here it follows that: $g_1 J_1 = -1.033$ and $g_2 J_2 = 1.836$

The fact that $g_1 J_1$ turned out to be very close to 1 means that here the single quark acts as elementary particle placed at the center of nucleon, some extra of 0.033 may be assumed here as a glueball correction. Here it is appropriate to recollect the Schwinger correction to magnetic moment of electron. Presumably this is the consequence of the quark recoil whenever a virtual quark-antiquark pair is emitted [5]. The fact that $g_2 J_2$ turned out to be less than 2 means that here diquarks are scalars with spin zero, i.e. that spins of quarks in a diquark are antiparallel what agrees with Pauli principle. The fact that here $g_2 J_2$ turned out to be non integer may signify that the center of masses and the centers of positive and negative charges of the nucleon do not coincide, that there is some displacement between these points, that nucleon is a tremulous particle.

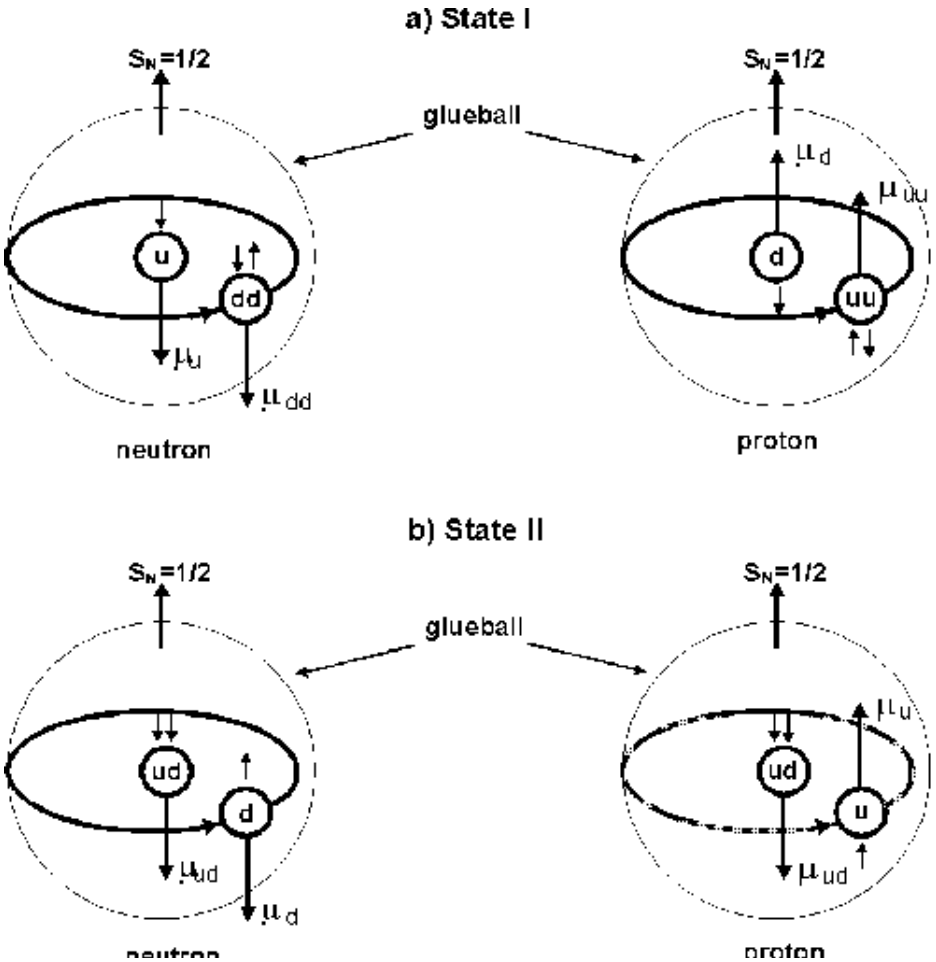
Case II. The similar equations can be written for the case when diquark **ud** is in a state $^3S_1$, only here $g_1 J_1$ is the value assigned to the single quarks, constituents of a diquark **ud**:

n = ud + d, p = ud + u

$$1/3 \cdot g_1 J_1 - 1/3 \cdot g_2 J_2 = -1.913$$

$$1/3 \cdot g_1 J_1 + 2/3 \cdot g_2 J_2 = 2.793$$

To satisfy this system one should take: $g_1J_1 = -1.033$ and $g_2J_2 = 4.7$. The fact that g_1J_1 turned out to be close to 1 (with the same glueball correction) perfectly agrees with the assumption $^3S_1$. In fact, we have two more states in this case: one with a spin of a single quark up, and another one - with a spin down. But for both these states there is no integer L which would correspond to the value $g_2J_2 = 4.7$. Because for a given $g_2J_2 = 4.7$ we will get different L for different orientation of spin of a single quark, this is a clear indication on spin-dependent forces between quark and diquark. The spin-dependence of the forces follows also from the fact that **ud** diquark can be constituent of nucleon (and occupy the place at the center of nucleon) only when spins of both quarks are parallel. As in a previous case the value $g_2J_2 = 4.7$ may signify the off-centered motion of the charge of the single quark. The good argument in favor that the model presented here is realistic is that one finds agreement with the measured magnetic moments of both nucleons while quarks at the center of nucleon act as elementary particles, this is observed here for all three states. Qualitatively this conforms the parton model of the nucleon and *x*-scaling behavior in deep-inelastic lepton scattering first observed over twenty years ago with electrons[6]. Figure 1 illustrates these states.



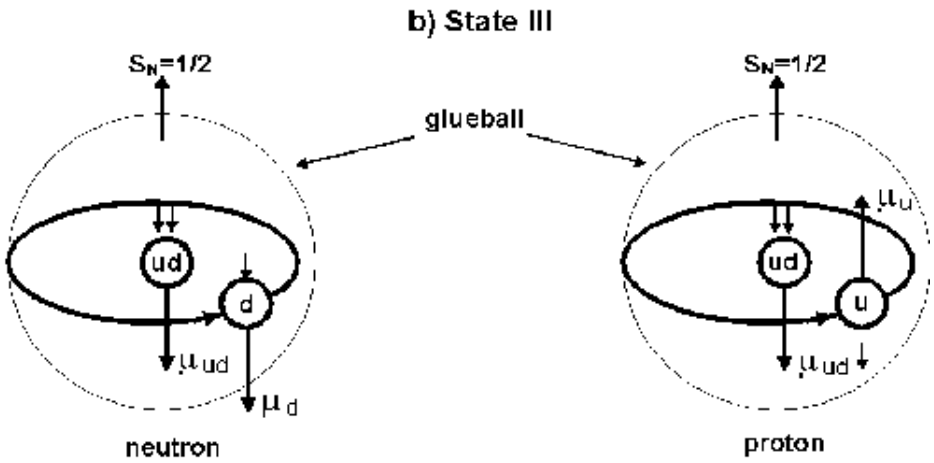


Figure 1. Illustration to the structure of nucleon.

What about the tremulous character of the nucleons the "impurities" in the wave functior of nucleon may be just the consequence of color hyperfine interaction discussed in many papers, see, for example Ref.7. Qualitatively it is in agreement with the smudged core observed, for example, in elastic electron-deuteron scattering [5]. There is some confirmation of this also from calculations in both three-quark and quark-diquark models, that the nucleon radius turns out to be too small (about 0.5 fm rather than experimental value of 0.8 fm) [5]. Potentially this can be the source of the anomalous electric dipole moment (EDM) oriented in the plane of a spin of the nucleon. For a free nucleon this is only a virtual characteristic because the particle has a rotational symmetry in the plane of a spin in the absence of external fields. But when magnetic field is applied then the symmetry may become broken because the magnetic moment of nucleon can precess in a magnetic field (if the spin of neutron is perpendicular to a magnetic field, the precession is physical), thus the virtual characteristic may become a physical one, which can be measured in experiment, see Ref.1.

Conclusions:

- The comparison of magnetic moments of neutron and proton reveals three possible states for nucleon:

  first state with a single quark as an elementary particle in the center of nucleon accompanied by a diquark composed of like quarks with a total spin ***zero*** moving around,

second state with a diquark ud composed of two quarks with parallel spins at the center of a nucleon and a single quark with the spin ***up*** moving around,

third state**:** the same as the second one, only the spin of a single quark is ***down*****.**

- In all three states the quarks at the center of nucleon act as elementary particles, the correction factor of 0.033 appears presumably as a consequence of recoil after quark-antiquark emission.

- The fact that a non integer orbital moments appear in both states may signify the off-centered motion of the diquark (quark) in this model which may potentially lead to the anomalous EDM of a nucleon as a virtual characteristic of a free nucleon.
- In a magnetic field due to the broken rotational symmetry this virtual characteristic of the nucleon may become a physical one, the object for measurements in experiment, see Ref.1.

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