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Beyond Standard Model: Electromagnetic Origin of Strong Interaction between Composite Structures Made of Basic Elementary ±e/3 Charges

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Abstract

Interaction between spinning composite structures of quarks is considered. In simple variants of the quark structures, one basic elementary particle of charge of magnitude |e|/3 is on the axis of rotation and several basic particles of an opposite sign are revolving in the circular orbit about the axis. Each charge in the structure contributes to the electric field and electric potential around the structure. But only revolving basic particles contribute to the spin and to the magnetic moment of the structure. Equations for the axial electric field and the electric potential of each structure at points on its axis are derived. It is shown that with decreasing distance from a quark, the electric potential goes through zero and changes its polarity to the opposite. As a result, the interaction between oppositely charged up and down quarks changes from attractive at large distances between two different quarks to repulsing at some small distances between them. Hence, the electromagnetic interaction between an up quark and a down quark in a nucleon can switch between attraction and repulsion depending on the distance between the quarks. This is the type of behavior that is assumed in the Standard Model for the strong interaction between quarks, and we think the strong interaction is of electromagnetic origin.

1. Introduction

Quarks and electrons are building blocks of matter. In the pre-quark era, when protons and neutrons were considered elementary particles, the fact that the positively charged protons could eco-exist in multi-proton nuclei was a puzzle that could not be explain by the laws of physics based on known at that time two fundamental interactions- the electromagnetic and the gravitational ones. To resolve that puzzle, a new fundamental force, the strong nuclear force, was introduced that could not be derived from the other two fundamental interactions. The strong nuclear force was initially declared as a new fundamental force, being only attractive, acting only at very short distances between nucleons, independent of charges of the nucleons. Later I was suggested that the strong interaction could switch from attractive to repulsive at very small distances.

Then, in 1964, it was predicted independently by Murray Gell-Mann and George Zweig and experimentally confirmed in 1968 by the experiments at the Stanford Linear Accelerator Center that protons and neutrons were not elementary but composite particles made of quarks, the elementary particles with fractional charges of -e/3 and +2e/3. A review of the history of quarks was presented by George Zweig [1], one of the authors of the concept of quarks.

With the introduction of quarks, with their fractional charges, the idea that the smallest observed +e charge of a proton can be in fact a combination of even smaller, fractional negative and positive charges was revolutionary. A proton, with its charge of +e, is a composition of two up quarks of charge +2e/3 each and one down quark of charge -*e*/3. A neutron, with its total zero charge, is a combination of one up quark and two down quarks. In the Standard Model, the up and down quarks and an electron are considered elementary particles (particles that do not consist of anything else). All attempts to

explain such intrinsic properties of elementary particles as a spin and a magnetic moment were unsuccessful so far. Writing about elementary particles in their excellent Undergraduate Lecture Notes in Physics book [2] , Silvie Braibant and her co-authors mention that some people think that smaller, more elementary particles can be imagined. We discuss in this paper a new approach to the structure of elementary particles, the approach that we think is feasible and productive.

2. Basic elementary charges. Models of electron and up and down quarks as composite structures made of basic elementary charges.

Following the fruitful concept of a proton and a neutron as particles with an integer charge (+e or 0) being compositions made of quarks with their fractional charges of -*e*/3 and +2*e*/3, we came out [3] with the suggestion that an electron, with its whole charge -*e* , can be a spinning structure composed of one +*e*/3 and four -*e*/3 fractional charges so that the total charge of the structure be -*e*. But going further that same way, we suggested that an up quark with its total charge of +2*e*/3, a down quark with its total charge of -*e*/3, and zero charge neutral particles can be spinning compositions of positive and negative charges of magnitude *e*/3. As a result, we suggested I [3] that all the charged and neutral particles listed in the Standard Model as the 1^{st} generation elementary particles are not elementary but spinning composite structures made of some number of just two elementary particles of charges +e/3 and -e/3. The suggested models of quarks and electrons allowed explaining their spin and spin magnetic moment properties. It will be shown below that with our models, the electromagnetic interaction coupling "constant" for each composite structure changes with the distance from the structure and can even be zero and change its sign.

The simplest possible composite spinning structures for a down quark, an up quark, and an electron suggested in [3] are:

- Down quark of charge -e/3 is modeled as a plane spinning structure with one +e/3 charge in the center and two -e/3 charges revolving about an axis passing through the central charge.
- Up quark of charge +2e/3 is modeled as a spinning planar trigonal structure with one-e/3 charge in the center and three +e/3 charges revolving about an axis passing through the central charge.
- Electron of charge -e is modeled as a spinning planar centered square structure with one +e/3 charge in the center and four -e/3 charges in the corners of the square revolving about an axis normal to the plane of the square and passing through the central charge.

At small distances from each such structure, the electric field and the electric potential functions will be not spherically symmetrical anymore, and each can be calculated as the sum of contributions from the individual electric charges in the structure. Below we show the calculation results for the potential function and the electric field at different positions along the axis of rotation. We will consider the plane of the structure as the xy-plane, then the axis of rotation (axis of symmetry) will go along the z-axis.

Fig. 1 shows the composite structure diagrams for the down quark model. The charge *q=+e/3* is at the origin, and each of two *-q* charges is at the distance *r* from the central charge.

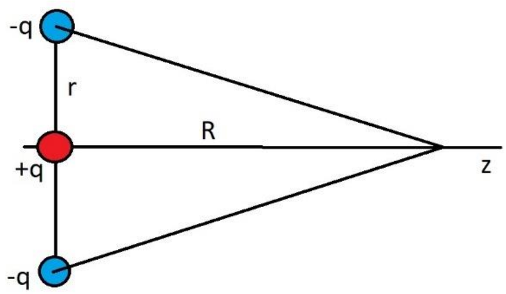

Fig. 1. A diagram of a down quark model as a structure consisting of one +q elementary basic charge in the center of the structure and two -q charges revolving in a circle of radius r about z-axis passing through the +q charge. The elementary basic charge magnitude is e/3.

The axial potential function and the z-component of the electric field on the z-axis for a quark structure can be easily calculated as the sums of contributions from all individual charges in the structure. The distance *R* from the center of the quark structure to the point on the z-axis equals the magnitude of the z-coordinate of the point. The revolving charges are at the distance *r* from the axis. For the down quark structure shown in Fig. 1,

$$V_z(R)_{down} = \frac{q}{4\pi\varepsilon R} - 2\frac{q}{4\pi\varepsilon\left(\sqrt{R^2+r^2}\right)} = \frac{q}{4\pi\varepsilon r}\left(\frac{r}{R}\right)\left(1 - \frac{2}{\left(\sqrt{1+\frac{r^2}{R^2}}\right)}\right) \quad (1)$$

$$E_z(R)_{down} = \frac{q}{4\pi\varepsilon r^2}\left(\frac{r}{R}\right)^2\left(1 - \frac{2}{\left(1+\frac{r^2}{R^2}\right)^{\frac{3}{2}}}\right) \quad (2)$$

In these equations, ε is the permittivity value that might be different from the free space permittivity ε_0 and can be used as an adjustment parameter. A quantity $\frac{q}{4\pi\varepsilon r}$ is the interaction constant.

These equations show that at R>>r the potential and the electric field of the down quark structure are the same as the potential and the electric field of a negative point charge -e/3. With decreasing the distance from the quark, the magnitude of the axial potential changes and becomes zero at $\frac{R}{r} = \frac{1}{\sqrt{3}}$. At even smaller distances, the axial potential of a down quark, with its total negative charge, is positive, as a potential of a positive charge.

If we express the electromagnetic potential of a down quark in terms of an electromagnetic interaction constant, as $V = \frac{\alpha_{EM}}{R}$, the electromagnetic interaction "constant" of a down quark is now a quantity dependent of the distance from the quark and can be positive, zero, or negative:

$$\alpha_{EM\ d} = \frac{q}{4\pi\varepsilon}\left(1 - \frac{2}{\left(\sqrt{1+\frac{r^2}{R^2}}\right)}\right) \quad (3)$$

The diagram and the calculation results for the up quark are like the ones in Fig. 2 and equations (1) and (2), with the difference that there are not 2 but 3 charges revolving about the axis through the central

charge, and the sign of each charge is changed for the opposite. The equations for the electric field and the axial potential of the up quark structure are

$$V_z(R)_{up} = \frac{-q}{4\pi\varepsilon r}\left(\frac{r}{R}\right)\left(1 - \frac{3}{\left(\sqrt{1+\frac{r^2}{R^2}}\right)}\right) \tag{4}$$

$$E_z(R)_{up} = \frac{-q}{4\pi\varepsilon r^2}\left(\frac{r}{R}\right)^2\left(1 - \frac{3}{\left(1+\frac{r^2}{R^2}\right)^{\frac{3}{2}}}\right) \tag{5}$$

The electromagnetic interaction "constant" of an up quark is now a quantity dependent of the distance from the quark and can be positive, zero, or negative:

$$\alpha_{EM\ u} = \frac{q}{4\pi\varepsilon}\left(1 - \frac{3}{\left(\sqrt{1+\frac{r^2}{R^2}}\right)}\right) \tag{6}$$

The axial potential of an up quark is positive at R>>r, changes with decreasing the distance, becomes zero at $\frac{R}{r} = \frac{1}{2\sqrt{2}}$ and is negative at shorted distances. At such small distances, the axial potential of an up quark, with its total positive charge, is negative.

Similarly, for the electron model, with four negative basic charges of -q = -e/3 revolving about one positive basic charge of q = +e/3,

$$V_z(R)_e = \frac{q}{4\pi\varepsilon r}\left(\frac{r}{R}\right)\left(1 - \frac{4}{\left(\sqrt{1+\frac{r^2}{R^2}}\right)}\right) \tag{7}$$

$$E_z(R)_e = \frac{q}{4\pi\varepsilon r^2}\left(\frac{r}{R}\right)^2\left(1 - \frac{4}{\left(1+\frac{r^2}{R^2}\right)^{\frac{3}{2}}}\right) \tag{8}$$

The electromagnetic interaction "constant" of an electron is now a quantity dependent of the distance from the quark and can be positive, zero, or negative:

$$\alpha_{EM\ e} = \frac{q}{4\pi\varepsilon}\left(1 - \frac{4}{\left(\sqrt{1+\frac{r^2}{R^2}}\right)}\right) \tag{9}$$

Nucleons are composed of up and down quarks which are at some small distances from each other. At distances R>>r, the down quark potential is the potential of a negative -e/3 point charge, and the up quark potential is the potential of a positive +2e/3 charge, so the electrostatic interaction of these two quarks is attractive. But with decreasing the distance between the up and down quarks, the axial potential of the down quark goes through zero at $\frac{R}{r} = \frac{1}{\sqrt{3}}$ and becomes positive so the down quark axial

potential is effectively a potential of a positive charge. The potential of an up quark stays positive while $\frac{R}{r} > \frac{1}{2\sqrt{2}}.$ Hence, when the distance between down and up quarks in a nucleon is relatively large, the interaction between the quarks is attractive. But for $\frac{R}{r}$ in the range between 0.35 and 0.58, the interaction between the up and down quarks is repulsing. This prevents the up and down quarks in a nucleon from bumping into each other and keeps them at some small equilibrium distance.

The electrostatic interaction alone between up and down quarks structures can provide the switching of the interaction from attractive to repulsive, the type of behavior of the interaction assumed to act between quarks in nucleons.

Fig. 2 shows graphs of the electrostatic axial potentials (in unis of the interaction constant $\frac{q}{4\pi\varepsilon r}$) of up and down quark composite structures as functions of relative distance from the quark. Both potentials are positive in the interval $\frac{1}{2\sqrt{2}} < \frac{R}{r} < \frac{1}{\sqrt{3}}$ so the interaction between a down quark and an up quark in a nucleon in this interval of distances is repulsing while otherwise it is attractive.

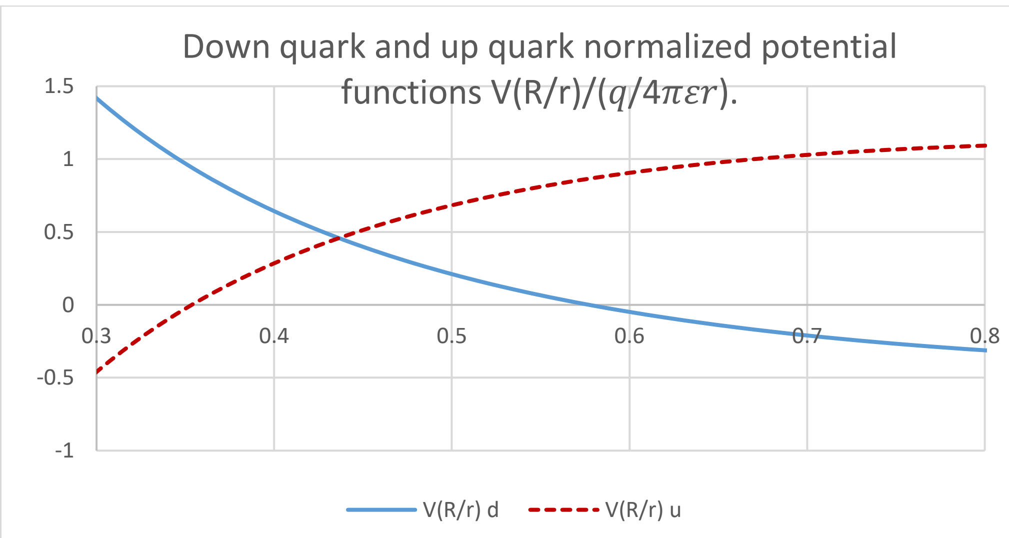

Fig. 2. Normalized potential functions of a down quark (solid blue line) and an up quark (dashed red line) on the axis of a structure as functions of relative distance R/r form the quark.

But the quarks have not only electric charges but also spin magnetic moments. The interaction between the magnetic moments contributes to the combined interaction between up and down quarks and must be considered.

A potential energy of a magnetic moment $\vec{M}$ in a magnetic field $\vec{B}$ is $U_M = -(\vec{M} \cdot \vec{B})$. For the suggested up and down quark models as composite particles, the revolving charges are three +q = +e/3 basic elementary charges of mass m =(1/6)m_e in an up quark and two -q = -e/3 basic elementary charges in a down quark. The magnetic field and the magnetic moment of the spinning quark structures can be calculated using the well-known equations for the magnetic field and the magnetic moment of a current-carrying loop given in all University Physics textbooks. The magnetic moments of the spinning structures of a down quark and an up quark are related to the spin as $\vec{M}_{down} = \frac{1}{2}\left(\frac{-|q|}{m}\right)\vec{S}$ and $\vec{M}_{up} = \frac{1}{2}\left(\frac{+|q|}{m}\right)\vec{S}$

where $\vec{S}$ is the spin of any quark assumed to be the same as the spin of an electron. The magnetic field in the point a distance z on the axis of a loop carrying a current I is

$$\vec{B} = \frac{\mu}{4\pi} \frac{Ir^2}{2(z^2+r^2)^{\frac{3}{2}}} \hat{z} \qquad (10)$$

The current due to N revolving charges of the same sign q in an orbit of radius r is

$$I = \frac{Nqv}{2\pi r} \qquad (11)$$

Taking into account the electrostatic interaction between the charges in quark structures as described above and the magnetic interaction between magnetic moments of the quarks, the complete equation for the interaction between quarks as well as between other structures composed of basic elementary charges can be derived.

Conclusion

We suggested that the first-generation elementary particles are not elementary, but the composite spinning structures made of elementary basic charges q = e/3 and -q = -e/3. For the model structures of a down quark, an up quark, and an electron, the potential and the electric field on the axis of a structure are calculated. Electric charges and magnetic moments of quarks are the essential sources of interactions, including any structures made of quarks, such as protons and neutrons. Equations for the axial electric field and the axial electric potential of each structure at the points along its axis has been derived and analyzed. It is shown that with decreasing distance from a quark, the electric potential goes through zero and changes its polarity to the opposite. As a result, the interaction between oppositely charged up and down quarks changes from attractive at large distances between two different quarks to repulsing at some small distances between the quarks. Hence, the electromagnetic interaction between an up quark and a down quark in a nucleon can switch between attraction and repulsion depending on the distance between the quarks. This is the type of behavior that is assumed in the Standard Model for the strong interaction between quarks. We think that the strong interaction between particles is of electromagnetic origin.

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