Abstract:

Elements of a new model of strong interactions are described. The model is based on an extension of electrodynamics that is derived from a regular Lagrangian density. Here the electric and magnetic fields of Maxwell equations play a symmetric role. It is shown that results are in accordance with general properties of nuclear and nucleon systems.
1. Introduction

It is well known that a physical theory describes, interprets and predicts the behavior of an objective physical reality. One result of this meaning of a theory is that the existence of one kind of theory does not exclude another theory that provides a different interpretation of the objective world. Therefore, the standard tests of the goodness of a theory are its fit to experimental data and its logical self-consistency. On the other hand, the (relative) success of one theory cannot be used as an argument against a different theory.

The history of science in general and of physics in particular provides many examples of different theories interpreting the same kind of physical objects. The long controversy concerning the structure of light is such an example. Assuming that a wave structure of an entity contradicts its corpuscular properties, scientists argued for more than two centuries in favor of one of these theories of light and against the other one. Thus, following Newton, most scientists have supported the corpuscular theory of light for more than one hundred years. Later, in the 19th century, the wave theory of light prevailed. It is only after the works of Plank on black body radiation, of Einstein on the photoelectric effect and, finally, the establishment of quantum mechanics, that people realized that wave phenomena do not contradict the corpuscular structure of particles in general and of light in particular. This is an example where two apparently contradictory theories merge. Obviously, the final relation between two alternative theories may be different.

A proof of the goodness of a new theory of strong interactions is a tremendous assignment that involves detailed calculations of many kinds of processes whose results should fit experimental data. On the other hand, in any field of physics, a new incorrect theory can generally be more easily refuted by
means of qualitative arguments. Thus, for example, assume that one looks at the interaction between a positive charge and a negative one. Finding the attractive force between these charges and being inspired by gravitation, he comes out with a ”theory” which says that ”all charges attract each other”. Obviously, this ”theory” can be refuted by an examination of the interaction between two charges of the same sign. In this case one does not need to use quantitative properties of the repulsive force in order to reject the electromagnetic ”theory” mentioned above.

As a first attempt in a new direction, the present work discusses several qualitative properties of nuclei and nucleons. It shows that the new approach described here fits well known basic properties of these systems. These results encourage a further investigation in the direction presented here.

The structure of this work is as follows. Similarities between strong and electromagnetic interactions are discussed in the second section. The third section presents some general properties of a new theory of charge-monopole systems. The $qq$ force is discussed in the fourth section. Results of scattering experiments of electrons and photons on nucleons are discussed in the fifth section. The sixth section reviews the correspondence between nuclear forces and molecular ones. The seventh section is devoted to the EMC effect where nucleons swell inside nuclei. The nuclear tensor force is discussed in the eighth section. In the ninth section it is shown that exotic states of strongly bound hadrons should not exist. Some concluding remarks are the contents of the last section.
2. Strong and Electromagnetic Interactions

Let us examine the following striking evidence concerning strong and electromagnetic interactions. Among the four established kinds of interactions, gravitation depends just on the mass of particles whereas the strong, electromagnetic and weak interactions are sensitive to specific properties of the interacting particles. Table 1 shows the validity of two conservation laws under the latter kind of interactions.

Flavor conservation indicates a qualitative physical property of interactions. It turns out that strong as well as electromagnetic interactions do not alter the flavor of a closed system of interacting particles. Thus, these interactions induce transitions of existing constituents (namely, quarks and massive leptons) between different configurations of energy states. It should be noted that strong and electromagnetic interactions can induce pair production of massive leptons and quarks. In the case of quarks, these processes take the form of meson production or of baryon pair production. However, as shown by Dirac, the electron (quark) of the pair is considered as a particle ejected from the sea of negative energy states whereas the positron (antiquark) of the pair represents the hole left in the sea by the created electron (quark). It can be concluded that strong and electromagnetic interactions can alter the configuration of a system of elementary particles while the overall flavor is conserved.

Consider for example the weak decay of the neutron $n \rightarrow p + e + \bar{\nu}_e$. In this process a $d$ quark is destroyed and a $u$ quark is created. Analogous consequences can be seen in other weak interactions. These flavor nonconservation transitions are clearly outside the scope of strong and electromagnetic interactions, because the latter ”see” quarks, electrons etc. as elementary
indestructible entities.

Parity conservation is another common property of strong and electromagnetic interactions. This property indicates mathematical symmetries of the Hamiltonians of these interactions. On the other hand, as is well known, weak interactions do not conserve parity.

The foregoing brief discussions of flavor and parity conservation in strong and electromagnetic interactions can be concluded as follows: experiment teaches us that strong and electromagnetic interactions have in common some fundamental properties, namely, flavor and parity conservation. Moreover, there are just two kinds of basic interactions that have these properties. This conclusion motivates the search for a common (or similar) basis for the strong and electromagnetic interactions. This search is the main objective of the present work.

3. Magnetic Monopoles

The idea that monopoles are constituents of hadrons is not new. It has already been suggested by Dirac[1] even before quarks have been discovered. Schwinger[2] has proposed a model of hadrons where quarks are dyons (namely, particles having both electric and magnetic charges) with a magnetic charge $\pm g_0$ or $\pm 2g_0$ and

$$g_0^2 = \frac{1}{4e^2} \approx 34.$$ (1)

Units where $\hbar = c = 1$ are used. Barut[3] discussed the applicability of the group $O(4,2)$ for a system of dyons. Sawada[4] claims in a series of works that a strong force which is analogous to the van der Waals force between molecules, is found in the hadron-hadron scattering amplitude. He interprets
this force as an indication that quarks are dyons and that strong interactions are associated with magnetic monopoles.

The present work relies on a new classical theory of charges and monopoles[5]. This theory is based on the following approach. Consider the fact that so far there is no experimental evidence for the existence of monopoles in general and for their equations of motion in particular. This experimental situation means that one is not bound to start building the theory from a specific form of monopoles equations of motion. On the basis of this state of affairs, the new theory postulates that the equations of motion of a charge-monopole system should be derivable from a regular Lagrangian density. In this way one obtains a charge-monopole theory that conserves the structure of ordinary classical electrodynamics of charges and fields[6]. Moreover, the standard way of constructing the corresponding quantum mechanical theory can be readily used[7,8].

This approach utilizes few additional self-evident postulates and arrives at the following form of the electromagnetic part of the Lagrangian density[5]

\[
L = -\frac{1}{16\pi} F_{\mu\nu}^{(e,w)} F_{(e,w)\mu\nu} - J_{(e)}^{\mu} A_{(e,w)\mu} \\
-\frac{1}{16\pi} F_{\mu\nu}^{(m,w)} F_{(m,w)\mu\nu} - J_{(m)}^{\mu} A_{(m,w)\mu} + \frac{1}{16\pi} F_{(w)\mu\nu}^{\mu\nu}
\]  

(2)

Here Greek indices range from 0 to 3, the metric \( g_{\mu\nu} \) is diagonal and its entries are (1,-1,-1,-1). The subscripts \( e, m \) and \( w \) denote quantities associated with charges, monopoles and free electromagnetic waves (namely, real photons), respectively.

Using a standard mathematical method[6,5], one obtains from this Lagrangian density the appropriate form of the Lorentz force exerted on charges and monopoles:

\[
Ma_{(e)}^{\mu} = q F_{(e,w)\mu\nu} v_{(e)\nu}
\]

(3)
\[ M_{\alpha(m)} = qF_{(m,w)}^{\mu\nu}(m)_{\nu} \]  

(4)

Results (3) and (4) of this theory can be put as follows:

(I) Charges do not interact with fields of monopoles; monopoles do not interact with fields of charges; charges and monopoles interact indirectly through fields of real photons.

Henceforth, these results are denoted by (I). Properties (I) are derived theoretically within the framework of classical electrodynamics. They rely upon a successful approach to the foundations of physics, namely the variational principle.

The possibility that the foregoing results are related to the real world is discussed in this work. Fortunately, (I) has an immediate correspondence to experimental data which can be put in the following statement:

(II) Electrons, as well as other charged leptons, do not participate in strong interactions.

This well established property of Nature corresponds to (I) if one regards electrons as pure charges, quarks as dyons and strong interactions as interactions between magnetic monopoles. This clear correspondence between experiment and theory provides an encouragement for a further investigation of the possibility that quarks are dyons.

Another result of reference 5 is used here. Unlike other monopole theories, the new theory does not impose any restriction on the strength of the elementary magnetic charge \( g_0 \) and leaves it as a free parameter. This conclusion is related to the following property of hadrons. The examination of a \( qq \) bound states where the two quarks are of the \( u, d \) flavors, shows pions of 135 Mev and other bound states of such mesons which are many times more massive. On the other hand, all states of the positronium, namely
the $e\bar{e}$ bound states, vary within an energy range which is about $10^{-5}$ of the system’s mass. This evidence indicates that the elementary magnetic charge should be much stronger than its electric counterpart. However, the extremely high value $g_0^2 \simeq 34$ of (I) is not imposed on any specific calculation associated with this work.

Another aspect of the fit of a charge-monopole system, as a theoretical interpretation of Nature, is as follows. The behavior of a pure monopole system is obtained from that of a pure electric one by the transformations

$$E \rightarrow B; \quad B \rightarrow -E; \quad e \rightarrow g.$$  \hspace{1cm} (5)

These relations show that there are no more than two kinds of related charges called electric charge and magnetic monopole. This point is in accordance with Nature which shows only two kinds of fundamental interactions that conserve flavor and parity, namely, electromagnetic and strong interactions. This point is explained here probably for the first time.

The previous discussion can be put in a different way. The theory presented here predicts the existence of two related kinds of fundamental interactions that conserve flavor and parity. This prediction is consistent with Nature. It could have been refuted if, for example, experiment would show three different kinds of fundamental interactions that share these properties. Thus, the success of the ideas described here in this simple but essential aspect, motivates a further research in this direction.

4. The qq Force

Quantum numbers of mesons are consistent with those of bound states of a $q\bar{q}$ pair. Hence, the $q\bar{q}$ force should be attractive. This property corresponds
to the attraction between electric particles of opposite signs. These states are analogous to those of the positronium where an electron and a positron are bound together.

As pointed out above, electrodynamics of monopoles is completely analogous to that of charges. Hence, one expects that the $qq$ force should be repulsive. As is well known, quantum numbers of baryons are derived if baryons are regarded as systems of three quarks. An explanation how these quarks form a bound state in spite of the repulsive $qq$ force, can be borrowed from the atomic system: a baryon has a core whose magnetic charge is $+3g_0$, to which three quarks are attracted. The magnetic charge of each quark is $-g_0$ and the overall magnetic charge of the system vanishes. (Hereafter $-g_0$ denotes the unit magnetic charge ascribed to a quark and not the huge value $I$..) Quantum states of baryons are known to be characterized by these three quarks. The last statement is analogous to the one saying that an atomic quantum state is characterized by its electronic part, namely a statement which is correct if effects of hyperfine interactions are ignored.

The idea that baryons have a core is not new. It has already been used in early baryonic models[9]. Gluons of QCD, which bear strong charge, provide another example of a charged baryonic core used in other models.

An indication that baryons have a core can be found in data on quarks’ portion of the nucleon’s momentum. Experiments show that this portion is about one half of the entire momentum of the nucleon[10]. Hence, nucleons are made of quarks and of other constituents. The latter are called here the baryonic core. It is shown below that other properties of nuclear and nucleon interactions are compatible with the theory used here and are explained without any further assumption.

An additional experimental evidence supporting the postulate of baryonic
structure described above is the momentum distribution of antiquarks in nucleons. This distribution is inferred from the width of their structure function as plotted in terms of Bjorken’s $x$. If one compares this width to that of quarks then he finds that antiquarks have a smaller Fermi motion. This outcome means that antiquarks are spread in a larger spatial volume than quarks do. This property is explained in a simple manner if one assumes that nucleons have a core whose strong charge is $3g_0$. Under the assumption that strong charge is analogous to electromagnetic one, it is expected that quarks, whose charge equals $-g_0$, are attracted to the core whereas antiquarks are repelled by it. Near the core, quarks do not completely screen the core’s field and antiquarks are repelled from that region to outer portions of the nucleonic volume. Hence, due to the uncertainty principle, one infers that a smaller Fermi motion should be found in experimental data of antiquarks in nucleons.

It can be concluded that hadronic features discussed here do not contradict the fundamental electrodynamic property where charges having the same sign repel each other. This property is manifested here in a new form where quarks are considered as magnetic monopoles.

5. Scattering of Electrons and Photons on Nucleons

Electrons and photons are electromagnetic entities. High energy scattering processes of these particles on nucleons reveal properties of nucleon constituents. In this section, results of deep inelastic electron scattering on protons are compared to those of neutrons. The same is done for hard $\gamma$ photons. In the case of electrons, one finds that the total cross section of
protons, $\sigma_p$, is greater than that of neutrons $\sigma_n[11]$. Indeed, the following neutron/proton structure function ratio is described well by the decreasing line

$$F_{n}^{en}/F_{p}^{ep} = 0.96 - 0.75x$$

(see fig. 7 in the article of [11] and the book mentioned there). Hence, since the mean value of $x$ is positive, one finds that the cross section of high energy electrons scattered off protons is greater than that of neutrons. On the other hand, the total cross section of hard photon scattering is the same for protons and neutrons[12].

These results indicate that high energy electrons "see" different electric charges inside the two kinds of nucleons. On the other hand, photons do not discriminate between protons and neutrons. This outcome is consistent with the Lagrangian (2) and the equations of motion (3) and (4). Indeed, the electron, which is a pure electric charge "sees" only the electric charges of the quarks in each kind of nucleons. Hence, because of the variation in nucleonic electric charge, electrons interact differently with constituents of protons and neutrons. On the other hand, photons "see" both electric charges and magnetic monopoles. Due to the strong magnetic charge ascribed to quarks, their electric charge can be ignored in an analysis of their interaction with hard photons. Hence, the proton and the neutron look alike in experiments with hard photons.

The foregoing discussion explains the different behavior of high energy electrons and photons scattered on protons and neutrons.
6. The Correspondence Between Nuclear and Molecular Forces

There are many similarities between nuclear forces and molecular ones. Molecular forces are relatively weak and are associated with interactions between electrically neutral molecules. In the following lines it is shown that analogous forces exist between nucleons in a nucleus.

According to the interpretation presented here, nucleons consist of magnetically charged particles in a way where the overall magnetic charge vanishes. Similarly, molecules are systems whose constituents are electrically charged particles having a null electric charge. This is the origin of the similarity between nuclear and molecular forces. Before turning to effects that demonstrate this similarity, let us point out several issues which show that the analogy between the two kinds of systems bound by these residual forces is not complete.

Molecules are neutral with respect to both electric charges and magnetic monopoles. Nucleons, on the other hand, are neutral only with respect to the stronger unit of elementary charge, namely the magnetic monopole. The net electric charge of protons is the origin of nuclear Coulomb interaction which increases with the number of protons in nuclei. This force is the reason for the instability of high $Z$ nuclei. No analogous property is found in molecular forces where a liquid can take a macroscopic size.

There is only one kind of electrons in stable atoms. On the other hand, there are two kinds of valence quarks in nucleons, namely the $u$ and $d$ quarks. This is the basis of isospin symmetry found in nuclear interactions. There is no counterpart to this symmetry in molecular interactions.

Remembering these points, let us turn to analogous features of the two forces discussed in this section.
The two forces are of a residual nature. The nuclear force is much weaker than the corresponding strong force between dyons and molecular forces are similarly related to Coulomb interactions between electrons. Indeed, the binding energy of a typical nucleus is about 8 Mev per nucleon whereas excited states of nucleons and of mesons are measured by hundreds of Mev. A similar relation holds in molecules. The binding energy of a molecule in a liquid is generally a fraction of ev. On the other hand, an excited state of electrons is of the order of 10 ev.

Both nuclear forces and molecular ones are characterized by a hard core, outside of which there exists an attractive force which falls off much faster than a Coulomb force. This is the reason for the constant density of nuclei and of liquids, a property which explains the success of nuclear liquid drop models[13,14].

7. The EMC Effect

The size of the nucleonic volume can be deduced from the nucleonic quarks’ momentum. It is found that the larger the number of nucleons \( A \) in a nucleus the larger is the mean self volume of nucleons of this nucleus. In other words, as the nucleus becomes heavier its nucleons swell. This property is compatible with the EMC effect[15]. A support for the swelling effect is found in a measurement of the cross section of \( K^+ \) scattering on nuclei[16]. On the other hand, the success of the nuclear liquid drop models is an indication that nuclear density is practically constant[17].

The swelling of the mean volume of a nucleon with the increase of the nuclear number \( A \) is compatible with screening properties of electrodynamics.
Consider a nucleon $N_i$ in a nucleus. A part of the wave function of quarks of neighboring nucleons penetrates into the volume of $N_i$. Thus, the attracting field of the core of $N_i$ is partially screened by quarks belonging to neighboring nucleons. It follows that quarks of $N_i$ "see" a weaker attracting field and settle in a larger volume. As the number of nucleons of a nucleus $A$ increases, the average number of neighbors of a nucleon increases too and the screening effect becomes more significant. This situation explains the EMC effect.

8. The Nuclear Tensor Force

The equations of motion (3) and (4) indicate that static electric field of a charge and electric field of a moving monopole have different dynamical properties. The same conclusion holds for the corresponding magnetic fields. A special case is found in the electric field of a polar dipole (which is made of two displaced electric charges having equal strength and opposite sign) and that of an axial electric dipole of a spinning monopole. The axial electric dipole of spinning monopoles is discussed in this section.

The neutron is known to be a spin-1/2 electrically neutral composite particle. Its nonvanishing magnetic dipole moment demonstrates that not all effects of its electrically charged constituents vanish. The analogy between electric charges and magnetic monopoles is the basis of the following statement. If quarks are dyons and strong interactions are interactions between magnetic monopoles then, by analogy with the existence of the neutron’s magnetic dipole moment associated with electrically charged spinning quarks, it is highly reasonable that neutrons should have a large electric dipole moment which is created by spinning monopoles. Indeed, it is extremely unlikely
that the overall electric dipole moment of a system of spinning monopoles vanishes whereas its total spin is nonzero. (It is evident that small CP violations are irrelevant to the neutron’s axial electric dipole moment associated with spinning monopoles which is completely analogous to the neutron’s axial magnetic dipole moment.) This discussion indicates that the very low upper bound measured for the electric dipole moment of the neutron[18,19] looks as a major argument against a hadronic theory where quarks are magnetic monopoles.

This argument does not hold in the case of the charge-monopole theory used here. This assertion relies on the following points. As mentioned above in section 3, the monopole theory derived in reference 5 concludes that charges do not interact with fields of monopoles. All experiments carried out for the measurement of the electric dipole moment of the neutron are eventually based on the interaction of an electric charge (with which a static electric field is associated) with the electric field of the searched electric dipole moment of the neutron[18,19]. It should be pointed out that according to (I) of section 3, charges interact with polar electric dipoles associated with a distribution of electric charges. On the other hand, they do not interact with axial electric dipoles associated with spinning monopoles. Thus, the very low upper bound measured for the electric dipole moment of neutrons is, in fact, an upper bound for its polar electric dipole moment. These measurements provide no information on the magnitude of the neutron’s axial electric dipole moment. Hence, results on the measurements of the neutron’s electric dipole moment are not incompatible with the monopole theory presented in this work whose main results are (2), (3) and (4).

As pointed out above, a nucleon is expected to have a nonvanishing axial electric dipole moment, due to its spinning quarks. In this way, one finds an
explanation for the tensor interaction between nucleons[17]

\[ V_T = \{3(\mathbf{\sigma}_1 \cdot \mathbf{r})(\mathbf{\sigma}_2 \cdot \mathbf{r}) - r^2 \mathbf{\sigma}_1 \cdot \mathbf{\sigma}_2\}U(r) \quad (7) \]

where \( r = r_2 - r_1 \) and \( \mathbf{\sigma} \) is the spin operator. This expression is a generalization of the dipole-dipole interaction between two static point dipoles \( \mathbf{\mu}_1 \) and \( \mathbf{\mu}_2 \)[20]

\[ V_{DIPole} = -\{3(\mathbf{\mu}_1 \cdot \mathbf{r})(\mathbf{\mu}_2 \cdot \mathbf{r}) - r^2 \mathbf{\mu}_1 \cdot \mathbf{\mu}_2\}/r^5 \quad (8) \]

Evidently, the nuclear tensor interaction cannot be exactly a dipole-dipole one because nucleons are not point dipoles but composite particles whose size is not much smaller than the distance between nucleons in a nucleus. For this reason the form of the function \( U(r) \) of (7) is determined phenomenologically.

It is interesting to note that the sign of the nuclear tensor force[17,21] is like that of two dipoles whose moment bear the same relation to the particles’ spin, namely, both moments are either parallel or antiparallel to the spin. Moreover, the strength of the tensor interaction is greater than that which exists between two magnetic dipoles associated with spinning charges, like the nucleons magnetic dipoles. This property is compatible with the behavior of spinning monopoles that have an axial electric dipole moment.

9. Exotic States of Hadrons

The approach presented in this work provides a simple explanation why \( q\bar{q} \) and \( qqq \) systems form tightly bound states. In mesons, which are bound states of a \( q\bar{q} \) system, the two quarks have the same absolute value of magnetic charge. Therefore, due to the opposite signs of these charges, the corresponding (magnetic) Coulomb force holds them tightly together. The system as a whole is neutral with respect to magnetic charges. The same is true for
baryons. The magnetic monopole charge of three quarks, each of which has
the amount of $-g_0$, balances the magnetic charge of the baryonic core which
is $3g_0$. Hence, quantum numbers of mesons correspond to a pair of $q\bar{q}$ and
those of baryons are created by $qqq$. The existence of sea quarks comply with
these conclusions because all terms of a quantum state of a particle should
have the same quantum numbers.

This structure of hadrons indicates that bound states of two hadrons take
place only due to residual forces, like the nuclear ones. In most nuclei, the
interaction energy of these forces is about 8 Mev per nucleon. In particular,
there should be no strongly bound state of a baryon and a meson, of two
mesons, of two baryons, of a baryon and an antibaryon etc. These results
are compatible with experimental data.

10. Concluding Remarks

The cornerstone of the approach presented in this work is the new classical
theory of charges and monopoles[5] whose basic results are given in the
Lagrangian (2) and the equations of motion (3) and (4). This theory is based
on some simple postulates, like the existence of a regular Lagrangian den-
sity from which the equations of motion are derived. As part of a classical
theory, these postulates are apparently irrelevant to strong interactions. In
other words, the main postulate is based on general principles and is not
adopted in order to fit specific data obtained from experiments with strongly
interacting systems. The consequences of this theory are examined here and
their compatibility with basic experimental evidence is encouraging. The
first conclusion (I) says that there is no direct interaction of charges with
fields of monopoles. The second conclusion shows that the elementary unit of monopoles is a free parameter. The third one predicts the existence of just two related interactions that conserve flavor and parity.

The first of these conclusions is relevant to the well established experimental fact that charged leptons do not participate in strong interactions. As discussed in section 8, it also removes a major objection based upon the very low upper bound measured for the electric dipole moment of the neutron. The second result pertains to the presently accepted elementary magnetic charge $g_0^2 = 1/4e^2 \approx 34$. A value like this looks too high for hadronic calculations. Obviously, the usefulness of $g_0$ as a free parameter is much better than the huge fixed value $g_0^2 \approx 34$. The third prediction is satisfied completely by Nature where one finds that only electromagnetic and strong interactions satisfy flavor and parity conservation.

The theory based on the Lagrangian density (2) is of a very general character and additional postulates are needed in order to fit specific properties of Nature. These postulates represent basic properties of hadrons and are used for the construction of the actual model described in this work. They state that the elementary unit of magnetic charge is much greater than the electric one, that baryons’ quantum numbers are determined by configurations of three valence quarks and that the net magnetic charge of hadrons vanishes.

The baryonic core utilized in this work results from the postulate stating that the overall magnetic charge of hadrons vanishes. This assumption paves the way for the interpretation of the $qq$ force as a simple repulsive force which is similar to the force between two electrons. In this case, quarks, like electrons, can be treated as ordinary Dirac particles and strong interactions are related to electromagnetic ones by the well known transformations $({\mathcal F})$. 
The kind of baryonic core used here also explains the experimental data concerning the portion of nucleonic linear momentum carried by quarks as well as the relatively small Fermi motion of antiquarks in nucleons.

Another conclusion found above is that electrons interact differently with protons and neutrons whereas these two kinds of nucleons are expected to be alike in experiments with hard $\gamma$ photons. As shown in the fifth section, this prediction is supported by experimental data.

Qualitative properties of nuclei are also explained here. The similarity between nuclear forces and van der Waals ones; the EMC effect where nucleons swell in nuclei; the existence, sign and order of magnitude of the nuclear tensor force are discussed.

It is also found above that there should be no exotic states of strongly bound hadrons. Thus, experiments should yield no strongly bound states of two mesons, of two baryons, of a baryon and an antibaryon and of a baryon and a meson. These predictions are compatible with experimental data.

If the approach presented in this work is found useful then a common foundation for strong and electromagnetic interactions becomes an element of the theory. This point is supported by the discussion carried out in section 2 which shows common physical properties of these two kinds of interactions, namely flavor and parity conservation. Another conclusion obtained is that Maxwell’s theory of electric and magnetic fields is extended and these fields take a completely symmetric form, as shown in the Lagrangian (2). The goal of showing a common foundation for strong and electromagnetic interactions is one of the motivations of Schwinger (see the second paper of reference 2) and of Sawada (see most of the papers of reference 4) for their work on dyon physics.

As stated in the introduction, the present work discusses only some quali-
tative properties of hadrons. Its main objective is to show that the approach used here does not fail on this elementary level of examination. Evidently, as a first attempt, the scope of this work does not cover all qualitative properties of hadronic systems.
References:

[1] P. A. M. Dirac, Phys. Rev. 74, 817 (1948).

[2] J. Schwinger, Phys. Rev. 173, 1536 (1968); Science, 165, 757 (1969).

[3] A. O. Barut, Phys. Rev. D3, 1747 (1971).

[4] T. Sawada, Phys. Lett., b43, 517 (1973); Nuc. Phys., B71, 82 (1974); Phys. Lett., B52, 67 (1974); Prog. Theor. Phys., 59, 149 (1978); Prog. Theor. Phys., 63, 2016 (1980); Nuovo Cimento, A62, 207 (1981); Phys. Lett., B100, 50 (1981); Nuovo Cimento, A80, 247 (1984).

[5] E. Comay, Nuovo Cimento, 80B, 159 (1984).

[6] L. D. Landau and E. M. Lifshitz, The Classical Theory of Fields (Pergamon, Oxford, 1975).

[7] H. J. Lipkin and M. Peshkin, Phys. Lett. B179, 109 (1986).

[8] E. Comay, Phys. Lett. B187, 111 (1987).

[9] B. T. Feld, Models of Elementary Particles (Blaisdell, Waltham Mass., 1969) p. 236.

[10] D. H. Perkins, Introduction to High Energy Physics (Addison-Wesley, Menlo Park CA, 1987). pp 275-283.

[11] J. I. Friedman, Rev. Mod. Phys. 63 (1991) 615; F. Halzen and A. D. Martin, Quarks and Leptons, An Introductory Course in Modern Particle Physics (John Wiley, New York, 1984) p. 200.

[12] T. H. Bauer, R. D. Spital, D. R. Yennie and F. M. Pipkin, Rev. Mod. Phys. 50, 261 (1978). (see pp. 269,293).
[13] R. D. Evans, The Atomic Nucleus (McGraw-Hill, New York, 1955) p. 365.

[14] W. D. Myers and W. J. Swiatecki, Ann. Phys. (NY), 84, 186 (1974).

[15] J. J. Aubert et al. (EMC), Phys. Lett. 123B, 275 (1983).
    A. Bodek et al., Phys. Rev. Lett. 50, 1431 (1983).

[16] R. Sawafta et al., Phys. Lett 307B, 293 (1993).

[17] A. deShalit and H. Feshbach, Theoretical Nuclear Physics (John Wiley, New York, 1974). Vol 1, pp. 3-14.

[18] N. F. Ramsey, Ann. Rev. Nucl. Part. Sci. 32, 211 (1982); Ann. Rev. Nucl. Part. Sci. 40, 1 (1990).

[19] D. Dubbers in Progress in Particle and Nuclear Physics, ed. A. Faessler (Pergamon, Oxford, 1991) p. 173.

[20] J. D. Jackson, Classical Electrodynamics (John Wiley, New York, 1975). p. 143.

[21] J. M. Blatt and V. F. Weisskopf, Theoretical Nuclear Physics (John Wiley, New York, 1952). p. 103.
Table Captions

Table 1:

Validity of flavor and parity conservation under three kinds of interactions.
Table 1.

|        | strong | electromagnetic | weak |
|--------|--------|-----------------|------|
| flavor | yes    | yes             | no   |
| parity | yes    | yes             | no   |