


The Origin of the Strong Force in Quantum Gravity

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Abstract

Quantum gravity is an attempt to resolve incompatibilities between general relativity and quantum theory. *Primordial field theory* incorporates gravity and electrodynamics and has derived fermion mass gap, half integral spin, and fractional charges. This paper extends PFT to hadron physics with a “solenoidal flux”-based explanation of quark confinement differing significantly from Lattice QCD “color flux”-based construction. The theory is presented qualitatively and used to predict hadronic and nuclear properties. Electrodynamics-based analogies help yield numerical results far more intuitively than corresponding QCD results. The origins of QCD and PFT are discussed. A more quantitative description of hadron dynamics is in progress.

Keywords

Primordial Field, Solenoidal Flux-Tube, Lattice QCD, Hadron Form Factor, Duality, Self-Interaction, Yang-Mills Gravity

1. Introduction to Quantum Gravity

Quantum Gravity notes that the two key theories of 20th century physics, *Relativity* and *Quantum Theory*, are incompatible with each other and this is unacceptable. Some wish to modify quantum theory, some to modify gravity theory, and some to reboot at a fundamental level. *Conversations on Quantum Gravity* [1] interviews 37 physicists working in this field to provide an excellent overview of the state of quantum gravity: Sorkin, in response to “*where does non-gravitational matter come from?*” says: “*that topological excitation could in principle give rise to all particles [...] would be the ultimate dream.*” Using gravitational topological arguments, *Primordial Field Theory* (PFT) *gives rise to fermions*, massive particles with discrete charge and quantized spin-1/2 [2]. This paper extends the theory

to hadrons.

It has long been believed that all forces converge to one force at the creation of the universe, but this has not been demonstrated. The logical corollary is that, beginning at the creation, *one field* should be able to account for the four forces and the particle zoo, *i.e.*, one force field should produce today's particle physics. This field is called *the primordial field*, assumed to be a perfect fluid. Some have problems with a singular "creation" and wish to push it back, postulating a cyclical universe that could somehow collapse to the Big Bang and then re-expand, often framed in terms of "causation". Gover, Kopinski and Waldron ask, "*Is the causal structure of our universe singular at the Big Bang?*" and claim to show that a well-defined causal structure at the initial Big Bang singularity imposes strong constraints on the matter content of the early universe and to extend the conformal structure *across the initial singularity*, essentially projecting into pre-Creation. Their presentation is self-contained, though many key definitions are relegated to footnotes [3]. We will assume that the Creation event is a singular occurrence.

The current standard model of particle physics assumes that all four forces (electromagnetic, weak, strong and gravity) converge to one force at the Big Bang but has been unable to demonstrate this mathematically. Primordial field theory assumes that one force at the Big Bang diverges to yield gravitational theory, electromagnetic theory, and the origin of fermions: neutrinos, electrons, and quarks. This work proposes a theory of the strong force derived from primordial field theory and contrasts it with the current theory of the strong force, Quantum Chromodynamics (QCD).

2. Overview of Quantum Chromodynamics and Primordial Field Theory

Before examining the approach to be taken in this paper, we briefly review QCD and the Standard Model (SM); standard particle physics has numerous shortcomings: lacking explanations for non-zero neutrino mass, the issue of dark matter, the matter-antimatter asymmetry of the universe, the hierarchy problem (why the weak force is 10^{24} times stronger than gravity), and the proliferation of quarks and leptons. The negative-core form factor of quarks in basic baryons remains a mystery; even the matter of the diameter of the proton is in question due to recent measurements on muonic hydrogen [4]. Until recently it was believed that the Standard Model *required* supersymmetry (SUSY), one of the primary reasons the Large Hadron Collider was built, but years of operation of the LHC have shown no sign of SUSY [5]. In short, there are so many unresolved problems with the SM that it is generally understood that the theory is incomplete.

Of *Quantum Chromodynamics*, the color-based theory of the strong force, *Dijkgraaf* observes: "... *we don't even know if fully understanding quarks and gluons is enough to make sense of QCD.*" There is a million dollar prize to find a rigorous mathematical definition of Yang-Mills theory. PFT derives a *mass gap*

existence theorem in *Particle Creation from Yang-Mills* where analysis of Yang-Mills non-abelian term, supposedly describing self-interaction, is seen not to make much physical sense. Instead, the gauge field interaction with itself, $[A_\mu, A_\nu]$, is replaced by the dynamic term $[A_\mu^{(i)}, A_\mu^{(i+2)}]$ representing self-interaction of higher-order self-induced fields. A fractal lattice is constructed, and path integrals defined on this lattice, showing that *these self-interactions reach a self-stabilizing zone* that potentially leads to a shrinking torus, consistent with earlier analysis of self-linked structures and compatible with *Horava's* statement: “*perhaps we can think of gravity... as similar to Yang-Mills theory* [in which case] *there is no need for space-time foam. ... having a smooth field* [the primordial field] *on a smooth spacetime manifold seems like a good starting point.*”

Hermann Nikolai notes: “*we don't know how to make fermions chiral*” however, fermions derived in primordial field theory from gravitomagnetism are *inherently* chiral. *Juan Maldacena* states: “*One should recall that string theory was motivated by experiment, in particular by seeing strings in collisions.*” The primordial field model of the proton develops in this paper a 3D dynamical model that instantiates a 1D form factor in collisions, providing string-like behavior. Thus, primordial field theory explains both *the experimental basis that caused string theory to be proposed* (but which still has predicted nothing) and *the Pauli Exclusion principle that caused color to be proposed*. These two aspects have occupied countless physicists for decades and are still not understood in any intuitive way.

Quantum field theory (QFT) provides a bookkeeping system in which symbolic creation operators bring particles into existence while annihilation operators subtract particles from the ledger. The operators operate on *particle-specific* quantum fields. In QFT quantum fields are more fundamental than particles, which are viewed as excited states of the fields. For quanta such as photons, oscillations in the field are viewed as arising from oscillators, which exist at every potential minimum. Zee [6] presents QFT as a mattress, idealized as a 2D-lattice of mass points connected to each other by springs, a series of harmonic oscillators. He remarks that, even after a century, the whole subject of QFT remains rooted in this harmonic paradigm; unable to break from the basic notions of oscillations and wave packets. He hopes to get beyond this conception, yet the math formalism fits the oscillator ladder beautifully, with “raising” and “lowering” operators promoted to “creation” and “annihilation” operators. The idea then extended to particles as excited states of quantum fields, with each particle arising from a specific field—the electron field, the muon field, etc., such that, when Feynman [7] developed a quantum field theory of gravity, he treated gravity as the “31st field”.

Against QFT’s “field per particle”, *primordial field theory* assumes a single field for the entire universe and asks how the field produces a known particle spectrum based on a *mass gap*, or finite energy above the vacuum state. PFT is a variant of *loop quantum gravity* (LQG); of the dozen-plus other approaches Armas reviews,

none have produced predictions of reproducible results.

Fermi detailed a key aspect of QED, remarking [8] about Dyson's reconciliation of Feynman's, Schwinger's, and Tomonaga's theories of quantum electrodynamics:

“There are two ways of doing calculations in theoretical physics. One way, and this is the way I prefer, is to have a clear physical picture of the process you are calculating. The other way is to have a precise and self-consistent mathematical formulation. You have neither.”

Fermi asked Dyson how many free parameters he had used to obtain the fit between experiment and calculation, and when told the answer was “four”, Fermi remarked:

“I remember my old friend Johnny von Neumann used to say, with four parameters I can fit an elephant, and with five I can make him wiggle his trunk.”

The key approach to the strong force is via lattice QCD calculations based on distinct types of quarks: valence and sea quarks. “*The valence quarks are those that give the hadron its quantum numbers.... The sea quarks are those that are produced as quark-antiquark pairs from energy fluctuations in the vacuum.*” [9] It is impossible to measure vacuum fluctuations, so this provides an ever-present parameter used to fit measurements. Durr *et al.* [10] use lattice QCD to compute the mass of the proton, neutron, and other light hadrons, with one to two percent accuracy, while in *Nature*, Wilczek states:

QCD... postulates elegant equations for quarks and gluons [such that]—roughly speaking, we should have to specify 84 numbers at each point in space ($= (3 \times 3 \times 4) + (8 \times 6)$). For the quark field there are three flavors, three colors, and four components accounting for spin and antiparticles; for the gluon fields there are eight directions in the space of its symmetry group, and for each direction there are six [color] fields, three electric and three magnetic [plus Higgs fields].

A numerical simulation based on 84 parameters *at each point on a lattice* can approximate numerical measurement data quite closely despite having no explanation in physical terms; in 2018 Bicudo, *et al.* stated [11]: “*Understanding the confinement of color remains a main theoretical problem of modern physics.*” In 2024 Hayashi and Tanizaki [12] concur: “*Understanding color confinement still lies in front of us as a long-standing problem in particle and nuclear physics.*”

Today QED produces infinities in every solution and still requires 30 free parameters and invokes one quantum field for every particle, hence Feynman's 31st field. In contrast, the physical theory of *one* primordial field is based on the existence of a hyperdense continuum at the moment of creation, symbolized by the Big Bang.

3. Origin of Primordial Field Theory

The key assumption is that the primordial field is singular; at the moment of creation *no other field exists*. How is this to be incorporated into a modern theory of physics? Today’s physics typically describes the change in one physical entity with respect to interaction with another physical entity, formulated in terms of a “change operator” $\nabla \sim \frac{\partial}{\partial \xi}$ where ξ is a parametric aspect of the first physical entity, denoted by $\psi = \psi(\xi)$, and change in ψ is written $\nabla \psi$. The problem is to determine what drives the change. There is no other physical entity to interact with, so any interaction experienced by ψ must be interaction with itself, leading to the self-interaction equation

$$\nabla \psi = \psi \psi . \tag{1}$$

For parametric aspect ξ this equation has a scalar solution $\psi(\xi) = -\xi^{-1}$. If we assume a vector character and let $\psi \psi = \psi \cdot \psi$ we derive $\psi(\xi) = \xi^{-1}$. It is reasonable to assume that the scalar parameter is time t and the vector parameter is position r . We further assume that the field obeys normal field relations—the term $\psi \psi = \psi^2$ is interpreted as field energy density, ρ , yielding $\nabla \psi = \rho$. If field ψ is gravity G , which has negative energy density, then $\nabla \cdot G = G \cdot G$ and

$$\nabla \cdot G = -\rho \tag{2}$$

reduces to Newton’s equation, which recovers one of the forces from the primordial field; even general relativity must touch base with Newton’s equation in order to have physical meaning. But Equation (1) was not expressed as inner product $u \cdot v$; the self-interaction equation is $\nabla \psi = \psi \psi$, where ∇ is the difference operator acting on the field ψ , assumed equivalent to the local field interacting with itself. Hestenes’ [13] defines geometric product $ab = a \cdot b + a \wedge b$ and duality operation $a \wedge b = -i(a \times b)$. Following electromagnetics $(E + iB)$ we assume $\psi = G + iC$ and since the solutions are additive, $\nabla = \nabla + \partial_i$, so the expansion contains terms $G \cdot G$, $C \cdot C$, $G \cdot C$, and derivative terms based on ∇ and ∂_i , and Equation (1) becomes

$$(\nabla + \partial_i)(G + iC) = (G + iC)(G + iC) \tag{3}$$

Expanding (3) as geometric products and grouping like terms (scalars, i^* scalars, vectors, i^* vectors):

Self-Interaction equations	Heaviside equations	
$\nabla \cdot G = G \cdot G - C \cdot C$	$\nabla \cdot G = -\rho$	(4a)
$i\nabla \cdot C = i2G \cdot C$	$\nabla \cdot C = 0$	(4b)
$\partial_i G - \nabla \times C = G \times C \pm C \times G$	$\nabla \times C = -\rho v + \partial_i G$	(4c)
$i\nabla \times G + i\partial_i C = 0$	$\nabla \times G = -\partial_i C$	(4d)

Since G and C are orthogonal fields, we let $G \cdot C = C \cdot G \equiv 0$, and further

assume that $\mathbf{G} \cdot \mathbf{G}$ and $\mathbf{C} \cdot \mathbf{C}$ are proportional to energy density of the \mathbf{G} and \mathbf{C} fields, with $\mathbf{G} \times \mathbf{C}$ resembling a Poynting vector interpreted as momentum density vector. Grouping like terms and re-expressing the equations in terms of mass density $\rho = \mathbf{G} \cdot \mathbf{G} + \mathbf{C} \cdot \mathbf{C}$ and $\rho \mathbf{v} \sim \mathbf{G} \times \mathbf{C}$ the self-interaction equation leads to Heaviside's equations [14] for gravitomagnetism, seen on the right of Equation (4).

Hestenes' *Geometric Algebra* is the only mathematical formalism in which *every term* has both a *geometric* and an *algebraic* interpretation, so it is deemed the appropriate formalism for physics. In addition, unlike terms can be added together. For example, the primordial field, $\psi = \mathbf{G} + i\mathbf{C}$ should not be interpreted as simply the G-field vector plus the imaginary number times the C-field vector. Instead, we note that the duality operator, i , acting on the C-field vector produces the bivector, $\tilde{\mathbf{C}}$, which is a *directed area*, a *two-dimensional object* representative of the circulation, and associated angular inertia of the C-field. Understanding this aspect of primordial field theory is crucial to fully appreciating the theory.

Equation $\nabla \cdot \mathbf{C} = 0$ with vector identity $\nabla \cdot \nabla \times \mathbf{A} = 0$ allows replacement of \mathbf{C} with $\nabla \times \mathbf{A}$, leading to gauge field equations: $\mathbf{C} = \nabla \times \mathbf{A}$, $\mathbf{G} = -\nabla\phi - \partial_t \mathbf{A}$, $\partial_t \phi + \nabla \cdot \mathbf{A} = 0$, in terms of four-potential $A = \{\phi, \mathbf{A}\}$, and Lorenz gauge condition, $\partial_\mu A^\mu = 0$. Scalar potential $\phi = -m/r$, and vector potential \mathbf{A} has dimensions of velocity with field strength $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$ and the familiar tensor constructed from the above [8]:

$$F_{\mu\nu} = \begin{bmatrix} 0 & G_x & G_y & G_z \\ G_x & 0 & -C_z & C_y \\ G_y & C_z & 0 & -C_x \\ G_z & -C_y & C_x & 0 \end{bmatrix} \Rightarrow \begin{array}{|c|c|c|} \hline & -C_z & C_y \\ \hline C_z & & -C_x \\ \hline -C_y & C_x & \\ \hline \end{array} \quad (5)$$

Gravitomagnetic terms $C_y = C_{xz}$ and $-C_x = C_{zy}$ represent bivectors rotating in the xz -plane equivalent to the rotation about the axial vector on the y -axis. In natural units $g = c = 1$ the C-field is described by $\mathbf{C} \sim \mathbf{r} \times \mathbf{p}$ with \mathbf{p} the momentum density inducing circulation equivalent to angular momentum density $\mathbf{L} = \mathbf{r} \times \mathbf{p}$. In fact, gravito-magnetic field \mathbf{C} essentially is angular momentum in the Einstein-deHaas sense. Also, Planck's constant $\hbar \approx ml^2/t \approx mvr$, so angular momentum is a feasible underlying quantizable degree of freedom.

In PFT, the electromagnetic field is introduced not as a new field, but as a *dual aspect* of the primordial field, coming into existence only when gravitomagnetic aspects of the primordial field yield a structure for which an electromagnetic equivalent structure existed. Jefimenko [15] showed that gravitomagnetism is dual to Maxwellian electromagnetism when mass does not depend upon velocity. This, and the scale-free nature of the self-interaction principle, imply that dual structures exist, as depicted by the dual $U(1) \times U(1)$ -symmetry in **Figure 1**.

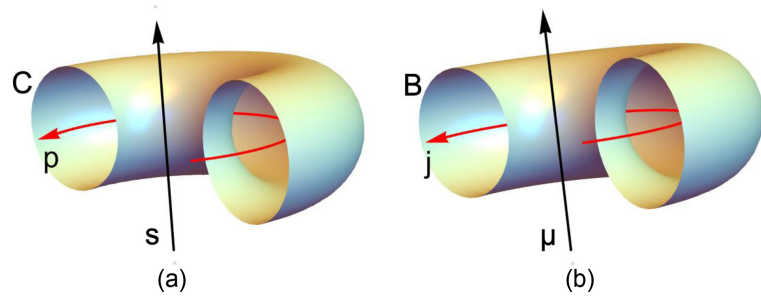


Figure 1. (a) Gravitomagnetic structure: momentum density p , field C and spin s . (b) Electrodynamics dual: electric current density j , field B , and magnetic moment μ .

This duality is significant, because it allows us to carry over much of the electrodynamic reality of the Maxwell fields directly to Heaviside fields, making use of a century and a half of intuition that is invaluable. For example, recall that while a current loop yields the induced field as shown in **Figure 1(b)**, swapping the current and field is equivalent to a solenoidal construction, well known in electromagnetic theory, while the approximate description of the solenoid yields strength of the induced field at the center of solenoid as a linear function of the number of “coils”.

4. Development of Solenoidal Aspects of the Strong Force

In the Aurora Borealis charged particles are trapped in the increasing field of the earth’s magnetic poles; particle orbits about the field lines tighten as particles approach the poles with acceleration causing the particles to emit visible radiation. This capture is described by Maxwell’s equations relating charges to fields and Heaviside’s equations yield a gravito-magnetic equivalent, see **Figure 2**, wherein mass acted on by a local unidirectional gravito-magnetic field can similarly be captured.

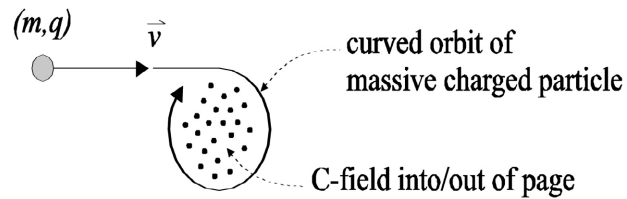


Figure 2. Gravitomagnetic field lines *out of the page* exert a force $F = m\mathbf{v} \times \mathbf{C}$ on mass m causing the mass to follow a curved path.

Heaviside’s equation for gravitomagnetic fields induced by mass density ρ and motion \mathbf{v} is:

$$\nabla \times \mathbf{C} \sim -\rho \mathbf{v} \tag{6}$$

The cross product $\nabla \times \mathbf{C}$ yields an axial vector perpendicular to the vector

differential operator ∇ and to gravitomagnetic field \mathbf{C} , such that induced \mathbf{C} is perpendicular to velocity \mathbf{v} . Consider the behavior of particles in strong external fields as expected at the Big Bang and when nuclei collide at the LHC. A particle with momentum density $\mathbf{p} = \rho\mathbf{v}$ induces a local circulation about \mathbf{p} , but velocity \mathbf{v} can also change due to the force $\mathbf{F} = m\mathbf{v} \times \mathbf{C}_{ext}$ where gravitomagnetic field \mathbf{C}_{ext} is separate and apart from the induced field. Consider a fermion trapped in such a strong external field, \mathbf{C}_{ext} . The motion of the trapped particle resembles the orbit of particles trapped in the *Northern Lights*. For simplicity we view the orbit as a coil centered on \mathbf{C}_{ext} .

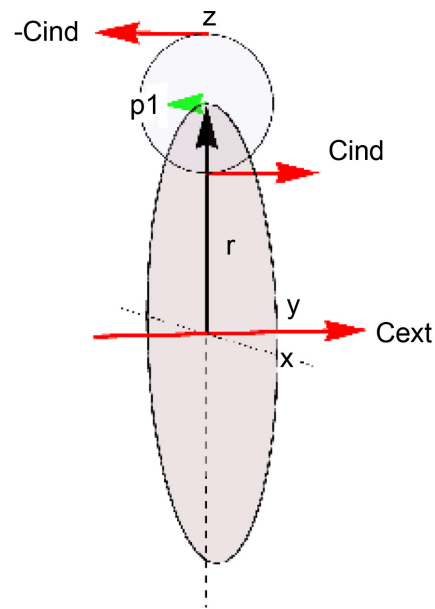


Figure 3. The \mathbf{C}_{ext} field line traps the particle with momentum \mathbf{p}_1 (green arrow) which induces the circular field with components \mathbf{C}_{ind} and $-\mathbf{C}_{ind}$. The induced field \mathbf{C}_{ind} is additive to \mathbf{C}_{ext} .

Figure 3 reveals that a portion of the induced field \mathbf{C}_{ind} is parallel to external field \mathbf{C}_{ext} and hence additive. Can this axial field induced by the trapped particle be made strong enough to *self-capture* the particle itself, if the external field were to be removed? There is no known evidence that this is the case, and symmetry arguments would appear to preclude this. This condition would imply

$$\mathbf{F} = m\mathbf{v} \times \mathbf{C}_{ext} \equiv m\mathbf{v} \times (\mathbf{r} \times \mathbf{p}) \quad (7)$$

where the entity within parentheses is the field \mathbf{C}_{ind} induced by \mathbf{p} . Next assume that a fermion cannot “capture itself” in its own self-induced field, \mathbf{C}_{ind} but *can be* captured in external field, \mathbf{C}_{ext} . Other particles can be captured by the external field. In **Figure 4** both trapped particles with momentum density \mathbf{p}_1 produce an induced field inside the “coils” oriented along the axis parallel to the local external field and an induced field outside of the orbits pointing in the

direction generally opposite to the external field in which the particles are trapped. Each fermion orbit is thus modeled as a coil in a gravitomagnetic solenoid. We will generally tend to show the C-field as oriented from left to right, but the known handedness of Equations (6) and (7) specify the field direction when seen from any perspective, given the orientation of the coil.

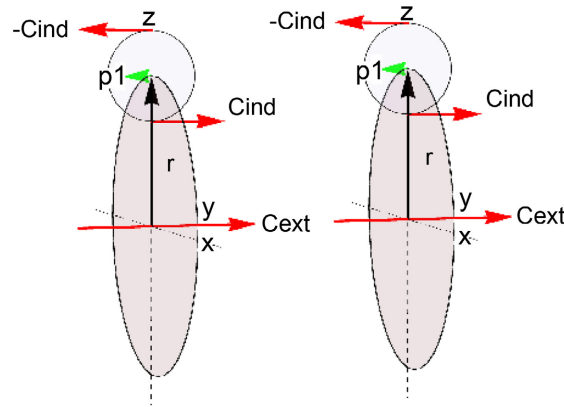


Figure 4. Two particles with momentum p_1 induce C-field circulation with two components C_{ind} that add to the external field C_{ext} in which the two particles are trapped.

We ignore the quark’s *spin dipole* and focus on the quark’s *orbital C-field dipole*, that is, we interpret the orbit as a *mass current loop*. For simplicity we initially assume that C-field dipoles are equal for *up* and *down* quarks, $C_u = C_d = C$. With this approximation, each quark dipole is associated with energy $|C|^2$. We extend our model to N coils, assuming that the addition of N particles/coils will yield an additive induced field:

$$C_{1ind} + C_{2ind} + C_{3ind} + \dots + C_{Nind} . \tag{8}$$

The question of whether a fermion can be self-captured in its own induced field, is generalized to the question of whether a fermion can be captured by the additive field of N fermions. Guided by the rich literature on electromagnetic solenoids, we substitute mass for charge and C for B . Before *removing* external field C_{ext} in which the N particles are trapped, recall that Heaviside’s equations are *density*-based, and that energy density of a field (E, B, G, C) is proportional to the square of the field strength. Thus, if our field is approximately N times the induced field, C_{ind} , then the energy density of the field induced by N -coils is proportional to

$$|N * C_{ind}|^2 = N^2 (C_{ind} \cdot C_{ind}) . \tag{9}$$

In this solenoidal model of the proton, we expect the density of the field strength of the proton to be approximately nine times that of the field associated with one quark. Focus on the proton, which apparently lives forever, even in the vacuum, depicted in **Figure 5**.

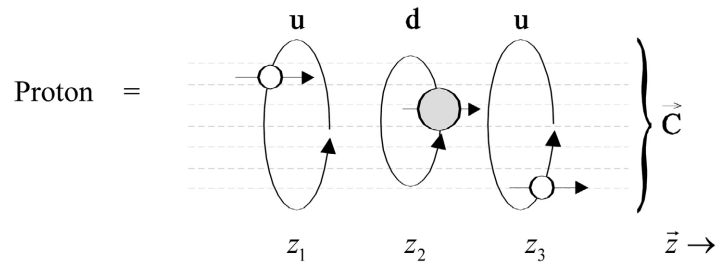


Figure 5. A model proton: two up quarks and a down quark, captured in self-induced C-field circulation.

Pre-QCD, there was a problem: the Pauli Exclusion Principle requires an anti-symmetric wave function, while the wave function was symmetric. Per Kerson Huang: [16].

In a simple model, one puts the quarks into orbitals in a central potential, like electrons in an atom. Experiments show that the magnetic moment of a nucleon is close to the sum of quark magnetic moments. This suggests that all three quarks are in the lowest orbital; but this is impossible for they have spin 1/2 and should obey the Pauli Exclusion Principle. The way out is to endow them with a new attribute, so the quarks are not identical.

In 1964 O.W. Greenberg *proposed* color as the new attribute to solve the symmetry problem. As **Figure 4** implies the *new attribute* we endow quarks with is their position along the z-axis of the C-field flux tube to which the three quarks are bound. An anti-symmetric wave function uses the axis of the flux tube to label quark states; a particle on either end remains on the end, since the heavier down quark separates the two up quarks, which repel each other, and thus the z-ordering is stable. In terms of this z-order the wave function can be written:

$$\begin{aligned} \psi(z_1, z_2, z_3) = & \psi_1(z_1)\psi_2(z_2)\psi_3(z_3) - \psi_1(z_2)\psi_2(z_1)\psi_3(z_3) \\ & + \psi_1(z_2)\psi_2(z_3)\psi_3(z_1) - \psi_1(z_1)\psi_2(z_3)\psi_3(z_2) \\ & + \psi_1(z_3)\psi_2(z_1)\psi_3(z_2) - \psi_1(z_3)\psi_2(z_2)\psi_3(z_1) \end{aligned} \quad (10)$$

This wave function satisfies the Pauli Principle: set $z_1 = z_2$, $z_1 = z_3$ or $z_2 = z_3$ and the wave function becomes zero; there is zero probability of any two quarks sharing *the same orbit* at location z_i . With this anti-symmetric wave function based on z-ordering, *color* solves a non-existent problem.

Note that, although the z-order for the proton is well defined, the “fixed” place of the down quark “between” two up quarks is simply determined by the only *electrodynamically stable* arrangement and holds only as long as the three-quark configuration is stable. An external particle can impart sufficient force to the configuration to overcome and disrupt this electro-dynamical stability.

To further address this issue, let us separate the two key forces involved. The primary force, that is responsible for capturing the quarks in orbit (like the electrons trapped in the *Northern Lights*), is the Lorentz force of the C-field, or gravitomagnetic field: $F = mv \times C$. This requires very strong field strength, assumed

present post-Big Bang. We choose our local coordinate system such that the quarks orbit in the xy -plane. The second force operating, far weaker in strength, is the Coulomb force between the charged quarks. If quarks are tightly bound to the external C-field and assumed co-axial on the z -axis (with z -axis velocity components in a small range) then charged-based quark interactions affect their z -position. For z -axis momentum components outside the range, quarks will not bind together. Within the energy-dependent range of velocities, quarks will stabilize for some arrangements. For example, an up-quark will be attracted to a nearby down-quark, while another up-quark on the “other side” of the down-quark orbit will also be attracted to the down-quark but will repel the first up-quark. This u - d - u construction will be assumed stable (calculations are now underway to prove this) for a given range of energies. The wavefunction in Equation (10) summarizes this stable ordering, for as long as no disturbance completely disrupts the stability. In the case of many protons, that appears to be “forever”, that is, since immediately post-Big Bang.

It is important to understand *the separation of the electromagnetic and gravitomagnetic forces*, based on the much stronger field that is required to cause the quarks to orbit the field lines. For example, based on the increase in field strength due to addition of the quarks’ self-induced fields, quarks will “spiral in” to a tighter orbit, and hence to speed up or “spin faster”. The speed of the construct along the z -axis is arbitrary, assuming all quarks end up with approximately the same speed. In essence, the speed of the orbiting quarks in the xy -plane is not arbitrary but is assumed to approach the speed of light [think of skater pulling in her arms to almost zero]. At quark orbit dimensions, we will treat the quark charges as “smeared over” the orbit; in other words, we will view the quark orbits as charged rings with equi-distributed charge on each ring. It is easier to see how three coaxial rings maintain their relative z -axis positions than it would be if the quarks were individually free to move in three dimensions. Thus, our model assumes three coaxial rings in the xy -plane, separated along the z -axis, such that the C-field preserves the ring geometry, while the Coulomb field interactions control dynamics along the z -axis. This effectively corresponds to *asymptotic freedom*, in which the quarks in orbit behave as if free. Of course, this construction is energy dependent and can be disrupted by sufficient energy input to the system by external particles; in which case the phenomenon of “quark confinement” will be seen to follow from the above model. Finally, there will be a *second order interaction* between the Maxwell E-field effects and the Heaviside C-field effects, but, while this will affect the internal dynamics and stability, we assume that it can be temporarily ignored for discussion of first order phenomena.

5. Primordial Field Theory Flux Tube vs Lattice-QCD Flux Tube

The basis for the speculative proposal of *color* was to satisfy the Pauli Principle, however we have just seen that another possibility exists, potentially obviating the

need for color. Nevertheless, color has been assumed for 60 years, despite its never having been seen, so it is appropriate to examine differences between QCD and PFT constructions. Unlike gravitomagnetism, which was initially derived from Maxwell's field equations and recently from *the Self-Interaction Principle*, color was not derived from Maxwell or any other theory or principle. However, it was assumed that "color charge" behaved as "electric charge" and therefore terminated on the color sources. The flux lines in this case are shown for a neutron in **Figure 6**. Call this the delta configuration, Δ .

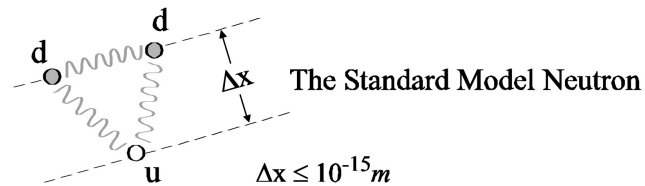


Figure 6. The Δ -configuration of the QCD-based Standard Model neutron, in which the chromo-electric flux lines terminate on the color sources, *i.e.*, the quarks. Another configuration, with no Maxwell equivalent, is the Y-configuration, in which three field lines connect in the center while terminating on the three quarks. The Δx distance is based on the size of the neutron.

Unlike QCD, in which the strong force field terminates on the quarks, the primordial C-field, which strongly holds the quarks in circular orbit, does *not* terminate on quarks; only electric field lines associated with quark electric charges originate and terminate on quarks. A major difference in QCD color and PFT C-field is that *color provides at least seven extra parameters*, which, in Fermi terms, is enough to make the elephant dance! And, though QCD does not specify, or even suggest, flux tubes, these are produced by numerical simulations based on lattice-QCD, a Monte Carlo-based process in which 84 numbers are associated with each point in space.

In 2024, Brodsky, *et al.* [17] noted that “QCD is so complicated we can’t use it to make direct calculation or precise predictions.” [and] “Quantum theory revealed that the ‘vacuum’ of space is actually full of tiny particles that are constantly appearing and disappearing in fluctuating clouds.” These virtual particles do not last long; hence the binding force works only over short distances. The fluctuations are not subject to measurement and hence provide effectively infinite-dimensional “free parameters” that can be used to fit any data as required. This can account for the fact that *QCD fits the data almost perfectly despite not being able to explain physically what is occurring in the hadrons*. QCD describes the strong force *statistically* according to measurements, consistent with Fermi’s *elephant analogy* related to the significance of free parameters used to fit physics theory to measurement data.

Within the above context flux tubes in QCD play important roles in confinement, quark pair creation, and hadron structure. Chromoelectric flux tubes can

be generated by quark pair creation in the process of hadron production. “Given enough energy, a quark pair $q\bar{q}$ is created at some point and then move away in opposite directions at a speed close to the speed of light. The chromoelectric flux tube is then formed when the distance between the quark pair becomes $\sim 1 \text{ GeV}^{-1}$ or more. New quark pairs can be created in a cascade way.” This production of jets is reproduced in primordial field theory, but the phenomenology differs. A major difference between QCD and PFT flux tubes is that *chromoelectric flux tubes terminate on quarks*, whereas gravito-magnetic flux tubes do *not* terminate on quarks; *they facilitate quark orbits that provide the basis for hadron form factors*, described above, and correspond to behaviors observed in colliders.

6. Explanation of Quark Confinement in Primordial Field Theory

Unlike electrons, which show up everywhere, *quarks have never been seen*, at least *quarks have never been seen except as confined to composite particles*. Electron probes inside a nucleon produce scattering results indicating that quarks themselves have roughly the dimension of electrons, approximately 10^{-18} meters or less, approximately $1/1000^{\text{th}}$ of the proton radius. And quarks tend to ignore their neighbors in the normal state, a behavior called *asymptotic freedom*. But the farther quarks move from their neighbors, the more strongly they feel a restoring force, exactly opposite the behavior of electrical forces. This is called *quark confinement*. In QCD the primary phenomenon is chromo-electric; chromo-magnetic effects generally play little part in the process. Primordial field theory is based on electro-magnetic *and* gravito-magnetic effects. The QCD strong force “holds quarks together” while the PFT strong force “holds quarks in orbit”.

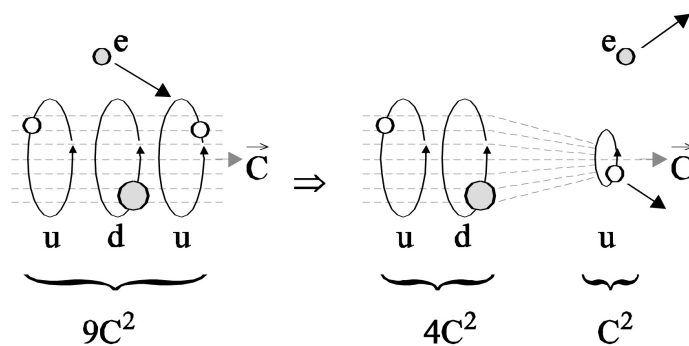


Figure 7. An incoming particle collides with the rightmost up quark, knocking it out of the proton. Orbit sizes not to scale. The process would work identically from right to left.

In PFT, electromagnetism is the primary force of quark-quark interactions, with significant consequences, energy-wise. Now attempt to knock a quark out of the hadron. To simplify, assume the quark mass of u and d are identical, although we know that they differ by a factor of 2 or so. Let an incoming particle strike the proton and interact very strongly with one of the quarks, say the rightmost quark,

leading to this quark being knocked out of the proton. The simplified problem is depicted in **Figure 7**. The presence of the *flux tube* or solenoidal core is such that the x-y planar motion continues to orbit the z-axis, the co-axial field line about which the quarks orbit. The electrodynamic interaction between the incoming particle and the quark primarily contributes to z-axis momentum, moving the up quark away from the other two quarks. So far, nothing special, just basic electrodynamic interaction. However, since N loops yields N times the field within the common loops, two quark orbits produce $|2C|^2 = 4C^2$ and three quark orbits produce $|3C|^2 = 9C^2$. This C-field *binds the quarks to the flux tube*, instantiating composite particles. In primordial field theory, if we remove a quark from a 3-quark composite, the initial state of the proton has energy $9C^2$ associated with the flux tube about which the three quarks orbit, producing a particle with mass energy ~ 931 MeV while the base quarks have less than 5 MeV each, thus $C^2 \approx 100$ MeV. *i.e.*, the majority of the proton energy (mass) is the associated self-induced C-field energy.

On the right hand side of the figure, if the electron succeeds in separating an up quark from the other two quarks, that quark, assumed to still orbit the flux tube, possesses C^2 energy, and the two remaining quarks account for $4C^2$ worth of energy. Thus:

$$9C^2 \rightarrow 4C^2 + 1C^2 + ? \quad (11)$$

How do we account for the differences in energy of the initial ($9C^2$) and final ($5C^2$) products? *Almost 400 MeV of energy disappears*. This energy was *not* required to separate the quarks based on electromagnetic attraction between up and down quarks. Yet the energy cannot just disappear.

Consider an electron in a hydrogen atom: bound to the nucleus with -13.6 eV we need merely impart greater than 13.6 eV to the electron to knock it loose, thereby ionizing the hydrogen atom. There is a significant difference between the electromagnetic binding of the hydrogen atom and the hadron. The binding energy is negative because of the difference in sign of the charges of the electron and the nucleus. In primordial field theory C-field energy is positive. No *negative mass* exists; rotational inertia equates to positive mass [18], hence, unlike the energy necessary to free bound particles in atoms, the primary energy involved here is additive.

Kinetic energy can be shown to be exactly equal to the C-field circulation energy of an accelerated particle, thus the incoming particle brings significant C-field energy to an already energy-rich construction. The actual calculation of the fluid dynamical interaction requires vast simplification, but the energy of the final products can be analyzed as follows.

Since quarks have radii approximately 10^{-18} meters or less while the proton is more like 10^{-15} m, the *volume of the proton is roughly a billion times larger than the volume of the quark*. Key is that the *orbital binding energy*, $4C^2 \approx 400$ MeV, is distributed over proton volume, in the form of the *C-field flux tube*.

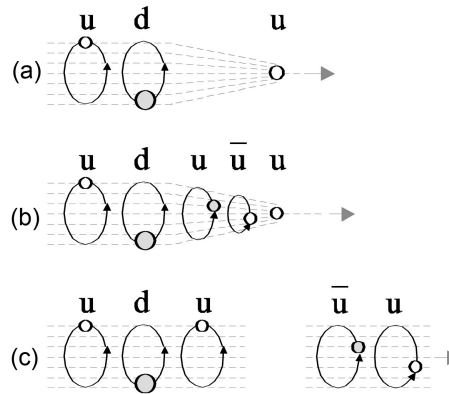


Figure 8. (a) Up quark knocked away from proton; (b) Energy difference yields pair production; (c) Proton plus meson moving away from proton.

If a quark is removed from the proton, that flux tube binding energy cannot simply vanish, but must be somehow imparted to the quark, *i.e.*, the energy previously distributed over the volume of the proton must be concentrated into the volume of the departing quark, yielding roughly a billion-fold increase in energy *density*, or energy per volume; we end with approximately 400 MeV associated with the volume of one quark, which *originally* had only ~ 5 MeV in its volume. Thus, we are attempting to squeeze ~ 80 quarks worth of energy into one quark volume: effectively enough energy to make 40 pairs of quarks and certainly enough energy to create one quark-anti-quark pair, as shown in **Figure 8**.

The flux tube with its associated binding energy is weakened as the right hand quark moves away from the proton. When the change in energy density in the neighborhood of the departing quark exceeds pair production energy a quark-antiquark pair, $u\bar{u}$, is produced. These particles move away from each other, the u quark of the new pair moves back toward the remaining ud of the proton while the \bar{u} anti-quark moves away from the proton with the departing u quark. This restores the proton to its original udu configuration and a $u\bar{u}$ meson flies off to the right. A $d\bar{d}$ pair also works, with a $u\bar{d}$ meson flying off.

In a more complicated case, *both* the u and \bar{u} of the newly produced pair continue moving to the right, and \bar{u} pairs with the departing u , creating a new hadron, while the u quark of the pair essentially becomes the departing quark and must therefore acquire the remaining binding energy to be dissipated. Local energy density exceeds pair production energy so another $u\bar{u}$ pair of quarks is produced. The process occurs a number of times; the result is a *jet* of hadrons flying off to the right as in **Figure 9**.

This process is seen in particle colliders. Hadron jets blast out of a proton when struck by a very high-energy particle, with the final products being the proton and the jet, which decays as the $u\bar{u}$ quarks annihilate each other. The difference between a static 3-quark system and a 2 + 1 quark system is 400 MeV, the binding energy that confines quarks to the 3-quark flux tube. Thus, primordial field theory, having explained fermions, [19]-[21] now explains hadrons.

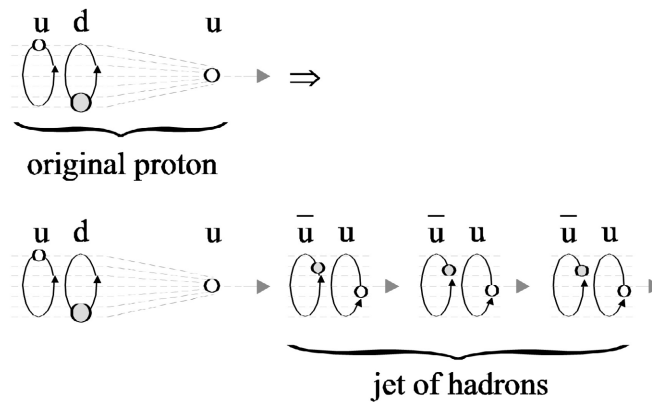


Figure 9. Illustrating the mechanism of *hadronic jets*.

The response of the system, when the electrodynamic forces are overcome, is determined by the much greater force and energy associated with the C-field. The impacting system can react in any direction, although statistically the induced angular momentum/inertia of the colliding beams tends to be either orthogonal to the colliding beams or “*orthogonal plus an offsetting momentum*” but is still symmetrical with respect to the colliding beams. The essentially “Lenz-like” response of the disturbed C-field is such that a collapsing field generates sufficient local “*gm^f*” (gravitomagnetic analog to “*emf^f*”) to occasion particle pair creation, in incremental fashion, such that every change in flux energy that exceeds *particle pair creation energy* produces a *replacement* quark for the one “knocked out” of the system and an antiquark, to pair with the knocked out particle and thus form an escaping meson. This is easier to visualize with some geometries, but the superfluid dynamics involved will yield angles that conserve momentum and energy as necessary.

7. Ontological Flux Tube Models of Hadrons

The previous section details a qualitative, intuitive, explanation of *quark confinement* and *hadron jets* based on the self-induced gravitomagnetic *flux tube*. The PFT model can be analyzed qualitatively while QCD until very recently was limited to solutions calculated only to within a few percent of measurements. Qualitatively, the PFT flux tube-based dynamic configuration should have *string-like* behavior, first noted by Veneziano in 1968 and interpreted as *strings* by Nambu. Susskind: “A half century of experimenting on nucleons has made it certain that they are elastic strings that can *stretch, rotate, and vibrate when excited by adding energy.*”

The C-field flux tube can *stretch, rotate, and vibrate when excited by adding energy*, and explains *string* behavior using a 3D-construction with a 1D-aspect, unlike the pure 1D-entity assumed by string theorists, which has never made any physical predictions. The *strong force*, associated with color in the Standard Model, is explained in gravitomagnetic field theory based on Heaviside’s equations derived from the primordial-field self-interaction equation. In QCD, while

electro-magnetic force decreases as distance grows, the color force increases [22] with distance. When two quarks within a proton are pulled apart from each other, the attraction between them becomes stronger such that it's essentially impossible to pry quarks away from each other—the strong force keeps them confined. Interactions are weak at short distances where quarks are more loosely bound. As noted, in contrast to our solenoidal construction, QCD's *flux tube* is *anchored on* quarks.

QCD treatments vary in detail but uniformly fail to provide an intuitive explanation. The quark model proposed in 1963 by Gell-Mann was described in a 1976 *Scientific American* article by Nambu [23]: “*Theorists, who invented the quarks in the first place, are now charged to explain their confinement within the particles they make up.*” Five decades later, we still *need to explain the confinement of quarks*. The 1976 “string” picture is the basis of most attempts, with *flux tubes anchored on quarks*, visualizable for quark-antiquark pairs, but unclear for three-quark baryons. A brief chronological summary of recent *flux tube*-based QCD work follows.

In 2013 *Xiong* [24] applied the Callan-Harvey anomaly-inflow mechanism to the study of QCD chromoelectric flux tubes, quark pair creation, and the chiral magnetic effect. Chromoelectric field lines between color sources, like a quark and antiquark pair, are squeezed into a narrow flux tube connecting the pair and provide a chromoelectric field strong enough for quark pair creation. *Only mesons' straight string-like color flux tubes are studied*, but he muses on more complicated cases like the Δ -shape and the Y-shape configuration for baryons. *i.e.*, mesons, consisting of quark-antiquark particles, form a linear flux tube terminating at each end on a particle, however baryons consisting of three quarks are considered to terminate the tube on each particle (Δ -shape) (Figure 6) or to join in the middle (Y-shape), differing significantly from the form factor developed in PFT.

In 2018, *Cea, et al.* [25] begin by stating:

“The confinement of quarks and gluons inside hadrons is a well-established experimental fact, but a theoretical explanation of the underlying dynamics within the theory of strong interactions, QCD, is still missing.”

A wealth of *Lattice Monte Carlo* numerical simulations in QCD show that a chromoelectric field *between two static quarks* distributes in *flux tubes*, producing a linear potential between static color charges, numerical evidence of color confinement. At zero temperature, color flux tubes, made up almost completely by the longitudinal chromoelectric field directed along the line joining a static quark-antiquark pair, can be successfully described within the dual superconductivity picture, both in SU(2) and in SU(3) gauge theories. Investigation of flux tube structure in SU(3) was extended to nonzero temperature; the flux tube between two static sources separated by a distance of about 0.76 *fm* survives even above critical temperature T_c , keeping a more or less constant transverse shape, but housing in it a weaker and weaker chromoelectric field as the temperature increases.

In 2021 *Chagdaa, et al.* [26] consider temperature and find that, in full QCD, dynamical quarks widen the flux tube in a short separation range of about $R = 1$ fm. Energy density and width of the flux tube vanish at about $R = 1.8$ fm and $R = 1.5$ fm, respectively, at all temperatures.

Sept 2024 *Baker, et al.* [27] present *lattice Monte Carlo* results on the chromoelectric field created by a static quark-antiquark pair in the vacuum of QCD for several values of the physical distances between the sources, ranging from about 0.5 fm up to the onset of string breaking and compare the results with a model of QCD vacuum as disordered chromomagnetic condensate. A Maxwellian flux tube leads to a mechanism for squeezing the electric fields into a narrow flux tube, assuring the presence of an almost uniform and narrow longitudinal electric field along the flux tube, leading to a nonzero string tension, but no firm claim can be made about the onset of string breaking. There is no reason to assume Maxwell's physics applies to color charges; it is merely *assumed*, whereas the primordial field theory equations are dual to Maxwell and identical to Heaviside's equations that were *derived from* Maxwell.

Baker *et al.* conclude: Monte Carlo numerical simulations of QCD show behavior of the non-perturbative gauge-invariant longitudinal electric field in the region between two static sources, a quark and an antiquark. After subtraction of the perturbative component, the longitudinal electric field takes the shape of a flux tube, whenever the distance between the sources does not exceed a value $d \simeq 1.1$ fm. This flux tube can be characterized by two quantities, σ_{eff} , related to the string tension, and width w , with good compatibility between predictions and numerical results. That is, *lattice QCD* treatments of chromoelectric and chromomagnetic flux tubes (with fitting parameters to spare) produce expected behaviors, but no definitive results.

8. Hadron Form Factors and Predictions of Properties

Flux tube-based behavior is intuitively predicted by the C-field model of the nucleons, while neither string theory nor QCD have solved the fundamental issue of how the spin of the nucleon is constructed from the spin and angular momentum distribution of the constituent quarks and gluons; the spin of the quarks contributes only 20% - 30% of the nucleon's spin. "*Nucleon Electromagnetic Form Factors*" [28] reviewed theoretical approaches to understanding the quark-based structure of protons and neutrons and concluded that after almost forty years of quark-based models of proton and neutron: "*The recent unexpected results in the nucleon electromagnetic form factors... have challenged our theoretical understanding of the structure of the nucleon.*"

Since distribution of quarks and color inside hadrons is unknown, the distribution of electric charge inside hadrons is unknown. Unlike color, which is never seen, only inferred, the distribution of electric charge *can* be probed via scattering experiments. Physicists don't really understand how the neutron's three quarks move within it, and a 2008 analysis revealed a negative charge at the center of the

neutron, attributed in *Physical Review C* to very fast moving “down” quarks. “The neutron consists of an up quark and two down quarks, continually moving around in random directions and at random speeds, but there are patterns.” The best understanding of neutron structure comes from scattering experiments where an electron beam hits a gas or liquid target that is full of neutrons. Elastic scattering experiments leave the neutron intact and reveal positions of charges within the neutron. For decades, such experiments have implied the neutron is a negatively charged cloud surrounding a *positive central region*, but Miller’s re-analysis showed surprisingly that *a negative charge also exists at the core of the neutron*, inside the positive region, **Figure 10** [29].

Study of the nucleon charge radius has been historically instrumental for understanding nucleon structure [30]. In QCD, the highly complicated dynamics of the strong force between quarks and gluons, and fermionic nature of quarks and spin-orbit correlations yield an asymmetric distribution of *u*- and *d*-quarks in the neutron and explanations of the negative core are non-intuitive.

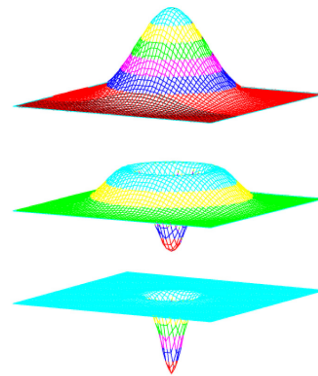


Figure 10. Charge at the center of the neutron is positive when looking only at low-momentum quarks (top) but is increasingly negative for quarks of higher momentum (middle and bottom).

Consider negative neutron cores in primordial field theory. Nucleons accelerated to high velocity generate a C-field circulation that is aligned with the axis of motion, our frame of reference. The co-axial flux tube is an internal C-field with its own specific direction. The global axis defined by the velocity of the nucleon will cause the local nucleon C-field axis to align with the direction of travel in the center-of-mass frame (see **Figure 11**), so, colliding nucleons will see each other *end-on*.

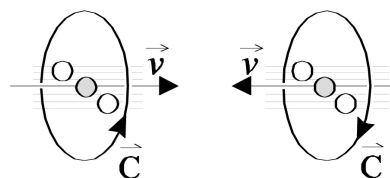


Figure 11. Depicting the alignment of the orbital dipole with the momentum induced dipole.

Analysis of quark orbits shows a down quark orbit to be smaller than an up quark orbit, so looking *end-on*, the negative down quark will be seen to be interior to positive up quark orbits explaining the negative core of the neutron (**Figure 12(b)**). No QCD model intuitively explains this.

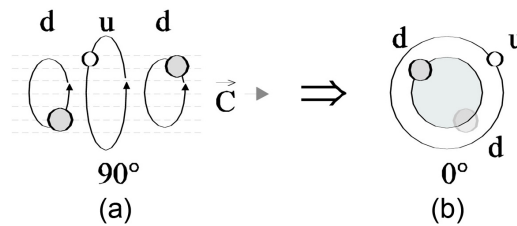


Figure 12. (a) The alignment of the orbital dipole with the velocity-induced helical C-field circulation implies that, (b) The center-of-mass-frame scattering will find a negative charge at the core of the proton.

9. Magnetic Moments of the Nucleons: Proton and Neutron

Consider deriving magnetic moments of proton and neutron; what are the *magnetic* dipoles created by the three charge current loops? Many lattice QCD simulations use mass values hundreds of times larger than the up and down quarks and also set quarks to the same mass. Three equal masses experience the same force in a C-field and orbit in the same direction, so with three identical electrical charges, the magnetic dipole field would be three times stronger. But neutron charges are *not* identical; two are negative and one is positive, and their dipole field vectors point in opposite directions; a negative magnetic dipole will cancel an equal positive magnetic dipole. PFT explains the *relative masses* of charged particles: the self-repulsion of charge limits the collapse of the C-field torus toward infinite mass density, so it follows that the greater the charge, the sooner collapse is halted, and the limit is reached. The longer toroidal collapse goes on, the greater is the mass of the resultant particle—the less the charge, the greater the mass—exactly what we find:

Particle	e	u	d
Charge	$\frac{3e}{3}$	$> \frac{2e}{3}$	$> \frac{e}{3}$
Mass	m_e	$< m_u$	$< m_d$

There is no Standard Model explanation of the relative mass ordering of charged particles. Electron-proton collisions at SLAC indicated that the proton was a composite of two *up* quarks with charge $2e/3$ and a *down* quark with charge $-e/3$, thus, *d* quarks should be more massive than *u* quarks. If quarks have almost the same orbital velocity, the $mv \times C$ force results in tighter orbits of *d* quarks (**Figure 13**).

A neutron consists of two downs and an up quark, so our conclusion concerning relative quark mass supports the heavier neutron, as down quarks are heavier

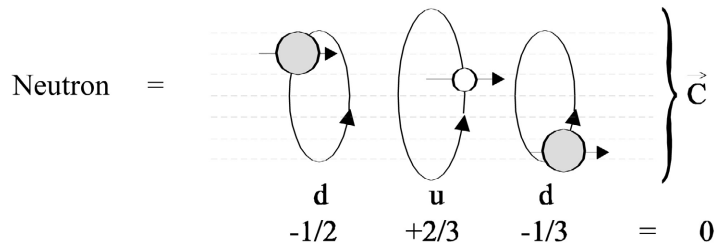


Figure 13. The primordial field theory schematic of the neutron.

than up quarks and have smaller orbits, reflecting the $mv \times C$ force if quark orbital velocities are approximately equal. But how determine the *ratio* of up quark to down quark mass? Based on quark charges, we could hope to use the Lorentz force to find the q/m ratio as was done for the electron, but this would require an isolated quark moving in an electromagnetic field. Since no one ever has seen a lone quark, how can we *weigh* quarks? If we view a nucleon’s magnetic dipole as the sum of the three constituent quark orbital dipoles, assuming equal orbital velocities, then each quark dipole is given by $\mu_B = IA$ where I is the “current” in the orbital “loop” and A is the area enclosed by the loop. Dirac invented the approach that evolved into quantum field theory, but Dirac theory was based on elementary particles, *not* composite particles, and predicted one nuclear magneton for the proton dipole and zero for the neutron, whereas the measured values are:

$$\mu_p = 2.79\mu \quad \mu_n = -1.91\mu \tag{12}$$

where μ is the nuclear magneton (unit of measurement) and μ_p and μ_n are proton and neutron magnetic moments, respectively. The negative sign indicates that the direction of the magnetic moment is opposite to that of the spin, largely determined by the orbital motion of the quarks, and the charge of the down quarks in the neutron is negative. **Figure 14** depicts relative areas based on primordial field theory protons and neutrons.

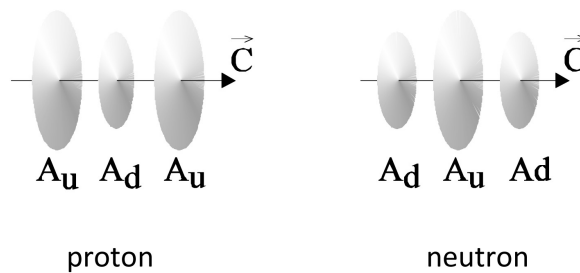


Figure 14. Schematic depicting relative areas of quark orbits determined by magnetic moments.

The u -loop area is A_u and the d -loop area is A_d . These parameters, when analyzed with the relevant current loops lead to the equations:

$$\mu_n = \frac{2}{3}(A_d - A_u) = -1.91 \tag{13}$$

$$\mu_p = \frac{1}{3}(4A_u - A_d) = 2.79 \quad (14)$$

The relevant “current”, I , is the charge times velocity. The quark charges are known, and velocities of quarks are assumed approximately equal, so these equations can be solved to find that $A_d \sim 1.02$ and $A_u \sim 1.83$ which indicates that the lighter u quark sweeps out a greater orbital area than the heavier d quark, as shown in **Figure 14**. Using this information, we can solve to find

$$m_u = m_d/1.83 \quad (15)$$

Based on the above, the *up/down* mass ratio is approximately 1.85. Based on the upper estimates of mass given in Wikipedia, the *up* mass is approximately 2.8 MeV, and *down* mass is ~ 5.2 MeV, in agreement with our *relative mass* prediction of ~ 1.83 based on a charge-limited particle creation process. Since quarks have never been seen, let alone measured in isolation, *all values of quark mass* are “*scheme-dependent*”, meaning that the value depends on the theoretical scheme being used to compute the mass. Nevertheless, our simple analysis and simple calculation agrees with the current idea of quark masses. Since these masses account for less than 9 MeV of the 900+ MeV of the nucleons, only about 1% of the nucleon mass is attributable to the native quark mass. In primordial field theory, the other 99% of the mass is attributed to the inherent circulation of the flux tube, including quark orbital angular momentum.

The PFT charge creation mechanism implies that mass should be inversely related to charge. Assuming approximately equal orbital velocities, down quark orbits are tighter than up quark orbits, implying that mass ratio is proportional to magnetic moments, yielding reasonable results.

10. Primordial Field Theory of Atomic Nuclei: The Deuteron

An intuitive explanation of confinement has been missing for 50 years. For those who believe that the purpose of physical theory is to understand physical reality this is significant. But to replace a 50 year old established theory, a theory must do more than just explain key features of quark-based hadrons. Ideally it will solve other problems that have evaded QCD solution. One area that might be expected to benefit from an intuitive understanding of the primordial field theory treatment of the strong force is nuclear physics. It is generally felt that QCD will never be of great relevance in nuclear physics, so it is appropriate to examine nuclear physics in terms of PFT.

For example, the nucleus of deuterium has been the subject of much study since 1932. As the only *two-nucleon bound state*, *the deuteron has been considered to be as fundamental in nuclear physics as the hydrogen atom in atomic theory*. The existence of *tetraquarks* and *pentaquarks* would seem to imply that six quarks would have a unique structure, based on strong interactions between all six particles, yet physicists are still looking for any quark effects in nuclear structure.

The C-field model makes sense of nucleons, that is, individual protons and neutrons, but does it make sense of atomic nuclei constructed of such nucleons?

Nuclei consist of protons and neutrons, from one each to hundreds, so ideally *PFT* nucleon models should be relevant to nuclear physics. The PFT model of the proton and the neutron can be applied to the simplest multi-particle nucleus, the deuteron, consisting of one proton and one neutron. How should two nucleons be combined? The *z*-ordered C-field flux tube symmetry implies that $np \approx pn$, as depicted in **Figure 15**.

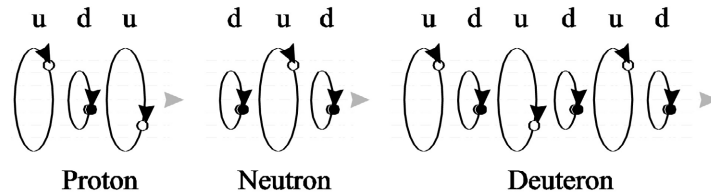


Figure 15. The proton and neutron *z*-ordered flux tubes align and augment each other as shown.

The direction of the C-field is parallel to the nucleon angular momentum or spin. Since the proton and neutron are fermions with spin-1/2 then combined as a single particle, we expect spin = 1 or spin = 0, as seen in **Figure 16**. The nature of the C-field flux tube is such that all quarks orbit in the same direction, so *deuterons would be expected to align the flux tube such that all six quarks orbit with the same handedness*, in which case spins will add, with spin $S = 1$. Hans Bethe’s 1999 nuclear physics review taught that the spin of the deuteron is 1 and that the $S = 0$ state is not bound. This empirical fact supports the PFT C-field model of the deuteron.

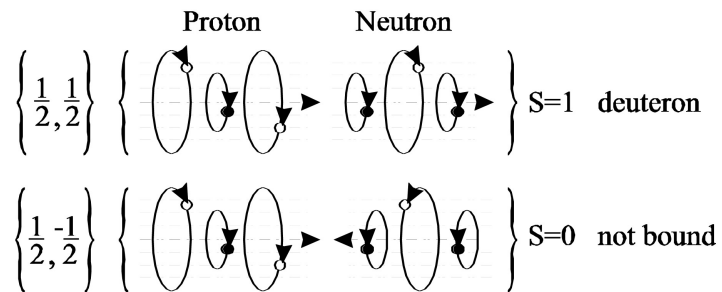


Figure 16. Possible alignments of proton and neutron *z*-ordered flux tubes, and consequent spin, S .

Next, consider the magnetic moment of the deuteron. Lattice QCD has no simple solution for this, but the C-field model implies that both proton and neutron will couple to the field as shown. Using the nucleon magnetic moments to derive the up/down quark mass ratio we found that the magnetic moments were the sums of orbiting charges where $\mu_p = 2.79\mu_n$ and $\mu_N = -1.91\mu_n$. Carrying this logic over to the six-quark deuteron of **Figure 15** we predict a magnetic moment:

$$\mu_D = \mu_p + \mu_N = 0.88 \mu_n \tag{16}$$

incredibly close to the deuteron’s measured value which is $0.857 \mu_n$. The lattice

QCD calculation yields $1.218\mu_n$ and an extremely sophisticated knowledge of both *nuclear physics* and *quantum chromodynamics* is required even to understand this calculation, compared to the C-field model's easily understood intuitive solution with minimal calculation. Based on understanding the PFT model, this may seem simple but try to guess what the magnetic moment of a six quark deuteron would be if all six quarks were interacting via three electric analog color charges and gluons of eight types as shown in **Figure 17**, adapted from a QCD lecture.

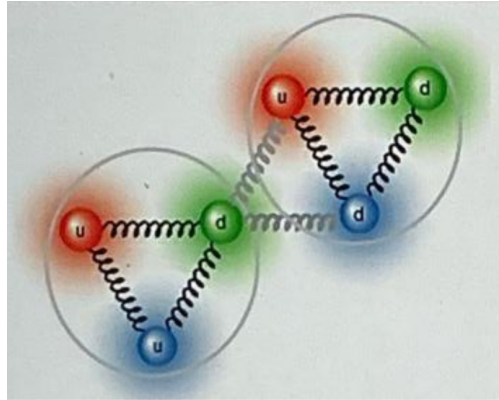


Figure 17. A schematic diagram of QCD model of deuteron adapted from the internet.

With this construction one might wonder how QCD calculations manage to even come close, but this has been explained by Fermi with his elephant analogy; with enough free parameters, one can fit a curve to almost any data. Yet, nuclei with simple two-body forces would be expected to have spherical shapes, so why does the deuteron not collapse into a tight 6q state? Pais pointed out that “*The deuteron’s cigar shape, manifested by its quadrupole moment, demanded a non-central force component*”. The PFT model explains the non-central force component, but QCD does not. Also, most QCD-based nuclear calculations are nearly independent of the nucleon-nucleon potential used, and results uniformly show some overlap, in agreement with deep inelastic scattering data. *PFT* models show in **Figure 18** just such an overlap, due to the extension of nucleons along the z-axis, parallel to the C-field dipole.

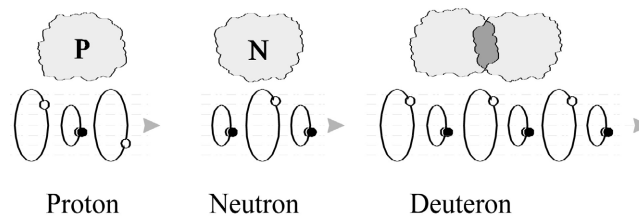


Figure 18. Depicting “overlap” of nucleons in deuteron.

Thus, short range correlations discovered in nuclear physics agree with and

therefore support *PFT* models of nucleons, but, amazingly, the QCD potentials all predict approximately similar results. This statement about *insensitivity to the potential used*, implies something very serious: if all of the potentials give approximately the same results, then we should conclude that we don't yet have the correct one. I believe this is a consequence of the fact that today's mathematical procedures, given a sufficient number of parameters, can match almost any data, without capturing underlying physics. Clearly, "*nucleus as a collection of two body interactions*" is an insufficient model. Without an organizing principle such as the C-field, all approaches are doomed to provide a *best fit* to specific data and a *poor fit* to other specific data—testifying to the power of fitting procedures, and to the ignorance of underlying physics. For example, a problem common to all is that potential models which have been fit only to neutron-proton data yield a poor match to proton-proton data. This is understandable in primordial field theory, which predicts the *pn* structure as the basis of nuclear physics. Subedi, *et al.* [31] have performed an experiment that provides the first estimate of the isospin structure (*pn* vs. *pp* vs. *nn* pairs) in nuclei.

It helps to visualize our model of these pairs:

$$pn = u d u - d u d$$

$$pp = u d u - u d u$$

$$nn = d u d - d u d$$

The *u-d* interaction of a *pn* pair is energetically preferred to *u-u* and *d-d* like-particle pair interactions. Unsurprisingly, Subedi found, in experiments on ^{12}C , which has an equal number of protons and neutrons, that probabilities of *pp* or *nn* short-range correlations are at least a factor of 6 smaller than that of *pn*. Again, this strongly supports the PFT C-field model of nuclei—another unique prediction of C-field nuclear theory. The C-field flux tube about which quarks orbit, provides an intuitive and simple means of computing the up/down quark mass ratio based on anomalous magnetic moment and also straight-forwardly predicts the deuteron magnetic moment and the neutron electric dipole. The C-field explains both quark confinement and asymptotic freedom in analytically simple fashion. The PFT model is also supported by a nuclear reaction in which the deuteron photo-disintegrates at large transverse moments into a proton and neutron, indicating the coherent transfer of the energy of the incident photon to the six quarks in the deuteron; Subedi found that when protons were knocked out of a carbon nucleus, 92% of the time, a neutron emerged from the nucleus with momentum almost equal and opposite in direction to the momentum of the proton.

The most likely decay mode is the half-wavelength mode, in which the 6Q particle decays to two 3Q nucleons (Figure 19). While photodisintegration supports the *intuitive* C-field model, QCD descriptions of nuclei in terms of nucleons and mesons or in terms of quarks and gluons are still not understood, nor are the nucleon and meson structures.

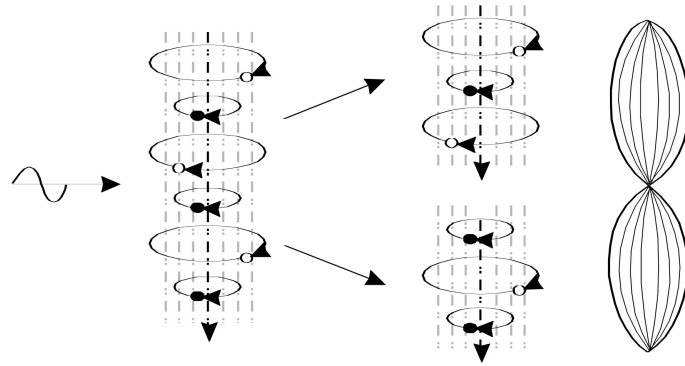


Figure 19. The proton and neutron z-ordered flux tubes dominant decay mode.

And all of these are in agreement with Segre’s claim that a velocity dependent potential that looks like the C-field has been in evidence for almost half a century. Contrasted with this, QCD-based nuclear physics is largely insensitive to the model potentials used and can’t explain the lack of spherical symmetry in key nuclei; it’s generally acknowledged that QCD will never apply to nuclear physics beyond deuterium, if that. A C-field-like force has been evident in nuclear physics experiments for half a century. Subedi’s results confirm a flux-like model and showcase the ease with which both qualitative and quantitative results are derived in PFT.

Finally, application of flux tubes to nuclear physics requires further analysis; solenoidal behavior is based on N “coils”, where field strength is multiplied by N and energy density is scaled by N^2 . Applied naively, this would imply that the energy of the deuteron, with six quarks, would be 6^2 or 36 times the basic quark self-induced flux, yielding $\sim 36 \times 100$ MeV or 3.6 GeV for the mass-energy of the deuteron, which is almost twice the actual mass. What is going on? Electromagnetic charges inducing flux in a physical solenoid are not orbiting the induced flux but are constrained to wires, and these wires can be placed next to each other and even stacked on top of each other. This is not the case for quarks orbiting a flux tube. Each nucleon has two quarks with like charges that repel each other, preventing the “close packing” possible with wires. This implies that the effect of each quark orbit or “coil” falls off with distance and only nearest neighbors yield maximum enhancement of the local induced field. Further details await actual calculations, which are underway and will be reported in a future paper.

11. Summary and Conclusions

When one extends a current theory in some manner, it is generally appropriate to view the current theory as sufficiently well understood and to focus on the extension to the theory. In this work we offer an extension to *primordial field theory* that is quite at odds with the current *Standard Model of Particle Physics*. We have, for this reason, focused on the state of understanding of confinement, which is the key aspect of quark physics of hadrons, *i.e.*, the *strong force*. Confinement is not

well understood in the Standard Model. Instead, the use of seven extra dimensions associated with color and approximately two dozen parameters associated with particle mass are used in a lattice formulation for numerical approximations. The extra parameters implied by virtual particles (“sea quarks”) are effectively limitless—a continuous fitting parameter. And, as noted, lattice QCD calculations are based on 84 numbers at each lattice point. In addition, Consa points out that “*all calculations performed in QED always produce an infinite value... [and the renormalization] techniques are not mathematically legitimate [but] provide results that fit perfectly with the experimental results*”.

Review of the origin of color in QCD revealed a very *ad hoc* speculative proposal to avoid a misconceived problem with Pauli symmetry. Most applications of symmetry to physics, often initially treated as if exact, are only *approximate symmetry*, due to the lack of equal mass. Unlike most real physics, “massless” color yields an *exact symmetry*, $SU(3)$, superseding approximate $SU(3)$ *flavor symmetry* which had already prepared many physicists for such. *Primordial field theory* also has *exact* $SU(3)$ symmetry of the wave function (Equation (10)) in the context of the Pauli exclusion principle, but with seven fewer parameters. Until 2006 *QCD physics* expected a “quark gas” when atom-atom collisions reached sufficient energy to disrupt the nucleons comprising the atoms. Instead, the LHC data suggested a *perfect fluid*—completely consistent with primordial field theory (of course, the Standard Model was modified to accept this new data). Finally, in the current context we note that the lack of comprehension of quark dynamics in QCD applies also to the distribution of quark electric charge and, again recent data has caused the Standard Model to be modified to accept a negative charge at the center of nucleons, a fact completely explicable in PFT. That hundreds of thousands of physicists are very heavily invested in QCD may account somewhat for continued acceptance of flawed *Standard Model of Particle Physics*, despite general recognition that the theory is incomplete.

Finally, reviewers have questioned the composition of the primordial field, $\psi = \mathbf{G} + i\mathbf{C}$, claiming that a field in Quantum Field Theory “*cannot take complex values*”. This invites a discussion of the fact that Hestenes’ *Geometric Algebra* is the only mathematical formalism in which *every term* has both a *geometric* and an *algebraic* interpretation, and that fact alone is sufficient to convince many that *Geometric Algebra* and its extension to *Geometric Calculus*, is the correct formulation for physics. Physics has always been correlated with algebraic equations, typically written on a blackboard, and geometric designs, usually written on the same board, alongside the equations, with algebraic terms drawn on the geometric design to correlate the two presentations. But the interpretations, and their correlation, has always been *in the mind of the physicist, not in the formulation of the problem*. It is obvious that a formulation which contains the interpretations is more appropriate. But how can this be justified other than as a physicist’s aesthetic judgment? Here is an example, arising in the review of this paper. The reviewer is correct, that QFT fields cannot take complex values, (however the complex i can

be used to switch between statistical mechanics and quantum mechanics via a process known as Wick rotation). Nevertheless, as stated from the beginning, primordial field theory is not a variant of quantum field theory, which is based on one-field-per-type-of-particle; *all* particles are derived from the primordial field. We have shown this for fermions and herein extend the treatment to hadrons: baryons and mesons. Thus, the primordial field, $\psi = \mathbf{G} + i\mathbf{C}$ should not be interpreted as simply the G-field vector plus the imaginary number times the C-field vector, but as *the duality operator* i that acts on the C-field vector to produce bivector $\vec{\mathbf{C}}$, which is a *directed area*, *i.e.*, a *two-dimensional object* representative of the circulation and associated angular inertia of the C-field. Understanding this aspect of primordial field theory is crucial to fully appreciating the theory. The very nature of the C-field is rotational, as opposed to the radial nature of the G-field, and this is captured in the use of the bivector $\vec{\mathbf{C}} = i\mathbf{C}$ to represent the C-field in the definition of the field $\psi = \mathbf{G} + i\mathbf{C}$. Another reviewer remarked that “*common wisdom tells us that one cannot just add a scalar and a vector*”, despite his recognition that “*There is something in this calculation that makes sense.*” However, it is a major property of Hestenes’ mathematical formulation that one can add unlike terms. Most readers are familiar with the fact that in complex analysis, one multiplies through all relevant terms and then groups the *reals* and the *imaginaries* separately for solving. It is essentially this process that takes us from Equation (3) to the left side of Equation (4), all within the mathematical formalism. We then leave the mathematical formalism to add the physical interpretation that the energy density of real physical fields is proportional to the square of the field strength, and this takes us the rest of the way to Heaviside’s equations, shown on the right side of Equations (4). I am sure that many readers will be as impressed as I am that *Heaviside’s equations*, and through duality, *Maxwell’s equations* fall out in such straightforward manner from merely postulating that, *at the Creation, only one field existed*. What is to be emphasized here is that this physics result will occur *if and only if* the physics is interpreted in terms of Hestenes’ mathematical formulation! Elsewhere it is shown that General Relativity and Heaviside’s theory are equivalent, despite a century of belief that Heaviside is the “weak field formulation”, sustained almost certainly through ignorance of self-interaction and of the fact that *the equations are not energy-based but are energy-density-based*. I believe the above constitutes convincing proof that Hestenes mathematics is the natural and correct mathematics to describe the physical universe [32] [33].

I have focused on qualitative aspects of the primordial field theory of the strong force, and its intuitively understandable ontology, application of which yields very close approximations to mass ratios, and magnetic moments of simple nuclei, as well as explaining both asymptotic freedom and quark confinement and accounting for the fact that nucleons retain their identity in nuclei rather than collapsing to a spherical shape expected from a two-body force such as color supplies. Of course, a detailed quantitative treatment should support this comprehensible model of the strong force. This treatment will be presented in a future paper.

Conflicts of Interest

The author declares no conflict of interest regarding the publication of this paper.

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