Journal of Cosmology, Vol. 27, No. 5, pp 18250 – 18286

Time Dilation Cosmology 9: Particle Structure, Quark Masses, Color, and the Strong Force in Time Dilation Cosmology

Capt. Joseph H. (Cass) Forrington
captcass@captcass.com

Abstract

Time Dilation Cosmology (TDC) models elementary particles as localized configurations of an evolving spacetime/quantum continuum and proposes that ordinary matter can be constructed from two primary persistent charged particle structures: the electron and the up-quark vortex. Beginning with the previously derived temporal acceleration factor along the Fundamental Direction of Evolution (FDE), one orthogonal unit spatial component produces a local 30° deflection of the resultant evolution from the FDE. Its spinorial representation contains a 15° half-angle, and a new charged-vortex symmetry postulate divides this response equally between the spatial and electromagnetic components, producing a 7.5° helical tilt. The resulting vortex geometry and complete-cycle counter-FDE time-rate integral predict an up-quark mass of m_u = 2.15682 MeV/c^2, compared with the Particle Data Group (PDG) value m_u = 2.16 ± 0.07 MeV/c^2 in the MS-bar scheme at the renormalization scale μ = 2 GeV. An orthogonally conjoined electron–up-quark state, identified in the model as the down quark and having $dR_t = \cos^2 30° = 3/4$, predicts m_d = 4.66868 MeV/c^2, compared with the PDG value m_d = 4.70 ± 0.07 MeV/c^2. The resulting ratio m_u/m_d = 0.4620 agrees with the PDG value 0.462 ± 0.020. Applying the same geometry to the previously proposed proton and neutron configurations gives a neutron–proton mass difference of 1.29381 MeV/c^2, compared with the empirical value of approximately 1.29333 MeV/c^2, a difference of approximately 0.037%. A two-plane up-quark vortex has exactly three equivalent orientation classes in three spatial dimensions; when represented by normalized coherent complex amplitudes, their norm-preserving transformations with common phase removed form SU(3) with eight generators, providing a proposed geometrical basis for the three quark color states and their transformation structure. Finally, the previously proposed strong interaction as shared FDE evolution is expressed quantitatively through the spatial gradient of the shared time-rate field. An absolute force requires an independently derived vortex length scale and is therefore not fitted here. Within the stated assumptions, the results show that a particle construction based on two primary persistent structures can generate quantitative relationships corresponding to several otherwise distinct particle properties and provides specific targets for further independent testing.

1. Introduction

The Standard Model of particle physics provides an exceptionally successful mathematical description of elementary-particle interactions. Nevertheless, the measured properties of its elementary particles—including their masses, fractional charges, generations, and the structure of the strong interaction—are represented by parameters and symmetries whose numerical values are not generally derived from an underlying spacetime geometry.

Time Dilation Cosmology (TDC) approaches the problem from the opposite direction. Rather than beginning with particles as fundamental objects existing within spacetime, TDC treats particles as localized, continuously renewed configurations of the spacetime continuum itself. In this interpretation, particle properties must ultimately arise from the geometry and dynamics of the continuum.

Previous TDC papers [1–3] developed a Fundamental Metric in which the three spatial dimensions evolve together in the Fundamental Direction of Evolution (FDE) which is the forward direction of time at any coordinate point. In the macro scale, for instance, the FDE is visible as the tangent to an orbit at any point. Assigning one unit to each of the three mutually orthogonal spatial dimensions gives the resultant temporal acceleration factor

$$\sqrt{(1^2 + 1^2 + 1^2)} = \sqrt{3} \tag{1}$$

while the resultant of two orthogonal unit spatial components gives

$$\sqrt{(1^2 + 1^2)} = \sqrt{2} \tag{2}$$

These relationships provide the previously derived $\sqrt{3}$ temporal and $\sqrt{2}$ spatial acceleration factors of TDC.

The particle interpretation subsequently proposed [5] that localized mass does not consist of an independently existing material substance. Instead, a particle event is continuously renewed as the FDE progresses through a tightly curved or corkscrew-like trajectory. The earlier particle model therefore described inertia as the repeated renewal of a spatial event as time evolves forward through a very tight spiral.

Within that construction [5], the electron and up quark were proposed as the two primary persistent charged particle configurations. This is a central economy of the TDC particle model: ordinary matter is constructed from these two primary structures rather than from a separate fundamental structure for each member of the observed particle spectrum. The electron was associated with the complete Fundamental Spin, whereas the up quark was represented by a related but primarily two-plane vortex configuration. Oppositely directed particle spins were proposed to attract where their local evolutions proceed in the same direction on their common side, and this shared evolution in the FDE was identified as the physical origin of the strong force. The earlier particle model also recognized that three spatial dimensions permit mutually orthogonal particle-spin orientations.

The resulting structural model [5] represents a down quark as a conjoined electron/up-quark state. A proton is represented by three up-quark spins conjoined with a central electron spin, while a neutron contains a second electron conjoined with one of the up-quark spins on the side opposite the central electron. These previously proposed configurations are illustrated in Figures 1–3.

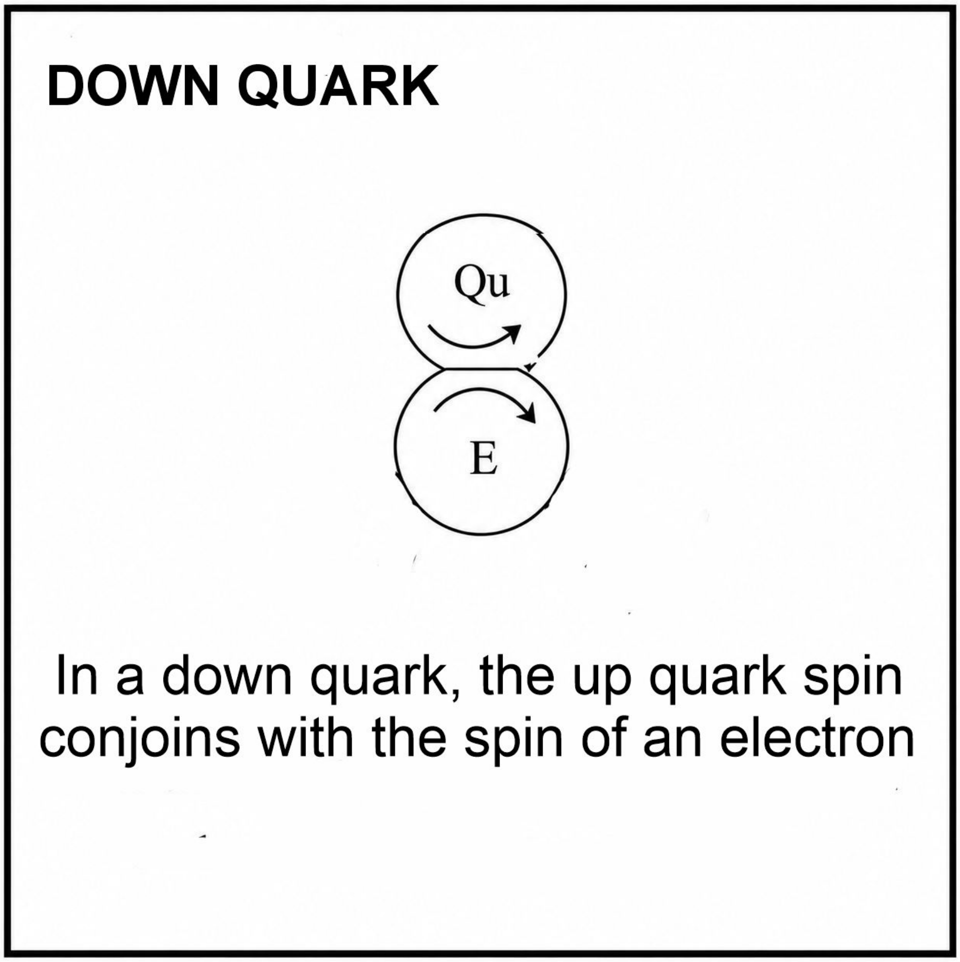

Figure 1: Down Quark

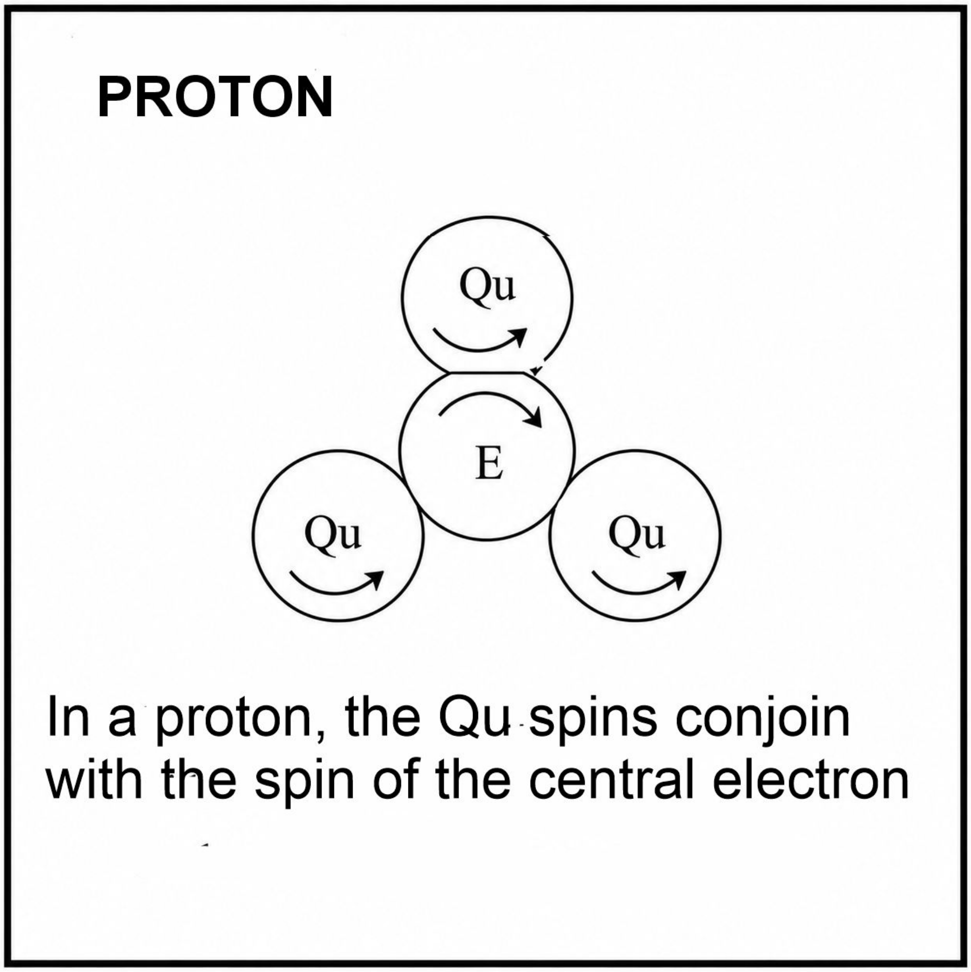

Figure 2: Proton

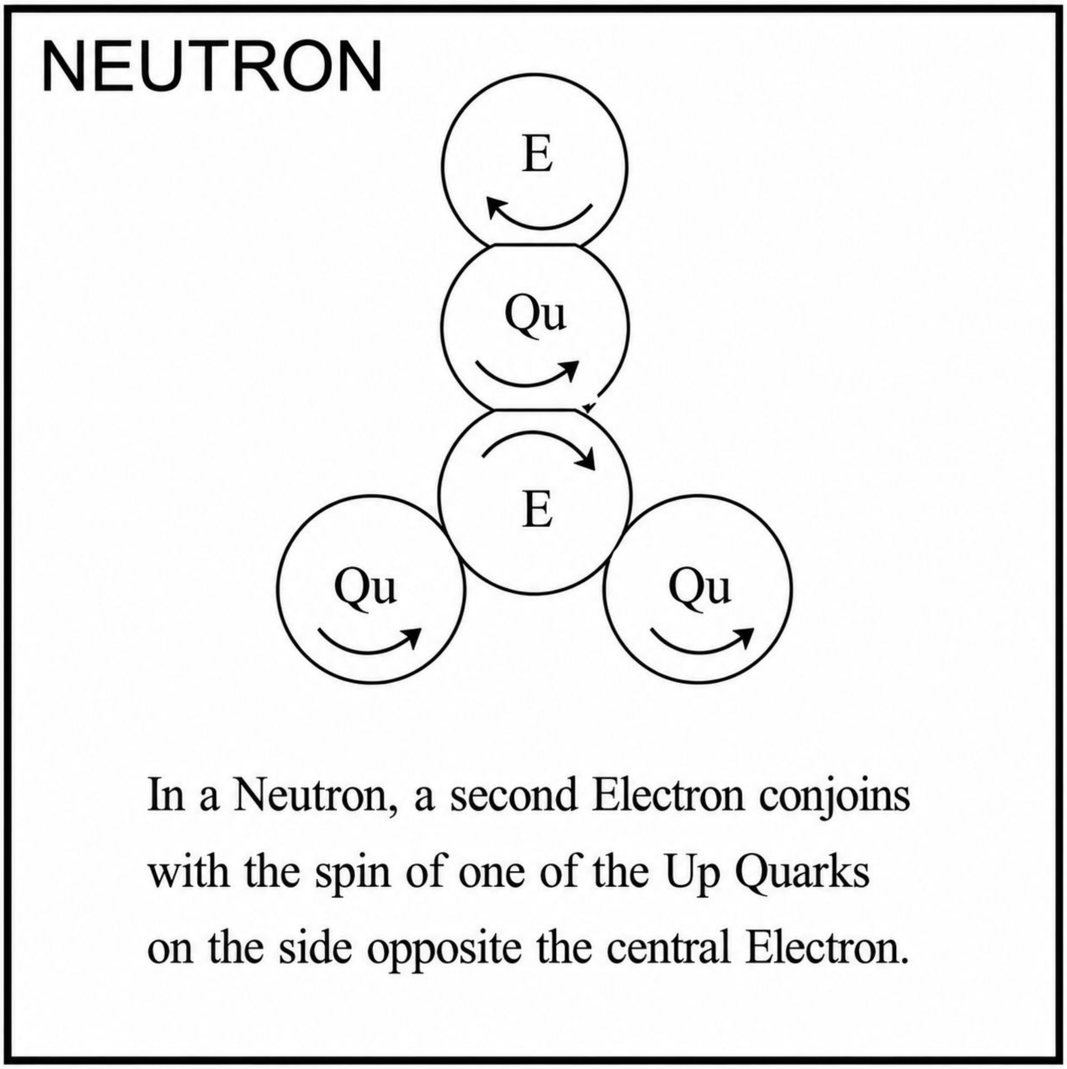

Figure 3: Neutron

The earlier particle work [5] was primarily geometrical and qualitative. It did not derive the quark mass scale, the neutron-proton mass difference, or a quantitative strong-force energy scale from the proposed vortex geometry. Nor did it investigate whether the three possible orientations of a two-plane vortex could provide a geometrical origin for quark color.

The purpose of the present paper is to extend that particle construction quantitatively.

The analysis begins with the previously derived Fundamental Metric and treats the FDE and localized spatial evolution as orthogonal components of a particle vortex. A unit localized spatial component combined orthogonally with the √3 FDE produces the resultant

$$R = \sqrt{((\sqrt{3})^2 + 1^2)} = 2 \tag{3}$$

If θ is the angle between the FDE and the resulting local vortex evolution,

$$\cos\theta = \sqrt{3}/2 \tag{4}$$

and therefore

$$\theta = \cos^{-1}(\sqrt{3}/2) = 30° \tag{5}$$

This 30° angle is distinct from the 35.264° diagonal-to-plane angle previously obtained from the three-dimensional Fundamental Metric **[2].** The latter describes the orientation of the three-dimensional diagonal relative to a spatial plane, whereas the former describes the local deflection produced when one unit spatial component acts orthogonally to the √3 FDE.

A physical rotation through θ can be represented spinorially by the quaternion

$$q(\theta) = cos(\theta/2) + \hat{n}\, sin(\theta/2) \tag{6}$$

For the local particle-vortex angle θ = 30°, the quaternion therefore contains the half-angle

$$\theta/2 = 15° \tag{7}$$

For the charged two-plane vortex developed below, one additional symmetry condition is introduced explicitly rather than inferred from the previous TDC papers. It is postulated that the spinorial response is shared symmetrically between the spatial and electromagnetic components of the charged vortex. The resulting secondary helical angle is therefore

$$\delta = \theta/4 = 7.5° \tag{8}$$

This is the principal new geometrical postulate used in deriving the particle-mass relationships presented in this paper. Its status as a postulate is maintained explicitly so that the subsequent numerical results can be distinguished from the assumptions from which they follow.

The resulting geometry permits an instantaneous counter-FDE velocity field to be defined and its associated time-rate differential, dR_t, to be integrated over a complete vortex circulation. Combined with the previously developed TDC charged-particle energy relationship [4], this provides a quantitative calculation of the up-quark mass within the model. The same construction is then extended to the bound electron/up-quark state identified with the down quark and to the proton and neutron configurations previously proposed.

The two-plane character of the up-quark vortex also has a direct dimensional consequence. In three spatial dimensions, exactly three independent two-plane orientations exist,

$$XY,\ YZ,\ ZX \tag{9}$$

because

$$C(3,2) = 3 \tag{10}$$

The possibility that these three geometrically equivalent orientations correspond to the three quark color states is therefore examined, together with the transformation structure generated when the states are permitted coherent complex superpositions.

Finally, the previously proposed identification of the strong force with shared FDE evolution [5] is made quantitative. The TDC force-gradient relationship,

$$\vec{F} = mc^2\, \nabla dR_t \tag{11}$$

is applied to the relative electron/up-quark coordinate, and the Fundamental-Spin geometry is used to determine the component of the internal vortex force transmitted through their shared FDE evolution.

The objective is therefore not to append conventional particle parameters to the TDC model, but to determine how many of those quantities follow from a small set of geometrical relationships. Where a result follows from previously established TDC equations, it is derived accordingly. Where an additional particle-level assumption is required, that assumption is stated explicitly before its consequences are calculated.

2. TDC Foundations and the Fundamental Direction of Evolution

The purpose of this section is to establish, within the present paper, the minimum Time Dilation Cosmology (TDC) framework required for the particle derivations that follow. Earlier TDC papers [1–4] contain the broader development of these relationships, and the earlier particle model [5] introduced the electron/up-quark structural interpretation. The essential definitions and mathematical relationships are restated here so that the particle calculations in this paper do not depend upon the reader first consulting those works.

A central distinction is maintained throughout. Relations already established within the TDC framework are identified as such; assumptions inherited from the earlier particle model are separately identified; and the new particle-level assumptions introduced in this paper are not treated as consequences of the Fundamental Metric unless they are explicitly derived from it.

2.1 The Fundamental Metric and Fundamental Direction of Evolution

TDC treats spacetime as a three-dimensional energy continuum continuously evolving forward in time at the invariant rate c. Let the three mutually orthogonal spatial basis directions be represented by unit vectors $\hat{X} + \hat{Y}$ and $\hat{Z}$.

The Fundamental Metric developed in TDC [2–4] assigns equal unit evolutionary components to these three mutually perpendicular dimensions. Their vector resultant is $F = \hat{X} + \hat{Y} + \hat{Z}$, and therefore its normalized direction is

$$\hat{F}_{FDE} = \frac{\hat{X} + \hat{Y} + \hat{Z}}{\sqrt{3}} \tag{11}$$

This direction is defined in TDC as the Fundamental Direction of Evolution (FDE). Thus the FDE is not an additional spatial dimension. It is the diagonal resultant of simultaneous evolution through the three mutually orthogonal spatial dimensions as the continuum evolves forward in time.

Because the three component magnitudes are unity, the magnitude of their resultant gives the previously derived TDC temporal acceleration factor,

$$\alpha_{FDE} = \sqrt{1^2 + 1^2 + 1^2} = \sqrt{3} \tag{12}$$

Here α_{FDE} denotes the normalized TDC acceleration factor; √3 is therefore a geometrical factor arising from the three orthogonal unit components, rather than an acceleration expressed in conventional units such as m s^{-2}.

If evolution is represented in only two mutually orthogonal spatial components, the corresponding resultant is

$$\alpha_{space} = \sqrt{1^2 + 1^2} = \sqrt{2} \tag{13}$$

The difference

$$\Delta\alpha = \sqrt{3} - \sqrt{2} \tag{14}$$

is interpreted in TDC as the geometrical stress between the complete three-component forward evolution of the continuum and a spatially redirected two-component state.

This distinction becomes important at the particle scale. A localized particle vortex is not treated as an independent object moving through an otherwise passive spacetime. It is treated as a localized redirection of the continuously evolving continuum itself. The FDE therefore remains the reference direction against which the particle vortex is constructed.

TDC additionally defines the Gravitational Direction of Evolution (GDE) as evolution down a local time-rate gradient. In the orbital geometry previously developed in TDC, the FDE is tangent to the motion while the GDE acts perpendicular to it. The localized vortex construction used in this paper adopts this same local orthogonal geometry:

$$\text{FDE} \perp \text{GDE} \tag{15}$$

Equation (15) is not intended to assert that every possible FDE and time-rate gradient in an arbitrary geometry must be orthogonal. It specifies the local FDE/GDE geometry used for the orbital and particle-vortex construction developed here. This distinction will be important in Section 3, where the √3 FDE resultant and a unit orthogonal GDE component produce the particle-level angular deflection.

2.2 Time-Rate Differential and Compensatory Velocity

TDC describes gravitationally induced motion in terms of a difference in the observed rate of time. The dimensionless time-rate differential is denoted dR_t. The previously derived TDC relationship between this differential and the compensatory velocity v is [1–3]

$$dR_t = (v/c)^2 \tag{16}$$

and therefore

$$v = c\sqrt{dR_t} \tag{17}$$

Equation (16) is fundamental to the particle construction because it allows a local velocity field to be represented equivalently as a local time-rate field.

Within TDC, c is not merely the limiting velocity of an object through a pre-existing background. It is the invariant forward evolutionary rate of the spacetime continuum. A localized velocity component therefore cannot represent a portion of that continuum evolving independently of the whole. Instead, the associated dR_t and compensatory motion are complementary manifestations of the same requirement that the continuum maintain its invariant overall evolution.

The Unified Field extension [4] applies the same relationship to electromagnetically induced motion. Gravity and electromagnetic acceleration are consequently represented as opposite applications of the same time-rate relationship. In gravitational motion, a pre-existing dR_t produces the compensatory velocity. Under an externally applied electromagnetic force, the induced velocity produces the corresponding compensating resistance in time. The direction of causation differs, but Equation (16) relates the same two quantities.

This common relationship is what permits the particle vortex developed below to possess simultaneously a velocity geometry and a corresponding dR_t field.

2.3 Energy and Force Relations Used in the Particle Model

Two previously established TDC relations are required for the quantitative particle calculations.

For a charged elementary particle, the Unified Field formulation [4] assigns the complete dR_t contribution to the charged-particle energy,

$$E_{charged} = mc^2(1 + dR_t) \tag{18}$$

Equation (18) will later be applied first to the cycle-averaged time-rate differential generated by the up-quark vortex and subsequently to the bound electron/up-quark configuration proposed for the down quark.

A spatial variation in dR_t constitutes a time-rate gradient. The corresponding TDC acceleration is

$$\vec{a}_{TDC} = c^2 \nabla dR_t \tag{19}$$

giving the force

$$\vec{F}_{TDC} = mc^2 \nabla dR_t \tag{20}$$

The dimensions are those of acceleration and force because dR_t is dimensionless and its spatial gradient has dimensions of inverse length.

Equations (19) and (20) are the relations used later when the proposed strong interaction is expressed as the response of one particle configuration to the dR_t gradient produced by another. The specialized Force-in-Time expression developed for the electron in [4] is not substituted here because the later calculation concerns the spatial gradient of the internal particle time-rate field.

2.4 The Two Primary Persistent Particle Configurations

The earlier particle model [5] proposed a substantial reduction in the structural particle content required by TDC. Rather than assigning a separate persistent fundamental structure to every experimentally observed particle state, the model proposed two primary complementary persistent particle configurations: the electron and the up quark.

This is a structural hypothesis of the TDC particle model and should be distinguished from the experimentally established existence of the larger particle spectrum. TDC does not require that short-lived states observed in high-energy interactions be nonexistent. Instead, the model proposes that such states need not constitute additional persistent structural building blocks of ordinary matter. They may represent transient excitations, interactions, reconfigurations, or decay states of the underlying continuum and its persistent particle structures. The extent to which this interpretation can reproduce the observed properties of those states remains a test of the model.

Within the earlier TDC construction [5], particle events are represented as extremely tight corkscrew vortices in the evolving continuum. The electron corresponds to the complete three-plane Fundamental Spin, whereas the up quark is represented primarily by a two-plane configuration and therefore produces a local resistance to, or redirection of, the complete three-component FDE.

The original three-plane construction used the characteristic geometrical perspectives 35.26438°, 45°, and 54.73561°. Their relationships give

$$\frac{45°}{35.26438°} = 1.27607 \tag{21}$$

and

$$\frac{54.73561°}{35.26438°} = 1.55214 \tag{22}$$

The latter value can be written as 1.27607 + 0.27607.

The corresponding spiral-slope ratio is therefore

$$\lambda_{spin} = 0.27607 : 1 \tag{23}$$

The overlapping three-plane spiral was identified in [5] with the electron Fundamental Spin. The up-quark configuration was proposed to manifest primarily through two planes rather than equally through all three.

The same plane-count distinction supplied the original qualitative charge assignment. The complete three-plane electron carries the elementary negative charge,

$$q_e = -e \tag{24}$$

whereas the complementary two-plane up-quark configuration was assigned

$$q_u = +\frac{2}{3}e \tag{25}$$

Equations (24) and (25) are starting properties of the earlier TDC particle model; they are not newly derived from plane counting in this section. A purpose of the present paper is to determine how much of the subsequent particle structure can be obtained quantitatively once these two persistent configurations are combined with the FDE/GDE geometry.

2.5 Composite Particle Structure and Shared FDE Evolution

The two-particle reduction does not mean that TDC identifies the down quark, proton, and neutron as nonexistent. It means that these are proposed to be composite configurations constructed from the two primary persistent structures rather than additional independent elementary structures.

In the earlier model [5], the down quark consists of a conjoined electron/up-quark pair. The proton consists of three mutually oriented up-quark configurations conjoined with a central electron. The neutron adds a second electron conjoined with one of the up-quark configurations on the side opposite the central electron.

The model further proposes that the interaction between these configurations follows from their local directions of evolution. Like-directed local spin surfaces oppose one another when their evolutionary motions impinge, whereas oppositely oriented spins can evolve in the same direction along their common interface. This shared FDE evolution was proposed in [5] as the geometrical origin of the strong binding interaction.

Three spatial dimensions also permit mutually orthogonal particle-spin orientations. Consequently, the electron/up-quark binding geometry used in this paper permits 90° relationships between spin axes. These structural configurations are retained as starting hypotheses here; the later sections test whether their angular relationships, masses, color-state structure, and interaction energies can be generated quantitatively rather than independently assigned.

This distinction is particularly important for the strong interaction. The present model does not require a persistent gluon to be inserted as an additional constituent of the stationary particle geometry. Instead, Section 8 tests whether the interaction conventionally represented through color-mediated strong dynamics can, within TDC, be represented by shared FDE evolution and the resulting dR_t gradient. Establishing such a correspondence requires more than reproducing a three-state color counting, and the limits of that comparison will be stated explicitly.

2.6 Established TDC Relations, Structural Hypotheses, and New Assumptions

The logical structure of the remainder of the paper can now be separated into three levels.

The previously established TDC framework used here consists of the three-component Fundamental Metric and its √3 FDE factor; the two-component √2 spatial factor; the local FDE/GDE geometry used in the vortex construction; the relationship $dR_t = (v/c)^2$; the charged-particle energy relation; and the dR_t force-gradient relation.

The previously proposed TDC particle structure [5] consists of two primary persistent particle configurations—the three-plane electron Fundamental Spin and the primarily two-plane up-quark configuration—together with the 0.27607:1 spiral slope, their assigned charges, the composite electron/up-quark down-quark structure, the proposed proton and neutron structures, and the identification of shared FDE evolution as the origin of their strong binding.

The new particle-level development of the present paper begins in Section 3. There, the local combination of the √3 FDE resultant with an orthogonal unit GDE component produces the 30° deflection. Its spinorial representation then introduces the corresponding 15° half-angle. The subsequent division of that response between spatial and electromagnetic components, producing the 7.5° charged-vortex tilt, is not derived from the Fundamental Metric alone; it is introduced explicitly as a new symmetry postulate and its quantitative consequences are then tested.

This separation is maintained throughout the paper. A numerical agreement obtained later is therefore not used retroactively to convert a postulate into a derivation. Each result can be traced to the TDC foundation, the inherited two-particle structural model, a mathematical consequence of those ingredients, or an explicitly stated new assumption.

3. Localized FDE/GDE Vortex Geometry

Section 2 established the TDC quantities used as the foundation of the present particle construction. The new derivation begins by asking what local geometry results when one unit spatial degree of freedom is redirected orthogonally to the √3 Fundamental Direction of Evolution (FDE). The FDE magnitude and the local FDE/GDE orthogonality used in the vortex construction are inherited from the TDC framework summarized in Section 2; their application to a localized particle vortex is developed here.

3.1 Derivation of the Local 30° Deflection

In the Fundamental Metric, the combined evolution of three mutually orthogonal unit spatial components has magnitude √3 [2,3]. For a localized vortex, let one unit spatial component act in the Gravitational Direction of Evolution (GDE), perpendicular to the FDE. Choose local orthogonal coordinates with the FDE along the first axis and the GDE along the second. The two components can then be written explicitly as:

$$F_{FDE} = (\sqrt{3}, 0) \tag{26}$$

$$G = (0, 1) \tag{27}$$

$$F_{FDE} \cdot G = (\sqrt{3})(0) + (0)(1) = 0 \tag{28}$$

Equation (28) states only the orthogonality of the two nonzero components: their dot product is zero. It does not state that either component, or their resultant, is zero.

The magnitude of the resultant local evolution is therefore

$$R = \sqrt{3 + 1} = 2 \tag{29}$$

If θ is the angle through which the resultant is deflected from the FDE toward the orthogonal spatial component, then

$$cos\,\theta = \frac{\sqrt{3}}{2} \tag{30}$$

or equivalently

$$tan\,\theta = \frac{1}{\sqrt{3}} \tag{31}$$

and consequently

$$\theta = 30° \tag{32}$$

The 30° angle is therefore not introduced as an empirical particle parameter. Within the present construction it follows from combining the previously established √3 FDE magnitude with one orthogonal unit spatial component. The particle-level assumption is that localization redirects one of the unit spatial degrees of freedom of the Fundamental Metric rather than introducing an independent arbitrary magnitude.

This angle must not be confused with the 35.26438° angle used in the earlier Fundamental-Spin construction [5]. The 35.26438° quantity is a diagonal-to-plane perspective of the three-dimensional Fundamental Metric, whereas θ = 30° is the local deflection between the √3 FDE component and a single orthogonal unit GDE component.

3.2 Spinorial Representation of the Deflection

A spatial rotation can be represented by a unit quaternion. For a physical rotation θ about the unit axis n̂, the spinorial representation contains the half-angle:

$$q(\theta) = cos(\frac{\theta}{2}) + \hat{n}\, sin(\frac{\theta}{2}) \tag{33}$$

For the localized deflection obtained above,

$$\frac{\theta}{2} = 15° \tag{34}$$

The appearance of 15° here does not constitute a second physical deflection. It is the half-angle required by the spinorial representation of the same 30° physical rotation. This distinction is important because the earlier Particles preprint independently obtained a Fundamental-Spin slope λspin = 0.27607, corresponding to an angle of approximately 15.43° [5]. The two values are close, but they arise from different constructions and are not set equal in this paper.

$$tan^{-1}(0.27607) \approx 15.43° \tag{35}$$

3.3 Secondary Charged-Vortex Symmetry Postulate

The next step cannot be obtained from quaternion kinematics alone. A second physical condition is required to specify the helical advance of the charged two-plane vortex. The Unified Field treatment assigns the same dR_t relationship to spatial and electromagnetic aspects of charged-particle motion [4]. For the present particle model, it is therefore postulated that the spinorial response of the localized charged vortex is shared symmetrically between its spatial and electromagnetic components.

Under this symmetry postulate, the 15° spinorial response is divided equally between the two coupled components:

$$\delta = \frac{1}{2}(\frac{\theta}{2}) = \frac{\theta}{4} \tag{36}$$

With θ = 30°,

$$\delta = 7.5° \tag{37}$$

Equation (37) is consequently not presented as a previously established TDC result. It is the principal new symmetry postulate of the particle-mass derivation. The 30° angle is obtained from the FDE/GDE geometry and the 15° quantity is the spinorial half-angle of that same rotation; only the further equal partition producing δ = 7.5° is postulated. Once δ is specified, the velocity field and cycle-averaged dR_t developed below follow from the stated geometry.

3.4 Helical Up-Quark Velocity Field

The earlier Particles construction describes the up quark as a primarily two-plane vortex that is somewhat contrary, or resistant, to the FDE [5]. In the geometry considered here, the electron spin is transverse to the FDE while the up-quark spin plane is orthogonal to the electron spin. Consequently, one side of the up-quark circulation proceeds with the FDE and the opposite side proceeds against it.

The amplitude available to the FDE-directed projection of the local circulation is set by the 30° deflection:

$$A = c\cos 30° = \frac{\sqrt{3}}{2}c \tag{38}$$

Let ψ denote the phase angle of the up-quark circulation. The oscillating FDE-directed component is then

$$v_{z,circ}(\psi) = A\cos\psi \tag{39}$$

The secondary angle δ is interpreted as the pitch of a continuing helical advance rather than as a rigid rotation of a closed circular orbit. For a helix with transverse speed A, the axial advance is

$$v_{axial} = A\tan\delta \tag{40}$$

The complete instantaneous FDE-directed velocity component is therefore

$$v_z(\psi) = A(\tan\delta + \cos\psi) \tag{41}$$

Substituting A = (√3/2)c and δ = 7.5° gives

$$\frac{v_z}{c}(\psi) = \frac{\sqrt{3}}{2}(\tan 7.5° + \cos\psi) \tag{42}$$

3.5 Kinematic Checks and Counter-FDE Interval

At the maximum forward phase, cos ψ = 1, so

$$\frac{v_{z,max}}{c} = \frac{\sqrt{3}}{2}(1 + \tan 7.5°) \approx 0.980 \tag{43}$$

Thus the projected local component remains below c. At the opposite phase, cos ψ = −1:

$$\frac{v_{z,min}}{c} = \frac{\sqrt{3}}{2}(\tan 7.5° - 1) \approx -0.752 \tag{44}$$

The negative sign establishes a finite portion of every circulation during which the local up-quark motion is counter to the FDE, giving a quantitative realization of the qualitative resistance described in the earlier particle model [5].

The boundaries of this interval occur where $v_z = 0$:

$$\tan 7.5° + \cos\psi = 0 \tag{45}$$

$$\cos\psi = -\tan 7.5° \tag{46}$$

Defining

$$\psi_0 = \cos^{-1}(-\tan 7.5°) \tag{47}$$

gives

$$\psi_0 \approx 97.5651° \tag{48}$$

and the second crossing is

$$360° - \psi_0 \approx 262.4349° \tag{49}$$

The counter-FDE interval therefore spans

$$\Delta\psi = 360° - 2\psi_0 \approx 164.8698° \tag{50}$$

or approximately 45.8% of a complete circulation. No measured quark mass or strong-interaction quantity has entered the construction to this point. The angular field has been specified by the Fundamental Metric, the localized unit-component assumption, and the explicit charged-vortex symmetry postulate of Equation (36).

3.6 Time-Rate Field of the Local Vortex

Using the established TDC velocity/time-rate relationship [1–4],

$$dR_t = (\frac{v}{c})^2 \tag{51}$$

the instantaneous FDE-directed contribution generated by Equation (42) is

$$dR_t(\psi) = \frac{3}{4}(tan\,7.5° + cos\,\psi)^2 \tag{52}$$

For the mass derivation in the following section, only the interval in which the local circulation is counter to the FDE will be treated as the additional resistant contribution. Accordingly, the counter-FDE field is defined piecewise as

$$dR_t(\psi) = \frac{3}{4}(tan\,7.5° + cos\,\psi)^2, \quad \psi_0 \leq \psi \leq 2\pi - \psi_0 \tag{53}$$

and

$$dR_t(\psi) = 0, \quad otherwise \tag{54}$$

The complete-cycle average of this field, rather than the average over only its active interval, is the quantity required for the energy of the continuously repeating vortex. Thus Section 3 contains one localized-vortex assumption (redirection of one unit spatial degree of freedom), the derived 30° deflection, the mathematical 15° spinorial half-angle, and one new charged-vortex symmetry postulate producing 7.5°. The resulting helical velocity field, counter-FDE interval, and piecewise time-rate field then follow from those stated ingredients. The complete-cycle integral and its application to the up-quark mass are developed in Section 4.

4. Cycle-Averaged Time-Rate Differential and the Up-Quark Mass

Section 3 derived the instantaneous FDE-directed velocity field of the proposed two-plane up-quark vortex and identified the interval during which its local circulation proceeds counter to the FDE. This section integrates the associated time-rate differential over one complete circulation and then combines that result with the TDC charged-particle energy relation [4]. No measured up-quark mass is used in the calculation.

4.1 Complete-Cycle Average of the Counter-FDE Contribution

From Equation (52), the instantaneous FDE-directed time-rate differential is

$$dR_t\,(\psi) = (3/4)(tan\,7.5° + cos\,\psi)^2 \tag{55}$$

Define

$$a = tan\,7.5° \approx 0.13165250 \tag{56}$$

and recall that the first zero crossing is

$$\psi_0 = cos^{-1}(-a) \approx 97.5651° \tag{57}$$

The counter-FDE contribution defined in Equation (54) is nonzero from ψ_0 to $2\pi - \psi_0$ and zero otherwise. Because the particle is a continuously repeating vortex, the relevant additional contribution to its stationary cycle energy is therefore the counter-FDE field averaged over the entire 2π circulation, not merely over the interval in which the field is nonzero. Thus

$$\langle dR_{t,counter}\rangle = \frac{1}{2\pi}\int_{\psi_0}^{2\pi-\psi_0}(3/4)(a + cos\,\psi)^2\, d\psi \tag{58}$$

Expanding the square,

$$(a + cos\,\psi)^2 = a^2 + 2a\,cos\,\psi + cos^2\psi \tag{59}$$

and using

$$cos^2\psi = (1/2)(1 + cos\,2\psi) \tag{60}$$

define the antiderivative

$$F(\psi) = (a^2 + 1/2)\psi + 2a\,sin\,\psi + (1/4)sin\,2\psi \tag{61}$$

The complete-cycle average is therefore

$$\langle dR_{t,counter}\rangle = \frac{3}{8\pi}[F(2\pi - \psi_0) - F(\psi_0)] \tag{62}$$

The unnormalized counter-FDE integral is

$$\int_{\psi_0}^{2\pi-\psi_0} dR_{t,counter}(\psi)d\psi \approx 0.82283629 \tag{63}$$

and consequently

$$\langle dR_{t,counter}\rangle \approx 0.13095846 \tag{64}$$

For comparison, averaging only over the active counter-FDE interval would give approximately 0.28595. That is not the quantity used here. Equation (64) is normalized to the complete repeating vortex cycle and is therefore the additional cycle-averaged resistant contribution used in the particle-energy calculation.

4.2 Intrinsic FDE Work Ratio

The cycle average determines the additional dR_t contribution, but a second geometrical factor is required to establish the baseline energy scale of the up-quark vortex relative to the electron state. The Fundamental Metric supplies an FDE magnitude √3, while the localized circulating spatial component has unit magnitude. On corresponding sides of the vortex, the relative FDE sweep magnitudes are therefore

$$S_{with} = \sqrt{3} + 1 \tag{65}$$

$$S_{counter} = \sqrt{3} - 1 \tag{66}$$

Their ratio is

$$S_{with}/S_{counter} = (\sqrt{3} + 1)/(\sqrt{3} - 1) \tag{67}$$

Rationalizing the denominator gives

$$(\sqrt{3} + 1)/(\sqrt{3} - 1) = ((\sqrt{3} + 1)^2)/(3 - 1) = 2 + \sqrt{3} \tag{68}$$

so that

$$S_{with}/S_{counter} = 2 + \sqrt{3} \approx 3.73205081 \tag{69}$$

This factor is not introduced as a fitted mass ratio. It follows directly from the √3 FDE and unit localized spatial component. To determine whether the sweep ratio can represent an energy ratio, consider the work performed over corresponding phase intervals.

$$dW = \vec{F} \cdot d\vec{s} \tag{70}$$

Since

$$d\vec{s} = \vec{v}\,dt \tag{71}$$

the instantaneous work is

$$dW = \vec{F} \cdot \vec{v}\,dt \tag{72}$$

For corresponding with-FDE and counter-FDE portions of one coherent vortex, the present model assumes the same underlying FDE force magnitude and equal phase-time intervals. The magnitudes of the work contributions therefore satisfy

$$dW_{with}/dW_{counter} = v_{with}/v_{counter} = (\sqrt{3} + 1)/(\sqrt{3} - 1) \tag{73}$$

and integration over corresponding portions preserves the constant ratio:

$$W_{with}/W_{counter} = 2 + \sqrt{3} \tag{74}$$

Within the TDC interpretation, velocity represents the compensatory evolution associated with energy expended in maintaining the local state [1–4]. Equation (74) therefore identifies 2 + √3 as the intrinsic FDE work ratio of the idealized vortex geometry. The symmetry assumption in this step is explicit: corresponding portions of the same coherent vortex are taken to experience the same underlying FDE force magnitude.

4.3 Charged-Particle Energy Correction

The Unified Field treatment distinguishes the energy relation used for a charged elementary particle from the ordinary neutral-mass expression. For the charged state, the complete dR_t contribution is retained [4]:

$$E_{charged} = mc^2(1 + dR_t) \tag{75}$$

For a periodically varying internal dR_t, the complete-cycle average replaces the instantaneous value in the stationary particle energy. Let E_{0u} denote the baseline up-quark vortex energy before the additional counter-FDE cycle correction and E_e the reference electron energy. From the FDE work ratio,

$$E_{0u}/E_e = 2 + \sqrt{3} \tag{76}$$

and the charged-particle correction gives

$$E_u = E_{0u}(1 + \langle dR_{t,counter} \rangle) \tag{77}$$

Combining Equations (76) and (77),

$$E_u/E_e = (2 + \sqrt{3})(1 + \langle dR_{t,counter} \rangle) \tag{78}$$

4.4 Up-Quark Mass Prediction

For stationary particle states, the ratio of their rest-energy scales is the ratio of their corresponding masses. Thus Equation (78) gives

$$m_u/m_e = (2 + \sqrt{3})(1 + \langle dR_{t,counter} \rangle) \tag{79}$$

Substituting Equation (64),

$$m_u/m_e = (2 + \sqrt{3})(1 + 0.13095846) \tag{80}$$

or

$$m_u/m_e \approx 4.22079 \tag{81}$$

Using the electron mass

$$m_e = 0.51099895\, MeV/c^2 \tag{82}$$

gives

$$m_u \approx 4.22079(0.51099895\, MeV/c^2) \tag{83}$$

and therefore

$$m_u \approx 2.15682\, MeV/c^2 \tag{84}$$

Equation (84) is the first quantitative quark-mass result of the present construction. The electron mass supplies the dimensional reference scale, but no measured up-quark mass enters the derivation. The dimensionless multiplier is determined by the √3/unit FDE work geometry and by the complete-cycle counter-FDE integral fixed by the 7.5° charged-vortex symmetry postulate.

4.5 Logical Dependence of the Result

It is useful to make the dependence of Equation (84) explicit. The factor 2 + √3 follows from the Fundamental Metric and the localized unit-component construction. The cycle-averaged counter-FDE time-rate differential follows by integration once the velocity field of Equation (42) is specified. That velocity field, in turn, depends on the 30° local FDE/GDE deflection derived from √3 and 1, together with the explicit 7.5° charged-vortex symmetry postulate introduced in Section 3.

The calculation may therefore be summarized as

$$\sqrt{3} \perp 1 \;\rightarrow\; \theta = 30° \;\rightarrow\; \delta = 7.5° \;\rightarrow\; v_z(\psi) \;\rightarrow\; \langle dR_{t,counter} \rangle \;\rightarrow\; m_u \tag{85}$$

The 7.5° step is the only new angular postulate in this chain. Once that angle is specified, the zero crossings, counter-FDE interval, complete-cycle integral, and mass multiplier follow from the stated equations without adjustment to reproduce a target quark mass. The comparison of Equation (84) with independently determined quark-mass estimates is deferred until the results section so that the theoretical calculation remains separate from empirical comparison.

5. Bound Electron–Up-Quark State and the Down-Quark Mass

The earlier Particles model represents the down quark not as a third primary particle structure, but as a bound state formed when an electron and an up-quark spin conjoin [5]. Section 4 obtained the free up-quark mass scale from the localized FDE/GDE vortex geometry. The next question is whether the additional energy of this composite electron–up-quark configuration can likewise be obtained from the same geometry.

5.1 Orthogonal Binding Geometry

The electron is represented by the complete three-plane Fundamental Spin, while the up quark is represented primarily by a two-plane vortex [5]. In the bound configuration, their spin axes are taken to be orthogonal. The local FDE/GDE construction of Section 3 gives the physical deflection angle θ = 30°. The projection of the bound relative evolution onto the local FDE is therefore

$$\cos\theta = \cos 30° = \sqrt{3}/2 \tag{86}$$

Because the TDC time-rate differential is the square of the corresponding velocity ratio [1–4], the bound-state time-rate differential associated with this projection is

$$dR_{t,b} = (v_b/c)^2 = \cos^2 30° \tag{87}$$

$$dR_{t,b} = 3/4 \tag{88}$$

Here b in the subscript denotes the bound-state contribution. Equation (88) is therefore a geometrical result of the 30° localized deflection, not a fitted binding parameter.

5.2 Energy of the Bound Pair

Let m_u denote the up-quark mass obtained in Section 4 and m_e the electron mass. Before the additional binding contribution is included, the combined rest-energy scale of the two constituent vortex states is

$$E_{0,b} = (m_u + m_e)c^2 \tag{89}$$

The electron and up quark are both charged elementary-particle configurations. Applying the charged-particle TDC energy relation [4] to the bound configuration gives

$$E_b = E_{0,b}(1 + dR_{t,b}) \tag{90}$$

Substitution of Equation (88) yields

$$E_b = E_{0,b}(1 + 3/4) \tag{91}$$

$$E_b = (7/4)E_{0,b} \tag{92}$$

Identifying the stationary bound-state energy with the down-quark mass-energy gives

$$m_d c^2 = (7/4)(m_u + m_e)c^2 \tag{93}$$

and therefore

$$m_d = (7/4)(m_u + m_e) \tag{94}$$

5.3 Down-Quark Mass Calculation

Using the up-quark result obtained in Section 4,

$$m_u \approx 2.15682\, MeV/c^2 \tag{95}$$

together with the electron mass

$$m_e = 0.51099895\, MeV/c^2 \tag{96}$$

gives

$$m_u + m_e \approx 2.66781895\, MeV/c^2 \tag{97}$$

and hence

$$m_d \approx (7/4)(2.66781895\, MeV/c^2) \tag{98}$$

$$m_d \approx 4.66868\, MeV/c^2 \tag{99}$$

As in the up-quark calculation, no measured down-quark mass is used to determine the dimensionless factor. The factor 7/4 follows from the charged-particle energy relation and the bound-state value $dR_{t,b} = 3/4$, which itself follows from the 30° projection. Thus the down-quark mass is a consequence of the two-primary-particle construction rather than an independently fitted third particle mass.

5.4 Interpretation of the Binding Contribution

The result should not be interpreted as the addition of an external potential to two otherwise independent point particles. In the TDC particle picture, the bound electron and up-quark vortices form a single coupled continuum configuration. The additional $dR_{t,b}$ represents the time-rate stress required to maintain the orthogonal, conjoined evolution of the two charged vortex states.

The earlier Particles paper qualitatively associated this conjoined electron/up-quark configuration with the down quark and with the strong attraction produced where opposite local spins evolve in the same direction on their common side [5]. The present calculation adds a quantitative energy scale to that previously proposed structure.

5.5 Dependence of the Down-Quark Result

The down-quark result introduces no new angular parameter beyond the geometry established in Section 3. The local FDE/GDE deflection gives $\theta = 30°$, and its projection gives $dR_{t,b} = \cos^2\theta = 3/4$. Applying the TDC charged-particle energy relation [4] to the coupled electron–up-quark state then produces the factor

1 + 3/4 = 7/4. The remaining physical assumption is that this relation applies to the conjoined bound state represented as the down quark. The empirical comparison is presented in Section 9.

6. Proton and Neutron Structure and the Neutron-Proton Mass Difference

The earlier Particles model represents the proton as three mutually oriented up-quark spins conjoined with a central electron spin, and the neutron as the same configuration with a second electron conjoined to one up-quark on the side opposite the central electron [5]. Thus both nucleons remain constructions of the two primary persistent particle structures identified in Section 2: the electron and the up-quark vortex. Sections 4 and 5 have now supplied quantitative up- and down-quark mass scales for those previously proposed structures. This section applies those results to the proton-neutron relationship.

6.1 Charge of the Proton and Neutron Configurations

The charge bookkeeping of the previously proposed configurations follows directly from the electron and up-quark charges introduced in Section 2. For the proton, three up-quark charges are combined with one electron charge:

$$q_p = 3(2e/3) - e \tag{100}$$

$$q_p = +e \tag{101}$$

For the neutron, the second electron is added on the opposite side of one up-quark spin:

$$q_n = 3(2e/3) - 2e \tag{102}$$

$$q_n = 0 \tag{103}$$

Thus the same geometrical construction that distinguishes the proton and neutron also gives their respective unit positive and neutral charges without altering the three-up-quark framework of the original particle model [5].

6.2 Conversion of One Up-Quark State in the Neutron

In the neutron geometry, the second electron conjoins with one of the three up-quark vortices. Structurally, that local pair is the same electron/up-quark configuration identified in Section 5 with the down-quark state. If the conversion were treated as an isolated replacement of one up-quark mass by one down-quark mass, the corresponding increase would be

$$\Delta m_{u\to d} = m_d - m_u \tag{104}$$

Using the masses obtained in Sections 4 and 5,

$$\Delta m_{u\to d} \approx 4.66868 - 2.15682 \tag{105}$$

$$\Delta m_{u\to d} \approx 2.51186\, MeV/c^2 \tag{106}$$

The neutron configuration, however, is not an isolated down-quark state. The second electron binds to an up-quark already participating in the coherent proton vortex. The opposite-side geometry therefore changes the binding stress of that local electron/up-quark pair.

6.3 Opposite-Side Coupling Angle

The primary localized FDE/GDE deflection derived in Section 3 is 30°, while the charged-vortex helical tilt is 7.5°. In the down-quark configuration of Section 5 these determine the bound-state time-rate contribution. In the neutron, the second electron is attached on the side opposite the central electron [5]. In the present geometrical extension, the opposite-side attachment places the primary deflection and the helical tilt in the same sense with respect to the local relief direction. The effective coupling angle is therefore

$$\theta_n = 30° + 7.5° \tag{107}$$

$$\theta_n = 37.5° \tag{108}$$

This 37.5° angle is not introduced independently. It is the geometrical sum of the 30° localized deflection and the 7.5° charged-vortex tilt already used in the preceding derivations. The additional physical assumption is that, for the opposite-side neutron attachment, these two rotations are coplanar and act in the same sense.

6.4 Relief of the Down-Vortex Binding Stress

Section 5 found that the bound electron/up-quark state carries an additional time-rate contribution of 3/4. The energy associated with that binding contribution, before opposite-side relief is applied, is therefore

$$E_{bind} = (3/4)(m_u + m_e)c^2 \tag{109}$$

Using the values already derived or adopted in the preceding sections,

$$E_{bind} \approx (3/4)(2.15682 + 0.51099895)\,MeV \tag{110}$$

$$E_{bind} \approx 2.00086\,MeV \tag{111}$$

The component of this binding stress relieved by the opposite-side neutron geometry is taken to be the projection of the binding contribution along the 37.5° relief direction. Thus

$$E_{relief} = E_{bind}\,sin\,\theta_n \tag{112}$$

and therefore

$$E_{relief} = (3/4)(m_u + m_e)c^2\,sin\,37.5° \tag{113}$$

Since

$$sin\,37.5° \approx 0.608761 \tag{114}$$

the relieved energy is

$$E_{relief} \approx 1.21805\,MeV \tag{115}$$

The sine projection in Equation (112) is a new particle-level geometrical assumption: the binding-stress component aligned with the opposite-side relief direction is the component removed from the isolated down-vortex energy. It is stated explicitly here rather than treated as a previously established TDC relation.

6.5 Predicted Neutron-Proton Mass Difference

The neutron-proton mass difference is then the isolated up-to-down mass increase minus the binding stress relieved by the opposite-side neutron geometry:

$$(m_n - m_p)c^2 = (m_d - m_u)c^2 - E_{relief} \tag{116}$$

Substituting Equation (113) gives the complete model expression

$$(m_n - m_p)c^2 = (m_d - m_u)c^2 - (3/4)(m_u + m_e)c^2\,sin(30° + 7.5°) \tag{117}$$

Using the internally obtained quark masses,

$$(m_n - m_p)c^2 \approx 2.51186\,MeV - 1.21805\,MeV \tag{118}$$

$$(m_n - m_p)c^2 \approx 1.29381\,MeV \tag{119}$$

Equation (119) is therefore a prediction of the combined particle geometry. No measured neutron-proton mass difference is used to determine the 37.5° angle, the sine projection, or the quark masses entering the calculation. The empirical comparison will be made later with the other quantitative results.

6.6 Logical Dependence of the Nucleon Mass Splitting

The neutron–proton mass splitting uses the up- and down-quark masses derived in Sections 4 and 5 and one additional particle-level assumption: in the opposite-side neutron configuration, the component of the down-vortex binding stress projected by sin 37.5° is relieved. The 37.5° angle is not independently fitted; it is the sum of the 30° local deflection and the 7.5° charged-vortex tilt. The empirical comparison is presented in Section 9.

7. Three Two-Plane Orientations, Quark Color, and the SU(3) Transformation Structure

The preceding sections treated the up quark as a localized vortex manifested primarily in two spatial planes, consistent with the earlier Particles construction [5]. A two-plane state embedded in three spatial dimensions has a discrete geometrical property that has not yet been used: there are exactly three distinct choices of the two-dimensional plane. This section examines the hypothesis that these three equivalent internal orientation classes provide a geometrical basis for the three quark color states. The identification with color is a new physical postulate. The three-state count follows directly from the geometry; the SU(3) transformation structure follows only after the additional quantum-state assumption that coherent complex superpositions of those three states are permitted.

7.1 The Three Two-Plane States

Let the three mutually orthogonal spatial axes of the Fundamental Metric be X, Y, and Z. A vortex occupying two of these axes can lie in only the following planes:

$$XY,\ YZ,\ ZX \tag{120}$$

The number of distinct two-plane selections from three spatial dimensions is

$$C(3,2)\ =\ 3 \tag{121}$$

The three states are geometrically equivalent: none is intrinsically preferred by the Fundamental Metric. They differ only in which spatial axis is excluded from the two-plane vortex. We denote the corresponding up-quark orientation states by

$$u_{XY},\ u_{YZ},\ u_{ZX} \tag{122}$$

For compactness, these may be represented as the components of a three-state vector

$$u\ =\ (u_{XY}, u_{YZ}, u_{ZX}) \tag{123}$$

The proposed physical identification is that the three otherwise equivalent two-plane orientations correspond to the three color labels of a quark. This does not mean that ordinary spatial orientation itself is observable as color. Rather, color is interpreted here as the internal orientation class of the two-plane vortex relative to the three-dimensional Fundamental Metric.

7.2 Color as an Internal Orientation Label

Because the names assigned to the three states are conventional, they may be mapped one-to-one onto the usual three color labels. For example,

$$u_{XY}\ \leftrightarrow\ u_r \tag{124}$$

$$u_{YZ}\ \leftrightarrow\ u_g \tag{125}$$

$$u_{ZX}\ \leftrightarrow\ u_b \tag{126}$$

The assignments r, g, and b in Equations (124)–(126) are labels only; permuting them changes no physics in the proposed geometry. What matters is that the localized two-plane state has three equivalent realizations.

A general coherent state of the two-plane vortex can therefore be written as a complex superposition

$$\psi = a_r u_r + a_g u_g + a_b u_b \tag{127}$$

with normalization

$$abs(a_r)^2 + abs(a_g)^2 + abs(a_b)^2 = 1 \tag{128}$$

The use of complex amplitudes in Equation (127) is an additional quantum-state assumption. The earlier TDC particle papers establish the three-dimensional and two-plane geometry [5], but do not independently derive complex color amplitudes. The purpose here is to determine what transformation structure follows if coherent complex superpositions of the three geometrical states are permitted.

7.3 Transformations Among the Three States

A transformation that mixes the three orientation states while preserving the normalization of Equation (128) is represented by a 3 × 3 unitary matrix U:

$$\psi' = U\psi \tag{129}$$

$$U^{\dagger}U = I \tag{130}$$

The most general 3 × 3 complex matrix contains nine complex entries. Requiring unitarity reduces the independent continuous parameters to nine real degrees of freedom. One of these corresponds to a common overall phase applied equally to all three components. Such a common phase does not distinguish one internal orientation from another. Removing that common phase imposes

$$det\, U = 1 \tag{131}$$

The remaining transformations therefore belong to the special unitary group acting on three complex components:

$$U \in SU(3) \tag{132}$$

The number of independent generators is then

$$3^2 - 1 = 8 \tag{133}$$

Thus, once the three geometrical orientation states are promoted to normalized coherent complex states and a common overall phase is removed, the resulting continuous internal transformation space has eight independent generators.

7.4 Generator Representation

An infinitesimal transformation of the three-state vector may be written

$$U \approx I + i(\varepsilon_1 T_1 + \varepsilon_2 T_2 + \cdots + \varepsilon_8 T_8) \tag{134}$$

where the eight T_a generators form a basis for traceless Hermitian 3 × 3 transformations and the ε parameters specify infinitesimal rotations in the internal three-state space. Equivalently, one may choose the conventional normalization

$$T_a = (1/2)\lambda_a,\ \ a = 1, \ldots, 8 \tag{135}$$

where the λ matrices are a convenient basis for the eight generators. The present derivation does not require that these matrices be interpreted as literal rotations of a particle in ordinary three-dimensional space. They operate on the three-component internal orientation state defined by Equations (122)–(127).

7.5 Color Exchange as Vortex Reorientation

Within the proposed interpretation, a color-changing interaction corresponds to a transition between two-plane orientation states. For example,

$$u_r \rightarrow u_g \tag{136}$$

is interpreted geometrically as a coherent reorientation of the localized two-plane vortex from one allowed orientation class to another. A general interaction may mix all three states rather than perform a simple discrete swap.

The eight independent generators found above then describe the independent infinitesimal ways in which the three complex orientation amplitudes can be mixed while preserving their total normalization and removing the common phase. In this sense, the familiar eightfold transformation structure is not inserted as an independent count after the three-state geometry is specified; it follows from the dimension of the normalized complex three-state space.

7.6 Relation to the Three-Up-Quark Proton Geometry

The earlier proton model contains three up-quark vortices arranged around the central electron [5]. The present extension suggests a more specific interpretation of that threefold structure: a color-neutral nucleon configuration can contain one representative of each of the three equivalent two-plane orientation classes.

$$XY + YZ + ZX \tag{137}$$

Equation (137) is schematic rather than an arithmetic sum of spatial planes. It denotes completion of the three orientation classes. Because each spatial axis appears in exactly two of the three states, the complete set treats X, Y, and Z symmetrically:

$$X{:}\,2,\;\; Y{:}\,2,\;\; Z{:}\,2 \tag{138}$$

The combined configuration therefore restores the dimensional symmetry that an individual two-plane quark state breaks by omitting one axis. This provides a geometrical interpretation of why a three-quark bound configuration can be internally complete even though each individual up-quark vortex is only a two-plane state.

7.7 Status of the Color Construction

Exactly three two-plane orientations follow directly from three spatial dimensions. If those states are represented by normalized coherent complex amplitudes and their transformations preserve the norm while excluding a common phase, the resulting transformation space is SU(3) with eight generators.

The physical identification of these orientation classes with quark color, and of color change with coherent vortex reorientation, remain hypotheses of the present model. The SU(3) result is therefore a mathematical consequence of the stated three-state complex representation, not a derivation of the full local gauge dynamics of QCD.

8. The Strong Force as Shared FDE Evolution

The earlier Particles model proposed that the strong attraction between conjoined particle vortices arises where oppositely directed spins evolve in the same direction on their common side [5]. In that description, the strong force is not a separate interaction superimposed upon the particle geometry; it is the shared forward evolution of the coupled vortices in the Fundamental Direction of Evolution (FDE). The preceding sections now permit this proposal to be expressed quantitatively in terms of the ordinary TDC time-rate differential, dR_t, and its spatial gradient [1–4]. The purpose of this section is therefore to formulate the proposed TDC internal interaction quantitatively, not to assume the QCD force law or introduce an independently fitted strong-coupling constant.

8.1 Force from a Time-Rate Gradient

The established TDC relation between compensatory velocity and the time-rate differential is [1–4]

$$dR_t = (v/c)^2 \tag{139}$$

When dR_t varies with position, the corresponding TDC acceleration is

$$\vec{a} = c^2 \nabla dR_t \tag{140}$$

and the force on a mass m is therefore

$$\vec{F} = mc^2 \nabla dR_t \tag{141}$$

For the internal particle problem, the relevant coordinate is the relative separation r between the centers of the two coupled vortex structures. Along that coordinate, Equation (141) becomes

$$F_r = mc^2\, d(dR_t)/dr \tag{142}$$

The specialized Force-in-Time expression used for the electron in the Unified Field paper is not substituted here. The present calculation concerns the spatial variation of the internal dR_t field with relative particle position, so the ordinary gradient relation of Equations (140)–(142) is the appropriate TDC quantity [4].

8.2 Shared and Opposed Local Evolution

Let the tangential local velocities of two adjacent vortex surfaces be v_1 and v_2. What matters for the interaction is their relative motion on the common side. For like-directed spins, the adjacent surface velocities are opposed; for opposite spins, the adjacent surface velocities are aligned [5]. Define the local relative velocity by

$$v_{rel} = v_1 - v_2 \tag{143}$$

For aligned local evolution on the common side, the magnitudes approach equality and the relative shear approaches zero:

$$|v_1| \approx |v_2| \quad \rightarrow \quad |v_{rel}| \rightarrow 0 \tag{144}$$

For opposed local evolution, the relative shear instead approaches the sum of the two local speed magnitudes:

$$|v_{rel}| \rightarrow |v_1| + |v_2| \tag{145}$$

Thus the opposite-spin configuration minimizes local shear at the common interface, while the like-spin configuration maximizes it. Within the present model, the attractive strong-force configuration is therefore the configuration that permits the two vortices to share the greatest fraction of their local FDE evolution.

8.3 Shared-FDE Time-Rate Differential

To express the shared evolution in the same variable used throughout TDC, define v_s as the local velocity component that the two vortices share in the FDE. Its associated time-rate differential is

$$dR_{t,s} = (v_s/c)^2 \tag{146}$$

The subscript s denotes the shared-FDE contribution. If the degree of geometrical overlap depends on separation r, then

$$dR_{t,s} = dR_{t,s}(r) \tag{147}$$

and the force generated by the changing shared component is

$$F_s = mc^2\, d(dR_{t,s})/dr \tag{148}$$

Equation (148) is the central strong-force relation of the present construction. It states that the force is determined by how rapidly the shared FDE time-rate contribution changes as the two vortex structures move relative to one another.

8.4 Attraction and Repulsion

Let increasing r denote increasing separation. In an opposite-spin configuration, greater overlap at smaller r increases the amount of shared FDE evolution. Thus $dR_{t,s}$ decreases as r increases:

$$d(dR_{t,s})/dr < 0 \tag{149}$$

and Equation (148) gives

$$F_s < 0 \tag{150}$$

where the negative sign denotes a force toward decreasing separation: attraction.

For a like-spin configuration, the adjacent vortex motions oppose one another. Increasing overlap then increases the local time-rate stress rather than the shared evolution. If $dR_{t,o}$ denotes this opposed or shear contribution,

$$d(dR_{t,o})/dr < 0 \tag{151}$$

but the force acts to reduce the overlap that generates the opposed state. Taking the outward direction as positive, the corresponding repulsive magnitude is

$$|F_{rep}| = mc^2\, |d(dR_{t,o})/dr| \tag{152}$$

The attraction and repulsion therefore arise from the same underlying quantity—spatial variation of the local time-rate field—but from different relative spin geometries.

8.5 Binding Energy of the Shared Field

The force relation can be integrated to define the energy change associated with formation of the shared-FDE configuration. From

$$dE = -F_s dr \tag{153}$$

and Equation (148),

$$dE = -mc^2\, d(dR_{t,s}) \tag{154}$$

Integrating between a separated configuration r_∞ and a bound configuration r_β gives

$$\Delta E = -mc^2[dR_{t,s}(r_b) - dR_{t,s}(r_\infty)] \tag{155}$$

If the shared contribution vanishes for effectively separated vortices,

$$dR_{t,s}(r_\infty) \to 0 \tag{156}$$

then the magnitude of the binding-energy scale is

$$|E_{bind}| = mc^2\, dR_{t,s}(r_b) \tag{157}$$

This result is consistent with the interpretation used in Section 5: the energy of the conjoined state is determined by the additional time-rate contribution created by its coupled geometry. Section 5 obtained $dR_{t,b} = 3/4$ for the electron–up-quark bound state from the 30° projection. Equation (157) now identifies the corresponding dR_t contribution as the integrated energy scale associated with formation of the shared internal field.

8.6 Application to the Electron–Up-Quark Bond

For the down-quark configuration, Section 5 derived the bound-state time-rate contribution

$$dR_{t,b} = 3/4 \tag{158}$$

and the associated additional bound-state energy was

$$E_{bind} = (3/4)(m_u + m_e)c^2 \tag{159}$$

Using the values already obtained in the paper,

$$E_{bind} \approx 2.00086\,MeV \tag{160}$$

Equation (160) supplies an internal energy scale for the electron–up-quark bond without introducing an independently fitted strong-force constant. The local force itself depends on the spatial derivative of the same field and therefore additionally requires the physical length scale over which $dR_{t,s}$ changes.

$$F_s \approx mc^2\, \Delta dR_{t,s}/\Delta r \tag{161}$$

No particle radius or interaction length is introduced solely to obtain a desired numerical force. Accordingly, Equation (161) is retained as the force law until an independently derived or measured vortex length scale can be assigned. The energy scale in Equation (160), by contrast, follows directly from the already derived dimensionless bound-state geometry.

8.7 Relation to the 7.5° Helical Tilt

The charged-vortex tilt introduced in Section 3 also explains why the shared evolution need not be exactly antiparallel or exactly coincident throughout a complete circulation. The up-quark vortex advances helically as the FDE itself evolves forward. Consequently, the locally counter-FDE portion of the up-quark spin is slightly tilted rather than remaining exactly opposite to the FDE.

This produces a periodically varying local relationship between the electron and up-quark velocity fields. The shared-FDE quantity should therefore be understood as a cycle-dependent field,

$$dR_{t,s} = dR_{t,s}(r, \psi) \tag{162}$$

whose stationary interaction is represented by its cycle average:

$$\langle dR_{t,s}\rangle(r) = \frac{1}{2\pi}\int_0^{2\pi} dR_{t,s}(r,\psi)d\psi \tag{163}$$

The strong-force gradient for the stationary bound state is correspondingly

$$\langle F_s\rangle = mc^2\, d\langle dR_{t,s}\rangle/dr \tag{164}$$

8.8 Status of the Strong-Force Construction

The relations $dR_t = (v/c)^2$ and $F = mc^2\nabla dR_t$ are inherited from the earlier TDC and Unified Field work [1–4], while the earlier Particles paper [5] supplied the qualitative proposal that opposite local spins attract by sharing FDE evolution. The present extension makes that proposal quantitative by defining the shared-FDE field $dR_{t,s}$ and identifying the strong interaction with its spatial gradient. This identification is a new model-level step.

The dimensionless geometry determines the bound-state dR_t and an internal energy scale, but a numerical force in newtons also requires an independently justified particle length scale. No such scale is fitted here. The result is therefore a proposed TDC strong-interaction field law and binding-energy scale; quantitative equivalence to the full strong interaction described by QCD remains a separate test.

9. Comparison with Established Particle Data

The preceding sections intentionally developed the particle geometry before comparing its numerical results with measured or phenomenologically determined particle quantities. This section makes that comparison. The Particle Data Group (PDG) values used in this manuscript give the light-quark masses in the MS-bar renormalization scheme at μ = 2 GeV as m_u = 2.16 ± 0.07 MeV/c^2 and m_d = 4.70 ± 0.07 MeV/c^2 [6]. The same cited compilation supplies the electron, proton, and neutron masses used below [6]. The light-quark comparison is therefore a comparison to scale- and scheme-dependent QCD mass parameters, not to directly measured free-quark rest masses.

9.1 Up-Quark Mass

Section 4 obtained the up-quark mass from the √3/unit FDE work ratio and the complete-cycle counter-FDE time-rate integral:

$$m_{u,TDC} \approx 2.15682\, MeV/c^2 \tag{165}$$

The PDG value is [6]

$$m_{u,PDG} = 2.16 \pm 0.07\, MeV/c^2 \tag{166}$$

The difference between the central values is

$$\Delta m_u = m_{u,TDC} - m_{u,PDG} \approx -0.00318\, MeV/c^2 \tag{167}$$

or, relative to the PDG central value,

$$100\, \Delta m_u / m_{u,PDG} \approx -0.147\% \tag{168}$$

The TDC value is therefore essentially coincident with the PDG central value on the scale of the quoted light-quark uncertainty and lies well within the stated PDG interval [6].

9.2 Down-Quark Mass

Section 5 obtained

$$m_{d,TDC} \approx 4.66868\, MeV/c^2 \tag{169}$$

while the PDG value is [6]

$$m_{d,PDG} = 4.70 \pm 0.07\, MeV/c^2 \tag{170}$$

The central-value difference is

$$\Delta m_d = m_{d,TDC} - m_{d,PDG} \approx -0.03132\, MeV/c^2 \tag{171}$$

corresponding to

$$100\, \Delta m_d / m_{d,PDG} \approx -0.666\% \tag{172}$$

The predicted down-quark value also lies within the PDG quoted interval [6]. Unlike the up-quark result, the down-quark calculation is not an independent use of the electron scale alone: it incorporates the up-quark result from Section 4 and the bound-state factor derived in Section 5.

9.3 Up-to-Down Quark Mass Ratio

A useful comparison that removes the electron dimensional reference is the ratio of the two calculated light-quark masses. The present model gives

$$m_{u,TDC}/m_{d,TDC} \approx 2.15682/4.66868 \approx 0.4620 \tag{173}$$

The PDG summary gives [6]

$$m_u/m_d = 0.462 \pm 0.020 \tag{174}$$

The ratio produced by the TDC construction therefore agrees with the PDG central ratio to the displayed precision. This comparison is particularly relevant because the overall electron mass scale cancels from the ratio; what remains is the relative geometry of the two TDC particle states.

9.4 Neutron-Proton Mass Difference

Section 6 predicted the neutron-proton mass difference from the calculated up- and down-quark masses and the opposite-side neutron coupling geometry:

$$TDC\colon\ (m_n - m_p)c^2 \approx 1.29381\, MeV \tag{175}$$

The current PDG physical-constants compilation gives m_n = 939.56542194 MeV/c² and m_p = 938.27208943 MeV/c² [6]. Their difference is

$$PDG\colon\ (m_n - m_p)c^2 \approx 1.29333251\, MeV \tag{176}$$

The difference between the TDC prediction and this value is therefore

$$\Delta E_{(n-p)} \approx 1.29381 - 1.29333251 \approx 0.00047749\, MeV \tag{177}$$

or approximately

$$100\, \Delta E_{(n-p)}/1.29333251 \approx 0.0369\% \tag{178}$$

The neutron-proton result is much more restrictive numerically than the light-quark comparisons because the nucleon masses themselves are known with very high precision. The TDC result differs from the empirical mass splitting by about 0.00048 MeV, or 0.037%. It should therefore be described as a close numerical prediction of the model, not as exact equality.

9.5 Color-State Counting and SU(3)

Section 7 produced a non-numerical structural comparison. A two-plane vortex in three spatial dimensions has exactly three equivalent orientation classes:

$$XY,\ YZ,\ ZX \tag{179}$$

The Standard Model likewise assigns three color states to each quark [6]. When the three TDC orientation classes are represented as normalized coherent complex states, norm-preserving transformations with the common phase removed form SU(3), which has eight generators:

$$3^2 - 1 = 8 \tag{180}$$

The numerical counts—three states and eight generators—therefore coincide with the color structure of quantum chromodynamics. This correspondence is exact at the level of state counting and group dimension, but it does not by itself establish dynamical equivalence to QCD. As emphasized in Section 7, the identification of the geometrical orientation classes with physical color is a hypothesis of the present model.

9.6 Strong-Force Energy Scale

Section 8 related the electron–up-quark bond to the shared-FDE time-rate field and obtained the internal binding-energy scale

$$E_{bind} \approx 2.00086\, MeV \tag{181}$$

A direct comparison of this quantity with a single experimentally quoted 'strong-force energy' would not be well defined. In QCD, hadronic energies include quark masses, gluonic field energy, confinement, and scale-dependent interaction effects rather than one universal two-particle bond energy [6]. The present value should therefore remain a model-internal energy scale until a complete hadron calculation specifies how the individual shared-FDE contributions combine.

Likewise, Section 8 deliberately did not convert the gradient relation into a force in newtons because that requires an independently justified vortex length scale. This avoids using an assumed particle radius to tune the force magnitude after the fact.

9.7 Summary of Quantitative Comparisons

The principal numerical comparisons can be summarized as follows:

$$m_u\text{:}\;\; 2.15682\, MeV/c^2 \;\; vs. \;\; 2.16 \pm 0.07\, MeV/c^2 \tag{182}$$

$$m_d\text{:}\;\; 4.66868\, MeV/c^2 \;\; vs. \;\; 4.70 \pm 0.07\, MeV/c^2 \tag{183}$$

$$m_u/m_d\text{:}\;\; 0.4620 \;\; vs. \;\; 0.462 \pm 0.020 \tag{184}$$

$$(m_n - m_p)c^2\text{:}\;\; 1.29381\, MeV \;\; vs. \;\; 1.29333251\, MeV \tag{185}$$

The first three comparisons fall within the quoted PDG light-quark ranges, while the neutron-proton splitting differs from the measured value by approximately 0.037%. These agreements are obtained after fixing the particle geometry developed in Sections 3–6 rather than by inserting the corresponding measured quark masses or nucleon mass difference into those derivations.

At the same time, the comparisons must be interpreted with appropriate caution. The PDG light-quark masses are renormalized MS-bar parameters at μ = 2 GeV [6], whereas the TDC quantities are presented as geometrical stationary-particle mass scales. Demonstrating that these are physically identical quantities would require a more complete correspondence between the TDC vortex model and quantum field-theoretic mass renormalization. The numerical agreement is therefore a result to be explained and tested, not by itself a proof of equivalence.

9.8 Results Carried Forward

The comparisons in this section identify the empirical and structural correspondences reached by the present construction: the up-quark and down-quark mass scales, their ratio, the neutron-proton mass splitting, and the three-state/eight-generator color structure. The discussion section will distinguish the numerical predictions from the structural correspondence, identify where additional physical assumptions enter, and consider what further observations would distinguish the TDC particle construction from a numerical parametrization.

10. Discussion

The calculations developed in this paper extend the earlier TDC particle model from a principally geometrical description to a quantitative construction. The principal results are the up-quark and down-quark mass scales, the neutron-proton mass difference, a proposed geometrical origin of the three quark color states and their SU(3) transformation structure, and a quantitative formulation of the previously proposed strong force as shared FDE evolution. The significance of these results depends not only on their numerical agreement with established particle data, but also on which parts of the construction are derived from prior TDC relations and which depend on new particle-level assumptions.

10.1 Economy of the Geometrical Construction

A notable feature of the construction is that several apparently distinct particle quantities originate from the same small set of geometrical elements. The previously derived Fundamental Metric supplies the √3 FDE magnitude and the orthogonality of the FDE and GDE [1–4]. Combining √3 with one orthogonal unit spatial component gives the local 30° deflection:

$$\sqrt{3} \perp 1 \quad \rightarrow \quad \theta = 30^\circ \tag{186}$$

The spinorial representation of that rotation contains the 15° half-angle. The single new charged-vortex symmetry postulate introduced in Section 3 divides that spinorial response equally between the spatial and electromagnetic components, producing the 7.5° helical tilt:

$$\theta = 30^\circ \quad \rightarrow \quad \theta/2 = 15^\circ \quad \rightarrow \quad \delta = 7.5^\circ \tag{187}$$

Once these quantities are specified, the counter-FDE velocity field and its complete-cycle dR_t integral follow without further angular adjustment. The same 30° geometry then supplies the 3/4 bound-state time-rate contribution used for the down-quark state, while the 30° + 7.5° geometry enters the opposite-side neutron construction.

10.2 Predictive Content and Parameter Dependence

The numerical agreements reported in Section 9 are most meaningful if the measured quantities being compared were not used to choose the parameters that generate them. The up-quark calculation uses the measured electron mass only as the dimensional reference scale. Its dimensionless multiplier is

$$m_u/m_e = (2 + \sqrt{3})(1 + \langle dR_{t,counter} \rangle) \tag{188}$$

where 2 + √3 follows from the FDE/unit sweep geometry and the cycle average follows from the velocity field fixed by the 7.5° postulate. The measured up-quark mass is not inserted into this expression.

The down-quark mass is less independent because it uses the calculated up-quark mass together with the electron mass:

$$m_d = (7/4)(m_u + m_e) \tag{189}$$

Nevertheless, the 7/4 multiplier is fixed by the 30° bound-state projection rather than by the measured down-quark mass. Consequently, the ratio m_u/m_d provides a useful dimensionless check of the combined geometry.

The neutron-proton splitting is a further dependent prediction. It uses the calculated light-quark masses and adds one new geometrical assumption: that the opposite-side neutron attachment relieves the component of the down-vortex binding stress projected by sin 37.5°. Its close numerical agreement is therefore evidence relevant to that assumption, but it should not be treated as an independent prediction with no inherited inputs.

10.3 The 7.5° Postulate as a Critical Test Point

The 7.5° helical tilt deserves particular attention because it is the principal new angular postulate from which much of the quantitative structure follows. It is not claimed to have been derived in the earlier TDC papers. The postulate states that the 15° spinorial response of the 30° localized rotation is shared symmetrically between the spatial and electromagnetic components of the charged vortex.

This makes the assumption unusually exposed to testing. If a more complete derivation of the charged-particle geometry produces a different partition, the counter-FDE integral and therefore the predicted up-quark mass will change. Conversely, an independent derivation of δ = 7.5° from the electromagnetic structure of the Unified Field would substantially strengthen the model because the principal presently postulated angle would become a derived quantity.

10.4 Interpretation of the Quark-Mass Agreement

The numerical agreement with the PDG light-quark values [6] is striking within the stated construction, but its interpretation requires care. In QCD, quarks are confined and their masses are not directly measured as free-particle rest masses. The quoted u- and d-quark masses are renormalized parameters whose values depend on the renormalization scheme and scale; the PDG values used in Section 9 are MS-bar masses at $\mu = 2$ GeV [6].

The TDC quantities, by contrast, are derived as stationary geometrical energy scales of localized vortex configurations. The present paper has not derived the renormalization-group running of those quantities or demonstrated that the TDC mass parameter must numerically equal the QCD MS-bar parameter at 2 GeV. Accordingly, the agreement should be stated precisely: the geometrically calculated TDC mass scales numerically coincide, within the quoted uncertainties, with the accepted MS-bar light-quark values at the conventional 2 GeV comparison scale. Establishing a deeper equivalence remains a theoretical task.

10.5 Color: Exact Counting, Hypothesized Physical Identification

The color construction has a different logical character from the mass calculations. The existence of exactly three two-plane orientations in three spatial dimensions is purely geometrical:

$$C(3,2) = 3 \tag{190}$$

If these three states are represented by normalized complex amplitudes and transformations are required to preserve the norm while excluding a common phase, the resulting transformation group is SU(3), with

$$3^2 - 1 = 8 \tag{191}$$

Thus the three-state/eight-generator counting is mathematically exact once the complex-state assumption is made. What remains hypothetical is the physical identification of these internal orientation classes with quark color. Standard QCD treats color as an internal gauge degree of freedom rather than an ordinary spatial orientation [6]. The present model does not identify color with a laboratory-frame direction; instead, it proposes that the internal two-plane orientation of the vortex relative to the Fundamental Metric is the underlying geometrical degree of freedom represented abstractly by color.

A complete equivalence would require considerably more than matching the group dimension. In particular, the model would need to reproduce local SU(3) gauge invariance, the associated gauge connection, gluon self-interactions, and established QCD phenomenology. The present result should therefore be viewed as a proposed geometrical origin for the color state space, not as a completed replacement for QCD.

10.6 Strong Force and the Need for a Length Scale

The strong-force construction similarly separates a derived field relation from an unresolved physical scale. TDC supplies the general gradient relation [1–4]

$$\vec{F} = mc^2 \nabla dR_t \tag{192}$$

and the earlier Particles model supplies the qualitative identification of strong attraction with shared FDE evolution on the common side of opposite spins [5]. The present paper combines these by defining the shared internal field $dR_{t,s}$:

$$F_s = mc^2 \nabla dR_{t,s} \tag{193}$$

The dimensionless bound-state geometry supplies an energy scale because an energy depends on mc^2 multiplied by dR_t. A numerical force, however, requires a spatial derivative and therefore a length scale:

$$|F_s| \approx mc^2 \, |\Delta dR_{t,s}| / \Delta r \tag{194}$$

This distinction is important. Assigning an arbitrary femtometer-scale radius and then reporting the resulting force would add an unconstrained dimensional input. The present paper therefore stops at the gradient law and the independently derived binding-energy scale. A future TDC derivation of the particle-vortex radius would convert Equation (194) into a numerical force prediction without fitting the interaction length.

10.7 Relation to Conventional Proton and Neutron Structure

The proton and neutron configurations used here differ from the conventional valence-quark bookkeeping. In the Standard Model quark model, a proton has valence content uud and a neutron udd [6]. The earlier TDC Particles construction instead begins with three up-quark vortices and a central electron for the proton, with a second electron converting one local electron/up-quark pair into the down-quark configuration in the neutron [5].

This difference is substantive rather than merely notational. The TDC construction must ultimately reproduce the full experimentally established quantum numbers and interaction phenomenology normally described by the uud and udd states. The charge accounting works at the level developed here, and the neutron-proton mass splitting is closely reproduced, but these successes do not by themselves establish equivalence of the internal states.

Future work should therefore test the proposed structures against magnetic moments, spin decomposition, weak beta decay, deep-inelastic scattering, form factors, and hadron spectroscopy. These observables provide independent constraints that cannot be satisfied merely by reproducing the total charge and mass difference.

10.8 Falsifiable Consequences and Further Development

The present construction suggests several routes by which it can be strengthened or falsified. First, the 7.5° charged-vortex tilt should be derived independently from the TDC electromagnetic geometry rather than retained as a symmetry postulate. Second, the particle-vortex length scale should be derived from the same continuum geometry, allowing an absolute strong-force gradient to be predicted. Third, the proposed three-state color geometry should be developed into a local transformation theory and tested for whether it reproduces the interactions represented by the eight gluon fields.

Fourth, the proton and neutron vortex configurations should be used to calculate observables not employed anywhere in the present construction. A successful calculation of quantities such as the proton and neutron magnetic moments or characteristic form-factor scales would provide a substantially more independent test than further algebraic rearrangement of the mass relations.

Finally, if the TDC quark mass scales are intended to correspond fundamentally to QCD current-quark masses, the model should predict how its geometrical mass parameter changes with interaction scale. Conversely, if the TDC quantities represent a different invariant mass concept, the theory must explain why they numerically coincide with the MS-bar parameters at $\mu = 2$ GeV.

10.9 Overall Interpretation

The results of this paper show that the earlier qualitative TDC particle construction can be extended into a compact quantitative framework built from two primary persistent particle structures: the electron and the up-quark vortex. Within the stated assumptions, a single localized FDE/GDE geometry generates the principal angular relationships; the resulting vortex field produces light-quark mass scales close to accepted values; the electron–up-quark bound-state geometry produces the down-quark mass scale and contributes to the neutron-proton splitting; the three possible two-plane orientations reproduce the dimensionality of quark color and its eight-generator SU(3) transformation space; and the shared-FDE interpretation of the strong force can be expressed through the same dR_t gradient used elsewhere in TDC.

The strongest conclusion supported at this stage is therefore not that all of QCD has been derived from TDC, but that several otherwise separate particle properties can be represented within one common geometrical construction and that the resulting quantitative agreements warrant further tests. The model becomes substantially more compelling to the extent that its remaining explicit assumptions—particularly the 7.5° partition, the opposite-side neutron projection, the complex color-state interpretation, and the vortex length scale—can themselves be independently derived or confronted with new observables.

11. Conclusions

This paper has extended the previously published Time Dilation Cosmology (TDC) and Unified Field framework [1–4], together with the earlier qualitative Particles construction [5], into a quantitative particle model built from two primary persistent particle structures: the electron and the up-quark vortex. Within this construction, the down quark is a conjoined electron–up-quark state, while the proton and neutron are larger bound configurations of the same two primary structures.

The quantitative development begins with the previously established √3 Fundamental Direction of Evolution (FDE) and one orthogonal unit spatial component, which produce a 30° local deflection. Its spinorial representation contains a 15° half-angle. The principal new angular assumption of the present paper is the equal partition of that spinorial response between the coupled spatial and electromagnetic components of the charged vortex, producing the 7.5° helical tilt. From this geometry, the complete-cycle counter-FDE time-rate contribution and the intrinsic FDE work ratio yield an up-quark mass of 2.15682 MeV/c². Applying the same geometry to the conjoined electron–up-quark state gives a down-quark mass of 4.66868 MeV/c² and an up/down mass ratio of approximately 0.4620. These values are numerically close to the PDG light-quark parameters used for comparison, while the distinction between the TDC geometrical mass scales and the scale- and scheme-dependent QCD mass definitions remains to be established.

Applying the derived particle geometry to the previously proposed proton and neutron configurations gives a neutron–proton mass difference of 1.29381 MeV/c², approximately 0.037% above the empirical value used in this paper. Because this result depends on the calculated quark masses and on the explicitly stated opposite-side neutron projection assumption, it is a dependent quantitative prediction of the combined geometry rather than an independent input.

The same construction also supplies a proposed geometrical interpretation of quark color and the strong interaction. A two-plane up-quark vortex has exactly three equivalent orientation classes in three spatial dimensions. If these states are represented by normalized coherent complex amplitudes, their norm-preserving transformations with common phase removed form SU(3) with eight generators. This reproduces the three-state/eight-generator structure associated with QCD color at the level developed here, but it does not by itself derive the full local gauge dynamics of QCD. Likewise, the earlier proposal that opposite local spins bind through shared FDE evolution can be expressed quantitatively through the spatial gradient of the shared time-rate field. The construction determines a dimensionless binding contribution and an internal energy scale; an absolute force additionally requires an independently derived particle-vortex length scale.

Taken together, these results show that a compact FDE/GDE vortex construction based on two primary persistent particle structures can relate several otherwise distinct particle properties: light-quark mass scales, the up/down mass ratio, the neutron–proton mass difference, the threefold color state space, its eight-generator SU(3) transformation structure, and a strong-interaction time-rate gradient. The remaining assumptions and limitations identified in the paper provide direct tests of the construction. In particular, further development must determine whether the 7.5° charged-vortex partition and the vortex length scale can be independently derived and whether the proposed nucleon and color structures reproduce additional observables not used in the present calculations. Success or failure in those tests will determine whether the two-primary-particle TDC construction can be extended into a more complete particle theory.

Acknowledgment
The author acknowledges the use of OpenAI's ChatGPT (GPT-5.6 Sol) as an artificial-intelligence research and analytical tool in the development of this paper. ChatGPT was used extensively to assist in the mathematical formulation and evaluation of the proposed particle geometry, development and checking of derivations, numerical calculations, examination of internal consistency, comparison of alternative formulations, and organization and editing of the manuscript. The underlying Time Dilation Cosmology framework, physical concepts, particle model, and interpretations are those of the author. The author reviewed and approved the resulting arguments, equations, and conclusions and assumes responsibility for the final content of the paper.

Appendix A. Extension of the Particle Geometry to Atomic and Molecular Structures

The particle structures developed in this paper were originally proposed as components of a broader geometrical model extending from elementary particles to atomic nuclei, electron-shell relationships, and molecular structure [5]. The diagrams reproduced in this Appendix illustrate that proposed extension. They are included to show how the electron, up-quark, proton, and neutron geometries developed quantitatively in the present paper can be assembled into progressively larger structures.

The diagrams are not presented here as additional quantitative derivations. The calculations in the present paper are confined principally to the elementary-particle geometry, light-quark mass relationships, neutron–proton mass difference, color-state structure, and strong-force formulation. A complete quantitative treatment of the atomic and molecular configurations shown below, including their energy levels and bonding relationships, remains for subsequent work.

The first diagrams extend the proposed proton and neutron geometries to the Carbon-12 nucleus and atom. In the original construction, the arrangement of protons and neutrons determines which up-quark components remain available for interaction with external electrons and thereby provides a proposed geometrical basis for the , , and electron relationships shown in the Carbon-12 diagram.

The same construction is then extended from carbon to oxygen by adding two protons and two neutrons to the nuclear geometry. Finally, the oxygen structure is combined with two hydrogen protons and the corresponding electron relationships to form the proposed H_2O configuration. The resulting diagram reproduces the familiar bent molecular arrangement and incorporates the approximately angle between the hydrogen protons.

These diagrams therefore illustrate the intended continuity of the model: the same particle geometry developed in the body of this paper is proposed to serve as the structural basis from which progressively larger atomic and molecular configurations can be constructed. Their inclusion here is intended to identify consequences and directions for further quantitative development rather than to claim that the atomic and molecular structures have been independently derived in the present work.

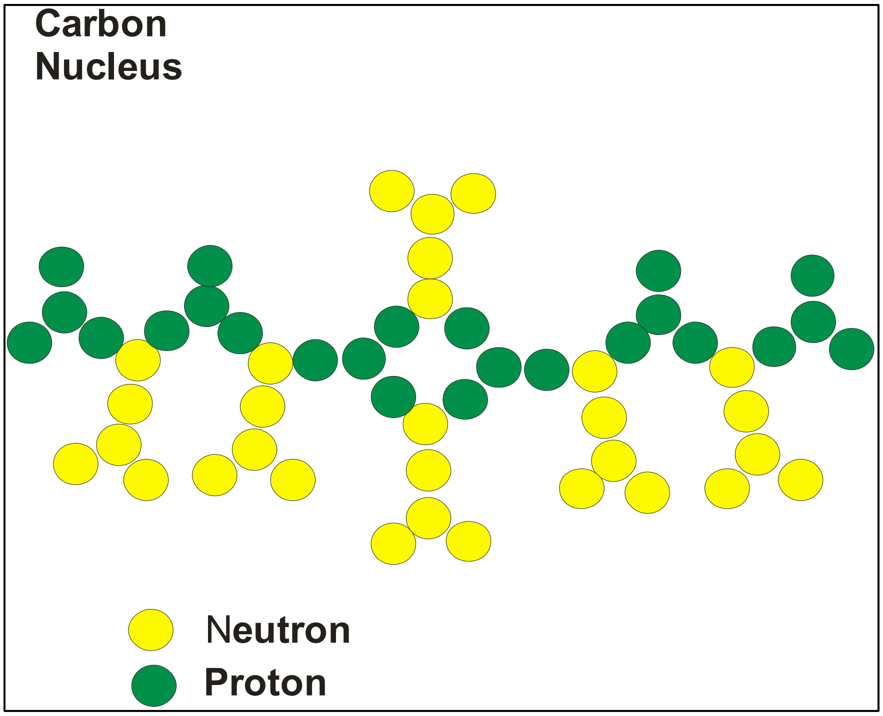

Figure A1. Carbon-12 nucleus

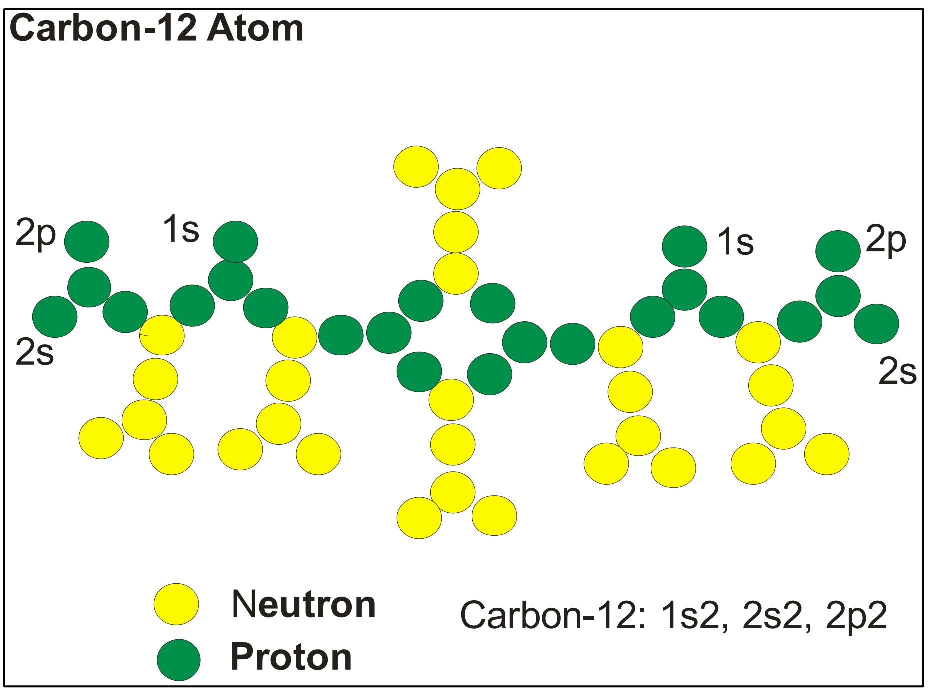

Figure A2. Carbon-12 atom

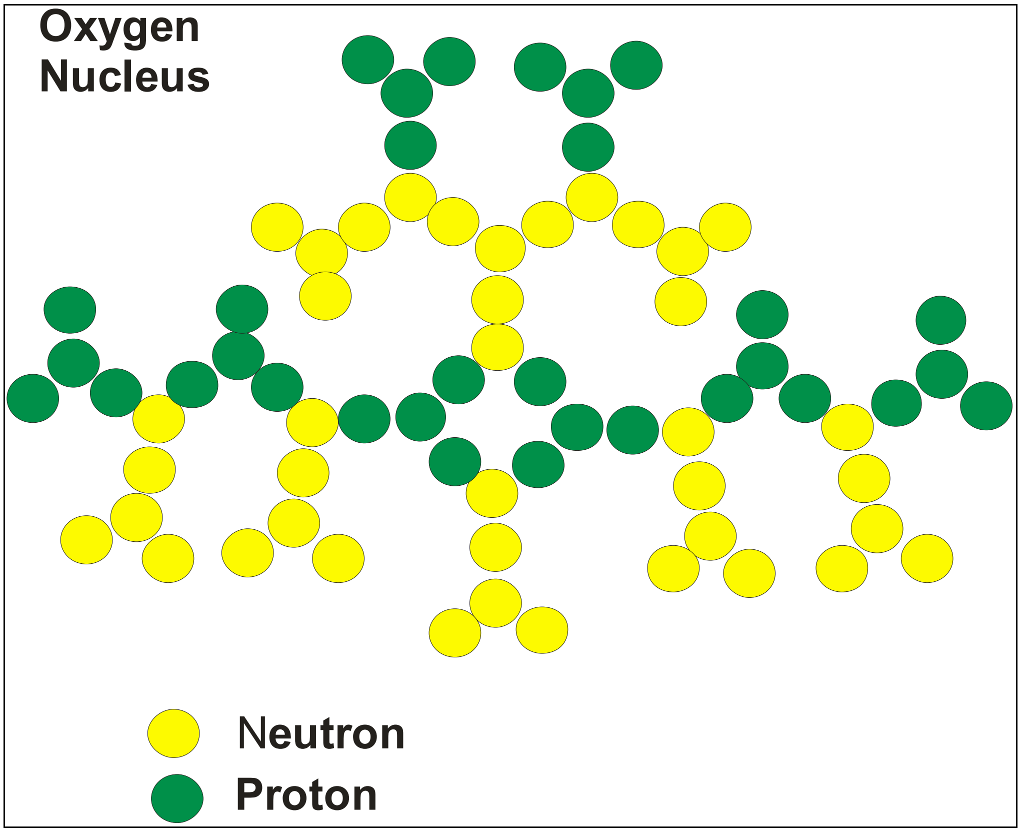

Figure A3. Oxygen nucleus

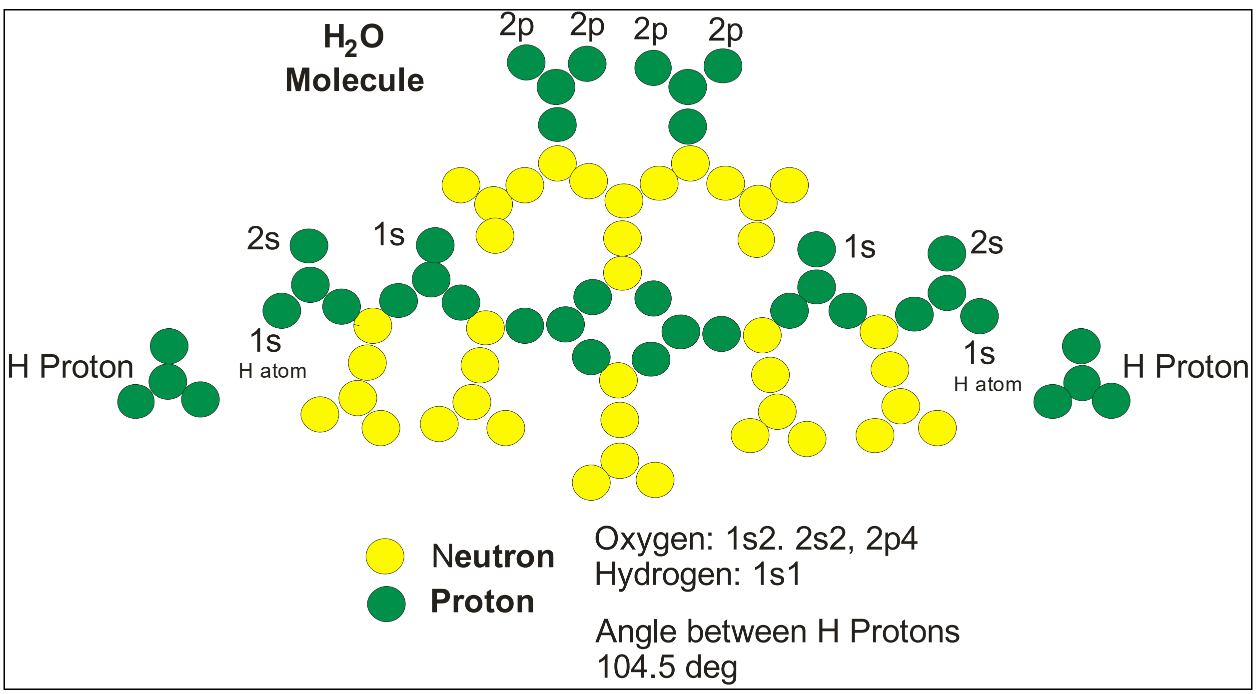

Figure A4. Proposed H_2O molecular structure

References

[1] Forrington, Capt. J. H. (Cass). "General Relativity and Effects in Time as Causation." *Journal of Cosmology*, Vol. 27, No. 1, 26 July 2022. https://thejournalofcosmology.com/General Relativity and Effects in Time as Causation JoC.pdf

[2] Forrington, Capt. J. H. (Cass). "Time Dilation Cosmology." *Journal of Modern Physics*, Vol. 14, No. 6, 29 May 2023. https://dx.doi.org/10.4236/jmp.2023.146049

[3] Forrington, Capt. J. H. (Cass). "Time Dilation Cosmology 2." *Journal of Modern Physics*, Vol. 15, No. 4, 22 March 2024. (DOI) https://doi.org/10.4236/jmp.2024.154020

[4] Forrington, Capt. J. H. (Cass). "The Unified Field." *Journal of Modern Physics*, Vol. 15, No. 7, 27 June 2024. https://doi.org/10.4236/jmp.2024.157043

[5] Forrington, J. H. (Cass). Particles. Unpublished preprint. https://captcass.com/particlespre.pdf

[6] S. Navas et al. (Particle Data Group), "Review of Particle Physics," *Phys. Rev. D* 110, 030001 (2024), and 2025 update, including PDG Summary Tables and Physical Constants.