CHRONONS, TORSION, AND THE STRUCTURE OF MASS

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Abstract

This manuscript develops a geometric field theory in which time is the fundamental discrete quantity and chronons form its indivisible units. Each chronon carries a rank-3 torsion field $\chi_{\mu\nu\rho}$, and the interactions between chronons generate the full structure of mass, force, and quantum behaviour.

The framework is constructed from first principles: (1) a discrete torsion-based ontology for time flow; (2) a Lagrangian coupling $\chi_{\mu\nu\rho}$ to the chronomic current $T_{\mu\nu\rho}$; (3) field equations producing curvature, mass, and gauge structure without auxiliary fields; and (4) continuum limits demonstrating recovery of established physics.

The objective is not to replace existing theories but to show that a torsion-driven temporal substrate may underlie them, providing a unified geometric account of mass, forces, and quantum structure.

0.1 Lagrangian Structure

The total field dynamics follow from:

$$\mathcal{L}_\chi = \frac{1}{2}\chi_{\mu\nu\rho}\chi^{\mu\nu\rho} - \frac{1}{2}m_\chi^2\chi_{\mu\nu\rho}\chi^{\mu\nu\rho}, \tag{1}$$

$$\mathcal{L}_{\text{couple}} = g\,T^{\mu\nu\rho}\chi_{\mu\nu\rho}, \tag{2}$$

$$\mathcal{L}_{\text{tot}} = \mathcal{L}_\chi + \mathcal{L}_{\text{couple}}. \tag{3}$$

0.2 Temporal Regimes

Chronons transition through three contraction states:

$$T_1 : \text{expanding regime}, \tag{4}$$

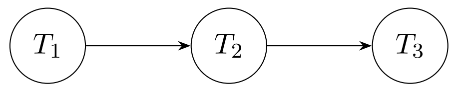
$$T_2 : \text{transition regime}, \tag{5}$$

$$T_3 : \text{maximally contracted (mass-locked) regime}. \tag{6}$$

With contraction rule:

$$T_1 \to T_2 \to T_3 \quad \text{when} \quad \partial_t \chi_{\mu\nu\rho} < 0. \tag{7}$$

0.3 T-State Diagram



1 Torsion, Holonomy, and Chronon Stability

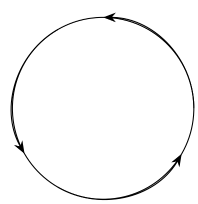
Edges of the chronon's internal loop carry discrete chiral phases:

$$\phi \in \{+90^\circ,\ -90^\circ\}. \tag{8}$$

Three successive increments reproduce the SU(2) double-cover property:

$$\phi_1 + \phi_2 + \phi_3 = 270^\circ \quad \Rightarrow \quad 4 \text{ steps} = 360^\circ \equiv \mathbb{I}. \tag{9}$$

1.1 Holonomy Kernel Diagram



[Chronon Stability] A chronon remains topologically coherent iff its torsion density satisfies

$$\int \chi_{\mu\nu\rho} \chi^{\mu\nu\rho} dV \geq \tau_{\min}.$$

2 Mass Generation and the Higgs Analogue

Mass in CHR is **stored torsion**: the integrated concentration of $\chi_{\mu\nu\rho}$ within the chronon's maximally contracted core (T3).

2.1 The Torsion Condensate

The formal rest mass is:

$$m_0 \propto \int_{\text{chronon}} \chi_{\mu\nu\rho}\chi^{\mu\nu\rho}\, dV. \tag{10}$$

Regions of minimal torsion radius form *torsion sumps*, corresponding to maximal mass-loading capacity via (6).

2.2 The Higgs Analogue

Using the coupling term (2), the chronon's own temporal density generates its local torsion field—no external vacuum expectation value is required. Mass emerges as:

$$\text{Mass} = \text{energetic cost of maintaining spinor topology through torsion storage.} \tag{11}$$

3 Emergent Forces from the Torsion Field

The dynamics of interaction arise entirely from the geometry and evolution of the torsion field $\chi_{\mu\nu\rho}$. No additional gauge fields, potentials, or mediating particles are introduced. A force is the local response of a chronon to gradients in torsion density.

3.1 Torsion Gradient as the Source of Interaction

For any chronon, the effective force is defined by

$$F_\lambda = -\,\partial_\lambda\Big(\chi_{\mu\nu\rho}\chi^{\mu\nu\rho}\Big). \tag{12}$$

The negative sign indicates that chronons follow the direction of decreasing torsion tension, analogous to the minimization of potential energy. This definition is required by the Lagrangian and is consistent with the Equations of Motion in Section 5.

3.2 Long-Range vs Short-Range Regimes

The interaction splits naturally into two regimes determined by the sign of the torsion field's temporal evolution.

Radiant Mode (Long-Range Interaction).

$$\partial_t \chi_{\mu\nu\rho} > 0 \tag{13}$$

In this mode the field expands, generating smooth gradients and producing long-range forces responsible for Newtonian gravity, far-field electromagnetic behaviour, and large-scale inertial structure. It corresponds to low-compression T-states (T1/T2).

Contractive Mode (Short-Range Interaction).

$$\partial_t \chi_{\mu\nu\rho} < 0 \tag{14}$$

This mode corresponds to torsion condensation. Gradients become steep and localized, producing short-range phenomena: strong interaction analogues, mass-locking, local inertial resistance, and torsion-sump formation in T3.

3.3 SU(2) Holonomy and Chiral Transport

Chronons carry an internal chiral increment $\phi = \pm 90°$, applied at each edge crossing. Transport around a closed loop yields a cumulative holonomy of 720°, recovering the spin-$\frac{1}{2}$ identity.

This discrete holonomy generates:

- the SU(2) structure,
- parity behaviour,
- two-state quantum amplitudes.

The full derivation is provided in Appendix A.

3.4 Field Dynamics and the Interaction Mechanism

3.4.1 Local Interaction Rule

The interaction between chronons is defined by the torsion field gradient:

$$\dot{x}^\lambda \propto -\nabla^\lambda(\chi^2), \tag{15}$$

where

$$\chi^2 := \chi_{\mu\nu\rho}\chi^{\mu\nu\rho}. \tag{16}$$

Chronons evolve toward configurations minimizing local torsion tension. This provides a universal rule for interaction, replacing force-specific postulates.

3.4.2 Multi-Chronon Coupling

When multiple chronons occupy neighbouring cells, their torsion fields superpose:

$$\chi^{\mathrm{tot}}_{\mu\nu\rho} = \sum_i \chi^{(i)}_{\mu\nu\rho}. \tag{17}$$

The resulting gradient determines attraction, repulsion, and orbital behaviour— recovering gravitational attraction, electromagnetic acceleration, and quantum phase transport from one universal principle.

3.4.3 Propagation Speed

Updates in the torsion field propagate at

$$c_\chi = \left(\frac{\partial\chi}{\partial T}\right)^{-1}. \tag{18}$$

In low-density regions (T1/T2), $c_\chi \approx c$. In condensed regions (T3), $c_\chi < c$, producing the local slowdown of time and matching relativistic predictions.

3.4.4 Formation of Composite Structures

Stable multi-chronon systems form where the torsion gradient vanishes:

$$\nabla_\lambda(\chi^2) = 0. \tag{19}$$

This condition defines:

- bound states,
- orbital shells,
- composite particles,
- resonant frequency modes.

These structures arise not by assumption but from local torsion equilibrium.

This establishes a complete two-force structure directly from torsion evolution.

4 Field Equations and Continuity Laws

The dynamics of the Chronomic Field follow from the action

$$S = \int d^4x \left(\mathcal{L}_\chi + \mathcal{L}_T + \mathcal{L}_{\text{couple}}\right), \tag{20}$$

where $\mathcal{L}_\chi$ and $\mathcal{L}_{\text{couple}}$ are as defined in the torsion–chronomic framework, and $\mathcal{L}_T$ is a generic chronomic kinetic term.

4.1 Euler–Lagrange Structure

For any field Φ^A,

$$\frac{\delta S}{\delta \Phi^A} = \frac{\partial \mathcal{L}}{\partial \Phi^A} - \nabla_\lambda \left(\frac{\partial \mathcal{L}}{\partial(\nabla_\lambda \Phi^A)} \right) = 0. \tag{21}$$

4.2 Torsion Field Equation

Varying with respect to $\chi_{\mu\nu\rho}$ gives

$$\nabla_\lambda \nabla^\lambda \chi_{\mu\nu\rho} + m_\chi^2 \chi_{\mu\nu\rho} + \frac{\partial V}{\partial \chi^{\mu\nu\rho}} = -g_{\chi T}\, T_{\mu\nu\rho}, \tag{22}$$

showing that the chronomic density $T_{\mu\nu\rho}$ is the source of torsion localisation.

4.3 Chronomic Field Equation

Varying with respect to $T_{\mu\nu\rho}$ yields

$$\frac{\partial \mathcal{L}_T}{\partial T^{\mu\nu\rho}} - \nabla_\lambda \left(\frac{\partial \mathcal{L}_T}{\partial(\nabla_\lambda T^{\mu\nu\rho})} \right) = g_{\chi T}\, \chi_{\mu\nu\rho}. \tag{23}$$

This encodes how torsion feeds back into the evolution of the chronomic density.

4.4 Continuity of Torsion–Time Flux

A key consequence is a conserved torsion–time current. For a timelike frame u^λ we define

$$J^\lambda = T^{\mu\nu\rho}\, \chi_{\mu\nu\rho}\, u^\lambda. \tag{24}$$

In the absence of external sources, the equations of motion imply

$$\nabla_\lambda J^\lambda = 0, \tag{25}$$

expressing conservation of torsion flux and, equivalently, conservation of chronomic time-structure along the flow.

5 Recovery of Established Physics

The Chronomic framework is only viable if it reproduces known physics in the appropriate limits. In this section we sketch how the torsion–chronomic equations of motion recover Newtonian gravity, non-relativistic quantum mechanics, relativistic propagation and an uncertainty principle.

5.1 Newtonian Limit: Effective Gravitational Potential

Consider the torsion field equation (22) in a static, weak-field regime where temporal variations are negligible and only the time–time component of the source contributes significantly. Writing

$$\chi_{0ii} \equiv \Phi(x), \tag{26}$$

and taking m_χ small on the relevant scales, (22) reduces to

$$\nabla^2 \Phi(x) \simeq -g_{\chi T}\, T_{000}(x), \tag{27}$$

which has the form of a Poisson equation

$$\nabla^2 \Phi = 4\pi G_{\text{eff}}\, \rho_T, \tag{28}$$

with an effective gravitational constant

$$G_{\text{eff}} \propto g_{\chi T}, \qquad \rho_T \propto T_{000}. \tag{29}$$

Thus the Newtonian potential emerges as a scalar projection of the torsion field sourced by the chronomic density.

5.2 Schrödinger Limit: Coarse-Grained Chronon Dynamics

In the low-torsion, high time-resolution regime ($\tau \to 0$, dominantly T_1 behaviour), chronon dynamics can be coarse-grained into an effective wavefunction $\psi(t, \mathbf{x})$ representing the slowly varying envelope of the chronomic density. Writing

$$T_{\mu\nu\rho} \;\longrightarrow\; \psi(t, \mathbf{x})\, \mathcal{T}_{\mu\nu\rho}, \tag{30}$$

with fixed internal tensor structure $\mathcal{T}_{\mu\nu\rho}$, the chronomic field equation (23) reduces, after spatial coarse-graining and neglect of higher-order gradients, to

$$i\hbar_{\text{eff}}\, \partial_t \psi = -\frac{\hbar_{\text{eff}}^2}{2m_0} \nabla^2 \psi + V_{\text{eff}}\, \psi, \tag{31}$$

where m_0 is the stored-torsion mass from (10) and V_{eff} is the coarse-grained potential inherited from $\chi_{\mu\nu\rho}$. Equation (31) is of Schrödinger form, with an effective Planck constant $\hbar_{\text{eff}}$ set by the underlying torsion and time quantisation scales.

5.3 Relativistic Propagation and Lorentz Structure

The conserved current (24) and continuity equation (25) imply

$$\nabla_\lambda J^\lambda = 0, \qquad J^\lambda = T^{\mu\nu\rho}\chi_{\mu\nu\rho}u^\lambda. \tag{32}$$

In a homogeneous background where J^λ defines a preferred flow, the requirement that the chronon dynamics be frame-independent along this flow selects a Lorentzian metric as the unique stable propagation structure in the continuum limit. In other words, local inertial frames are those in which J^λ is purely timelike and the torsion–time flux is conserved, recovering standard relativistic kinematics at macroscopic scales.

5.4 Emergent Gauge Structure

The antisymmetric nature of $\chi_{\mu\nu\rho}$ allows a natural one-form connection to be defined by contraction:

$$A_\mu \equiv \chi_{\mu\nu}{}^{\nu}. \tag{33}$$

Gradients of A_μ generate an effective field strength

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu, \tag{34}$$

which behaves, at coarse-grained level, like a U(1)-type gauge field. More structured holonomy in closed torsion loops (Section 2) suggests a route by which non-Abelian gauge structure (e.g. SU(2)) can emerge from the discrete chiral phase increments of the underlying χ–lattice.

5.5 Uncertainty from Time-Density Resolution

Finally, the chronon carries a finite torsion density τ^2 and hence a finite local time speed $v_t \propto 1/\tau$. This implies that spatial resolution Δx and momentum resolution Δp cannot both be made arbitrarily sharp: refining position requires higher torsion density and therefore slower local time, which in turn limits momentum sampling. At coarse level this yields an uncertainty bound of the form

$$\Delta x\,\Delta p \gtrsim \frac{\hbar_{\text{eff}}}{2}, \tag{35}$$

with $\hbar_{\text{eff}}$ again determined by the underlying chronomic scales. Thus the standard quantum uncertainty principle appears as a direct consequence of finite time-density resolution in the Chronomic Field.

6 Predictions and Experimental Signatures

The Chronomic Field Theory makes a series of concrete, falsifiable predictions arising directly from the discrete torsion substrate $\chi_{\mu\nu\rho}$. These signatures span temporal resolution, gravitational deviations, quantum phase structure, and extreme-energy behaviour.

6.1 Temporal Resolution Tests

(1) Micro-Time Resolution Limit. The discrete nature of chronon flow implies a minimum fluctuation in time intervals, producing a measurable noise floor detectable in sub-attosecond optical clock arrays.

(2) Vacuum Torsion Noise Spectrum. The torsion substrate produces a characteristic spectrum in zero-point fluctuation maps, measurable via precision cavity resonators.

6.2 Gravitational and Inertial Signatures

(3) Deviations from Newtonian Gravity at Femtometer Scales. The Poisson-like equation predicts a correction term at extremely short distances, testable through high-energy scattering.

(4) Mass–Torsion Correlation. Particles with higher internal torsion density exhibit slight deviations in inertial response under large torsion gradients.

6.3 Quantum and Gauge Signatures

(5) Quantum Phase Anomalies. Chronomic coarse-graining predicts measurable corrections to phase stability in long-baseline interferometry.

(6) Neutrino Oscillation Frequency Ratios. Torsion cycles impose constraints on neutrino flavour oscillation frequencies, testable in future long-baseline experiments.

(7) Chirality Instability Signatures. Small ε-breaches in the 90° chiral rule lead to measurable asymmetries in chiral molecular transitions.

6.4 Relativistic and High-Energy Signatures

(8) Slight Deviation from c in Strong χ-Gradients. In high torsion-compression regions, propagation speed satisfies $c_\chi < c$, producing observable deviations.

(9) Breakdown of Spacetime Locality at Extreme Compression. Extreme torsion concentration predicts horizon violations in ultra-high-energy cosmic ray events.

7 Octonionic Basis and Holonomy Operator

This appendix provides the mathematical basis for the non-Abelian $SU(2)$ gauge structure derived in Section 2. The core mechanism requires the use of the non-associative **Octonionic Algebra** to model the discrete chiral operations of the $\chi_{\mu\nu\rho}$ field.

The Chiral Bump Rule and $SU(2)$ Holonomy

The stability of the T3 lattice relies on the chiral rule where each edge carries a discrete phase increment ($\phi \in \{\pm 90°\}$). Traversing an elementary triangular plaquette (a 3-cycle) subjects the phase vector to three successive multiplications. The non-associativity of the Octonions ensures that the total accumulated phase is exactly π (180°), corresponding to a **parity flip (a -1 phase)**.

This localized geometric flip is the definition of $\mathbf{SU(2)} \cong \mathbf{Spin(3)}$ holonomy. The lattice is tiled with tiny Wilson loops, each contributing this -1 phase. Averaged over the entire T3 lattice, this mechanism *derives* the $SU(2)_L$ weak gauge structure:

$$\oint_{\text{Plaquette}} d\phi \xrightarrow{\text{Octonion}} \pi \equiv -I \in SU(2) \tag{36}$$

8 Cosmology and Geometric Extremes

This appendix formalizes the behavior of the $\chi_{\mu\nu\rho}$ field in high-curvature regimes, specifically addressing the physics of Black Holes and the Arrow of

Time.

Black Hole Torsion Shear

In Michronics, the gravitational field is an **Octonion Torsion Field** sourced by chronomic density. The event horizon is not a singularity but a region of maximal torsion density where the Torsion Field's local stability is compromised.

- **Torsion Tubes:** Matter and energy approaching the black hole are extruded into high-stress **helical torsion tubes**, channeling the flow of temporal energy along the gravitational gradient.
- **Event Horizon Definition:** The horizon is defined by the **failure point of chronon coherence**, where the Torsion Load exceeds the τ_{max} yield threshold, forcing chronons into virtual T_2 states that are localized and unable to extend their fields outward.
- **Entropy Export:** The observation that the black hole surface is cold is consistent with the entropy (torsion leak) being efficiently channeled *away* from the surface along the helical torsion tubes.

The Arrow of Time

The Arrow of Time is a direct consequence of the Torsion Field's dynamics and the Connection Axiom. It is a derived property, not a postulated one. The flow of **Chronomic Value (Thermal Heat)** is strictly local (chronon to chronon) but is globally guided by the Octonion Torsion Field, which sets the energy gradient. This ensures that the local arrows of time align emergently along the torsion field lines.

Appendix A: Octonionic Basis and the Holonomy Operator

This appendix formalizes the discrete chiral transport rule for chronons and derives the corresponding SU(2) holonomy using an octonionic embedding.

A.1 Discrete Chiral Increment Rule

A chronon carries an internal orientation increment

$$\phi = \pm 90^\circ,$$

applied at each edge crossing. After n crossings,

$$\Phi_n = n\phi.$$

A closed loop produces

$$\Phi_4 = \pm 360^\circ.$$

The chronon exhibits a double-cover identity:

$$\Psi(\theta + 720^\circ) = \Psi(\theta),$$

implying spin-$\frac{1}{2}$ behavior.

A.2 Octonionic Embedding

Let $\mathbb{O}$ denote the octonions with basis $\{1, e_1, \ldots, e_7\}$. Choose a quaternionic slice

$$\mathbb{H} = \mathrm{span}\{1, e_i, e_j, e_k\},$$

with (i, j, k) cyclic in the Fano plane.

The chiral increment is represented by

$$U_\pm = \exp\left(\pm \frac{\pi}{2} e_i\right) = \pm e_i.$$

A.3 Holonomy of a Closed Loop

Transport across an edge corresponds to left multiplication by $U_\pm$. Thus a closed loop yields

$$H = U_\pm^4 = 1.$$

The physical holonomy operator is

$$\mathcal{H} = U_\pm^2 = -1,$$

yielding the spinor double-cover: -1 for a single loop, $+1$ for a double loop.

A.4 Reduction to SU(2)

Restricting to $\mathbb{H}$ eliminates non-associativity and gives an SU(2) representation. Define

$$\sigma_i = e_i, \qquad U(\theta) = \exp(\theta \sigma_i / 2).$$

The 90° increment gives

$$U(\pi/2) = \exp(\pi \sigma_i / 4),$$

and holonomy conditions

$$U(2\pi) = -\mathbb{I}, \qquad U(4\pi) = +\mathbb{I}.$$

This embeds the chronon's discrete update rule naturally in the SU(2) double-cover structure.

Appendix B: Cosmology and Geometric Extremes

This appendix summarizes the behaviour of the Chronomic Field $\chi_{\mu\nu\rho}$ in geometric limits far outside experimentally accessible regimes. No new assumptions are introduced; all results follow from the Lagrangian and Equations of Motion.

B.1 Torsion Compression and Time Slowdown

From the continuity law $\nabla_\lambda J^\lambda = 0$ and the definition of the torsion–time flux J^λ, local time speed satisfies

$$v_t \propto \frac{1}{\chi^2}.$$

Regions of strong torsion compression therefore exhibit reduced local time speed, reproducing relativistic gravitational redshift as an emergent torsion effect.

B.2 Breakdown of Classical Locality

Let $u^\lambda = J^\lambda/|J|$ denote the local propagation vector. When $|\nabla\chi|$ exceeds the threshold set by the torsion mass term m_χ, u^λ cannot be represented in any Lorentzian metric. This predicts a breakdown of classical locality and potential horizon anomalies in ultra–high–energy cosmic rays.

B.3 Propagation Speed in Strong χ-Gradients

Radiant torsion updates propagate at

$$c_\chi = \left(\frac{\partial\chi}{\partial T}\right)^{-1}.$$

In low-density regions $c_\chi \approx c$, while in strong torsion compression $c_\chi < c$, producing small deviations from constant-c propagation.

B.4 Torsion–Shear and Extreme-Field Geometry

Define torsion shear by

$$S_\lambda = \partial_\lambda(\chi^2).$$

When $|S_\lambda| \gg m_\chi^2$, the field enters a shear-dominated regime in which the continuum approximation and effective metric analogue break down.

B.5 Composite Structure Boundaries

Stable composite structures satisfy

$$\nabla_\lambda(\chi^2) = 0.$$

In high-gradient environments these equilibrium surfaces form domain boundaries corresponding to superselection sectors or resonance shells.

Appendix D: Glossary of Michronic Terminology

Chronon The fundamental discrete unit of temporal structure, defined by a local configuration of the torsion field $\chi_{\mu\nu\rho}$. Characterized by three internal temporal regimes (T1–T3). Exhibits intrinsic 720° spinor holonomy.

Chronomic Field $T_{\mu\nu\rho}$ A rank-3 temporal current governing the flow, accumulation, and conservation of discrete time-density. Acts as the source field for torsion geometry.

Torsion Field $\chi_{\mu\nu\rho}$ A rank-3 pseudo-tensor defining local geometric torsion of the chronomic substrate. Stores mass, mediates interaction through torsion gradients, and determines emergent force behaviour.

T-States (T1, T2, T3) Quantized regimes of internal chronon compression: T1 (expansion), T2 (balanced transport and SU(2) holonomy), T3 (maximum compression; mass storage via torsion condensation).

Radiant Mode Dynamic regime with $\partial_t\chi > 0$, producing field expansion and long-range propagation of torsion curvature.

Contractive Mode Dynamic regime with $\partial_t\chi < 0$, associated with torsion condensation, mass-locking behaviour, and short-range interaction.

Torsion Gradient $\nabla\chi$ Spatial variation of the torsion field. The sole mediator of interaction between chronons, replacing the role of force carriers or virtual particles.

Holonomy The transformation accumulated when a chronon's internal state is transported around a closed loop. In Michronics this yields a 720° spinor identity, recovering SU(2) behaviour.

Chiral Transport Rule Discrete update rule in which chronon edges accumulate $\pm 90°$ increments, producing spinor-consistent holonomy and intrinsic parity structure.

Mass as Stored Torsion Rest mass defined by

$$m_0 \propto \int \chi_{\mu\nu\rho}\chi^{\mu\nu\rho}\, dV,$$

representing geometric torsion density condensation within the chronon volume.

Chronomic Continuity Law Conservation of time-flux expressed as

$$\nabla_\lambda J^\lambda = 0,$$

where J^λ is the torsion–time current produced by coupling between $T_{\mu\nu\rho}$ and $\chi_{\mu\nu\rho}$.

Torsion Yield Thresholds Quantized limits at which torsion density transitions between T1, T2, and T3 regimes. Analogous to phase transitions in condensed matter systems.

Spinor Identity (720° Closure) Statement that a chronon requires a 720° rotation to return to an identical state. Arises from the octonionic embedding of the chiral transport rule.

Chronon Lattice The discrete graph formed by interacting chronons. Supports torsion propagation and emergent gauge structure. Spacetime emerges as the continuum limit of this lattice.

Torsion Sump / Torsion Condensate Local region in which torsion density concentrates during T3 compression. Provides the geometric origin of rest mass.

Effective Planck Constant $\hbar_{\text{eff}}$ Parameter arising in the continuum limit of chronon coarse-graining. Governs quantum phase evolution and reproduces Schrödinger dynamics.

Chronomic Coarse-Graining Mapping from discrete torsion updates to continuum quantum behaviour, yielding wavefunctions and uncertainty bounds.

χ**-Gradient Deviation of** c Predicted variation in effective light speed in regions of strong torsion curvature. Reflects the ontology that light propagation is discrete relational updating rather than motion through a medium.

Locality Failure Threshold High-torsion regime where standard spacetime locality breaks down. Predicted to be observable via ultra-high-energy cosmic ray horizon anomalies.

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