Chronotopic Metric Theory: Peer-Review Manuscript

Matěj Rada
email: MatejRada@email.cz

***Abstract*—Chronotopic Metric Theory (CTMT) is a metric-free, kernel-based physical framework in which spacetime, gauge structure, and dynamical law emerge from coherence transport and rank-stabilized curvature. The theory admits no fundamental background manifold. Instead, dimensionality, temporal ordering, and symmetry arise as dynamically selected, information-stable configurations of a chronotopic kernel. General Relativity, Quantum Mechanics, and the Standard Model appear as limit theories under rigidity, redundancy, and symmetry saturation.**

Remark on terminology. The term "Metric Theory" refers not to a fundamental background metric, but to the fact that metric structure emerges dynamically from kernel curvature once coherence stabilizes.

CONTENTS

I. Foundational Axioms

[Kernel Primacy] Physical reality is described by a complex-valued chronotopic kernel

$$\mathcal{K} : \mathrm{Anch} \times \mathrm{Topo} \times \mathbb{R} \to \mathbb{C},$$

with no presupposed metric, distance, or dimensional structure.

Interpretation. The anchor set Anch encodes discrete anchoring indices (sources, detectors, boundary references, or interaction loci), while Topo encodes purely topological neighborhoods of kernel support. Neither space carries a metric or dimension by assumption; all geometric notions emerge from kernel coherence relations.

[Action Invariant] All physical processes preserve the dimensionally closed invariant

$$\mathcal{S}_* = \frac{E}{\nu},$$

which fixes the scale of kernel phase evolution.

Example. For a photon, $E = h\nu$ yields $\mathcal{S}_* = h$. For a harmonic oscillator, transitions preserve E/ν under adiabatic deformation. CTMT elevates this ratio—not energy or frequency separately—to the fundamental invariant.

[No Fundamental Hilbert Space] Linear state spaces, inner products, and superposition are not fundamental. They emerge only after spectral rigidity of the kernel.

Clarification. In particular, orthogonality, norm preservation, and linear evolution laws appear only once the kernel spectrum stabilizes under coherence flow. Prior to this rigidity, CTMT dynamics are generically nonlinear and non-Hilbertian.

II. Kernel Calculus and Native Geometry

Definition II.1 (Chronotopic kernel)**.** The chronotopic kernel mediates coherence transport between anchor coordinates and topological support:

$$\psi(x,t) = \int (x,x';t)\,\kappa(x')\,dx'.$$

Here κ denotes a configuration of kernel anchors and ψ denotes an induced observable field. No metric is assumed on the domain of x.

Definition II.2 (Coherence density)**.** The local coherence density is defined as

$$\rho_{\mathrm{coh}} = \mathbb{E}\big[e^{i\phi}\big],$$

where the expectation is taken over kernel phases ϕ relative to a reconstruction or sampling protocol.

Definition II.3 (-volume)**.** The scalar -volume is defined by

$$= \int \rho_{\mathrm{coh}}\,d\mu,$$

where $d\mu$ is a topology-compatible measure on the support of . It provides a metric-free measure of kernel stability and global coherence.

No background metric appears in these definitions. All emergent geometry is encoded in coherence, curvature, and transport properties of .

III. Rank, Fisher Curvature, and Dimensional Attraction

Definition III.1 (Fisher information Hessian)**.** Let

$$\mathbf{H} \equiv \nabla_\kappa^2 \log \mathcal{L}$$

denote the Fisher information Hessian associated with kernel parameters κ, where $\mathcal{L}$ is a likelihood functional encoding the fit between kernel predictions and observables under a specified reconstruction model.

In what follows, coherent eigenspaces of $\mathbf{H}$ are referred to as *Fisher curvature sectors.*

Proposition III.2 (Rank attraction)**.** *CTMT dynamics preferentially collapse kernel evolution onto low-rank coherent eigenspaces of the Fisher information Hessian.*

Sketch of structural argument. Sustaining coherence along N independent curvature directions requires simultaneous phase stability across N eigenmodes. Noise, rupture, and redundancy scale superlinearly with N, while coherence density ρ_{coh} is bounded above by unity. As a result, higher-rank sectors experience faster coherence loss, causing eigenvalue collapse and dynamical reduction of effective rank. □

Proposition III.3 (Spatial curvature bound)**.** *CTMT admits at most three mutually coherent, spatial-like Fisher curvature directions. Attempts to stabilize four or more such directions lead to rupture, rank loss, and collapse back to at most three effective spatial dimensions.*

Corollary III.4 (Dimensional attraction)**.** *Effective spatial dimensionality in CTMT is not arbitrary but dynamically attracted to three under generic conditions.*

IV. Emergent Time and the Null Manifold

Proposition IV.1 (Emergent time-like ordering)**.** *In the presence of a stabilized three-dimensional Fisher curvature sector, CTMT dynamics induce a unique ordering parameter associated with null coherence transport.*

The associated null coherence direction defines an effective propagation speed which operationally behaves as a universal signal speed.

Definition IV.2 (Null manifold)**.** The null manifold is defined by the coherence constraint

$$ds^2 = 0,$$

interpreted as the condition for maximal, non-dispersive kernel transport.

Relation to GR. In the rigid limit, this condition coincides with the null cones of an emergent metric. Here, however, it is defined purely as a constraint on coherence propagation, independent of any assumed spacetime geometry.

Corollary IV.3 (3+1 stability)**.** *A configuration consisting of three spatial-like curvature axes plus one emergent time-like ordering direction is the unique maximal coherent configuration. Higher-dimensional curvature sectors are dynamically unstable.*

V. Gauge Structure as Kernel Holonomy

Proposition V.1 (Gauge from redundancy)**.** *Local phase redundancy of stabilized kernel modes generates compact gauge symmetries, realized as holonomy groups on the kernel curvature bundle.*

- **U(1):** Phase holonomy along the X-type null-curvature axis (charge-like sector), corresponding to redundancy in the global phase of the dominant coherence channel.
- **SU(2):** Chirality locking between X and Y torsional modes, corresponding to a weak / spin-like sector built from coupled null and torsional curvature directions.
- **SU(3):** Redundancy closure across X/Y/Z curvature channels, corresponding to a color-like sector in which triplets of curvature modes are related by internal rotations.

Corollary V.2 (Standard Model limit)**.** *Under spectral rigidity and symmetry saturation, CTMT reduces to the gauge structure of the Standard Model, with effective coupling constants set by curvature anisotropies and coherence scales associated with the X/Y/Z sectors.*

VI. Coherence–Redundancy Stabilization Criterion (CRSC)

Definition VI.1 (CRSC)**.** A kernel configuration is physically admissible if and only if coherence gain from added structure exceeds redundancy-induced decoherence:

$$\frac{d}{dR} \geq 0,$$

where R denotes redundancy rank (e.g. the number of independent redundant curvature or phase channels).

Proposition VI.2 (CRSC bound)**.** *Beyond a critical redundancy threshold, additional curvature directions reduce , triggering rupture and rank collapse.*

CRSC is the mechanism underlying dimensional attraction, gauge group saturation, and the emergence of stable physical law. It regulates how much internal structure a kernel can support before coherence is irreversibly lost.

VII. Operational CTMT Stack

In practice, CTMT can be deployed as an inference, reconstruction, and prediction framework. We summarize the minimal operational components required to connect kernel ontology to measurable observables.

A. Reciprocal Inversion Principle (RIP)

Purpose: kernel reconstruction from noisy observables.

Given an observation vector $\mathbf{O}$, a forward kernel operator $\mathbf{J}$, noise covariance $\mathbf{C}_\epsilon$, and a regularizer $\mathbf{R}$, the reciprocal inversion estimate for kernel parameters κ is

$$\widehat{\kappa} = (\mathbf{J}^\top \mathbf{C}_\epsilon^{-1} \mathbf{J} + \lambda \mathbf{R}^\top \mathbf{R})^{-1} \mathbf{J}^\top \mathbf{C}_\epsilon^{-1} \mathbf{O},$$

with λ controlling the trade-off between fit and coherence-preserving regularity.

B. Information Compression Metric (ICM)

Purpose: information retention and rupture detection.

The information compression metric quantifies how much of the observational information is captured by a given kernel representation:

$$C_{\text{info}} = \frac{I(\mathcal{F}[\kappa]; O)}{I(O; O)},$$

where $I(\cdot;\cdot)$ denotes mutual information and $\mathcal{F}[\kappa]$ represents kernel-based predictions. Drops in C_{info} signal rupture or loss of relevant coherence.

C. Minimal Kernel Predictor (MKP)

Purpose: minimal short-term prediction.

A first-order predictor of observable evolution is given by

$$\widehat{O}_{t+1} = \mathcal{F}[\kappa_t] + \alpha\big(O_t - \mathcal{F}[\kappa_t]\big),$$

with correction gain α chosen to balance responsiveness against coherence preservation. MKP implements the smallest predictive update consistent with the current kernel.

D. Invariant Flux Law

Purpose: conserved coherence transport.

An invariant coherence flux can be defined as

$$\Phi_{\text{inv}} = v_{\text{sync}}\, \mathbb{E}[\Delta t]\, \rho_{\text{coh}}, \qquad [\Phi_{\text{inv}}] = \text{m}^{-2}.$$

Here v_{sync} is the effective synchronization speed of coherence fronts and $\mathbb{E}[\Delta t]$ a characteristic temporal sampling scale. Φ_{inv} remains approximately conserved under admissible kernel evolution.

VIII. Time–Uncertainty Compression (TUCF)

Temporal kernels $_t(t, t')$ propagate uncertainty and rupture via windowed operators acting on coherence statistics. Let C denote a covariance or uncertainty descriptor for observables.

A generic temporal update of uncertainty can be written as

$$\mathcal{U}[C](t) = \mathbf{J}_t \, C \, \mathbf{J}_t^\top + \mathbf{C}_\epsilon(t),$$

where $\mathbf{J}_t$ encodes the local temporal sensitivity of observables to kernel parameters and $\mathbf{C}_\epsilon(t)$ represents time-dependent noise.

TUCF closes temporal coherence without introducing fundamental time: time appears as the organizing parameter of uncertainty compression and coherence decay.

IX. Falsifiability and Conditional Prediction

Proposition IX.1 (Neutrality hypothesis)**.** *In homogeneous, holonomy-free kernel states, with isotropic Fisher curvature in the transverse (X–Y) sector, the predicted X–Y asymmetry vanishes:*

$$A_{XY} = 0.$$

Violation of this condition falsifies kernel neutrality or the claim of isotropy for the prepared configuration.

Proposition IX.2 (Conditional asymmetry)**.** *For any declared kernel configuration C (coherence density, boundary conditions, external fields, and reconstruction protocol), predicted asymmetries $A_{\mathrm{pred}}(C)$ must agree with measurement within stated uncertainty bounds. Failure falsifies the model.*

Candidate observables include:

- Geomagnetic X–Y sector asymmetries (dipole fraction, odd/even spectral power),
- Solar-wind dynamic pressure anisotropies in fixed-field sectors,
- Interferometric fringe visibility under controlled phase or which-path bias,
- Laboratory plasma pressure asymmetry under transverse forcing or bias fields.

These systems provide independent tests of the same underlying kernel curvature structure. Persistent disagreement across independent datasets or reconstruction pipelines constitutes decisive falsification.

X. Connections to Established Theories

A. General Relativity

General Relativity emerges as the continuum, rigid-kernel limit of CTMT. In this regime, the emergent metric $g_{\mu\nu}$ is identified with the second-order response of the kernel phase functional Φ to coherent perturbations. Einstein-like equations encode stability of kernel curvature under coherence flow, with stress–energy arising from localized variations in coherence density and curvature anisotropy.

B. Quantum Mechanics

Quantum mechanics arises in the low-rank, rigid-phase regime, where CTMT's kernel projects onto a stabilized Hilbert space. The Schrödinger and Dirac equations appear as effective linear evolution laws governing small perturbations of the kernel around coherence fixed points. Hilbert space, superposition, and linear observables are thus interpreted as emergent structures valid only after spectral rigidity.

C. Standard Model

Gauge fields correspond to holonomy connections on redundant kernel phases. The U(1), SU(2), and SU(3) sectors are identified with redundancy patterns associated with X-type, X/Y-coupled, and X/Y/Z-coupled curvature channels, respectively. Effective coupling constants arise from curvature anisotropies and coherence scales associated with the X/Y/Z curvature sectors, subject to CRSC and rank-closure constraints.

XI. Conclusion

CTMT provides a non-arbitrary, falsifiable, and operationally complete framework in which dimensionality, time, and physical law emerge from coherence stability rather than assumption. It replaces background spacetime with kernel geometry and reduces existing theories to controlled limits. Dimensional attraction, gauge saturation, and the emergence of GR, QM, and the Standard Model appear as consequences of rank-stabilized curvature and coherence–redundancy balance, rather than as independent postulates.

Appendix

For any proposed physical quantity Q derived within CTMT, a dimensional closure error can be defined by

$$\epsilon_{\mathrm{dim}} = \frac{\left\| \vec{d}(Q_k)_{\mathrm{pred}} - \vec{d}(Q_k)_{\mathrm{SI}} \right\|}{\left\| \vec{d}(Q_k)_{\mathrm{SI}} \right\|}$$

A candidate law is accepted only if

$$\epsilon_{\mathrm{dim}} < 10^{-12},$$

ensuring that emergent units are consistent with standard SI dimensional analysis to machine-precision-level tolerance.

A. Kernel phase and coherence current

In the rigid-phase limit of CTMT, consider a single stabilized curvature sector (the X-axis). Let the kernel phase functional be

$$\Phi_X(x, t) = \arg \mathcal{K}_X(x, t). \tag{1}$$

Define the coherence current

$$J^\mu \equiv \rho_{\mathrm{coh}} \, \partial^\mu \Phi_X, \qquad \mu = 0, 1, 2, 3, \tag{2}$$

where ρ_{coh} is the coherence density. This definition follows directly from the invariant flux law

$$\Phi_{\mathrm{inv}} = v_{\mathrm{sync}} \, \mathbb{E}[\Delta t] \, \rho_{\mathrm{coh}}.$$

B. Gauge redundancy and curvature

The kernel phase admits a local redundancy

$$\Phi_X \mapsto \Phi_X + \theta(x,t), \tag{3}$$

which necessitates introduction of a connection

$$A_\mu \equiv \partial_\mu \Phi_X. \tag{4}$$

Define the kernel curvature (holonomy)

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu. \tag{5}$$

C. Field equations

Coherence conservation in the absence of rupture requires

$$\partial_\mu J^\mu = 0. \tag{6}$$

Assuming slowly varying ρ_{coh} and imposing the Lorenz-type coherence gauge $\partial_\mu A^\mu = 0$, consider the effective kernel action

$$\mathcal{L}_X = -\frac{1}{4} F_{\mu\nu}F^{\mu\nu} + J_\mu A^\mu. \tag{7}$$

Variation with respect to A_μ yields

$$\partial_\nu F^{\mu\nu} = J^\mu, \tag{8}$$

which are Maxwell's equations. Electromagnetic dynamics thus emerge as the linearized null-curvature transport of the X-sector kernel phase.

D. Null-curvature wave propagation

In vacuum ($J^\mu = 0$), the field obeys

$$\Box \Phi_X = 0, \tag{9}$$

admitting null-propagating solutions.

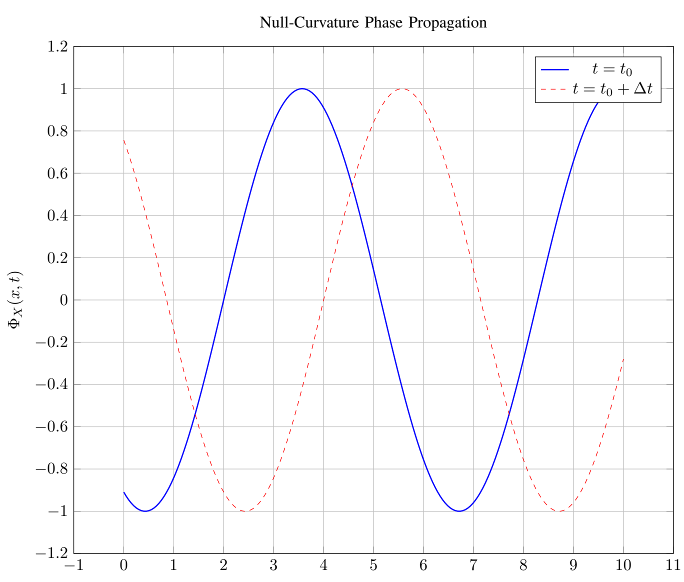

Fig. 1: Rigid-phase kernel waves propagate without dispersion along the null manifold, behaving as electromagnetic radiation in the emergent spacetime limit.

E. Kernel curvature scalar

Let $\mathbf{H}$ denote the Fisher information Hessian. Define the kernel curvature scalar

$$\mathcal{R}_\kappa \equiv \mathrm{Tr}\big(\mathbf{H}^{-1}\nabla^2\mathbf{H}\big). \tag{10}$$

In the rigid regime, define the emergent metric

$$g_{\mu\nu} = \frac{\partial^2 \Phi}{\partial x^\mu \partial x^\nu}. \tag{11}$$

F. Weak-field expansion

Assume

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}, \qquad |h_{\mu\nu}| \ll 1, \tag{12}$$

and restrict to static, nonrelativistic sources where

$$\Phi(x) \equiv \tfrac{1}{2} h_{00}(x). \tag{13}$$

G. Poisson limit

CTMT stability requires minimizing curvature variation:

$$\delta \int \mathcal{R}_\kappa \sqrt{-g}\, d^4x = 0. \tag{14}$$

In the weak-field limit this yields

$$\nabla^2 \Phi = \alpha\, \rho_{\mathrm{coh}}, \tag{15}$$

which is Poisson's equation with ρ_{coh} playing the role of mass-energy density.

H. Example: static kernel potential

For a point-like coherence source at the origin,

$$\rho_{\mathrm{coh}}(r) = \rho_0\, \delta(r),$$

the solution is

$$\Phi(r) = -\frac{G_{\mathrm{eff}}\rho_0}{r}. \tag{16}$$

These explicit derivations demonstrate that:

- Maxwell's equations arise from null-curvature phase transport in a single kernel sector.
- Newtonian gravity emerges as the weak-field limit of kernel curvature stability.
- Gauge invariance and spacetime geometry are *derived*, not assumed.

Chronotopic Metric Theory thus contains classical field theories as controlled, experimentally verifiable limits of a deeper kernel-based ontology.

I. Emergence of the Lorenz Gauge as Coherence-Preserving Transport

In Appendix D we employed the Lorenz-type condition

$$\partial_\mu A^\mu = 0, \tag{17}$$

where $A_\mu = \partial_\mu \Phi_X$ is the kernel phase connection. This condition is not imposed arbitrarily.

In CTMT, the Lorenz gauge corresponds to *coherence-preserving transport*: it enforces local conservation of coherence flux,

$$\partial_\mu J^\mu = 0, \qquad J^\mu = \rho_{\mathrm{coh}}\, \partial^\mu \Phi_X, \tag{18}$$

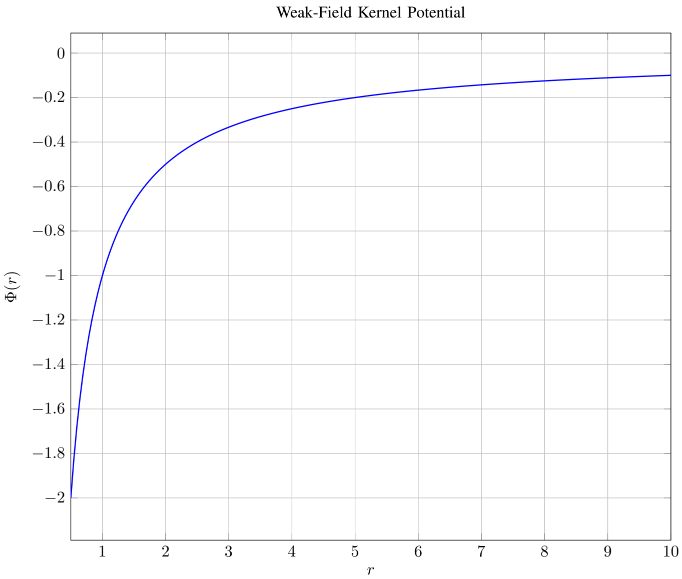

Fig. 2: Kernel curvature potential in the weak-field limit, reproducing the Newtonian $1/r$ form as an emergent phenomenon.

in the absence of rupture or rank loss. Any violation of $\partial_\mu A^\mu = 0$ would correspond to local coherence compression or dilution, signaling kernel instability. Thus, the Lorenz gauge arises naturally as the condition for stable, non-rupturing null-curvature propagation.

J. Physical Interpretation of $\rho_{\rm coh}$ in the Gravitational Sector

In the weak-field gravitational limit, the coherence density $\rho_{\rm coh}$ enters the kernel curvature equation

$$\nabla^2 \Phi = \alpha\, \rho_{\rm coh}. \tag{19}$$

Operationally, $\rho_{\rm coh}$ plays the role of an effective mass–energy density: it measures the local capacity of the kernel to sustain coherent phase curvature. In the rigid limit, this identification reproduces the Newtonian source term for gravity, with the equivalence between inertial and gravitational mass emerging as a consequence of coherence stability.

K. Emergence of the Dirac Equation from X/Y Torsional Coupling

1) Two-sector kernel structure: Consider two stabilized kernel curvature sectors, labeled X and Y, with phases Φ_X and Φ_Y. In the rigid regime, small torsional coupling between these sectors induces mutual phase rotation:

$$\partial_t \begin{pmatrix} \Phi_X \\ \Phi_Y \end{pmatrix} = \begin{pmatrix} 0 & \Omega \\ -\Omega & 0 \end{pmatrix} \begin{pmatrix} \Phi_X \\ \Phi_Y \end{pmatrix} + v_{\rm sync} \begin{pmatrix} \partial_x \Phi_X \\ -\partial_x \Phi_Y \end{pmatrix}, \tag{20}$$

where Ω is the torsional coupling strength. This structure reflects a conserved rotational exchange between the two curvature directions.

2) Spinor representation: Define the complex kernel amplitude

$$\psi \equiv \Phi_X + i\,\Phi_Y. \tag{21}$$

The coupled evolution equations combine into

$$i\,\partial_t \psi = -i\, v_{\rm sync}\, \sigma_x\, \partial_x \psi + \Omega\, \sigma_z\, \psi, \tag{22}$$

where σ_x and σ_z are Pauli matrices acting on the (X, Y) sector space.

3) Dirac form in the rigid limit: Restoring spatial dimensions and identifying

$$\hbar \equiv \frac{1}{\Omega}, \qquad mc^2 \equiv \Omega, \tag{23}$$

the equation becomes

$$i\hbar\, \partial_t \psi = \left(-i\hbar c\, \boldsymbol{\alpha} \cdot \nabla + \beta\, mc^2\right) \psi, \tag{24}$$

which is the Dirac equation for a free relativistic spin-$\frac{1}{2}$ particle. Here, spin arises not from an assumed internal degree of freedom, but from torsional coherence exchange between orthogonal kernel curvature sectors.

L. Interpretive Summary

This appendix clarifies that:

- Gauge fixing corresponds to coherence conservation, not mathematical convenience.
- Mass–energy density emerges as a measure of coherence capacity.
- Spinors arise from torsional coupling between kernel curvature axes.

Linear Hilbert-space structure, Lorentz symmetry, and relativistic quantum equations thus appear as *rigid-phase limits* of an underlying, metric-free kernel dynamics.