Chronotopic Metric Theory: Coherence Geometry and Fisher–Rigid Kernel Transport

Matěj Rada
Email: MatejRada@email.cz

Abstract

Chronotopic Metric Theory (CTMT) is presented as an information–geometric admissibility framework for kernel–generated forward maps. No spacetime, metric, gauge group, or dynamical law is postulated. The only primitive structure is an oscillatory transport kernel whose induced forward map admits a Fisher information geometry.

The theory characterizes when such kernels define stable, composable, and causally admissible descriptions of observables across regimes. Central concepts are Fisher rigidity, coherence density, and informational proper time. All quantities are operationally computable from Jacobians and data, and all claims are falsifiable through rank loss or instability of the Fisher spectrum.

Contents

1 Scope and non–assumptions

CTMT is not a physical theory in the traditional sense. It does not assume:

- background spacetime or metric,
- equations of motion,
- quantization rules,
- fundamental constants beyond an empirically extractable action scale.

CTMT addresses a single question:

> *When does a coarse–grained kernel define a stable and transportable forward map with a well–conditioned inverse problem?*

All structure arises from information geometry induced by observables.

2 Kernel transport as primitive structure

2.1 Forward kernel

Let $T(t)$ denote a forward–ordered kernel transport:

$$T(t) = \int_{t_0}^{t} \Xi(t') \exp\left(\frac{i}{\mathcal{S}_*} \Phi(t,t') - \epsilon(t') \right) dt', \tag{1}$$

where:

- $\Phi(t,t') \in \mathbb{R}$ is a differentiable phase functional,
- $\Xi(t')$ is a bounded modulation,
- $\epsilon(t') \geq 0$ ensures integrability,
- $\mathcal{S}_* > 0$ is an action scale inferred from phase sensitivity.

No geometric interpretation of t is assumed; it is merely an ordering parameter.

2.2 Observables and parameters

Let $\theta \in \mathbb{R}^d$ parametrize (Φ, Ξ, ϵ). An observable is any deterministic functional

$$Y = \mathcal{F}_\theta[T]. \tag{2}$$

Examples include delays, fluxes, spectra, or integrated responses.

3 Jacobian and Fisher geometry

3.1 Jacobian of the forward map

Assuming differentiability,

$$J(\theta) = \frac{\partial Y}{\partial \theta}. \tag{3}$$

The existence and boundedness of J is a *hard admissibility requirement*. Kernels that destroy differentiability are excluded.

3.2 Fisher information

With observational noise covariance C,

$$F(\theta) = J^\top C^{-1} J. \tag{4}$$

By Čencov's theorem, the Fisher metric is the unique monotone Riemannian metric on statistical models under Markov morphisms [1, 2]. No alternative metric is admissible.

4 Rigidity and redundancy

Definition 4.1 (Informational dimensionality)**.** The effective dimensionality of a kernel is

$$d_{\text{eff}} = \text{rank} F. \tag{5}$$

Definition 4.2 (Redundancy)**.** Directions in $\ker F$ are informationally redundant: variations along them do not affect observables to leading order.

Definition 4.3 (Fisher rigidity)**.** A kernel is *rigid* on a domain if

$$\text{rank} F(t) = \text{const} \quad \text{and} \quad \text{spec}(F(t)) \text{ remains bounded} \tag{6}$$

under forward extension.

Rigidity is an empirical property of the forward map, not a dynamical assumption.

5 Coherence geometry

5.1 Coherence density

Definition 5.1 (Coherence density)**.** On a region Ω of volume $V(\Omega)$,

$$\rho_{\text{coh}} = \frac{1}{V(\Omega)} \text{Tr} F. \tag{7}$$

This quantity measures identifiable information per unit volume and is directly computable from data.

5.2 Bounded coherence

Theorem 5.2 (Coherence bound)**.** *For stationary–phase dominated kernels satisfying Fisher rigidity,*

$$\rho_{\text{coh}} \leq \frac{C(d_{\text{eff}})}{\mathcal{S}_*}, \tag{8}$$

where C depends only on effective dimensionality.

Remark 5.3. This bound is not postulated. It follows from phase resolution limits and breakdown of Fisher conditioning when exceeded.

6 Causality as informational admissibility

CTMT does not assume time causality. Instead:

Definition 6.1 (Forward admissibility)**.** A kernel is admissible iff:

(i) J exists and is bounded,

(ii) $\mathrm{rank}F$ is preserved,

(iii) ρ_{coh} remains finite.

Anti–causal constructions are allowed mathematically but are rejected because they destroy Fisher conditioning.

7 Kernel composition

Proposition 7.1 (Stacking admissibility)**.** *Two kernels K_1 and K_2 may be composed if and only if they belong to the same Fisher coherence class:*

$$\mathrm{rank}F_{K_1} = \mathrm{rank}F_{K_2}, \quad \mathrm{spec}(F_{K_1}) \sim \mathrm{spec}(F_{K_2}). \tag{9}$$

This criterion replaces heuristic multi–scale matching.

8 Falsifiability

CTMT is falsified if any of the following occur:

- regime–dependent rank loss in F,
- divergence of $\mathrm{Tr}F$ under forward propagation,
- failure of parameter transport across operating points,
- loss of differentiability of the forward map.

These are observable and testable conditions.

A Coherence proper time

Definition A.1 (Coherence proper time)**.** The coherence proper time accumulated along a forward path is

$$\tau(t) = \int_{t_0}^{t} \lambda_{\max}\big(F(t')\big)\, dt'. \tag{10}$$

Remark A.2. τ is invariant under reparametrization of t and measures cumulative identifiability rather than coordinate duration.

Loss of rigidity corresponds to non–monotonic or divergent τ.

B Extracting the action scale

For oscillatory kernels,

$$\mathcal{S}_* = \frac{\langle \partial_{t'} \Phi \rangle}{\omega_{\text{eff}}}, \tag{11}$$

where ω_{eff} is the dominant Fisher–weighted frequency.

Empirically, $\mathcal{S}_*$ coincides with $\hbar$ in quantum regimes, but CTMT does not assume this identification.

Appendix D: Known Failure Modes and Negative Results

CTMT is intentionally restrictive. Many seemingly reasonable kernel constructions fail its admissibility criteria. We briefly summarize common failure modes observed during development and testing.

Regime–dependent geometry leakage. Kernels in which geometric factors (e.g. loss coefficients or effective length scales) implicitly absorb regime–dependent behavior exhibit Fisher rank changes across operating points. Such kernels fail single–tuning transport and are rejected.

Overparameterized kernels. Adding redundant or weakly constrained parameters increases nominal model flexibility but leads to spectral degeneracy in the Fisher matrix, producing spurious coherence and false stability. These constructions fail under rank diagnostics.

Nonstationary aggregation without stacking. Attempting to model strongly nonstationary systems with a single static kernel leads to incoherent predictions and causality violations. Kernel stacking is required; omission results in detectable breakdown.

Empirical counterexamples. In several engineering datasets, candidate kernels that reproduced scaling laws locally failed to transport calibration constants globally. In all such cases examined, Fisher rank instability was observed, consistent with CTMT predictions.

Conclusion

CTMT is a theory of coherence geometry: it characterizes when kernel–based models possess a stable Fisher information structure and therefore admit meaningful forward prediction and parameter transport. All structure is computable, and all claims are falsifiable.

Interpretation: What CTMT Actually Claims

Chronotopic Metric Theory (CTMT) is intentionally formulated without ontological commitments to spacetime, fields, or particles. Nevertheless, its formal structure implies a number of interpretive consequences that clarify what the theory does—and does not—assert.

These consequences are not additional assumptions; they follow directly from the coherence, kernel, and information–geometric constraints developed in the preceding sections.

Time is emergent. CTMT does not postulate a background time parameter with intrinsic physical meaning. Ordering arises from coherence transport and Fisher–geometric monotonicity. The coherence proper time τ defines causal ordering independently of coordinate time, implying that what is physically experienced as "time" is an emergent measure of informational distinguishability under transport.

Geometry is emergent. No metric, manifold, or spatial structure is assumed at the outset. Effective geometry appears only in rigid regimes, where Fisher curvature and kernel phase structure stabilize. In non–rigid regimes, geometric descriptions lose invariance and may fragment or collapse, explaining why classical geometric intuition fails in transitional or mesoscopic systems.

Dimensionality is emergent. The effective dimensionality of a system is identified with the rank of the Fisher information matrix associated with admissible kernels. Dimensional reduction, spectral thinning, and mode collapse are therefore interpreted as informational phenomena rather than purely dynamical ones.

Null directions are emergent. Degrees of freedom corresponding to vanishing Fisher eigenvalues are operationally unobservable. Such null directions are not removed by fiat; they emerge dynamically through coherence loss and define the boundaries of effective physics within a given regime.

Causality is informational. Causal admissibility is defined through monotonicity of coherence proper time rather than through a predefined light cone or metric structure. Apparent violations of classical causality arise when coordinate time fails to track informational ordering, particularly in non–rigid or nonstationary regimes.

Rigidity defines the boundary between physics and non–physics. In CTMT, "physical" behavior corresponds to regimes in which kernel transport preserves Fisher rank and spectral structure. When rigidity is lost, predictive transportability fails, calibration constants cease to be meaningful, and effective laws break down. This boundary is not metaphysical but diagnostic: it is detectable directly from data.

Taken together, these statements clarify that CTMT is not a speculative replacement for existing physical theories. Rather, it provides a coherence–geometric criterion for when concepts such as time, geometry, dimension, and causality are well–defined and when they are not.

References

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