Invariance and Curvature

What Remains Meaningful in General Relativity

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Abstract

This paper investigates which quantities retain observer-independent semantic meaning in General Relativity by analyzing curved spacetime through an invariance-based semantic framework Theory and analyzing curvature-relative invariance. Observational outcomes form local semantic regimes under diffeomorphism-preserving equivalence, with no guarantee of global comparability. An invariant descent criterion is established: a quantity carries semantic meaning if and only if it descends to the curvature-relative quotient regime space. Coordinate time, global length, and simultaneity fail this criterion, while causal structure survives locally. Horizons and singularities are characterized as boundaries and breakdowns of semantic continuation rather than necessary physical discontinuities. Geometry constrains the scope of semantic invariants without introducing new semantic primitives.

Contents

1 Motivation and Scope

1.1 Why Invariance Determines Meaning

Observer-independent meaning requires invariance under admissible transformations. Without invariance, quantities cannot survive comparison across observational contexts.

1.2 From Geometry to Semantic Survivors

Geometry supplies representational freedom. Semantic meaning survives only where invariance persists under curvature-relative equivalence.

2 Core Definitions

Let (M, g) be a Lorentzian manifold.

Definition 2.1 (Observational Context)**.** An observational context is a triple $(U, \chi, \mathcal{P})$ consisting of an open domain $U \subset M$, representational structure χ, and admissible procedures $\mathcal{P}$ executable within U.

Definition 2.2 (Observational Outcome Space)**.** Let $\mathcal{O}_U$ denote outcomes obtainable in context U. Define $\mathcal{O} = \bigsqcup_{U \subset M} \mathcal{O}_U$.

Definition 2.3 (Admissible Transformation)**.** An admissible transformation is a diffeomorphism $\varphi : U \to U'$ preserving operational predictions under pullback.

Definition 2.4 (Curvature-Relative Equivalence)**.** $o \sim_{\text{curv}} o'$ if an admissible transformation maps o to o'.

Definition 2.5 (Curvature-Relative Invariant Space)**.** The curvature-relative invariant space is the quotient $\mathcal{I}_{\text{GR}} = \mathcal{O}/\sim_{\text{curv}}$.

Definition 2.6 (Semantic Invariant)**.** A quantity Q is semantically invariant if it factors uniquely through the canonical projection $\pi : \mathcal{O} \to \mathcal{R}_{\text{GR}}$.

Lemma 2.7 (Locality of Semantic Structure)**.** *Semantic regimes and invariants in curved spacetime are generally local.*

3 Invariance in General Relativity

3.1 Diffeomorphism Invariance Revisited

Diffeomorphism invariance expresses representational freedom, not semantic content.

3.2 Local vs. Global Invariance

Curvature restricts the domains over which invariance can be maintained.

3.3 Invariance Without Comparability

Invariance may persist locally even when global comparability fails.

4 Semantic Invariants Under Curvature

Definition 4.1 (Semantic Survivor). A quantity Q is a semantic survivor if $Q(o) = Q(o')$ whenever $o \sim_{\text{curv}} o'$.

Theorem 4.2 (Invariant Descent Criterion). *A quantity carries observer-independent semantic meaning iff it descends to a well-defined function on $\mathcal{R}_{\text{GR}}$.*

Proposition 4.3 (Failure of Metric Absolutes). *Coordinate time, global length, and simultaneity fail to descend as semantic invariants.*

Lemma 4.4 (Localization of Invariants). *Semantic invariants are generally defined only on restricted domains.*

Proposition 4.5 (Partial Semantic Descent). *Quantities may descend locally without admitting global extension.*

Remark 4.6. Curvature acts as a semantic filter, not a distortion mechanism.

5 Observation and Invariance

Definition 5.1 (Observation as Projection). Observation preserves invariant structure while discarding representational detail.

Proposition 5.2 (Epistemic Limits). *Observation cannot recover invariants eliminated by curvature-relative equivalence.*

Proposition 5.3 (Horizons as Invariant Boundaries). *Horizons mark limits of invariant extension rather than physical discontinuities.*

6 Consequences for General Relativity

Corollary 6.1 (Time Without Global Meaning). *General Relativity admits no globally meaningful notion of time.*

Corollary 6.2 (Length Without Absolute Scale)**.** *Spatial length is semantically meaningful only locally.*

Corollary 6.3 (Causality Without Synchronization)**.** *Causal structure survives as a semantic invariant; simultaneity does not.*

Corollary 6.4 (Singularities as Semantic Breakdown)**.** *Singularities correspond to failure of semantic continuation.*

Remark 6.5. Meaning disappears before geometry does.

7 Geometry, Invariance, and Semantic Minimalism

7.1 Why Geometry Overdescribes Meaning

Most geometric structure exceeds semantic necessity.

7.2 Semantic Economy

Physical theories should retain only invariant semantic survivors.

7.3 Curvature as Invariant Filter

Curvature restricts which quantities survive semantic descent.

8 Epistemic Scope and Non-Goals

8.1 What This Paper Does Not Add

No new dynamics or observables are introduced.

8.2 Why No New Observables Are Proposed

Semantic clarification requires elimination, not invention.

9 Conclusion

Semantic meaning in General Relativity is carried exclusively by quantities that survive curvature-relative invariance. Geometry bounds semantic scope without creating new semantic primitives. Curvature eliminates candidates for global meaning before distorting physical structure.

Curvature does not bend meaning. It removes global meaning first.

Appendix F: References

References

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