The Coherence Selection Principle

A Structural Completion of the Wheeler–DeWitt Framework

Abstract

The canonical quantization of gravity yields the Wheeler–DeWitt equation, which provides a formally consistent description of quantum spacetime dynamics but leaves unresolved the problem of selecting physically realized spacetime histories from the full space of mathematical solutions. While extensive work has addressed the associated Problem of Time, the equally fundamental Problem of Selection—the absence of any criterion distinguishing physically realizable quantum–geometric configurations—remains structurally unresolved.

In this work, we propose the **Coherence Selection Principle (CSP)** as a non-dynamical structural axiom completing the Wheeler–DeWitt framework at the level of physical admissibility. The CSP introduces a global coherence constraint on coupled quantum–geometric configurations, expressed as a diffeomorphism-invariant functional

$$\mathcal{C}(\psi, g_{\mu\nu}) = 0,$$

selecting only coherence-preserving configurations as physically realizable. The principle does not modify local dynamics, introduce collapse mechanisms, or add new degrees of freedom. Instead, it functions as an admissibility filter on the solution space of quantum gravity. Within this framework, classical spacetime structure and effective temporal ordering emerge relationally from sequences of admissible configurations. Observable consequences may arise as constraints on macroscopic quantum coherence, global consistency of semiclassical histories, and admissibility bounds on quantum–gravitational superpositions.

Introduction

Canonical approaches to quantum gravity achieve formal consistency while leaving unresolved questions at the level of physical realization. The Wheeler–DeWitt equation,

$$\hat{H}\Psi[g_{\mu\nu}, \phi] = 0,$$

provides a timeless constraint on the quantum state of spacetime but does not specify which solutions correspond to physically realized universes.

Two foundational deficiencies arise. The first is the **Problem of Time**, reflecting the absence of a fundamental temporal parameter. The second, less explicitly addressed, is the **Problem of Selection**: the absence of any criterion distinguishing physically realizable quantum–geometric configurations from the unrestricted solution space of the Wheeler–DeWitt equation.

This work argues that the Problem of Selection is logically prior. Without an admissibility principle, no notion of emergence, probability, or classical spacetime can be uniquely grounded. We propose the Coherence Selection Principle as a minimal structural axiom resolving this deficiency.

Structural Incompleteness of the Wheeler–DeWitt Equation

The Wheeler–DeWitt equation defines a constraint surface over the space of quantum–geometric configurations, treating all solutions that satisfy the Hamiltonian constraint as formally admissible. Within the canonical framework, no distinction is made between configurations that correspond to stable classical spacetimes and those that fail to support consistent large-scale structure.

In particular, the formalism provides no mechanism for selecting a definite classical spacetime, excluding globally inconsistent or unstable configurations, grounding probabilities over alternative histories, or explaining the observed dominance of semiclassical geometries. All such configurations remain equally permitted at the level of the Wheeler–DeWitt constraint.

This omission is not a technical deficiency of the equation but a structural incompleteness of the framework itself. While the Wheeler–DeWitt equation enforces local dynamical consistency, it remains silent on the criteria governing global physical realizability.

Minimal Coherence Requirement

We begin from a domain-independent physical requirement: any configuration that persists as physically realized must admit a globally consistent relational structure under environmental coupling. Physical realizability therefore requires the existence of stable relational records, bounded variance in relational observables, suppression of globally inconsistent histories, and self-consistent evolution across scales.

Configurations that fail to satisfy these conditions may be mathematically definable within the solution space of the Wheeler–DeWitt equation, but they do not stabilize as physical reality. Such configurations lack the global coherence necessary to support persistent relational structure across scales.

This requirement is non-dynamical and does not invoke observers, measurements, or agency. It functions as a truth condition on physical realizability rather than as a dynamical law governing evolution.

Statement of the Coherence Selection Principle

Coherence Selection Principle (CSP):
Among all quantum–geometric configurations permitted by local dynamical laws, only those satisfying a global coherence constraint are physically realizable.

Formally, this constraint is expressed as

$$\mathcal{C}(\psi, g_{\mu\nu}) = 0,$$

where ψdenotes the quantum state, $g_{\mu\nu}$the spacetime geometry, and $\mathcal{C}$a diffeomorphism-invariant functional encoding global coherence. Configurations for which $\mathcal{C} \neq 0$remain mathematically admissible but are physically unrealized.

Structural Properties of the Coherence Functional

While the explicit fundamental form of $\mathcal{C}$ is not fixed, it is assumed to satisfy a set of minimal structural properties required for physical admissibility. In particular, the coherence functional must be diffeomorphism invariant, ensuring coordinate-independent admissibility, and must depend globally and nonlocally on relational degrees of freedom rather than on any preferred foliation or local observable.

For physically realizable configurations, $\mathcal{C}$ is required to vanish for stable semiclassical geometries, while exhibiting positive-definite deviation for globally inconsistent or unstable configurations. These properties ensure that the coherence constraint discriminates between admissible and inadmissible configurations without introducing dynamical modification or probabilistic weighting.

In effective descriptions, $\mathcal{C}$ may be instantiated as a functional bounding variance in relational observables, instability in semiclassical backreaction, or the growth of incompatible entanglement structures across foliations. The Coherence Selection Principle does not require a unique realization of $\mathcal{C}$, only that physically realizable configurations satisfy the coherence constraint.

In this sense, $\mathcal{C}$ defines a necessary condition for physical realizability rather than a sufficient dynamical criterion.

Nature of the CSP

The Coherence Selection Principle is non-dynamical in character and does not modify the equations of motion governing quantum or gravitational degrees of freedom. It introduces no stochastic elements, collapse mechanisms, or probabilistic dynamics, and it does not rely on observers, measurements, or agency in any form.

Instead, the CSP functions as a global consistency condition defining the physically admissible subspace of the Wheeler–DeWitt solution space. It constrains realizability without altering local dynamics, serving solely as an admissibility criterion on the space of quantum–geometric configurations.

CSP as an Admissibility Filter

Local dynamical laws generate a space of possible histories. Decoherence explains the suppression of interference within candidate histories but does not explain why a particular global history structure is realized. The CSP supplies this missing selection criterion by excluding globally incoherent configurations.

Decoherence without selection therefore remains structurally incomplete.

Reframing the Problem of Time

Within the CSP framework, time is not fundamental but emergent. Effective temporal ordering arises from sequences of coherence-preserving configurations supporting consistent relational records. Classical time appears when the coherence constraint remains satisfied across sequences and variance in relational observables remains bounded.

The Problem of Time is thus reframed as a consequence of selection rather than the absence of a temporal variable.

Relation to Existing Approaches

The CSP does not deny the mathematical existence of branching structures in many-worlds formulations. It asserts that only branch structures admitting global coherence and stable relational records are physically realizable.

Dynamical collapse models may be interpreted as phenomenological encodings of coherence constraints, though the CSP does not require such mechanisms.

Phenomenological Encodings and Testability

Although non-dynamical, the Coherence Selection Principle constrains the class of admissible effective theories. In particular, it implies bounds on macroscopic quantum coherence in curved spacetime, suppression of globally inconsistent interference patterns, selection biases in early-universe initial conditions, and constraints on the global consistency of black-hole information histories.

Failure to observe any such admissibility constraints in regimes where global coherence bounds are theoretically required would falsify the principle.

Scope and Limitations

The CSP does not predict collapse rates, specify mass thresholds, or replace quantum dynamics. It provides a **structural completion** rather than a new force or interaction.

Conclusion

The Wheeler–DeWitt equation is dynamically complete but structurally underdetermined. The Coherence Selection Principle supplies the missing admissibility condition governing which quantum–geometric configurations are physically realizable. By introducing a minimal global coherence constraint, the CSP resolves the Problem of Selection and reframes the Problem of Time without modifying established physics. It constitutes a foundational principle governing physical realizability in quantum spacetime.