Collapse Geometry as a Minimal Ontology

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April 13, 2026

Abstract

Across modern physics, diverse frameworks describe the emergence of stable structure under constraint. Quantum mechanics, classical dynamics, thermodynamics, renormalization group theory, and decoherence each identify persistent configurations within their respective domains, yet none fully accounts for the generative origin of that persistence.

This work proposes Quantum Collapse Geometry (QCG) as a minimal ontological framework in which physical structure arises through selection under constraint. Collapse is treated not as a measurement artifact or dynamical anomaly, but as a primitive operation acting on a relational configuration space. Observable structure is identified with configurations that persist under repeated collapse-selection.

Within this framework, effective dynamical generators are derived as scale-local descriptions of collapse, and physical laws are shown to correspond to fixed points under collapse-induced renormalization. Entire theoretical frameworks—including quantum mechanics, classical mechanics, and thermodynamics—are reinterpreted as attractor regimes in the space of collapse-generated dynamics. Transitions between these regimes are described as flows between attractor basins, while the breakdown of theories is explained by their application outside their domain of stability.

The framework further establishes the existence of epistemic horizons separating attractor regimes, implying that no single theory can fully reconstruct the generative structure beneath it. This leads to a general principle of emergent–primitive misassignment: when an emergent descriptive structure is treated as fundamental, a theory loses access to the regime in which that structure is generated.

Finally, collapse itself is identified as the generative boundary of physics: all physical theories describe only the invariant residue of collapse-selection, while collapse defines the limit beyond which no physical description can extend.

QCG does not replace existing theories, but situates them within a unified generative architecture, providing a coherent account of why physical laws, structures, and limitations arise.

The ontology underlying QCG is collapse-first and relational.

We assume a configuration space of relational structure, together with a primitive collapse operator that enforces admissibility under constraint. Physical structure corresponds to configurations invariant under repeated collapse, while dynamical laws arise as effective, scale-local descriptions of persistence.

Geometry, time, and quantum structure are therefore emergent, not fundamental, and correspond to stable regimes of collapse-induced dynamics. The categorical formulation models this selection process as a lax idempotent comonad whose coalgebras represent collapse-stable structure.

1 Introduction

The Problem of Structure. Modern physics provides an extraordinary collection of successful theoretical frameworks. Quantum mechanics predicts microscopic phenomena with remarkable precision. Classical mechanics accurately describes macroscopic motion within its domain. Thermodynamics captures universal constraints on large-scale systems, independent of microscopic detail. Renormalization group theory explains why diverse systems exhibit identical large-scale behavior, and decoherence heory clarifies the emergence of classical structure from quantum dynamics.

Despite these successes, a common feature persists: each framework describes *stable structure within a regime*, yet none fully explains the *generative origin* of that structure.

Quantum theory leaves unresolved the transition from superposition to definite outcomes. Classical mechanics presupposes well-defined trajectories without accounting for their emergence. Thermodynamics describes equilibrium without deriving the admissibility of its state space. Renormalization explains the persistence of structure under scale transformation, but not why such persistence arises in the first place.

These are not isolated gaps. They reflect a deeper pattern.

A Recurring Structure. Across otherwise distinct domains, a common structure appears:

> A space of possibilities is constrained, and a subset of configurations persists.

In quantum systems, interaction with the environment suppresses unstable superpositions and selects robust states. In statistical mechanics, coarse-graining eliminates microscopic detail while preserving macroscopic invariants. In renormalization, irrelevant degrees of freedom are removed while fixed-point structure remains. In dynamical systems, stable trajectories and attractors emerge under iteration.

Each of these frameworks identifies persistence under constraint, yet treats the mechanism of selection as secondary or external.

From Persistence to Selection. This work proposes that the recurring pattern above is not incidental, but reflects a more fundamental generative principle.

Rather than treating collapse, decoherence, or coarse-graining as auxiliary processes, we elevate selection under constraint to a primitive operation. Within this perspective, the central question is not how systems evolve, but:

> Which configurations are admissible, and which persist under repeated constraint?

Quantum Collapse Geometry. Quantum Collapse Geometry (QCG) introduces a minimal ontological framework in which physical structure arises through collapse-selection acting on relational configurations.

At its core, the framework assumes:

- a relational configuration space Σ,
- a collapse-selection operator $\Phi : \Sigma \to \Sigma$,
- persistence under Φ as the criterion of observable structure.

This shift in perspective reinterprets familiar physical concepts:

- geometry emerges from stable relational structure,

- dynamical laws arise as effective descriptions of persistent behavior,
- equilibrium reflects post-selection ordering of admissible states.

QCG does not modify existing physical formalisms. Instead, it provides a generative interpretation of the structures that appear within them.

Scope and Approach. The aim of this work is not to replace established theories, but to situate them within a unified ontological framework. To this end, we:

- formalize collapse-selection as a generative operation,
- derive local effective generators describing observable dynamics,
- show that physical laws correspond to fixed points under renormalization,
- identify entire theories as attractor regimes of collapse dynamics,
- demonstrate the existence of epistemic horizons limiting cross-regime description,
- establish collapse as the generative boundary of physical theory.

The framework is constructed to remain compatible with existing empirical results while clarifying their structural origin.

Emergence and Limitation. A key consequence of this approach is a general principle:

> When an emergent structure is treated as primitive, a theory loses access to the regime in which that structure is generated.

This principle explains why otherwise successful frameworks encounter predictable limitations when extended beyond their domain of validity.

Positioning. The perspective developed here is deliberately conservative in its empirical claims and ambitious in its conceptual scope.

- Conservative, in that it preserves all established physical results within their domains,
- Ambitious, in that it proposes a unifying generative principle underlying those domains.

Guiding Idea. The central idea of this work may be summarized succinctly:

> Physical reality consists of configurations that persist under constraint.

Everything else—geometry, dynamics, and law—arises as an effective description of that persistence.

Roadmap. The remainder of this work develops this idea in stages. We begin by formalizing collapse-selection and its induced generator structure, then establish the renormalization hierarchy linking scales. We show how laws emerge as fixed points, how theories correspond to attractor regimes, and why epistemic horizons limit cross-regime description. Finally, we identify collapse itself as the generative boundary of physics and summarize the framework as a minimal ontology.

The goal is not to provide a final theory, but to articulate a coherent structure within which existing theories can be understood as parts of a larger whole.

2 Summary: Collapse Geometry as a Minimal Ontology

Overview. This work has proposed Quantum Collapse Geometry (QCG) as a minimal ontological framework in which physical structure arises not from pre-existing geometric or dynamical primitives, but from selection under constraint.

Rather than beginning with spacetime, fields, or evolution laws, QCG takes as primitive a single generative operation:

$$\Phi : \Sigma \to \Sigma,$$

interpreted as collapse-selection acting on a relational configuration space Σ.

Core Claim. The central thesis of QCG can be stated concisely:

> Observable physical structure consists of configurations that persist under repeated collapse-selection.

Everything else—geometry, dynamics, and law—arises as an effective description of this persistence.

Generative and Descriptive Layers. A key distinction throughout this work has been between:

- **Generative structure:** the collapse-selection process Φ that defines admissibility,
- **Descriptive structure:** effective generators $\mathcal{G}_\lambda$ that summarize stable behavior within a given regime.

This distinction resolves long-standing ambiguities in physical theory, in which descriptive constructs are often implicitly treated as primitive.

Emergence of Physical Law. Within this framework, physical laws are not fundamental prescriptions, but stable fixed points of collapse-induced renormalization. That is:

> A physical law corresponds to a generator that remains invariant under coarse-graining.

Different laws correspond to different fixed-point structures in the space of admissible dynamics.

Hierarchy of Theories. Entire theoretical frameworks emerge as attractor regimes:

- Quantum mechanics describes weakly constrained regimes with large admissibility spaces,
- Classical mechanics describes regimes in which only stable trajectories persist,
- Thermodynamics describes extreme coarse-grained regimes in which only aggregate invariants remain.

These are not competing descriptions, but successive layers in a hierarchy of collapse-selected structure.

Epistemic Limits. The framework naturally yields limits on physical description. Each attractor regime is bounded by an epistemic horizon:

- information eliminated by collapse cannot be reconstructed,
- no theory can fully describe the generative layer beneath it,
- cross-regime descriptions fail when applied outside their basin of validity.

Thus, incompleteness is not a deficiency of specific theories, but a structural feature of collapse.

Emergent–Primitive Misassignment. A recurring source of conceptual difficulty is the elevation of emergent structure to primitive status. QCG formalizes this as:

> A theory fails when it treats its attractor-level description as fundamental, ignoring the generative layer that produces it.

This principle explains why geometry-first, quantum-first, and thermodynamic-first ontologies each encounter predictable limitations.

The Generative Boundary. All descriptive frameworks terminate at a common boundary: collapse itself.

> Physics describes the invariant residue of collapse-selection, while collapse defines the boundary beyond which no physical description can extend.

This boundary is not empirical but structural, arising from the non-invertibility of collapse.

Unification. From this perspective, unification is not achieved by reducing all phenomena to a single equation, but by identifying the shared collapse structure that generates all attractor regimes.

- Laws are fixed points,
- theories are attractors,
- observables are invariants,
- collapse is the generative origin of all of them.

Minimal Ontology. QCG therefore proposes a minimal ontological basis for physics:

1. A relational configuration space Σ,
2. A collapse-selection operator Φ,
3. Persistence under Φ as the criterion of reality.

No additional primitive structure is required.

Final Statement. The framework developed here may be summarized in a single line:

> Reality is the set of configurations that remain invariant under collapse.

All physical description follows from this principle.

Collapse Geometry does not replace existing theories. It explains why they exist, why they work, and why they fail.