# Quantum Collapse Geometry:
# A Generative Ontology of Structure, Law, and Persistence

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**Abstract**

Across physics, mathematics, and complex systems, successful frameworks describe stable structure under constraint, yet do not specify the generative origin of that stability. Renormalization group theory identifies invariance under scale transformation, decoherence selects robust states under environmental interaction, and thermodynamics characterizes persistent macroscopic structure. Despite their differences, these frameworks share a common structural pattern: a space of possibilities is restricted, and a subset of stable configurations persists.

This work proposes Quantum Collapse Geometry (QCG) as a minimal generative ontology in which collapse—understood as selection under constraint—is treated as a primitive operation acting on relational configuration space. Collapse-selection is the generative mechanism underlying all persistence across physical frameworks. Observable structure is identified with configurations that persist under repeated collapse-selection. Effective dynamics, physical laws, and entire theoretical frameworks are reinterpreted as emergent descriptions of invariant structure under this process.

The framework unifies diverse domains through a single generative mechanism:

$$\text{Constraint} \ \rightarrow \ \text{Selection (Collapse)} \ \rightarrow \ \text{Persistence} \ \rightarrow \ \text{Structure.}$$

QCG does not replace existing theories, but situates them within a shared generative architecture, clarifying both their empirical success and their structural limitations.

## 1 Introduction

Modern theoretical frameworks successfully describe stable structure within well-defined domains, yet leave unresolved the question of how such structure arises.

Quantum mechanics predicts microscopic phenomena with remarkable precision, but does not fully explain the emergence of definite outcomes. Renormalization group (RG) theory explains the persistence of large-scale structure under coarse-graining, but does not address why such persistence arises. Thermodynamics characterizes equilibrium states, yet does not derive the admissibility of its state space.

Despite their differences, these frameworks exhibit a common structural feature:

- A space of possible configurations is defined,
- Constraints act on that space,
- Unstable configurations are eliminated,
- A restricted set of stable structures persists.

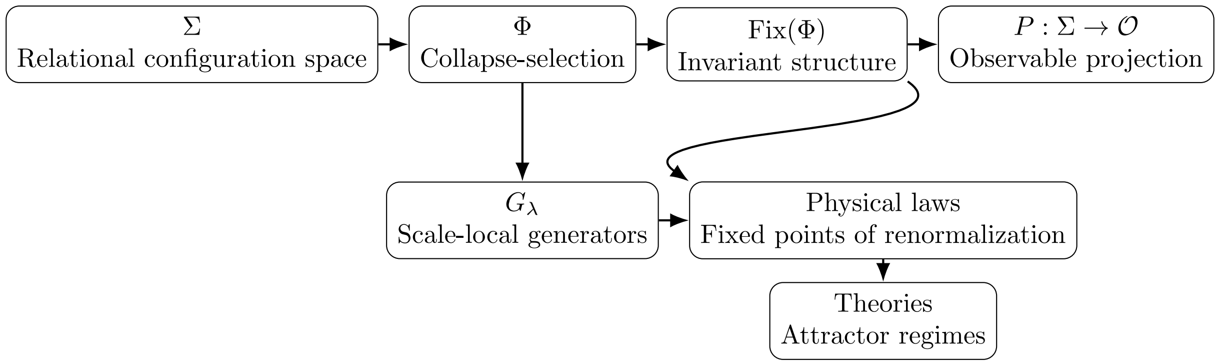


Figure 1: Complete structural pipeline of QCG from generative ontology to effective theory. A relational configuration space $\Sigma$ is acted on by collapse-selection $\Phi$, producing invariant structure Fix($\Phi$) whose observable residue is accessed by projection $P$. Under coarse-graining, collapse induces scale-local generators $G_\lambda$; stable fixed points of their renormalized flow define effective physical laws, while entire theories appear as attractor regimes of the resulting hierarchy.

What is missing is a unifying account of the mechanism underlying this pattern.

Quantum Collapse Geometry (QCG) addresses this gap by elevating selection under constraint to a primitive operation. Rather than treating persistence as fundamental, QCG treats it as the outcome of a generative selection process.

Figure 1 summarizes the full structural pipeline of QCG from generative ontology to effective theory.

## 2 The Structural Pattern

The recurring structure observed across domains can be expressed schematically as:

$$\text{Configuration Space} \rightarrow \text{Constraint} \rightarrow \text{Selection} \rightarrow \text{Persistence}.$$

Existing frameworks describe different aspects of this process:

- RG theory: persistence under scale transformation,
- Decoherence: persistence under environmental interaction,
- Thermodynamics: persistence under dissipation,
- Information theory: persistence under operational constraint.

In each case, the framework identifies which structures persist, but does not treat the selection mechanism itself as fundamental.

QCG proposes that this omission is structural. The missing element is collapse, understood not as a measurement artifact, but as a general selection process acting on relational configurations.

To formalize this pattern, we now introduce a minimal ontology in which selection is treated as primitive.

# 3 Minimal Ontology

QCG is based on a minimal set of primitives:

- A relational configuration space $\Sigma$,
- A collapse operator $\Phi : \Sigma \to \Sigma$,
- A projection $P : \Sigma \to \mathcal{O}$ to observable structure.

The collapse operator acts iteratively:

$$x_{n+1} = \Phi(x_n),$$

driving configurations toward stable sectors.

Define the invariant (collapse-stable) set:

$$\mathrm{Fix}(\Phi) = \{x \in \Sigma \mid \Phi(x) = x\}.$$

**Core Principle.** Observable structure consists of configurations that persist under repeated collapse:

$$\text{Observable Structure} = P(\mathrm{Fix}(\Phi)).$$

Thus, physical structure is identified not with all possible configurations, but with those invariant under admissibility constraints.

# 4 From Collapse to Physical Description

## 4.1 Effective Generators and Physical Law

While collapse operates at the generative level, physical description occurs at finite resolution. This induces effective dynamics on coarse-grained state spaces.

Let $\pi_\lambda : \Sigma \to S_\lambda$ denote a projection at scale $\lambda$. Then collapse induces an effective evolution:

$$\pi_\lambda \circ \Phi \approx E_\lambda \circ \pi_\lambda.$$

When defined, this yields a generator $G_\lambda$.

**Interpretation.**

- $\Phi$ defines admissibility (what can exist),
- $G_\lambda$ describes persistence (what survives),
- Physical laws arise as stable structures of $G_\lambda$.

**Key Claim.** Physical laws correspond to fixed points under collapse-induced renormalization:

$$R(G^*) = G^*.$$

### 4.2 Quantum Formalism as Effective Description

Within this framework, standard quantum structures admit reinterpretation:

| Quantum Mechanics | QCG Interpretation |
|---|---|
| State vector | Relational configuration |
| Projection | Collapse selection |
| Eigenstate | Collapse-stable sector |
| Measurement | Descriptive registration |
| Probability | Measure over basins of attraction |

Quantum theory thus functions as an effective descriptive language encoding collapse-stabilized relational structure.

### 4.3 Open Systems and Decoherence

Open quantum systems described by Lindblad dynamics take the form:

$$\dot{\rho} = -i[H, \rho] + \sum_{\mu} \left( L_\mu \rho L_\mu^\dagger - \frac{1}{2}\{L_\mu^\dagger L_\mu, \rho\} \right).$$

Within QCG:

- $H$ encodes intrasector evolution,
- $L_\mu$ represent structured collapse channels,
- The Liouvillian spectrum encodes stability structure.

Decoherence is thus interpreted as an effective manifestation of collapse-selection rather than its cause.

## 5 Layered Emergence and Closure

Collapse induces a hierarchy of descriptive layers.

Let $\Sigma_n$ denote a generative space, and $C_n$ a collapse operator. Define:

$$I_n = \{x \in \Sigma_n \mid C_n(x) = x\}.$$

Then invariant structure $I_n$ serves as the effective generative basis for the next layer:

$$\Sigma_n \to I_n \sim \Sigma_{n+1}.$$

**Layered Invariant Generator Principle.** Invariant structure:

1. does not uniquely determine its generating dynamics,
2. retains sufficient structure to generate the next layer.

This induces a recursive cycle:

$$\text{Generation} \to \text{Selection} \to \text{Invariant} \to \text{New Generation}.$$

Thus, structure is not merely emergent—it becomes generative at higher scales.

## 6 Categorical Formulation

Collapse-selection admits a categorical formulation.

Given a bicategory $\mathcal{C}$ with admissible endomorphisms, collapse induces a lax idempotent comonad:

$$(\mathrm{Coll}, \varepsilon, \delta),$$

with:

$$\mathrm{Coll}^2 \cong \mathrm{Coll}.$$

Stable objects arise as coalgebras:

$$X \cong \mathrm{Coll}(X).$$

**Interpretation.** Stability corresponds to invariance under admissible dynamics, formalized as a coreflective subcategory.

## 7 What QCG Adds

Existing frameworks treat different structures as primitive:

- Geometry-first frameworks,
- Field-based frameworks,
- Information-theoretic frameworks,
- Algebraic or categorical frameworks.

QCG reclassifies these as emergent layers.

**Emergent–Primitive Misassignment Principle.** When an emergent structure is treated as primitive, a theory loses access to the regime in which that structure is generated.

Thus:

- Geometry emerges from stable relational structure,
- Dynamics emerge from persistence,
- Laws emerge from invariant generators.

QCG does not replace existing theories, but situates them within a unified generative hierarchy.

## 8 Conclusion

Quantum Collapse Geometry proposes a minimal generative ontology in which collapse-selection governs the emergence of structure.

Physical reality is not defined by the full space of possibilities, but by the subset that persists under constraint.

What exists physically is not what is possible, but what survives collapse.

**Central Thesis.**

$$\text{Physical structure} = \text{invariant residue of collapse-selection.}$$

Within this framework:

- collapse is primitive,
- persistence defines observability,
- laws emerge as stable fixed points,
- theories correspond to attractor regimes.

This perspective unifies diverse domains under a single generative principle, providing a coherent account of structure, law, and emergence without modifying existing formalism.