Quantum Collapse Geometry: The Generative Ontology of Physical Law

Paper I: Foundations of Collapse, Phase, and Coupling

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December 9, 2025

Abstract

This paper introduces the foundational ontology underlying Quantum Collapse Geometry (QCG), a framework in which collapse events, phase relations, and coupling constraints jointly generate physical structure. In contrast to approaches that treat fields, forces, or spacetime geometry as fundamental, QCG posits that phase coupling is ontologically primary, collapse is the universal update mechanism, and time is the macroscopic synchronization of collapse-induced periodicity. A discrete collapse-phase lattice is proposed as the primitive structure, equipped with a Lagrangian and a collapse action governing both smooth evolution and stochastic state updates. From this ontology emerge energy, charge, force, geometric structure, and temporal ordering. This paper articulates the conceptual architecture, formal definitions, and foundational dynamics of QCG, establishing a generative framework for future mathematical development.

1 Introduction

Most physical theories begin with established structures—fields on manifolds, Hilbert spaces, gauge symmetries—and derive dynamics from those primitives. Quantum Collapse Geometry (QCG) reverses this approach. It posits that the basic ingredients of physical reality are:

- collapse events,
- phase relations between local degrees of freedom,
- coupling constraints governing how phase information propagates.

Spacetime geometry, temporal ordering, and fundamental forces arise from the collective behavior of these primitives on a dynamically evolving lattice. Collapse is not tied to measurement or observers; instead, it is a ubiquitous generative process that continuously reorganizes local configurations and propagates influence. Phase relations encode relational tension, while coupling constraints mediate how disturbances spread through the system.

This paper establishes the ontology, mathematical structure, and dynamical principles underlying QCG. It presents the first formal Lagrangian, the collapse action functional, and precise definitions of energy, charge, and force within this generative framework.

2 Ontological Primitives

QCG is defined on a discrete collapse-phase lattice

$$G = (V, E),$$

where V is the set of sites and E is the set of edges. The lattice need not be embedded in any pre-existing geometry; geometry will emerge from the relational structure.

Each site $i \in V$ carries:

- a phase variable $\phi_i(\tau) \in S^1$,
- optional amplitude or occupation degrees of freedom,
- access to a local collapse rate.

Each edge $(i, j) \in E$ carries a symmetric coupling strength $K_{ij}(\tau) = K_{ji}(\tau) \in \mathbb{R}^+$.

The system evolves according to two intertwined processes:

1. smooth phase evolution governed by a Lagrangian,
2. stochastic collapse events that reset local phases and update couplings.

The variable τ is a pre-temporal evolution parameter; emergent time t will be defined later from synchronization properties of the phase field.

Collapse events are treated as ontologically real and dynamically primary. They act as state updates that propagate phase-correction fronts through the lattice, generating coherence and structure.

3 Energy, Charge, and Force as Derived Quantities

In QCG, physical quantities emerge from phase-coupling structure.

3.1 Energy as Phase Tension

Define the phase energy functional:

$$E = \sum_{(i,j)\in E} K_{ij} \left[1 - \cos(\phi_j - \phi_i)\right]. \tag{1}$$

This functional is minimized when neighboring phases are aligned. Misalignment stores tension; collapse events reduce local tension and propagate corrective influence. Energy is thus not primitive, but a measure of relational strain in the phase-coupling network.

3.2 Charge as Phase Winding

Given a closed loop γ in the lattice, define the winding number:

$$Q_\gamma = \frac{1}{2\pi} \sum_{(i,j)\in\gamma} \operatorname{Arg}\left(e^{i(\phi_j - \phi_i)}\right). \tag{2}$$

Charge is therefore a topological invariant of the phase field. Quantization follows naturally: $Q \in \mathbb{Z}$. Charges correspond to stable phase defects that persist under collapse dynamics.

3.3 Force as Gradient of Phase Tension

Differentiating the energy with respect to phase yields:

$$F_i = -\frac{\partial E}{\partial \phi_i} = -\sum_j K_{ij} \sin(\phi_j - \phi_i). \tag{3}$$

Force is the restoring influence that drives local synchronization. It is not a field or a primitive, but an emergent consequence of tension gradients.

4 Lagrangian Dynamics Between Collapse Events

Between collapse events, the system evolves smoothly according to the Lagrangian:

$$L_{\text{phase}} = \sum_i \frac{I_i}{2} \dot{\phi}_i^2 - \sum_{(i,j)} K_{ij} \left[1 - \cos(\phi_j - \phi_i)\right]. \tag{4}$$

Coupling parameters may also evolve dynamically,

$$L_{\text{coupling}} = \sum_{(i,j)} \left[\frac{M_{ij}}{2} \dot{K}_{ij}^2 - V_K(K_{ij})\right], \tag{5}$$

where V_K is a stabilizing potential.

The full smooth Lagrangian is:

$$L_{\text{smooth}} = L_{\text{phase}} + L_{\text{coupling}}. \tag{6}$$

Euler–Lagrange equations applied to ϕ_i and K_{ij} yield deterministic evolution between collapses.

5 Collapse Dynamics and the Action Functional

Collapse events occur at stochastic times $\{\tau_k\}$ at sites $\{i_k\}$ with rates depending on local tension. Define a collapse cost functional:

$$\mathcal{C}_i(\phi, K) = \alpha E_i + \beta f(\lambda_i), \tag{7}$$

where E_i is the local contribution to the phase energy and λ_i is the local collapse rate.

Define the collapse action:

$$S_{\text{collapse}} = \sum_k \mathcal{C}_{i_k}\big(\phi(\tau_k^-), K(\tau_k^-)\big). \tag{8}$$

The full action of a history is:

$$S_{\text{QCG}} = \int L_{\text{smooth}}\, d\tau + S_{\text{collapse}}. \tag{9}$$

This action weighs histories according to both smooth evolution and the "cost" of collapse events.

6 Emergent Time from Phase Synchronization

Define the Kuramoto order parameter:

$$re^{i\Psi} = \frac{1}{|V|}\sum_j e^{i\phi_j}. \tag{10}$$

The global phase Ψ increases approximately linearly in coherent regimes. Emergent time is defined by:

$$t = \alpha\, \Psi(\tau). \tag{11}$$

Thus, time is a large-scale synchronization artifact of collapse-driven phase alignment.

7 Emergent Geometry from Coupling Structure

Define an effective edge length:

$$w_{ij} = f(K_{ij}, \phi_j - \phi_i), \tag{12}$$

and graph distance:

$$d(i,j) = \min_{\gamma: i\to j} \sum_{(m,n)\in\gamma} w_{mn}. \tag{13}$$

In the continuum limit, this induces an emergent metric $g_{\mu\nu}(x)$.

Collapse density modulates curvature:

$$R(x) \sim h(\rho_C(x)). \tag{14}$$

Regions of intense collapse behave gravitationally by generating effective curvature.

8 Minimal Toy Model

A ring of N sites with uniform coupling K exhibits:

- collapse-induced synchronization,
- topological charge stability,
- propagating phase-alignment fronts,
- the formation of coherent structures resembling particle-like excitations.

Simulation studies will appear in a future paper.

9 Research Program and Future Work

Paper II will:

- derive continuum field equations,
- explore the emergent curvature tensor,
- formalize the collapse operator algebra.

Paper III will examine:

- force laws from synchronization dynamics,
- emergent gauge structure,
- analogues of electromagnetic and gravitational fields.

Additional papers will investigate cosmology, entropy, particle excitations, and observable signatures.

10 Conclusion

Quantum Collapse Geometry proposes that collapse events, phase relations, and coupling constraints form the generative ontology of physics. From these primitives emerge energy, charge, force, geometry, and time. This paper establishes the conceptual and mathematical foundation for a unified collapse-based framework of physical law.