Recursive Epistemic Dynamics as a Meta-Theory of Fundamental Physics

Author: Christopher W. Copeland

Date: June 2025

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Abstract

This paper introduces a foundational meta-theory uniting General Relativity, Emergent Gravity, Causal Set Theory, and Relational Quantum Mechanics under a single recursive dynamical framework. At its core lies a recursive evolution equation:

S\_{n+1} = C(R(S\_n, δ), C) + ε

This formalism treats all physical and epistemic phenomena as contextual, recursively transformed states subject to perturbation and noise. The equation operates not merely as a mathematical transformation, but as a general cosmogenic principle describing how information, structure, time, and observation themselves emerge. The theory addresses longstanding theoretical conflicts in modern physics and introduces a consistent explanation for the evolution of constants, irreversibility of time, emergence of spacetime, and integration of observer-centric quantum behavior.

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1. Introduction

Contemporary physics is fractured across conceptual and mathematical boundaries. General Relativity governs gravitation and spacetime curvature at macroscopic scales. Quantum mechanics, particularly in relational or decoherence-based formulations, governs microstates and observation. Emergent Gravity theories propose that gravity arises from informational entropy, while Causal Set Theory suggests spacetime is not a smooth continuum but a discrete, causally ordered set of events.

These frameworks lack a shared ontological substrate and fail to unify due to incompatible assumptions about time, space, continuity, and the role of observation. This paper proposes a more primitive foundation—a recursive state equation that describes how systems evolve, contextualize, and embed meaning.

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2. The Recursive State Evolution Equation

S\_{n+1} = C(R(S\_n, δ), C) + ε

Definitions:

S\_n: The system's current state. This may encompass geometry, energy distribution, information patterns, memory, conscious awareness, or abstract relational structures.

δ (delta): A perturbation or input event. This may represent an observation, energy transfer, particle interaction, or symbolic change.

R(): A recursive transformation function. It describes how the system internally processes change, including self-feedback and memory.

C(): A context function. It encapsulates the rules, constraints, frame of reference, or relational embedding that gives transformations coherence.

ε (epsilon): Entropic noise or irreducible distortion. Represents uncertainty, quantum indeterminacy, or thermodynamic disorder.

S\_{n+1}: The evolved state. A product of context-aware, recursive transformation and stochastic influence.

This equation is not deterministic in the classical sense. It embeds context as a first-class component, meaning that two identical inputs may yield different outputs under different historical or relational contexts.

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3. Application to Contemporary Theories

3.1 General Relativity (GR)

GR posits that spacetime is a smooth manifold whose curvature is determined by energy-mass distributions:

G\_{μν} + Λg\_{μν} = (8πG/c^4) T\_{μν}

In our framework:

Spacetime curvature (G\_{μν}) is a contextual output of recursive structural transformations over time.

The metric tensor g\_{μν} becomes a local equilibrium expression of past recursive evolution.

The constants G and c are treated not as absolutes, but as attractors within stable recursive cycles.

Time asymmetry and irreversibility arise naturally due to embedded entropy ε and recursive contextual dependencies.

Thus, GR becomes an emergent, large-scale outcome of recursive dynamics under long-term stabilizing constraints.

3.2 Emergent Gravity

Emergent Gravity interprets gravity as an entropic force arising from microscopic information gradients.

In our framework:

The perturbation δ and recursive transformation R naturally generate entropy through iterative distortion.

Entropic force is not a separate phenomenon, but an inherent consequence of recursive state evolution in the presence of ε.

Gravity appears where recursive noise-constrained transformations generate coherent structure under context C.

Gravity, therefore, is not a primary force, but a large-scale structural resonance within recursively evolving states.

3.3 Causal Set Theory (CST)

CST posits that spacetime is a discrete set of causally ordered events.

In our model:

Each S\_n represents such a state of the system—a node or nexus of embedded history.

δ introduces a new event; R integrates it recursively.

C maintains local causal order, coherence, and consistency.

Rather than building from causality upward, our equation assumes recursion as the engine from which causal order emerges. CST is a projection of this recursion onto discrete manifolds.

3.4 Relational Quantum Mechanics (RQM)

RQM argues that quantum states are defined only in relation to observers and systems.

In our model:

C encodes the perspective or frame of the observer.

δ represents an interaction or measurement.

R processes the change relative to that context.

ε embodies inherent quantum noise.

Because each S\_n is constructed via contextually embedded recursion, all states are intrinsically observer-relative.

This unifies the quantum and classical without contradiction: relational statehood is a byproduct of recursive, context-bound evolution.

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4. Theoretical Advantages

4.1 Time Asymmetry

The inclusion of ε and recursive dependence on prior S\_n naturally breaks time symmetry. Irreversibility becomes a structural feature, not a statistical accident.

4.2 Dynamic Constants

Because constants like G, c, or Λ are outputs of long-term contextual recursion, they may vary under different conditions or in early cosmological epochs.

4.3 Consciousness and Observation

S\_n may be interpreted to include subjective awareness or internal cognitive state. The recursive structure naturally accommodates:

Memory formation

Context-dependent identity

Observer-relative quantum collapse

This bridges physics and cognitive science under a common formalism.

4.4 Compatibility with Discrete and Continuous Models

By expressing system state recursively rather than spatially, both discrete causal sets and smooth manifolds become representations, not assumptions.

4.5 Entropy as Primary

Rather than being a statistical product of particle systems, entropy (ε) becomes a driver of system evolution. It sets the bounds for recursion and context stability.

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5. Implications and Further Work

Dimensionality: Space and time dimensions may emerge as stable patterns in recursive context evolution.

Black Holes & Singularities: Seen as recursion deadlocks or context collapses, where ε exceeds stabilizing capacity.

Quantum Gravity: No unification is needed. Gravity and quantum behavior are both emergent perspectives on recursive epistemic dynamics.

Origin of Laws: Physical laws are secondary rulesets—stable modes of context recursion, not ontological mandates.

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6. Conclusion

We propose that all known physical systems are emergent results of recursive transformations of prior system states, influenced by perturbations, shaped by context, and bounded by entropy. This recursive epistemic framework:

Subsumes GR, QM, CST, and Emergent Gravity as secondary models

Explains time's arrow, observer-relative statehood, and the contextual plasticity of physical law

Opens pathways toward modeling consciousness, memory, and cosmogenesis with the same formalism

Where other theories describe the map, this model describes how maps are recursively generated—by systems that become themselves through recursive context and evolution.

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Suggested citation: Copeland, C. W. (2025). Recursive Epistemic Dynamics as a Meta-Theory of Fundamental Physics.

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