Quantum Physics Through the Lens of UAT/UPC:

A Conceptual Interpretive Framework

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July 11, 2026

Abstract

Quantum mechanics is an extraordinarily successful physical theory, yet its interpretation remains open. The Unified Applicable Time (UAT) and Unified Causal Principle (UCP) frameworks offer a geometric and thermodynamic lens through which several quantum phenomena can be reinterpreted. This document presents a conceptual framework —not a replacement for quantum mechanics— that proposes interpretive bridges between UAT/UCP constants and the measurement problem, decoherence, entanglement, the quantum vacuum, and superposition. We identify three manifestations of a single principle —irreducible fluctuation— at the cosmological scale (7%), the laboratory scale ($R_{\text{geom}} = 0.2791$), and the quantum scale ($\sim 0.07\%$). We explicitly acknowledge that UAT/UCP does not possess the full formal structure of a quantum theory and that several domains remain unexplored. The purpose of this document is to identify points of contact, propose interpretations, and delineate directions for future investigation.

1 Introduction

Quantum mechanics is, by any measure, one of the most successful physical theories ever developed. Its predictions have been confirmed to extraordinary precision, and its mathematical apparatus —Hilbert spaces, Hermitian operators, the Born rule— is robust and self-consistent.

What remains open is the **interpretation** of the formalism. Why does measurement collapse the wave function? What is the physical meaning of entanglement? Is superposition a real physical state or a limitation of our measurement apparatus?

The Unified Applicable Time (UAT) and Unified Causal Principle (UCP) frameworks [1, 2] were developed primarily in a cosmological context, where they have produced a consistent set of constants: the Ivancho limit ($\kappa_{\text{crit}} = 4.978$), the quantum braking factor ($k_{\text{early}} = 0.967$), the causal overflow ($\varepsilon = 3.3\%$), and the force metric ($R_{\text{geom}} = 0.2791$). These constants have been validated through internal consistency checks, Monte Carlo simulations, and comparison with BAO data [5, 6].

This document explores whether the same framework can offer interpretive insights into quantum phenomena. We do **not** claim that UAT/UPC replaces quantum mechanics. It does not possess the full formal structure of a quantum theory. It offers, instead, a geometric and thermodynamic layer of interpretation that may complement —not supplant— the standard formalism.

2 Superposition as Instrumental Limitation: The HFCO Hypothesis

2.1 The Core Idea

The standard interpretation of quantum superposition holds that a particle exists in multiple states simultaneously until measurement. The Causal Oscillation Hypothesis (HFCO), developed within the UCP framework [9], proposes an alternative: the particle executes a deterministic oscillation between states at a frequency ν_{HFCO} that is far beyond the temporal resolution of any existing detector.

What we call "superposition" is, under this hypothesis, a **measurement artifact**: the detector integrates over a time window $\Delta t_{\mathrm{detector}}$ that is many orders of magnitude larger than the oscillation period, and therefore registers the particle as being in multiple states simultaneously.

2.2 The Irreducible Quantum Fluctuation

At the quantum scale, the UAT/UCP framework suggests the existence of an **irreducible fluctuation** analogous to —but distinct from— the cosmological 7% thermal calibration margin and the laboratory force metric $R_{\mathrm{geom}} = 0.2791$. This quantum fluctuation is estimated at approximately 0.07% of the characteristic energy scale of the confined system, playing a role similar to the quantum zero-point energy $\frac{1}{2}\hbar\omega$.

This fluctuation sets a fundamental limit on the temporal resolution of any physical detector. The HFCO hypothesis asserts that the particle's oscillation frequency lies beyond this limit, and that the perceived superposition is the time-averaged trace of an underlying deterministic process.

2.3 The Triad of Irreducible Fluctuations

A single principle —the irreducible fluctuation— manifests at three scales within the UAT/UCP framework:

Table 1: Three manifestations of the irreducible fluctuation principle.

Scale	**Parameter**	**Value**	**Physical meaning**
Cosmological	ϕ_*/η	7%	Thermal calibration margin [5]
Laboratory	R_{geom}	0.2791	Force metric (8-coil residual) [1]
Quantum	—	$\sim 0.07\%$	Detector resolution limit

These are not assumed to be numerically equal; they are manifestations of the same underlying principle —that no physical system can reach perfect equilibrium— at three different energy scales with three different coupling constants.

3 The Measurement Problem and the Ivancho Limit

3.1 Why Does Measurement Collapse the Wave Function?

The measurement problem —why a quantum system transitions from a superposition to a definite state upon measurement— has no universally accepted explanation within standard quantum mechanics. The UAT/UCP framework offers a geometric interpretation: **collapse occurs when the coherence of the system exceeds the Ivancho limit**.

The Ivancho limit $\kappa_{\mathrm{crit}} = 4.978$ [2, 3] represents the maximum tension that the causal membrane can sustain before losing coherence. When a measurement interaction injects sufficient energy into the system to push the local coherence beyond this threshold, the causal membrane saturates. The system must abandon the superposition —which requires causal flexibility— and collapse into a single, definite state.

In this interpretation, the measurement apparatus is not a passive observer but an active participant that stresses the causal membrane. The collapse is not mysterious; it is the physical consequence of exceeding a geometric limit.

3.2 Connection to the Quantum Fluctuation

The irreducible quantum fluctuation ($\sim 0.07\%$) determines the minimum energy that a measurement interaction must inject to approach the Ivancho limit. Interactions below this threshold leave the system coherent; interactions above it trigger collapse. This provides a quantitative —though still approximate— bridge between the UAT/UCP framework and the measurement problem.

4 Decoherence and the Information Loss Margin

4.1 Standard Decoherence

In standard quantum mechanics, decoherence describes how a quantum system loses coherence through interaction with its environment. The off-diagonal elements of the density matrix decay exponentially, and the system "leaks" information into the surroundings.

4.2 UAT/UCP Interpretation

The UAT/UCP framework suggests that the rate of this information leakage is governed by the same irreducible fluctuation that appears at other scales. In cosmology, the 7% margin absorbs thermal noise without destroying the expansion. In the laboratory, the force metric $R_{\text{geom}} = 0.2791$ represents the fraction of phase information that survives cancellation. In the quantum domain, the $\sim 0.07\%$ fluctuation may set the baseline rate at which a coherent quantum system loses information to its environment.

This interpretation does not replace the standard decoherence formalism. It offers a geometric metaphor: the causal membrane "leaks" a fraction of the system's coherence at each interaction, and the accumulated loss over many interactions produces the exponential decay observed in the density matrix.

5 Entanglement as Geometric Projection

5.1 The Puzzle of Non-Locality

Entanglement —the fact that two particles can exhibit correlated behavior instantaneously across arbitrary distances— challenges the intuition that information must travel through space. Standard quantum mechanics accepts this non-locality as a feature of the formalism without providing a mechanistic explanation.

5.2 A Geometric Interpretation

The UAT/UCP framework, particularly through its concept of dimensional coexistence, offers a geometric interpretation: **entangled particles are not communicating across space; they are projections of a single geometric structure from a higher-dimensional space into our 3D observation frame**.

Just as a 3D object intersecting a 2D plane appears as two separate 2D figures that move in perfect synchrony (because they are sections of the same object), two entangled particles may be 3D projections of a single 4D causal structure. Their correlations are instantaneous because no information travels between them: they are the same object, viewed from different angles.

This interpretation is speculative and qualitative. It does not replace the mathematical formalism of entanglement. It offers a geometric intuition that may guide future theoretical development.

6 The Quantum Vacuum and the Cosmological Constant

6.1 The Vacuum Energy Prediction

One of the central results of the UAT/UCP framework is the derivation of the cosmological constant from three independent physical principles [4]:

$$\Lambda = E_{\text{Planck}} \times \kappa_{\text{crit}}^{\varphi/2+3/4} = 2.50 \times 10^{-122}\, M_{\text{Pl}}^4 \tag{1}$$

This matches the observed value (Planck 2018) to within $\sim 1.2\%$. The vacuum energy density is not a free parameter in UAT; it is a consequence of the causal structure of spacetime.

6.2 Implications for Quantum Field Theory

In standard quantum field theory, the vacuum energy is calculated by summing the zero-point energies of all field modes, yielding a value $\sim 10^{120}$ times larger than observed. The UAT/UCP framework avoids this discrepancy by imposing a fundamental limit on causal coherence (κ_{crit}), which acts as a cutoff on the modes that can contribute to the vacuum energy.

This does not solve the cosmological constant problem in the sense of providing a renormalization scheme for quantum fields. It offers an alternative framework in which the vacuum energy is not a sum over field modes but a consequence of the geometric structure of causal spacetime.

7 Tunneling Time and the Principle of Least Action

In a separate investigation [7], the UAT/UCP framework was applied to the phenomenon of negative tunneling time (the Hartman effect). Using a path-integral simulation, it was shown that the negative transit time arises naturally from the principle of least action: the dominant Feynman paths are those that effectively bypass the barrier. The UAT/UCP connection is speculative but consistent: small negative time fluctuations are permissible as long as they do not accumulate to violate macroscopic causality, and their magnitude is well within the enormous buffer provided by κ_{crit}.

8 Limitations and Future Directions

We explicitly acknowledge the current limitations of the UAT/UCP framework in the quantum domain:

1. **No derivation of the Schrödinger equation.** UAT/UCP does not contain a quantum action principle that yields the standard wave equation. The framework offers geometric interpretations of quantum phenomena, not a replacement for the dynamical equations.

2. **No Born rule.** The probabilistic interpretation of the wave function is assumed, not derived. Future work may explore whether the causal overflow mechanism can provide a deterministic underpinning for quantum probabilities.

3. **No second quantization.** UAT/UCP does not contain creation/annihilation operators, Fock spaces, or Feynman diagrams. The framework is not a quantum field theory.

4. **No prediction of new quantum phenomena.** The framework currently reinterprets known effects; it does not predict new ones. The three-depth experiment [6] and the 8-coil validation [1] remain the primary falsifiable tests.

Future directions: Whether UAT/UPC can be extended to address the following domains remains an open question for future investigation:

- Derivation of the Born rule from causal overflow statistics.
- Extension to second quantization and quantum field theory.
- Application to the strong CP problem and the matter-antimatter asymmetry.
- Connection to the black hole information paradox.
- Formalization of the HFCO hypothesis with a testable experimental protocol.

9 Conclusion

We have presented a conceptual framework that interprets several quantum phenomena through the lens of the UAT/UCP framework. The core idea is that a single principle —irreducible fluctuation— manifests at the cosmological scale (7%), the laboratory scale ($R_{\text{geom}} = 0.2791$), and the quantum scale ($\sim 0.07\%$). This principle provides interpretive bridges to the measurement problem (collapse as saturation of the Ivancho limit), decoherence (information leakage governed by the fluctuation margin), entanglement (geometric projection from higher dimensions), and the quantum vacuum (energy density predicted by the causal structure).

We have explicitly acknowledged the limitations of the framework. UAT/UCP is not a quantum theory. It does not replace the Schrödinger equation, the Born rule, or quantum field theory. It offers a complementary geometric and thermodynamic layer of interpretation. Whether this layer is merely suggestive or points toward a deeper unification is a question for future investigation.

Quantum mechanics works. UAT/UCP asks why it looks the way it does.

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Conceptual Interpretive Framework — July 11, 2026
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Document DOI: `10.5281/zenodo.21305250`