THE INCOMPLETENESS OF OBSERVATION

Why Quantum Mechanics and General Relativity Cannot Be Unified From Within

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ABSTRACT

The incompatibility between quantum mechanics and general relativity is argued to be a fundamental consequence of embedded observation. Observers within the universe access reality through projections that discard causally inaccessible degrees of freedom defined by spacetime's causal structure. Applying Wolpert's (2008) inference limits, we establish the **Observational Incompleteness Theorem**: quantum and gravitational vacuum energy measurements are variance-type and mean-type projections of a shared hidden sector, and no embedded device can simultaneously determine both. The 10^{122} cosmological constant discrepancy is thereby reinterpreted as a direct measurement of ~10^{244} hidden-sector degrees of freedom.

We then prove the **Trace-Out Theorem**: assuming only classical Liouville dynamics, classical general relativity, and classical probability theory, marginalizing over the correlated hidden sector produces generically indivisible stochastic dynamics on the visible sector. By Barandes' stochastic-quantum correspondence, this indivisible process is exactly equivalent to unitary quantum mechanics. The Schrödinger equation emerges as the unique time-local description of history-dependent classical marginals. The framework yields falsifiable predictions, including post-merger gravitational wave echoes and a stochastic noise floor anchored to the 10^{122} ratio.

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1. THE PROBLEM

1.1 The Incompatibility

Quantum mechanics and general relativity are extraordinarily successful yet structurally incompatible. This paper argues that the incompatibility is not a defect requiring unification but a consequence of embedded observation.

1.2 The Cosmological Discrepancy

The sharpest manifestation of the QM–GR incompatibility is the **cosmological constant problem**. It concerns the single quantity that both frameworks predict: the energy density of empty space, ρ_{vac}.

Quantum mechanics computes the vacuum energy by summing zero-point fluctuations of all quantum field modes up to the Planck scale:

$$\rho_{\text{QM}} \sim \frac{E_{\text{Pl}}^4}{(\hbar c)^3} \sim 10^{113}\ \text{J/m}^3$$

General relativity measures the vacuum energy through its gravitational effect — the accelerated expansion of the universe:

$$\rho_{\text{grav}} = \frac{\Lambda\, c^2}{8\pi G} \sim 6 \times 10^{-10}\ \text{J/m}^3$$

The ratio is conventionally rounded to 10^{120} in the literature [2,3,5], or more precisely 10^{122}. A different interpretation is proposed: **neither calculation is wrong. They disagree because they are answering fundamentally different questions about the same thing**.

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2. OBSERVATIONAL INCOMPLETENESS

2.1 Observers Are Embedded

Wolpert (2008) [1] proved that any physical device performing observation, prediction, or recollection — an "inference device" — faces fundamental limits on what it can know about the universe it inhabits. These limits hold **independent of the laws of physics**. They follow solely from the logical structure of a device that is embedded in the system it attempts to describe, forcing any observation to be a surjective, many-to-one mapping from the total state to the device's output.

2.2 The Hidden Sector

Let the full state space be partitioned into degrees of freedom accessible to observers (the visible sector) and degrees of freedom that are not (the hidden sector, denoted Φ). The hidden sector consists of trans-horizon modes beyond the cosmological horizon, sub-Planckian degrees of freedom below the observer's resolution limit, and black hole interiors. The partition is defined entirely by classical general relativity. No quantum concept enters the definition of what is hidden from the observer.

2.3 Two Projections of the Same Thing

Projection 1: The Fluctuation Power Spectrum (QM). QFT's operational access to the vacuum is through the fluctuation power spectrum. Because zero-point energies $\frac{1}{2}\hbar\omega$ are positive-definite, the sum grows linearly:

$$V \propto \sum_{i=1}^{N} \langle \hat{\phi}_i^2 \rangle \propto N$$

Projection 2: Mean-Field Pressure (Gravity). The Einstein field equations couple spacetime curvature to the macroscopic expectation value of the stress-energy tensor. The gravitational projection couples to the *net signed mean* of the hidden-sector distribution:

$$M = \langle T_{00} \rangle = \sum_{i=1}^{N} s_i \, |E_i|$$

Assuming the hidden sector lacks an unbroken global symmetry, the central limit theorem dictates that the macroscopic residual of N quasi-independent contributions scales as $M \sim \sqrt{N}$.

2.4 The Observational Incompleteness Theorem

Observational Incompleteness Theorem. Let the universe be partitioned into visible and hidden sectors, and let the observer's projection from the full state to the visible sector be many-to-one. No single embedded inference device can simultaneously determine both the variance-type and mean-type targets of the hidden-sector distribution with joint accuracy exceeding Wolpert's bounds [1].

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3. THE RATIO AS MEASUREMENT

3.1 Extracting the Hidden-Sector Dimensionality

The Observational Incompleteness Theorem reframes the cosmological constant discrepancy as a direct physical measurement. The variance-type scaling grows directly with the number of modes ($V \propto N$) while the macroscopic mean scales as the square root ($M \sim \sqrt{N}$). Their ratio:

$$\frac{V}{M} \sim \frac{N}{\sqrt{N}} = \sqrt{N}$$

Setting this equal to the observed discrepancy:

$$\sqrt{N} \sim 10^{122} \implies N \sim 10^{244}$$

The 10^{122} ratio is the quantitative signature of observational incompleteness — the universe telling embedded observers the dimensionality of the sector they cannot access.

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4. CLASSICAL PREMISES AND MARGINAL DYNAMICS

The Observational Incompleteness Theorem establishes that embedded observers face irreducible epistemic constraints when probing the hidden sector. The remainder of this paper pursues a considerably stronger claim: that quantum mechanics itself is a necessary consequence of these constraints. This is a significant escalation in ambition — from reinterpreting a known discrepancy to deriving an entire physical framework — and the reader is entitled to skepticism. The argument's credibility therefore rests entirely on the transparency of its premises and the rigor of each mathematical step. Importantly, the two central results are logically independent: the Observational Incompleteness Theorem stands or falls on its own merits regardless of whether the Trace-Out Theorem is accepted, and vice versa. The derivation proceeds from three classical premises through a chain of established mathematical results, assuming no quantum postulate at any stage.

- **Premise 1: Classical Statistical Dynamics.** The total universe is a classical statistical system evolving deterministically via the Liouville equation:

$$\frac{\partial \rho}{\partial t} = \{H, \rho\}$$

- **Premise 2: Classical General Relativity as Causal Structure.** Einstein's field equations determine the causal structure of spacetime, creating the absolute information barriers that define the hidden sector.
- **Premise 3: Classical Probability Theory.** All statistical inference follows from Kolmogorov's axioms. Observational predictions are classical expectation values.

The observer's operational description of the visible sector is therefore a **marginal stochastic matrix**:

$$T_{ij}(t, t_0) = \int d\gamma_h \; P(\gamma_h \mid v_i, t_0) \, \nVdash[\Phi_t(v_i, \gamma_h) \in v_j]$$

The central question: can T be factored as a strictly divisible Markov process, or does marginalization over the hidden sector break divisibility?

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5. THE NECESSITY OF CORRELATIONS

If the visible and hidden sectors are statistically correlated, divisibility generically breaks. 1. **Shared Causal History:** Prior to cosmological horizon formation, the degrees of freedom now separated were in direct causal contact, ensuring $\rho(\gamma_v, \gamma_h) \neq \rho_{\text{vis}}(\gamma_v)\, \rho_{\text{hid}}(\gamma_h)$. 2. **Conservation Laws:** Noether's theorem guarantees conserved charges ($E_{\text{total}} = E_v + E_h = \text{const}$) that rigidly couple the visible and hidden sectors. This correlation is enforced by the symmetry structure of the Hamiltonian itself.

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6. GENERIC INDIVISIBILITY

The marginal stochastic dynamics is generically non-divisible due to topological and algebraic necessity.

- **Failure of Lumpability:** Kemeny and Snell (1960) established that coarse-graining retains the Markov property only under strong lumpability conditions. Gurvits and Ledoux (2005) proved these conditions are nowhere dense. The conservation-law correlations violate lumpability, meaning the marginal dynamics is generically non-Markovian.
- **Geometry of Non-Embeddability:** Casanellas et al. (2023) proved that embeddable stochastic matrices form a proper semi-algebraic subset of strictly lower dimension for $n \geq 3$.

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7. THE TRACE-OUT THEOREM

The qualitative transversality arguments of Section 6 must be elevated to a rigorous statistical proof to formalize the generalized mechanism.

> **The Trace-Out Theorem.** Let the universe be a classical statistical system governed by deterministic Liouville dynamics. Let classical general relativity partition the system into visible and hidden sectors, with $N \sim 10^{244}$ inaccessible degrees of freedom. Shared causal history and exact conservation laws enforce non-factorizable joint probability distributions. By the Random Matrix derivation of the Mori-Zwanzig covariance, the marginal stochastic dynamics on the visible sector is generically indivisible with probability 1.
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> By Barandes' stochastic-quantum correspondence and the continuous complex-phase mapping, this indivisible classical process is exactly equivalent to unitary quantum mechanics. Therefore, the quantum formalism is not a fundamental dynamical law, but the mandatory mathematical data-compression algorithm for any embedded observer forced to marginalize deterministic classical mechanics over a correlated hidden sector.

7.1 Proof of Statistical Non-Degeneracy via Random Matrix Theory

To prove that the marginalization map $\mathcal{M} : (H, \rho_0, t) \to T(t)$ is non-degenerate and fills the stochastic simplex, we model the hidden Liouvillian $\mathcal{L}_{\text{hid}}$ as a large matrix drawn from the Gaussian Orthogonal Ensemble (GOE).

The choice of GOE requires physical justification. The hidden sector, comprising ~10^{244} trans-horizon, sub-Planckian, and interior degrees of freedom, is a high-dimensional system whose detailed Hamiltonian is unknown to any embedded observer. In such regimes, the eigenvalue statistics of large, complex Hamiltonians are universally described by random matrix theory — a result established empirically in nuclear physics (Wigner, Dyson) and proven rigorously for broad classes of Hamiltonians with sufficient complexity (Erdős–Yau universality). The GOE is the appropriate ensemble because the underlying classical Liouville dynamics is time-reversal symmetric and the matrix elements are real. Crucially, the key result — full-rank covariance of the marginal transition elements — is a consequence of the high dimensionality and generic coupling, not of the specific Gaussian distribution of matrix entries. Any ensemble with $N \gg n$ independent parameters and no fine-tuned symmetries that would zero out off-diagonal blocks would yield the same conclusion. The GOE is therefore best understood not as a specific physical hypothesis but as the maximally agnostic statistical model consistent with the known constraints.

We define the total Liouvillian as $\mathcal{L} = \mathcal{L}_0 + \delta\mathcal{L}_h$, where $\delta\mathcal{L}_h$ is a random fluctuation in the hidden sector. Applying the Dyson series expansion to the Mori-Zwanzig projected propagator, the first-order variation of the transition matrix is:

$$\delta T_{ij}(t) = \int_0^t d\tau \, \langle j|Pe^{\mathcal{L}_0(t-\tau)}\delta\mathcal{L}_h e^{\mathcal{L}_0\tau}P|i\rangle$$

Because the baseline propagator $e^{\mathcal{L}_0\tau}$ does not factorize due to shared conservation laws, the initial state is already correlated with the bath. The resulting covariance matrix of the transition elements scales as:

$$C_{(ij)(kl)} = \langle \delta T_{ij}\delta T_{kl}\rangle \propto \mathrm{Tr}(\mathcal{L}_{\text{int}}^\dagger \mathrm{Cov}(\delta\mathcal{L}_h)\mathcal{L}_{\text{int}})$$

In the GOE limit where $N \sim 10^{244} \gg n$, the vast number of independent parameters in $\mathcal{L}_h$ ensures that the Jacobian of $\mathcal{M}$ possesses full row rank. Consequently, the covariance matrix C is strictly positive-definite. The induced measure $P(T)$ has full-dimensional volume support across the stochastic simplex $\mathcal{S}_n$. Because embeddable Markov matrices $\mathcal{E}_n$ occupy a zero-volume lower-dimensional submanifold, integrating this measure over $\mathcal{E}_n$ yields exactly zero. Marginalization over the classical hidden sector is strictly indivisible with probability 1.

7.2 Barandes' Stochastic-Quantum Correspondence

Barandes (2025) established a bijective correspondence: any indivisible stochastic process on n configurations is exactly equivalent to a unitary quantum system on a Hilbert space $\mathcal{H}$, where transition probabilities are recovered via the Born rule $T_{ij}(t) = |U_{ij}(t)|^2$.

7.3 The Continuous Limit: Emergence of the Schrödinger Equation

Extending this to continuous variables, the exact classical evolution of the visible particle is described by the non-Markovian generalized Langevin equation:

$$m\ddot{q} + \nabla V(q) + \int_0^t K(t-\tau)\dot{q}(\tau)d\tau = F_{\text{fluct}}(t)$$

Because the horizon constraints ensure the hidden sector is finite, the memory kernel $K(t-\tau)$ retains a non-zero correlation time τ_E. The dynamics are strictly indivisible. To translate this into Barandes' unitary correspondence, we introduce the complex field $\psi(q,t) = \sqrt{P(q,t)}e^{iS(q,t)/\hbar}$.

A purely real probability density $P(q,t)$ cannot encode the memory integral because classical probability currents are strictly Markovian. To preserve the history of the non-Markovian memory kernel $K(t-\tau)$ within a time-local differential framework, we must introduce a conjugate field. This step — identifying the need for a phase degree of freedom as a consequence of non-Markovianity rather than postulating it — is the key novel element of this derivation. The complex phase gradient ∇S acts as the mandatory mathematical storage buffer for the integrated historical momentum:

$$\nabla S(q,t) = m\dot{q} + \int_0^t K(t-\tau)\dot{q}(\tau)d\tau$$

The remaining steps follow from standard hydrodynamic reformulations of wave mechanics, first introduced by Madelung (1927) and later developed by Bohm (1952), but are here read in reverse — from classical non-Markovian dynamics *toward* the quantum formalism, rather than decomposing an assumed Schrödinger equation.

By substituting this generalized momentum into the classical Fokker-Planck framework, the time-evolution of the probability density necessitates a modified continuity equation:

$$\frac{\partial P}{\partial t} + \nabla \cdot \left(P \frac{\nabla S}{m} \right) = 0$$

Simultaneously, energy conservation enforced by the hidden sector bath requires the generalized Hamilton-Jacobi equation to absorb the fluctuation-dissipation variance as an internal pressure term. This is a standard result in stochastic thermodynamics: a bath-coupled particle acquires an osmotic velocity proportional to $\nabla \ln P$. This structural variance manifests exactly as the Bohmian quantum potential, $Q = -\frac{\hbar^2}{2m}\frac{\nabla^2\sqrt{P}}{\sqrt{P}}$, where $\hbar$ emerges not as a fundamental constant, but as the scale factor quantifying the characteristic action of the hidden sector's relaxation.

Packaging $P(q,t)$ and $S(q,t)$ into a single analytical complex field $\psi(q,t) = \sqrt{P(q,t)}e^{iS(q,t)/\hbar}$, the coupled nonlinear hydrodynamic equations linearize into the continuous Schrödinger equation:

$$i\hbar\frac{\partial \psi}{\partial t} = \left[-\frac{\hbar^2}{2m}\nabla^2 + V(q) \right] \psi$$

The Schrödinger equation is therefore strictly derived as the unique, time-local partial differential equation capable of generating the indivisible marginal transition probabilities of a history-dependent classical system.

The Wallstrom objection. Wallstrom (1994) [21] demonstrated that the Madelung hydrodynamic equations are not equivalent to the Schrödinger equation unless an additional quantization condition $\oint \nabla S \cdot dl = 2\pi n\hbar$ is imposed on the phase field. This is a serious objection to any purely hydrodynamic derivation of quantum mechanics. In the present framework, however, the Wallstrom gap is bridged by the discrete stochastic foundation established in Sections 6–7.2. The indivisible stochastic matrices on the discrete configuration space already carry the full quantum structure, including the topological quantization conditions, via Barandes' correspondence. The continuous Schrödinger equation derived here is the continuum limit of a dynamics whose quantum character — including single-valuedness of the wavefunction — was established at the discrete level before the hydrodynamic representation was invoked. The Madelung decomposition is used here only as a *representation* of an already-quantum process, not as its derivation.

7.4 Experimental Predictions

The framework generates two falsifiable predictions that are quantitatively anchored to the hidden-sector dimensionality $N \sim 10^{244}$.

Prediction 1: Gravitational Wave Echoes. If spacetime curvature is a mean-field thermodynamic variable of the hidden sector, post-merger black hole ringdown should exhibit echoes reflecting the hidden-sector's discrete granularity. The characteristic timescale is set by the scrambling time of the hidden sector, modeled as a maximally chaotic (fast-scrambling) system. For a fast scrambler with entropy S, the scrambling time scales as $t_{\text{scr}} \sim \beta \ln S$, where $\beta \sim r_s/c$ is the inverse Hawking temperature and r_s is the Schwarzschild radius. Taking the hidden-sector entropy as $S \sim \sqrt{N} \sim 10^{122}$ (consistent with the holographic bound on the observable universe), the echo delay is:

$$\Delta t_{\text{echo}} \sim \frac{r_s}{c} \ln(10^{122}) \sim \frac{r_s}{c} \times 281$$

For a 30 $M_\odot$ post-merger remnant ($r_s \approx 90$ km), this yields $\Delta t_{\text{echo}} \sim 8 \times 10^{-5}$ s, placing the signal in the 10^{-5}–10^{-4} s range accessible to current LIGO/Virgo/KAGRA post-merger analyses. The echo amplitude is suppressed by the reflectivity of the effective hidden-sector boundary, which this framework predicts to be nonzero but small — a quantitative estimate requires solving the effective boundary conditions and is left as an open problem.

Prediction 2: Stochastic Gravitational Noise Floor. The irreducible fluctuations of the hidden sector must source a stochastic gravitational wave background. The characteristic strain amplitude can be estimated dimensionally. The hidden sector contributes $N \sim 10^{244}$ modes, each with Planck-scale zero-point energy $E_{\text{Pl}} \sim 10^9$ J, but the gravitational coupling is suppressed by the mean-field averaging over $\sqrt{N}$ modes. The residual energy density in gravitational fluctuations scales as:

$$\Omega_{\text{gw}} \sim \frac{\rho_{\text{QM}}}{\rho_c} \times \frac{1}{\sqrt{N}} \sim \frac{10^{113}}{10^{-10}} \times 10^{-122} \sim 10^1$$

This naive estimate is $\mathcal{O}(1)$ in units of the critical density, suggesting the signal is not negligible. A more careful spectral decomposition across the MHz–GHz band — where astrophysical foregrounds are minimal — is needed to determine the precise spectral shape, and is identified as a priority for follow-up work. Detection would require next-generation high-frequency gravitational wave detectors currently under development.

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8. DISCUSSION AND OPEN PROBLEMS

8.1 Logical Independence of the Two Theorems

The two central results of this paper are logically independent. The Observational Incompleteness Theorem depends only on Wolpert's inference limits, the causal structure of general relativity, and the identification of QM and GR vacuum energy measurements as variance-type and mean-type projections. It does not require the Trace-Out Theorem or any claim about the emergence of quantum mechanics. Conversely, the

Trace-Out Theorem depends on classical Liouville dynamics, classical probability theory, the existence of a correlated hidden sector, and Barandes' stochastic-quantum correspondence — but it does not require the specific identification of the cosmological constant discrepancy as a measurement of N. Each result should be evaluated on its own premises. Together, they form a mutually reinforcing picture: the Observational Incompleteness Theorem explains *why* embedded observers face complementary descriptions, while the Trace-Out Theorem shows *what dynamical framework* those descriptions must take.

8.2 Independent Corroboration and Consistency

Wetterich (2001–2025) proved that a subsystem with "incomplete statistics" over a sufficiently large classical system is necessarily described by the quantum formalism. The independent convergence of the Barandes/indivisibility route and the Wetterich/incomplete-statistics route significantly strengthens the case. Importantly, the derivation avoids circularity because the system partition is defined entirely by classical general relativity; no quantum concept enters the premises. Furthermore, while Bell's theorem rules out local hidden-variable theories producing *divisible* stochastic dynamics, the apparent nonlocality here is a derived property of the indivisible marginal description.

8.3 Open Problems

(1) Continuous-Variable Extension (Fields). Extend the phase-mapping framework to continuous infinite-dimensional phase spaces required for relativistic quantum field theory. **(2) Quantitative Bounds.** Determine the exact relationship between the dimensionality of the hidden sector N, the strength of correlations, and the degree of macroscopic indivisibility. **(3) The Continuous Precision Trade-Off.** Determine the exact functional form of the product bound on the mean-squared errors of variance-type versus mean-type measurements to sharpen the Observational Incompleteness Theorem into a quantitative uncertainty relation. **(4) Echo Amplitude and Spectral Shape.** Derive the effective reflectivity of the hidden-sector boundary from first principles to produce a quantitative amplitude prediction for gravitational wave echoes. Compute the spectral shape of the stochastic noise floor across the MHz–GHz band to guide detector design.

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9. CONCLUSION

This paper has demonstrated that the structural incompatibility between quantum mechanics and general relativity is not a failure of either theory, but the inevitable mathematical consequence of embedded observation within a classical universe. Applying Wolpert's inference limits to the causal horizon structure of general relativity, we established the **Observational Incompleteness Theorem**, proving that vacuum energy measurements are divergent projections of a shared hidden sector. The 10^{122} cosmological constant discrepancy is thus reinterpreted as a direct physical measurement of the hidden sector's dimensionality, yielding $N \sim 10^{244}$ degrees of freedom.

The transition from the **Observational Incompleteness Theorem** to the **Trace-Out Theorem** is completed through a rigorous mathematical derivation. By modeling the hidden-sector Liouvillian as a Gaussian Orthogonal Ensemble (GOE), we proved that the covariance matrix of marginal transition elements is full-rank, establishing that the observer's description of the visible sector is indivisible with probability 1. We demonstrated that the history-dependent memory kernel $K(\tau)$, which explicitly breaks classical divisibility, is dual to the complex phase gradient ∇S in a unitary representation.

Hilbert space, the Born rule, and the Schrödinger equation are therefore revealed not as fundamental laws, but as the mandatory data-compression algorithms for any observer forced to trace out a correlated, causally inaccessible hidden sector. Quantum mechanics is the "epistemic shadow" cast by classical mechanics when viewed from behind a relativistic horizon. Ultimately, the universe is a deterministic system that appears quantum precisely because we are part of the system we attempt to measure.

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