Wavefunction Reality and Epistemic Randomness: How the Ignorant Observer Framework Resolves the Apparent Conflict

Aernoud Dekker
Independent Researcher
ORCID: 0009-0002-1053-4885

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Abstract

A recent experimental implementation of the Pusey–Barrett–Rudolph (PBR) theorem on IBM's superconducting processor claims to provide evidence against epistemic interpretations of quantum mechanics by demonstrating the "reality" of the wavefunction. I show this conclusion conflates two distinct questions: whether the wavefunction is real, and whether quantum randomness is fundamental. While the experiment successfully challenges purely ψ-epistemic interpretations (where the wavefunction represents only knowledge), it remains entirely consistent with—and indeed supportive of—the Ignorant Observer Framework (IOF). In IOF, the wavefunction is a real physical field (ψ-ontic) while quantum randomness is epistemic, arising from fundamental limitations on observer self-knowledge. This hybrid ontology not only accommodates the experimental findings but explains the appearance of wavefunction collapse, addresses entanglement without nonlocality, and makes testable predictions.

Clarification in light of BLQC v1.3

This response should be read as an interpretive clarification, not as evidence for the Bandwidth-Limited Quantum Control / phase-reference tracking hypothesis. PBR-type experiments test whether the wavefunction can be treated as merely epistemic under the assumptions of the PBR theorem. BLQC does not require a ψ-epistemic wavefunction. Its narrower scientific claim is different: visibility breakdown may depend on finite-rate tracking of the physical basis or phase reference, with

$$t_{\text{break}} \propto \frac{1}{h_{\text{KS}} - C_{\text{eff}} \ln 2}.$$

Therefore, PBR is compatible with BLQC but does not confirm it. The relevant empirical test for BLQC remains a controlled phase-reference experiment in which C_{eff} and h_{KS} are independently varied or imposed.

1 Introduction: The Experimental Claim

In a recent experiment, Yang, Yuan, and Barnes [1] implement the Pusey–Barrett–Rudolph (PBR) no-go theorem on IBM's 156-qubit Heron2 Marrakesh superconducting processor. By preparing qubits in non-orthogonal quantum states and measuring forbidden outcomes, they claim to demonstrate (under the PBR assumption of preparation independence) that quantum states cannot be interpreted as merely epistemic—reflecting ignorance about some underlying physical reality—but must directly represent physical truth.

Their technical achievement is noteworthy, and their central empirical claim appears sound: the wavefunction indeed behaves as a real physical entity with objective causal power. However, their philosophical conclusion overreaches. They have successfully challenged only one class of epistemic interpretations—those that are purely ψ-epistemic. A different epistemic interpretation, developed in the Ignorant Observer Framework [2], not only survives their evidence but is strengthened by it.

Sabine Hossenfelder has made a similar point in a public video commentary: PBR-type tests constrain purely ψ-epistemic models, but don't by themselves settle whether outcome randomness must be ontic. Notably, the authors themselves emphasize that their no-go result targets a specific ψ-epistemic ontological model class, not every conceivable epistemic account.

2 Two Distinct Epistemic Questions

The quantum interpretation landscape conflates two fundamentally different questions:

2.1 Is the Wavefunction Real? (ψ-ontic vs. ψ-epistemic)

ψ-Epistemic interpretations claim the wavefunction itself represents only knowledge or credences about an underlying reality. Examples include:

- **QBism**: Quantum states represent an agent's beliefs
- **Some Copenhagen variants**: The wavefunction as calculational tool
- **Relational Quantum Mechanics**: States are observer-relative

The PBR experiment successfully challenges these views by showing the wavefunction has objective, measurable consequences that cannot be reduced to subjective knowledge.

2.2 Is Quantum Randomness Fundamental? (Ontic vs. Epistemic Randomness)

This is a *separate* question. One can accept that the wavefunction is physically real while maintaining that measurement outcomes are predetermined but unknowable—that randomness arises from ignorance rather than fundamental indeterminism.

Outcome-epistemic interpretations accept:

- The wavefunction $|\psi\rangle$ is real and ontic
- Measurement outcomes are predetermined but unknowable
- "Collapse" represents knowledge update, not physical change

The PBR experiment says nothing about this second question, as it specifically tests the reality of ψ, not the origin of randomness.

3 The Ignorant Observer Framework: A Hybrid Ontology

The Ignorant Observer Framework (IOF) [2] provides a concrete realization of an outcome-epistemic interpretation with a rigorously derived ontology. Starting from the empirical fact that observers cannot trace why they chose particular measurement settings, IOF derives a minimal sufficient ontology:

3.1 Minimal Ontological Requirements

The IOF requires only:

1. **Wavefunction** $|\psi\rangle$: A real physical field evolving unitarily (never collapsing)
2. **Ontic state** ξ: A definite underlying state satisfying equivariance ($\rho = |\psi|^2$)
3. **Observer state** $\theta(t)$: The observer's internal physical state, evolving deterministically

This structure is *substrate-independent*—it does not assume particle positions, guidance equations, or any specific hidden-variable model. It is compatible with de Broglie–Bohm mechanics but does not require it. The only constraint is deterministic evolution preserving the Born distribution.

3.2 The Epistemic Mechanism

Quantum randomness arises from **causal self-ignorance**: observers cannot trace why their internal state $\theta(t)$ evolved to produce a particular measurement choice. The physical basis is straightforward: any physical system that processes information (biological neuron, silicon transistor, superconducting qubit controller) has finite bandwidth. Meanwhile, chaotic dynamics amplify microscopic uncertainties exponentially. When the rate of uncertainty growth exceeds the observer's capacity to track it, self-knowledge becomes impossible.

Motivated by data-rate style bounds [3], we summarize the chaos-wins regime by the deficit rate $\kappa = h_{\mathrm{KS}} - C_{\mathrm{eff}} \ln 2$ and define a corresponding loss timescale:

$$\tau_{\mathrm{loss}} \equiv \frac{1}{\kappa} \quad (\kappa > 0). \tag{1}$$

Beyond this timescale, the observer cannot know why it chose θ—not due to quantum indeterminacy, but due to classical information-theoretic limits.

4 How IOF Accommodates the Experimental Findings

The experimental evidence for wavefunction reality presents no challenge to IOF—it confirms it:

4.1 Wavefunction as Real Physical Field

IOF explicitly requires that $|\psi\rangle$ be a real physical field that structures and constrains what the hidden variable does, not merely epistemic. The PBR experiment provides direct evidence for this requirement.

4.2 Measurement Settings as Physical Variables

A key operational point is that state-preparation angles and measurement circuits are treated as implemented physical controls on a noisy device, making the test explicitly about what real hardware can and cannot support. This operationalizes exactly what IOF proposes: $\theta(t)$ is a physical dynamical variable of the observer with deterministic but informationally opaque evolution.

4.3 Deterministic completions and measurement dependence

The PBR theorem itself is not a Bell test; it constrains the *status* of ψ (epistemic or ontic), not the locality or determinism of the underlying dynamics. However, combining any ψ-ontic completion with Bell-violation results forces a choice: nonlocality *or* violation of measurement independence.

IOF is compatible with either route, but it provides a natural mechanism for the latter: observer self-ignorance means that measurement settings θ and ontic states ξ share a common causal past. On this picture, measurement dependence is not a conspiracy; it is the expected outcome of deterministic dynamics in a Block Universe.

5 Resolving the Quantum Riddles

IOF doesn't just accommodate the experimental findings—it uses them to solve longstanding problems:

5.1 The Measurement Problem

No physical collapse occurs because there was never ontological superposition of the ontic state. The superposition is in the wavefunction $|\psi\rangle$, while the ontic state ξ is always definite. What "collapses" is the observer's knowledge upon learning ξ.

5.2 Entanglement Without Nonlocality

EPR correlations arise from common past evolution of ontic states ξ and measurement settings θ. Like cells in a Sudoku puzzle, their correlation is structural (global constraint) not causal (fine-tuning).

5.3 The Born Rule

When the observer's uncertainty about θ is Gaussian-distributed, interference fringes are suppressed by the visibility factor $V_{\text{obs}} = V_{\text{QM}} e^{-\sigma^2/2}$. In the limit $\sigma \to \infty$ (full self-ignorance), this reproduces the no-interference (diagonalized) statistics; the Born weights themselves enter via the equivariant/quantum-equilibrium assumption of the deterministic completion.

5.4 The Quantum-Classical Transition

When observer capacity C_{eff} is insufficient relative to internal entropy production ($\kappa > 0$), visibility suppression creates effective classicality. This happens at characteristic timescale $\tau_{\text{loss}} \approx 68$ ms for biological observers—coinciding with Penrose's gravitational OR timescale [4], suggesting a deep connection between informational and geometric limits.

6 Testable Predictions

The PBR experiment tests whether the wavefunction is real—and confirms it is. But this leaves IOF's central claim untested: that quantum randomness arises from limitations on *observer capacity*. The following predictions target this distinct question and provide clear falsification criteria.

6.1 Visibility Suppression

For observers with limited effective capacity C_{eff} operating in the chaos-wins regime ($\kappa > 0$), IOF predicts measurable visibility suppression. The characteristic timescale $\tau_{\text{loss}} \approx 68$ ms cited for biological observers assumes typical neural parameters. For artificial observers (e.g., classical control electronics for quantum computers), different parameters apply, but the same information-theoretic framework holds: τ_{loss} scales with the controller's bandwidth and internal dynamics.

These predictions remain untested. The framework is consistent with existing data but has not yet received direct experimental confirmation.

6.2 Distinct Parameter Dependencies

IOF predictions are distinguishable from environmental decoherence and gravitational OR by their unique dependencies:

- **Power/Temperature dependent** (via $C_{\text{eff}} \leq P/(kT \ln 2)$)
- **Geometry independent** (unlike gravitational OR)
- **Mass scaling**: $\tau_{\text{loss}} \propto M^{\beta-1}$ (gentler than OR's M^{-2})

6.3 The Information-Zeno Test: A Decisive Falsification

The clearest way to test IOF is to vary controller bandwidth C_{eff} while holding system temperature constant:

- **IOF prediction**: Increasing C_{eff} extends coherence time ($\partial\tau/\partial C_{\text{eff}} > 0$)
- **Standard QM**: Coherence is thermally limited; $\partial\tau/\partial C_{\text{eff}} \approx 0$

This test directly probes the observer-capacity mechanism that distinguishes IOF from other interpretations. It can be performed on existing quantum hardware by comparing coherence times across control systems with different bandwidths but identical thermal environments. A null result ($\partial\tau/\partial C_{\text{eff}} \approx 0$) would falsify IOF; a positive result would provide evidence that observer capacity—not just environmental decoherence—shapes quantum behavior.

7 Conclusion

The experimental demonstration of wavefunction reality via the PBR theorem is an important advance, but it refutes only a subset of epistemic interpretations—those that are purely ψ-epistemic. The Ignorant Observer Framework presents a different epistemic interpretation where:

1. **The wavefunction is real** (confirming the experiment)
2. **Randomness is epistemic** (from observer self-ignorance)
3. **The ontology is minimal** and interpretation-independent
4. **The appearance of collapse is explained** without physical collapse or nonlocality
5. **Predictions are testable** with current technology

Rather than ending the epistemic interpretation debate, the experiment should redirect it: away from whether the wavefunction is real (it is) toward why measurement outcomes appear random (self-ignorance). The IOF provides a complete, testable answer.

The debate is not settled, but it can be advanced. The next step is an experiment that probes not just the reality of the wavefunction, but the capacity of the observer.

References

[1] S. Yang, H. Yuan, and C. H. W. Barnes, “Experimental Demonstration of the PBR Test on a Superconducting Processor,” arXiv:2510.11213 (2025).

[2] A. Dekker, “The Ignorant Observer: A Physical Realization of Advaita Vedanta’s Central Insight,” OSF Preprints, DOI: 10.17605/OSF.IO/FCDSN (2025).

[3] G. N. Nair and R. J. Evans, “Stabilizability of stochastic linear systems with finite feedback data rates,” *SIAM Journal on Control and Optimization*, 43(2), 413–436 (2004).

[4] R. Penrose, “On gravity’s role in quantum state reduction,” *General Relativity and Gravitation*, 28(5), 581–600 (1996).

[5] B. Libet, C. A. Gleason, E. W. Wright, and D. K. Pearl, “Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential),” *Brain*, 106(3), 623–642 (1983).