

Quantum Physics and the Preservation of Logical Consistency: Why the Three Fundamental Laws of Logic Remain Intact

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Abstract

Quantum mechanics, with its superpositions, entanglements, and probabilistic outcomes, has long appeared to challenge classical logic—particularly the laws of Identity, Non-Contradiction, and the Excluded Middle. However, this paper argues that quantum physics, properly interpreted, does not violate these fundamental laws of logic. Drawing from Logic Field Theory (LFT), we show that quantum states respect logical admissibility when understood as constrained projections from a space of potential information states. Superposition, entanglement, and measurement are all logically coherent under this model, and the 3FLL remain universally intact as ontological constraints on physical realization.

1 Introduction

Quantum mechanics has revolutionized our understanding of the physical world, yet it often appears to defy classical logic. Superposition, entanglement, and probabilistic collapse seem to violate the Three Fundamental Laws of Logic (3FLL):

- **Law of Identity:** $A = A$
- **Law of Non-Contradiction:** $\neg(A \wedge \neg A)$
- **Law of the Excluded Middle:** $A \vee \neg A$

This paper argues that these perceived violations are artifacts of epistemic or linguistic confusion, not genuine contradictions. Using the Logic Field Theory (LFT) framework [1], we show that quantum phenomena comply with the 3FLL when physical realization is understood as a filtered projection from a pre-physical space of information states.

2 Quantum Paradoxes: Misunderstood Logic

Quantum mechanics presents several paradoxes that seem to strain classical reasoning:

- **Superposition:** The state $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$ seems to imply simultaneous truth of $|0\rangle$ and $|1\rangle$.

- **Entanglement:** Measurement on one particle instantly affects another, challenging local identity and separability.
- **Schrödinger’s Cat:** The cat appears both alive and dead until observed.

However, these phenomena do not reflect actual contradictions; they describe potential states that await constraint resolution. What appears as violation is actually a category error—confusing logical potential with ontological realization.

3 Logic Field Theory: Constraint, Not Contradiction

Logic Field Theory posits that physical reality arises from a logic-constrained projection:

$$\Omega = L(S) \tag{1}$$

Here, S is the set of potential information states, and L enforces compliance with the 3FLL. Logical strain $D(\rho)$ measures a state’s deviation from logical admissibility. Only those states with $D = 0$ become physically real.

4 Superposition as Logical Potential

A superposed quantum state does not simultaneously instantiate multiple contradictory states. Instead, it encodes multiple possibilities that have yet to pass the logical filter. Upon measurement, logical strain drives collapse to a single admissible state.

Thus, the Law of Non-Contradiction is preserved: never does a physical system realize both A and $\neg A$ simultaneously.

5 Collapse as Logical Gradient Descent

In LFT, collapse is modeled as deterministic descent under a logical potential:

$$V_L = \kappa D, \quad F_L = -\nabla V_L \tag{2}$$

This replaces stochastic collapse with constraint-driven dynamics. Measurement is not a break in logic, but its completion.

6 Entanglement and Identity

Entangled particles do not share contradictory identities but participate in shared logical constraints. The state is globally consistent, even if locally indeterminate until measured. Logical strain in entangled configurations reflects high interdependency, not contradiction.

7 Excluded Middle and Determinacy

Quantum states satisfy the Law of the Excluded Middle when properly interpreted. A property A is either realized or its negation is. Superposition represents unresolved potential, not logical suspension.

8 Conclusion

Quantum mechanics does not violate the Three Fundamental Laws of Logic. Rather, it demonstrates the importance of distinguishing between epistemic uncertainty and ontological contradiction. Under Logic Field Theory:

- Superposition reflects potential, not conflict.
- Collapse follows deterministic resolution of logical strain.
- Entanglement encodes global coherence, not paradox.

The 3FLL—Identity, Non-Contradiction, and Excluded Middle—remain intact, not merely as tools of thought but as ontological filters on reality itself.

References

- [1] J. D. Longmire Jr., *Logic Field Theory: Logical Constraints as the Ontological Foundation of Physical Reality*, May 2025. Available: <https://github.com/jdlongmire/Logic-Field-Theory-Repo>