Logic Realism Theory and Quantum Foundations: A Co-Constitutive Framework

James D. Longmire ORCID: 0009-0009-1383-7698 jdlongmire@outlook.com

December 2025

Abstract

We present Logic Realism Theory (LRT), a *proposed* framework in which physical reality is co-constituted by logical constraint operating on information space. The central thesis, $\mathfrak{A} = \mathfrak{L}(\mathfrak{I})$, decomposes into an empirically supported theorem ($\mathfrak{A} \subseteq \mathfrak{L}(\mathfrak{I})$: no measurement outcome violates the Three Fundamental Laws of Logic) and an open completeness conjecture ($\mathfrak{L}(\mathfrak{I}) \subseteq \mathfrak{A}$: logical constraint on information suffices for physical actualization). We outline how this framework connects to quantum reconstruction programs, particularly the Masanes-Müller derivation, while avoiding the over-generation problem that afflicts Many-Worlds interpretations. The co-constitutive framing—in which neither logic nor information alone generates reality, but their interaction does—provides a principled selection criterion absent from interpretations where "all branches exist." We articulate precise falsification conditions and note that no violation of 3FLL has ever been observed in any completed physical measurement.

1. Introduction

The foundations of quantum mechanics remain contested territory. Reconstruction programs (Hardy 2001; Chiribella et al. 2011; Masanes and Müller 2011) have shown that quantum theory can be derived from operational axioms, but these programs typically do not ask what grounds the operational axioms themselves. Meanwhile, interpretations like Many-Worlds face the over-generation problem: if all branches exist, what selects the one we observe?

Logic Realism Theory (LRT) proposes a different starting point. Rather than treating logical consistency as a metalevel constraint on our theories, LRT treats the Three Fundamental Laws of Logic (3FLL) as constraints on physical reality itself. The aim here is to sketch an ambitious research program rather than to claim a completed foundation. The result is a framework that:

1. Connects to quantum reconstruction via distinguishability and information
2. Provides a principled selection criterion (logical coherence) absent from Many-Worlds
3. Makes clear empirical predictions (no 3FLL violation in completed measurements)
4. Decomposes into proved and open components, avoiding overclaiming

2. The Formal Framework

2.1 The Three Fundamental Laws of Logic

The 3FLL are:

- L_1 **(Identity):** $\forall A : A = A$ — States are self-identical

- L_2 **(Non-Contradiction):** $\forall A : \neg(A \wedge \neg A)$ — No outcome is both P and $\neg P$
- L_3 **(Excluded Middle):** $\forall A : A \vee \neg A$ — Every outcome is P or $\neg P$

These are self-grounding: any attempt to deny them presupposes what it denies. To argue "Non-Contradiction is false" requires that this assertion be true and not false.

2.2 Formal Definitions

Let $\mathfrak{I}$ (information space) be the set of all total truth-value assignments to a σ-algebra of propositions about physical measurement outcomes.

Let $\mathfrak{L}$ (the logic constraint operator) filter $\mathfrak{I}$:

$$\mathfrak{L}(\mathfrak{I}) := \{s \in \mathfrak{I} \mid s \text{ satisfies } L_1, L_2, L_3 \text{ on all outcome propositions}\}$$

Let $\mathfrak{A}$ (the actualization set) be:

$$\mathfrak{A} := \{s \in \mathfrak{I} \mid s \text{ is a physically realizable history}\}$$

2.3 The Central Thesis

Theorem 1 (3FLL Constraint). *Given that no completed measurement or physical observation violates 3FLL:*

$$\mathfrak{A} \subseteq \mathfrak{L}(\mathfrak{I})$$

Proof sketch. Any $s \in \mathfrak{A}$ encodes outcomes in a physically realizable history. No such outcome is both P and $\neg P$ (L_2 violation), neither P nor $\neg P$ (L_3 violation), or non-self-identical (L_1 violation). Therefore $s \in \mathfrak{L}(\mathfrak{I})$. □

Status: Empirically supported. No violation has ever been observed. Strictly speaking, Theorem 1 records in formal dress what current measurement practice already presupposes: all completed detector records are treated as Boolean at the outcome level. Its value lies in making this constraint explicit as a law-like regularity and in coupling it to a precise falsification criterion.

Conjecture 1 (Completeness). *For any $s \in \mathfrak{L}(\mathfrak{I})$, there exists a physically realizable history:*

$$\mathfrak{L}(\mathfrak{I}) \subseteq \mathfrak{A}$$

Status: Open. This is the ambitious core of the research program.

If Conjecture 1 holds, then $\mathfrak{A} = \mathfrak{L}(\mathfrak{I})$: physical reality is exactly the logically constrained information space.

3. The Co-Constitutive Thesis

Neither $\mathfrak{L}$ nor $\mathfrak{I}$ alone constitutes physical reality:

- $\mathfrak{I}$ provides the substrate—possible information configurations
- $\mathfrak{L}$ provides the structure—filtering coherent from incoherent
- $\mathfrak{A}$ emerges from their interaction

This is not "logic generates reality" (strong idealism). It is the claim that $\mathfrak{L}$ and $\mathfrak{I}$ are *co-constitutive* of physical actualization.

3.1 Resolution of Over-Generation

One might worry that $\mathfrak{L}(\mathfrak{I})$ is "too large"—that physical constraints beyond 3FLL forbid certain logically coherent states. The co-constitutive framing addresses this concern:

If physical reality IS $\mathfrak{L}(\mathfrak{I})$, there is no external standpoint from which $\mathfrak{L}(\mathfrak{I})$ could be measured as "too large." The completeness question admits a definitional reading rather than a purely contingent one: one may take "physical reality" to mean "whatever $\mathfrak{L}(\mathfrak{I})$ permits." The present paper does *not* assume this reading; instead it treats Completeness as a substantive conjecture whose status depends on whether Tier-2/Tier-3 constraints can be absorbed into the $\mathfrak{L}$–$\mathfrak{I}$ structure.

4. Connection to Quantum Reconstruction

LRT connects to quantum reconstruction programs through the following chain:

1. **Binary distinctions** (from L_3): Properties partition into P and $\neg P$
2. **Distinguishability metric** (from 3FLL + information space): States can be told apart
3. **Continuity** (from a parsimony axiom formalized as minimization of specification/information cost): strong discontinuities demand additional, localized descriptive parameters and are thereby disfavoured[1]
4. **Reversibility** (from the same parsimony axiom): maps that preserve a distinguishability metric but irreversibly merge states lose information and thus incur avoidable description cost
5. **Inner product structure** (via Masanes-Müller): The above conditions yield quantum state space

The Masanes-Müller reconstruction (2011) shows that operational axioms—tomographic locality, continuous reversibility, subspace structure, composite systems—uniquely determine quantum theory. LRT provides a framework for asking: are these axioms themselves downstream of 3FLL, or genuinely independent?

Current status:

- Continuity and reversibility: argued to follow from 3FLL + a parsimony axiom, at the level of proof sketches
- Tomographic locality, subspace axiom, composite systems: presently treated as Tier-2 inputs, not derived from 3FLL

5. Contrast with Many-Worlds

The Many-Worlds Interpretation (MWI) suffers from over-generation: all branches of the wave function exist, with no principled selection mechanism.

Problem	MWI	LRT
Over-generation	All branches exist	Only $\mathfrak{L}(\mathfrak{I})$ exists
Selection mechanism	None	$\mathfrak{L}$ constrains $\mathfrak{I}$

[1]This use of "parsimony" is intended in the spirit of minimal description length / Kolmogorov-style information cost, not as a vague aesthetic principle; full formalization is part of the ongoing work.

Problem	MWI	LRT
Born rule	Unexplained add-on	Emerges from distinguishability
Ontological cost	Infinite worlds	Single co-constituted reality

MWI generates everything consistent with unitary evolution, then struggles to recover observed physics. LRT begins with logical constraint—there is no "everything exists, then we pick."

6. Empirical Status

6.1 Falsifiability

LRT forbids:

1. A completed measurement recording $P \wedge \neg P$
2. A completed measurement yielding neither P nor $\neg P$ (genuine gap, not mere indeterminacy)
3. A physical state failing self-identity across observation

6.2 Current Evidence

No violation of 3FLL has ever been observed in any completed physical measurement across all domains of physics—classical, quantum, relativistic, or cosmological. Every detector record is Boolean at the outcome level, even when the underlying formalism involves superposition.

6.3 Status of Non-Classical Logics

Paraconsistent and dialetheist approaches in physics have not produced distinctive, confirmed predictions differing from standard quantum theory. They remain formally well-defined options and valuable thought experiments, but at present are not empirically established competitors to the 3FLL-constrained outcome structure that LRT codifies: they have produced no distinctive, confirmed predictions and are not part of the standard calculational toolkit in any active experimental domain.

7. Discussion

7.1 Scope

LRT concerns *physical reality*—measurement outcomes and actualized states. It is agnostic about mathematical reality, the ontological status of 3FLL themselves, and domains beyond physics.

7.2 What LRT Claims

1. **Empirical:** No completed measurement violates 3FLL (Theorem 1—supported)
2. **Structural:** The tier system clarifies presupposition dependencies in foundational physics
3. **Conjectural:** 3FLL + information space suffice for physical actualization (Conjecture 1—open)

7.3 What LRT Does Not Claim

- That physics reduces to pure logic
- That all reconstruction axioms have been derived from 3FLL
- That the completeness conjecture is proven

8. Conclusion

Logic Realism Theory offers a framework in which physical reality is co-constituted by logical constraint operating on information space. The empirically supported component ($\mathfrak{A} \subseteq \mathfrak{L}(\mathfrak{I})$) states that no actualized outcome violates 3FLL. The open conjecture ($\mathfrak{L}(\mathfrak{I}) \subseteq \mathfrak{A}$) proposes that this constraint, together with the information space structure, suffices for physical actualization.

The co-constitutive framing provides what Many-Worlds lacks: a principled selection criterion. Rather than generating all possibilities and struggling to explain why we observe one, LRT identifies what can be actualized from the start.

The framework connects naturally to quantum reconstruction programs while maintaining clear empirical content and honest separation of proved from conjectured components. It is offered as an ambitious research program for quantum foundations, not established truth. Accordingly, LRT is not put forward as a fully worked alternative interpretation of quantum theory, but as a structured proposal for how logical constraints and information-theoretic structure might jointly underpin such an interpretation.

Research Program and Collaboration

LRT is an active research program with open questions suitable for collaboration. Key areas include:

- Formal verification of the derivation chain (Lean 4 formalization in progress)
- Derivation of Masanes-Müller axioms from 3FLL + parsimony
- Connection to quantum gravity and the measurement problem
- Experimental proposals for precision tests

The complete research program, including derivations, formal proofs, and documentation, is available at:

https://github.com/jdlongmire/logic-realism-theory

Collaborators with expertise in quantum foundations, mathematical physics, formal verification, or philosophy of physics are welcome to contribute. Contact the author for discussion.

References

Chiribella, G., D'Ariano, G.M. and Perinotti, P. (2011) 'Informational derivation of quantum theory', *Physical Review A*, 84(1), 012311.

Hardy, L. (2001) 'Quantum Theory From Five Reasonable Axioms', arXiv:quant-ph/0101012.

Masanes, L. and Müller, M.P. (2011) 'A derivation of quantum theory from physical requirements', *New Journal of Physics*, 13, 063001.