Logical Emergence: A Research Project Deriving Physical Reality from the Three Fundamental Laws of Logic

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Abstract

This research project introduces *Logical Emergence*, a foundational framework positing that physical reality, including quantum mechanics (QM) and fundamental laws, derives necessarily from the Three Fundamental Laws of Logic (3FLL): Identity ($A = A$), Non-Contradiction ($\neg(A \wedge \neg A)$), and Excluded Middle ($A \vee \neg A$). Treated as ontic principles, the 3FLL form the minimal logical system permitting existence, from which mathematics, geometry, and physics emerge as inevitable consequences. The project encompasses: (1) Logic Field Theory (LFT), modeling reality as logically filtered graph configurations yielding quantum structures; (2) formal verifications in Lean theorem-proving; (3) an ontic logic ontology deriving physical laws; and (4) the Logical Resolution Model (LRM), reframing quantum measurement as continuous, logic-constrained resolution. Empirically equivalent to standard QM, Logical Emergence resolves paradoxes like wavefunction collapse and fine-tuning through logical necessity, offering testable predictions such as decoherence scaling laws and resolution thresholds. This interdisciplinary effort—spanning logic, physics, and philosophy—aims to unify foundations by demonstrating maximum complexity from minimal primitives, with implications for quantum gravity and consciousness.

Keywords: foundational physics, quantum mechanics, logical ontology, emergence, theorem proving

1 Introduction

The quest to understand the foundations of physical reality has long grappled with questions of contingency versus necessity: Why these laws and constants, rather than others? Interpretations of quantum mechanics, from Copenhagen's collapse postulate to Many-Worlds' branching universes, introduce ontological complexities without resolving the "why" of quantum structure [Everett, 1957].

Efforts to derive QM from alternative axioms—such as categorical semantics or space-time-action relativity—highlight the need for a minimal, logic-grounded approach [Abramsky and Coecke, 2004, Keller, 2001].

Logical Emergence proposes a paradigm shift: Physical reality emerges necessarily from the Three Fundamental Laws of Logic (3FLL)—Identity, Non-Contradiction, and Excluded Middle—as the simplest possible ontic system. These laws are prescriptive constraints, ensuring coherence and definiteness. From this irreducible minimum springs an emergence hierarchy: logic $\rightarrow$ mathematics $\rightarrow$ geometry $\rightarrow$ forces $\rightarrow$ particles $\rightarrow$ complex phenomena, including biology and consciousness.

The project integrates four components:

- **Logic Field Theory (LFT)**: A graph-based model filtering configurations via 3FLL to yield quantum Hilbert spaces and dynamics.
- **Lean Formalizations**: Theorem-proving code verifying key derivations, such as complex scalars and the Born rule.
- **Ontic Logic Framework**: Philosophical derivation of physical laws (e.g., conservation from Identity) and uniqueness arguments.
- **Logical Resolution Model (LRM)**: Application to QM measurement, replacing collapse with continuous resolution.

This framework resolves foundational issues—measurement problem, fine-tuning—through logical necessity, while remaining empirically equivalent to QM. It predicts deviations testable in mesoscopic systems and inspires unification with gravity. The project draws inspiration from quantum logic derivations [Birkhoff and von Neumann, 1936] and categorical axiomatics [Coecke, 2003], but grounds everything in classical 3FLL for parsimony.

Section 2 outlines the 3FLL foundations. Sections 3–6 detail the components. Section 7 discusses predictions, and the conclusion explores implications.

2 Foundations: The Three Fundamental Laws of Logic as Ontic Primitives

The 3FLL form the minimal logical system permitting coherent existence:

- **Identity** ($A = A$): Ensures persistent, distinct entities, generating conservation laws via Noether symmetries.
- **Non-Contradiction** ($\neg(A \land \neg A)$): Prohibits inconsistencies, yielding uncertainty relations and causal structure.
- **Excluded Middle** ($A \lor \neg A$): Demands definiteness, underpinning measurement outcomes and eigenvalue spectra.

As ontic principles, the 3FLL prescribe reality: Fewer laws lead to incoherence (e.g., no Identity implies no entities). This primacy precedes mathematics (e.g., Peano axioms emerge from 3FLL) and physics, creating an emergence hierarchy where complexity unfolds from minimal foundations—the "profound economy" of nature [Longmire, 2025c].

Unlike quantum logic [Birkhoff and von Neumann, 1936], which modifies classical rules for QM, Logical Emergence retains Aristotelian 3FLL, interpreting quantum "weirdness" as epistemic resolution of logical possibilities. This approach aligns with efforts to formalize logical constraints in physics [Doering and Isham, 2008], but emphasizes classical logic's sufficiency.

3 Logic Field Theory: From Graphs to Quantum Structures

LFT models reality as information configurations filtered by 3FLL. The syntactic space $\mathcal{S}$ consists of finite directed graphs with vertices (literals), edges (implications), and negation involution τ. The logic operator $\mathbb{L}$ enforces 3FLL, yielding admissible set $\mathcal{A}$.

Quantum features emerge:

- Superpositions from logical incompleteness.
- Complex scalars from oriented cycles (proven unique in D02).
- Born rule from path counting (D04).
- Strain functional $D(\psi) = w_I v_I + w_N v_N + w_E v_E$, with weights derived from scale invariance (D05), explaining decoherence: $\tau_D \propto (\xi/\ell_0)^2/\Gamma$, where $\ell_0 \sim 10^{-35}$ m.

Gauge groups U(1)×SU(2)×SU(3) derive from symmetries (cycles → U(1), binary → SU(2), triadic → SU(3); D03). LFT predicts strain-modified transitions and sharp quantum-classical thresholds, distinguishing it from standard QM decoherence (e.g., $\tau_D \propto 1/\text{size}$) [Longmire, 2025b].

4 Formal Verifications in Lean

To ensure rigor, key LFT theorems are formalized in Lean theorem-proving:

- **D01 (Admissibility)**: Implements $\mathbb{L}$ via breadth-first search (O(—V—^{3})), $verifying3FLLongraphs.$**D0** $Proves\mathbb{C}$ as the unique scalar field satisfying orientation, commutativity, and completeness.
- **D03 (Gauge Emergence)**: Derives Standard Model groups and three fermion generations from logical symmetries.

- **D04 (Born Rule)**: Shows $|\psi|^2$ unique via normalization, additivity, phase invariance, and factorization.
- **D05 (Strain Weights)**: Derives ratios $(\xi/\ell_0)^2 : 1 : (\ell_0/\xi)^2$, predicting huge disparities (e.g., 10^{100} for electrons).

These formalizations, hosted in a GitHub repository, confirm logical consistency, though some proofs remain incomplete (marked 'sorry') [Longmire, 2025a]. Future work will integrate with Mathlib for full rigor.

5 Ontic Logic Framework: Deriving Physics from Necessity

Extending LFT philosophically, the Ontic Logic framework treats 3FLL as the "operating system" of reality. Physical laws emerge:

- Conservation from Identity (Noether as necessity).
- Relativity from Non-Contradiction (causal consistency).
- QM from all three (definiteness resolves superpositions).

The universe is unique—a "crystalline structure" from 3FLL seed—resolving fine-tuning. Mathematical beauty signals proximity to 3FLL; experiments uncover emergence despite necessity, as human cognitive limits necessitate empirical guidance [Longmire, 2025c]. This framework aligns with necessitarian philosophies but grounds them in verifiable physics [Putnam, 1969].

6 Logical Resolution Model: Applying to Quantum Measurement

LRM applies Logical Emergence to QM measurement: Superposition represents unresolved logical possibilities; measurement is continuous elimination via 3FLL-constrained interactions. The Lagrangian $\mathcal{L} = \mathcal{L}_{\text{field}} + \mathcal{L}_{\text{interaction}} + \mathcal{L}_{\text{logic}}$ enforces logical consistency (e.g., penalty for contradictions). Decoherence integrates as resolution; the Born rule emerges from Excluded Middle counting.

LRM resolves collapse (no discontinuity) and EPR correlations (via correlated resolutions), matching standard QM while parsimonious. It predicts measurable resolution thresholds in quantum erasers and Zeno effects [Walborn et al., 2002, Misra and Sudarshan, 1977].

7 Predictions, Testability, and Future Directions

Logical Emergence offers falsifiable predictions:

- **LFT**: Decoherence scaling deviations ($\tau_D \propto \xi^2$) versus QM's 1/size.

- **Ontic Logic**: No fifth force; derivable fundamental constants (e.g., fine-structure constant α).
- **LRM**: Resolution rates in mesoscopic systems (e.g., NV-centers [Doherty et al., 2013]).

These can be tested via interferometry, cavity QED, or quantum computing setups [Blais et al., 2021]. Future directions include:

- Deriving a constant (e.g., α) using logical constraints.
- Unifying gravity via a logical metric (LFT's diffeomorphism gauge).
- Simulating resolution processes in computational tools (e.g., QuTiP, SymPy).

8 Conclusion

Logical Emergence redefines physics as the deductive unfolding of the 3FLL, resolving QM paradoxes (e.g., measurement, fine-tuning) through logical necessity. Integrating LFT, Lean formalizations, Ontic Logic, and LRM, this project offers a unified, testable framework, inspiring a logic-first paradigm for foundational physics. Ongoing work focuses on completing Lean proofs, quantifying predictions, and collaborating with experimentalists to validate claims, potentially revolutionizing our understanding of reality as the inevitable consequence of minimal logic.

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