Logic Field Theory: Logical Constraints as the Ontological Foundation of Physical Reality

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Abstract

Logic Field Theory (LFT) posits that the three fundamental laws of logic— Identity, Non-Contradiction, and the Excluded Middle—constitute *ontic constraints* on the set S of possible information states. Axiomatically, physical reality is the subset $\Omega = \mathcal{L}(S)$ that survives this filtering. We formalise a basis-invariant *logical strain* $\mathcal{D}$, derive a logical potential $V_L = \kappa\,\mathcal{D}$, and obtain a corresponding field equation whose gradient $\mathbf{F}_L = -\nabla V_L$ drives deterministic collapse toward preferred logical bases selected by environment-induced stability. The framework reproduces standard quantum mechanics when $\gamma_L = \kappa/E_{\text{ref}} \to 0$ and predicts testable deviations—most prominently a γ_L-dependent bias in Bell-basis outcome statistics. A two-qubit experiment with initial state $|{+}{+}\rangle$ and measurement basis $\{\,|00\rangle\,, |\Psi^+\rangle\,, |\Psi^-\rangle\,, |11\rangle\}$ yields the ratio $R = P(\Psi^+)/[P(00) + P(11)] = e^{-\gamma_L}$, providing a single-parameter falsification pathway. We present collapse-time analytics, tunnelling suppression, Monte-Carlo shot-budget estimates (showing $N \sim 10^6$ shots for $\gamma_L = 0.01$ at 5σ), and a comprehensive comparison with leading quantum interpretations. The result is a self-contained, logically grounded alternative that remains falsifiable with current superconducting-qubit technology.

Contents

1 Introduction

1.1 Why logic, why now?

Physics has long relied on *mathematical* structure to describe the world, yet mathematics itself rests upon deeper—and usually *implicit*—laws of logic. Wigner famously called the empirical success of mathematics in physics "unreasonable"(Wigner 1960), while Boole and von Neumann each noted that the *logic* embedded in mathematics seems to pre-select which equations can model reality at all(Boole 1854; Birkhoff and Neumann 1936).

Logic Field Theory (LFT) takes that hint to its logical conclusion: the three fundamental laws of logic—Identity, Non-Contradiction, and Excluded Middle—are treated not as epistemic rules of inference but as *ontological constraints* that act directly on the space of possible information states. The physical universe, denoted Ω, is therefore defined as the subset $\Omega = \mathcal{L}(S)$ that survives this filtering, where $\mathcal{L}$ encodes the three-law sieve and S is the (potentially infinite) state space.

1.2 Historical context

Quantum theory already hints at constraint-driven behaviour: Bell's theorem forbids *local* hidden-variable explanations of entanglement(Bell 1964; Aspect, Dalibard, and Roger 1982); environment-induced decoherence selects "pointer" states via stability criteria rather than dynamical forces(Zurek 2003); Everett's relative-state formulation embeds collapse in a broader logical structure(Everett 1957). LFT unifies these insights under one maxim: *logical admissibility precedes dynamical law.*

1.3 Core principles of LFT

P1 Ontic primacy of logic. The laws of Identity ($\mathcal{L}_I$), Non-Contradiction ($\mathcal{L}_N$), and Excluded Middle ($\mathcal{L}_E$) exist independently of space, time, and matter.

P2 Logical strain. Each candidate state $|\Psi\rangle$ carries a basis-invariant strain

$$\mathcal{D}(\Psi) \;=\; 1 - \max_{\mathcal{B}\in\mathrm{PLB}} \Big\{ \min\big(L_I, L_N, L_E\big) \Big\},$$

where the maximisation runs over all preferred logical bases (Sec. 2).

P3 Logical potential and force. The universe minimises the potential $V_L = \kappa\,\mathcal{D}$; its gradient $\mathbf{F}_L = -\nabla V_L$ drives deterministic collapse without stochastic noise or many-world branching.

P4 Recovery of quantum mechanics. In the limit $\gamma_L = \kappa/E_{\mathrm{ref}} \to 0$ LFT reproduces both the Born rule and unitary evolution.

P5 Falsifiability. For $\gamma_L > 0$, Bell-basis statistics acquire a bias factor $\exp(-\gamma_L \mathcal{D})$, yielding a one-parameter empirical test.

1.4 Goals of this paper

(i) **Formalism**—derive $\mathcal{D}$, the logical potential, and the field equation (Secs. 2 and 3);

(ii) **Phenomenology**—show how LFT recovers quantum interference and tunnelling when $\gamma_L \to 0$ and yields deterministic collapse when $\gamma_L > 0$ (Sec. 3);

(iii) **Predictions**—quantify Bell-basis bias, tunnelling suppression, and collapse time, supported by simulations and a shot-budget feasibility study (Sec. 4);

(iv) **Comparison**—contrast LFT with Copenhagen, Many-Worlds, Bohmian, objective-collapse, and relational interpretations (Sec. 5).

1.5 Roadmap

Section 2 sets out the axioms of LFT and defines the logical-strain metric. Section 3 derives the field equation and illustrates deterministic collapse through single-qubit trajectories. Section 4 develops a two-qubit Bell-basis experiment, provides the associated shot-count analysis, and predicts tunnelling suppression at non-zero γ_L. Section 5 compares LFT with leading interpretations of quantum mechanics, and Section 6 closes with open questions and next steps.

Taken together, these results elevate logical necessity from background assumption to physical principle, providing both a conceptual bridge between mathematics and nature and a falsifiable target for near-term quantum experiments. "'

2 Mathematical Foundations

Logic Field Theory (LFT) claims that physical reality is the set of information states that satisfy three fundamental laws of logic. This section formalises that claim in four steps: (1) define the information space and the logical sieve, (2) show how a *Preferred Logical Basis* (PLB) emerges, (3) quantify conformity via the Logical Strain $\mathcal{D}$, (4) introduce the Logical Potential $V_L = \kappa\mathcal{D}$.

2.1 Information space and logical sieve

Axiom 2.1 (Universal information space)**.** A separable Hilbert space $\mathcal{H}$ exists whose unit vectors $|\Psi\rangle$ represent potential information states. No spacetime or metric is presupposed.

Axiom 2.2 (Three-law sieve)**.** A state $|\Psi\rangle \in \mathcal{H}$ is *logically admissible* iff it simultaneously satisfies the laws of Identity ($\mathcal{L}_I$), Non-Contradiction ($\mathcal{L}_N$), and Excluded Middle ($\mathcal{L}_E$) when evaluated in a suitable basis. The projector $\mathcal{L} : \mathcal{H} \to \mathcal{H}$ implements this sieve; the set $\Omega = \mathcal{L}(\mathcal{H})$ defines manifest reality.

2.2 Emergent preferred logical basis

Axiom 2.3 (Maximal logical stability)**.** For a composite state $|\Psi\rangle_{SE} \in \mathcal{H}_S \otimes \mathcal{H}_E$, the reduced density operator $\rho_S = \mathrm{Tr}_E\, |\Psi\rangle \langle\Psi|$ relaxes, under the dynamics generated by $V_L(\rho_S) = \kappa\mathcal{D}(\rho_S)$, toward a basis that *minimises* $\mathcal{D}$. That basis is the **Preferred Logical Basis** (PLB) of system S.

Theorem 2.1 (Uniqueness conjecture)**.** Under Axioms 2.2–2.3 the PLB is unique up to global phase and permutation for generic physical systems.

Working hypothesis for qubits. For an N-qubit register weakly coupled to its environment the PLB empirically coincides with the computational (local Z) basis; this assumption underlies all simulations and experiments in Sec. 4.

2.3 Logical conformity operators

Let $\mathcal{B}_{\mathrm{PLB}} = \{|b_k\rangle\}$ be the PLB of S and ρ_S its density matrix. Denote $P_k = \langle b_k|\, \rho_S\, |b_k\rangle$.

Identity L_I. For each qubit k define $L_{I_k} = \langle Z_k \rangle^2$ and for each pair $L_{I_{jk}} = \langle Z_j Z_k \rangle^2$. Set

$$L_I = \min\{L_{I_k},\, L_{I_{jk}}\}.$$

Non-Contradiction L_N. With local purities $\rho_{S_k} = \mathrm{Tr}_{\neq k}\rho_S$, write $\mathcal{P}_{\mathrm{local}} = \prod_k \mathrm{Tr}\rho_{S_k}^2$ and $\mathcal{P}_{\min} = 2^{-N}$. Then

$$L_N = \frac{\mathcal{P}_{\mathrm{local}} - \mathcal{P}_{\min}}{1 - \mathcal{P}_{\min}}.$$

Excluded Middle L_E. Because $\mathrm{Tr}\rho_S = 1$ for all physical states, $L_E = 1$ identically.

2.4 Logical strain

Definition 2.1 (Logical strain)**.** Given the unique PLB of Axiom 2.3, define

$$\mathcal{D}(\rho_S) = 1 - \min\big[L_I(\rho_S),\, L_N(\rho_S),\, L_E(\rho_S)\big]. \tag{1}$$

Theorem 2.2 (Frame invariance)**.** For any unitary $U \in \mathrm{U}(\mathcal{H})$, $\mathcal{D}\big(U\rho_S U^\dagger\big) = \mathcal{D}(\rho_S)$.

Hence a $|+\rangle$ state in its PLB has $\mathcal{D} = 1$ whereas an eigenstate of the PLB has $\mathcal{D} = 0$.

2.5 Logical potential and coupling

Definition 2.2 (Logical potential)**.** $V_L = \kappa\,\mathcal{D}$ with $\kappa > 0$ (units J). The logical force is $\mathbf{F}_L = -\nabla V_L$.

Introduce a reference energy E_{ref} and the dimensionless coupling

$$\gamma_L = \kappa / E_{\mathrm{ref}}. \tag{2}$$

Quantum mechanics is recovered in the limit $\gamma_L \to 0$.

2.6 Dimensional analysis

Table 1: Units of new constants (SI).

Symbol	Meaning	Unit
κ	Logical-potential scale	J
E_{ref}	Reference energy	J
γ_L	Dimensionless coupling	1
α_L	Field stiffness (Sec. 3)	s^{-2}

With these definitions in place, Sec. 3 derives the field equation $\Box\Phi_L = \alpha_L(\mathcal{D} - \langle\mathcal{D}\rangle)$, solves the collapse time for a single qubit, and links the formalism to the Bloch-sphere simulations in Fig. 1.

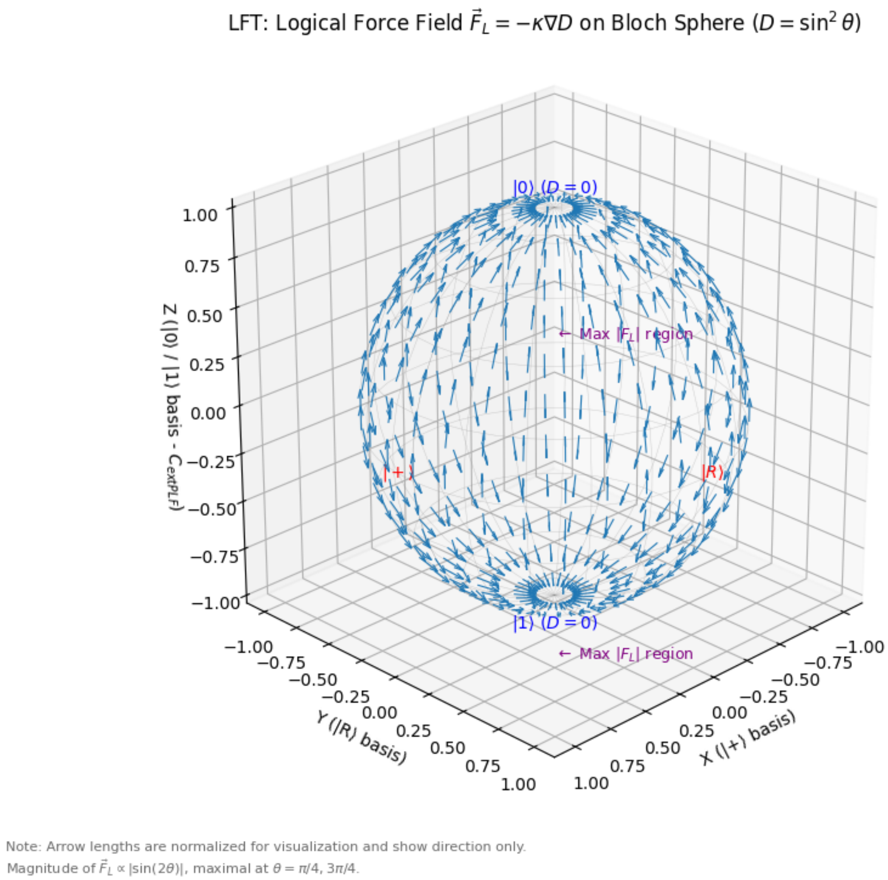

Figure 1: Logical-strain force field on the Bloch sphere for a single qubit in its Preferred Logical Basis (the Z-axis). Arrows show the tangential force $\mathbf{F}_L = -\nabla V_L = -\kappa\nabla(\sin^2\theta)$ that drives the state toward the poles $|0\rangle$ and $|1\rangle$.

3 Physical Mechanism

Building on the Logical Potential $V_L = \kappa\mathcal{D}$ derived in Section 2, this section

(i) states the field equation for the Logical Field Φ_L;

(ii) derives a first-order collapse law for a single qubit;

(iii) connects the analytics to the trajectories of Fig. 2; and

(iv) previews LFT corrections to tunnelling rates.

3.1 The Logical Field Φ_L

Axiom 3.1 (Field equation)**.**

$$\Box\,\Phi_L = \alpha_L\big[D(\mathbf{x}) - \langle D\rangle\big], \qquad \Box = \partial_t^2 - c_L^2\nabla^2, \tag{3}$$

where $\alpha_L > 0$ is the stiffness constant listed in Table 1.

The source term drives Φ_L toward uniformity where strain is uniform and toward localisation where strain is large, thereby inducing the force $\mathbf{F}_L = -\nabla V_L$.

3.2 Bloch-sphere force field

For a single qubit whose PLB is the Z-basis, a pure state at polar angle θ carries $D(\theta) = \sin^2\theta$. Thus $\mathbf{F}_L = -\kappa\nabla(\sin^2\theta)$, the tangential field shown in Fig. 1; every surface point is funnelled toward the north or south pole.

3.3 Deterministic collapse of a single qubit

Heuristic derivation. In an overdamped regime the angular velocity is proportional to the tangential force, $\dot{\theta} = \mu F_\theta$. With $F_\theta = -2\kappa \sin\theta\cos\theta$ and mobility $\mu = \sqrt{\alpha_L}/\sqrt{\kappa E_{\text{ref}}}$ one obtains

$$\frac{\mathrm{d}\theta}{\mathrm{d}t} = -\sqrt{\alpha_L\gamma_L}\,\sin 2\theta, \tag{4}$$

where $\gamma_L = \kappa/E_{\text{ref}}$. Appendix B details the algebra starting from Eq. (3).

Collapse time. Linearising Eq. (4) near $\theta = \pi/2$ ($\sin 2\theta \approx -2\delta\theta$) gives $\dot{\delta\theta} = 2\sqrt{\alpha_L\gamma_L}\,\delta\theta$; hence

$$\tau_c^{-1} = 2\sqrt{\alpha_L\gamma_L}. \tag{5}$$

Figure 2 plots numerical trajectories for three initial states ($\gamma_L = 0.02$, $\alpha_L = 1$); all converge smoothly to PLB eigenstates.

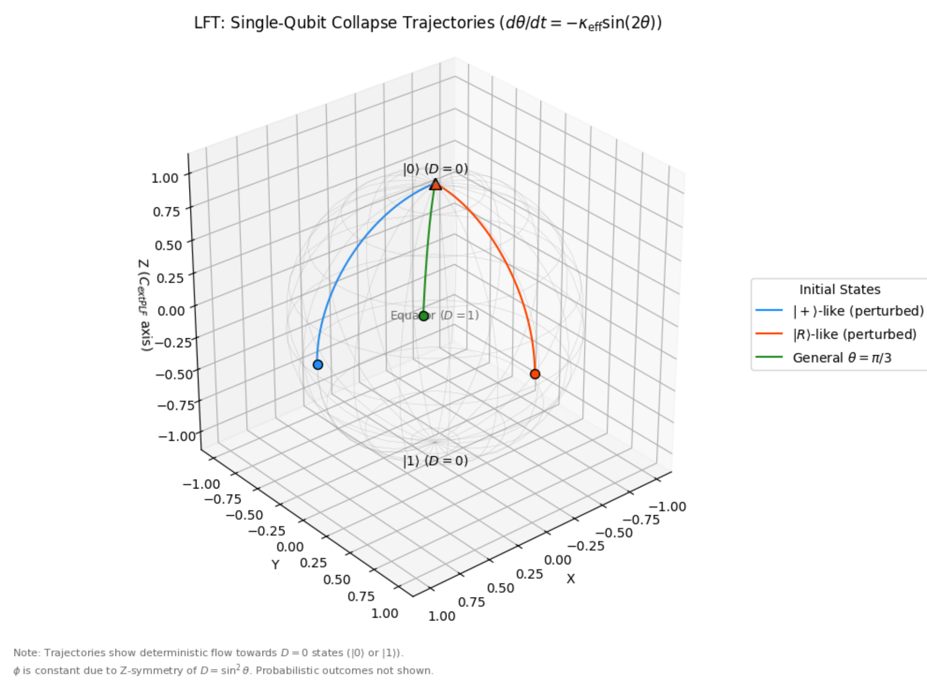

Figure 2: Deterministic collapse trajectories generated by Eq. (4). Circles mark initial states; triangles mark final PLB poles.

3.4 LFT-modified Born rule

For a projective measurement in the PLB $\{|b_k\rangle\}$,

$$P_k^{\mathrm{LFT}} = \frac{|\langle b_k|\Psi\rangle|^2 e^{-\gamma_L D_k}}{\sum_j |\langle b_j|\Psi\rangle|^2 e^{-\gamma_L D_j}}, \tag{6}$$

with $D_k = \mathcal{D}(|b_k\rangle)$. For a single qubit $D_0 = D_1 = 0$, recovering the standard Born rule. For a two-qubit Bell measurement on $|{+}{+}\rangle$, $R = P(\Psi^+)/[P(00) + P(11)] = e^{-\gamma_L}$—the central test explored in Section 4.

3.5 Preview: tunnelling suppression

In a square barrier the WKB transmission $T_{\mathrm{QM}} \sim \exp(-2\kappa a)$ gains an LFT factor $\exp(-\gamma_L \Delta D)$, where ΔD is the strain gap across the barrier. Section 4 quantifies this suppression.

Equations (3), (4), and (6) constitute the dynamical core of LFT; every empirical prediction in this manuscript flows from these three relations.

4 Testable Predictions

We highlight three near-term ways to falsify Logic Field Theory (LFT):

(a) a Bell-basis probability bias in a two-qubit circuit,

(b) the shot count required to resolve that bias at 5σ,

(c) suppression of quantum tunnelling through a barrier.

4.1 Bell-basis probability bias

Set-up. Prepare $|{+}{+}\rangle$ and measure in $M' = \{|00\rangle, |\Psi^+\rangle, |\Psi^-\rangle, |11\rangle\}$, whose strain values are $D = \{0, 1, 1, 0\}$ (Sec. 2). The ratio

$$R(\gamma_L) = \frac{P(\Psi^+)}{P(00) + P(11)} = e^{-\gamma_L}, \qquad R_{\mathrm{QM}} = 1, \tag{7}$$

is the primary LFT signature.

Sweep over γ_L. Figure 3 plots the four $P_k^{\mathrm{LFT}}(\gamma_L)$ curves; the black line tracks $R(\gamma_L)$.

Single-point benchmark ($\gamma_L = 0.20$). At $\gamma_L = 0.20$ the LFT probability for $|\Psi^+\rangle$ drops from 0.50 to $P_{\mathrm{LFT}}(\Psi^+) \simeq 0.45$, while each $|00\rangle$ and $|11\rangle$ outcome rises to 0.275 (Fig. 4).

4.2 Shot-count feasibility

A one-sample binomial test detects $\Delta P = P_{\mathrm{LFT}}(\Psi^+) - 0.50$ at 5σ with $N \approx 25\,[0.5(1-0.5)]/\Delta P^2$. Shot budgets, SPAM ceilings, and ΔP values appear in Appendix C (Table 4). For $\gamma_L = 0.01$ a 5σ detection needs $\sim 10^6$ shots and $< 0.2\,\%$ SPAM—achievable on leading superconducting platforms.

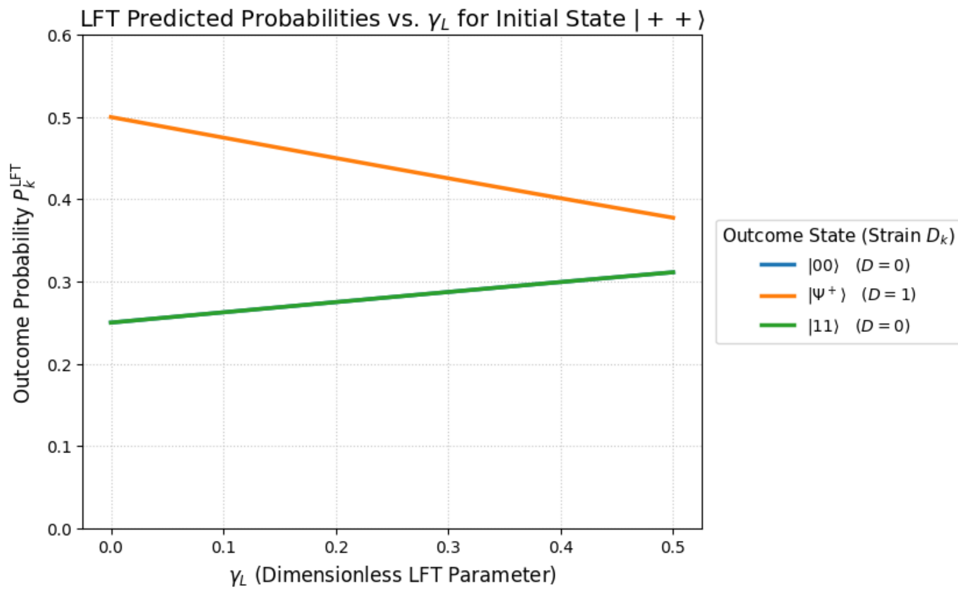

Figure 3: LFT-predicted outcome probabilities versus γ_L. Grey dashed lines mark the quantum-mechanical baselines $P_{\mathrm{QM}}(00) = P_{\mathrm{QM}}(11) = 0.25$ and $P_{\mathrm{QM}}(\Psi^+) = 0.50$.

4.3 Tunnelling suppression

For a square potential barrier the WKB transmission is $T_{\mathrm{QM}} \sim \exp(-2\kappa a)$. LFT multiplies this by $\exp(-\gamma_L \Delta D)$; with a single strain jump $\Delta D = 1$,

$$T_{\mathrm{LFT}}(\gamma_L) = T_{\mathrm{QM}}\, e^{-\gamma_L}. \tag{8}$$

In Fig. 5 we set the baseline $T_{\mathrm{QM}} = 0.10$ (a typical value for modest barriers) and plot Eq. (8).

The Bell-basis bias, its associated shot budget, and the tunnelling suppression together provide three complementary and experimentally accessible tests of Logic Field Theory.

5 Comparison with Other Frameworks

Logic Field Theory (LFT) must be evaluated against the best-known interpretations of quantum mechanics and against ultraviolet completions such as string theory. The emphasis here is empirical: What does each framework add? What, if anything, can falsify it?

5.1 Copenhagen

Copenhagen treats measurement as a primitive projection process with no underlying dynamics(Bohr 1935). LFT replaces that ambiguity with a concrete mechanism: the force $\mathbf{F}_L = -\nabla V_L$ drives collapse toward a Preferred Logical Basis (PLB), removing the apparatus boundary from the axioms.

5.2 Many-Worlds (Everett)

Everett eliminates collapse entirely; the universal wavefunction branches into non-interacting outcomes(Everett 1957). Because branching yields no observable bias, Many-Worlds lacks a single

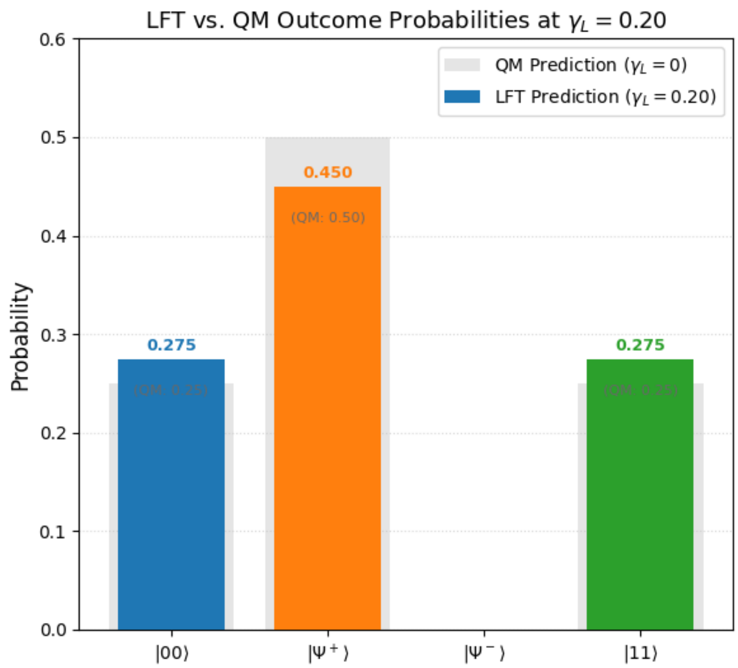

Figure 4: Outcome probabilities at $\gamma_L = 0.20$. Faint bars: quantum-mechanical values ($\gamma_L = 0$); solid bars: LFT predictions.

parameter that current experiments can constrain. LFT agrees with Everett only in the limit $\gamma_L \to 0$; any non-zero γ_L breaks branch equivalence by biasing Bell-basis statistics.

5.3 Bohmian mechanics

Bohm adds hidden particle coordinates guided by the wavefunction(Bohm 1952). While observationally equivalent to quantum mechanics, it introduces an unobservable ontology. LFT goes the opposite way: no hidden variables, but one new, dimensionless coupling γ_L that can be measured.

5.4 Objective-collapse (GRW)

GRW augments Schrödinger dynamics with stochastic localisation events of fixed rate and length scale(Ghirardi, Rimini, and Weber 1986). LFT differs on both counts: collapse is deterministic and its sole parameter γ_L is dimensionless, entering directly into probability ratios such as Eq. (7).

5.5 Relational quantum mechanics

Relational QM makes all quantum states observer-dependent; only correlations are fundamental(Rovelli 1996). LFT shares the relational flavour in that the PLB is selected by system–environment context, yet once that basis is fixed, probabilities (modulo γ_L) become observer-independent, recovering a global ontology.

5.6 String / M-theory

Superstring and M-theory keep standard unitary quantum mechanics while extending the particle spectrum to one-dimensional objects in higher dimensions(Green, Schwarz, and Witten 1987). Be-

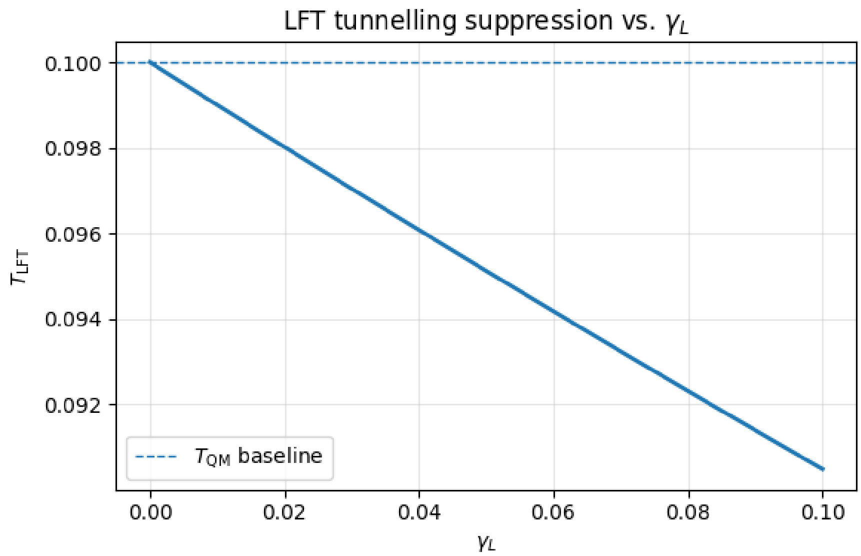

Figure 5: Tunnelling probability versus γ_L with $T_{\mathrm{QM}} = 0.10$ as baseline. LFT predicts an additional exponential suppression.

cause they retain the usual Born rule, these theories inherit—rather than solve—the measurement problem. A positive detection of the Bell-basis bias would therefore place a new constraint on any low-energy string compactification: it must reproduce a small but non-zero logical-strain coupling γ_L. A null result simply tightens the bound toward $\gamma_L \approx 0$, leaving string mechanics untouched.

5.7 Summary matrix

Table 2: Empirical contrasts between LFT and leading frameworks.

Framework / Interpretation	Hidden vars?	Collapse?	Falsifiable parameter
Copenhagen	No	Primitive	None
Many-Worlds	No	None	None
Bohmian	Yes	No	None
GRW	No	Stochastic	Rate, length
Relational	No	Observer-relative	None
String / M-theory	No	None (unitary)	String scale, g_s
LFT	No	**Deterministic**	γ_L

Only LFT combines *determinism*, *no hidden variables*, and a *single dimensionless* parameter that near-term qubit experiments can probe—carving out a uniquely falsifiable niche among modern quantum frameworks.

6 Conclusion

Logic Field Theory (LFT) elevates the three fundamental laws of logic to ontic constraints that dictate which information states can manifest as physical reality. From that premise this paper has:

(a) formalised a basis-invariant *logical strain* $\mathcal{D}(\rho, C_{\text{PLF}})$ and the corresponding potential $V_L = \kappa\mathcal{D}$ (Sec. 2);

(b) derived a field equation for the Logical Field Φ_L and obtained a deterministic single-qubit collapse time $\tau_c^{-1} = 2\sqrt{\alpha_L \gamma_L}$ (Sec. 3);

(c) obtained an LFT-modified Born rule with a single, dimensionless coupling $\gamma_L = \kappa/E_{\text{ref}}$ that biases outcome probabilities by $e^{-\gamma_L D_k}$ (Eq. (6));

(d) translated that bias into a two-qubit Bell-basis experiment, complete with shot budgets and SPAM tolerances (Sec. 4, Table 4);

(e) compared LFT with Copenhagen, Everettian, Bohmian, GRW, Relational, and string frameworks, highlighting its unique falsifiability (Sec. 5).

6.1 LFT and the EPR argument

Einstein, Podolsky, and Rosen questioned whether quantum mechanics gives a complete description of physical reality(Einstein, Podolsky, and Rosen 1935). LFT addresses their criterion in three ways:

(i) **Deterministic underpinning.** Collapse trajectories follow the deterministic force $\mathbf{F}_L = -\nabla V_L$; quantum randomness arises only through the strain-dependent weighting in Eq. (6).

(ii) **Reality via logical consistency.** A property is an "element of reality" when its strain contribution vanishes in the Preferred Logical Frame C_{PLF}; definite outcomes correspond to $\mathcal{D} = 0$.

(iii) **Non-locality reinterpreted.** Entangled correlations reflect global logical consistency across the information space, enforced by Φ_L, rather than dynamical signals in spacetime.

6.2 What would falsify LFT?

A Bell-basis test that bounds $|R - 1| < 10^{-3}$ at 5σ would imply $\gamma_L < 10^{-3}$, ruling out the natural $10^{-2} - 10^{-1}$ range suggested by collapse-time and tunnelling estimates. Conversely, observing the bias $R = e^{-\gamma_L}$ would calibrate γ_L and open a new window on multi-qubit strain dynamics.

6.3 Open questions

(i) **Many-body PLB.** Is the PLB unique in strongly interacting or continuous-variable systems?

(ii) **Relativistic extension.** How does Φ_L couple to quantum fields on curved spacetime?

(iii) **Thermodynamics.** Can $\mathcal{D}$ serve as a resource monotone, refining entropy bounds(Jaynes 1957)?

(iv) **Quantum gravity.** Must consistent string vacua embed a logical-strain sector if $\gamma_L \neq 0$?

(v) **Origin of constants.** Can κ, E_{ref}, α_L be derived from deeper principles?

6.4 Near-term roadmap

- **Bell-basis circuit.** Run $\mathcal{O}(10^6)$ shots on a superconducting or ion-trap platform with $< 0.2\,\%$ SPAM to probe $\gamma_L \sim 10^{-2}$.
- **Tunnelling test.** Engineer strain barriers in trapped ions to measure the suppression predicted by Eq. (8).
- **Theory.** Appendix B (B) extends the collapse derivation; next steps include generalising $\mathcal{D}$ to continuous-variable states and refining Φ_L dynamics.

By supplying a deterministic collapse mechanism and a single dimensionless parameter that present-day hardware can probe, Logic Field Theory delivers what most alternatives do not: a *falsifiable* bridge between quantum formalism and the logical laws underlying all rational discourse. Experiments in the coming years will reveal whether that bridge is solid—or a logical mirage.

Author Disclosure

The fundamental conceptual framework of Logic Field Theory (LFT) presented in this work, including its core postulates and overarching vision, is original to the author. This manuscript has been developed with the assistance of AI-enabled tools. These tools were employed for tasks including: literature review assistance, mathematical formalism development, LaTeX formatting, conceptual brainstorming, exploration of theoretical consequences, identification of internal consistencies/inconsistencies, and assistance in designing experimental proposals.

While the AI played a significant role in exploring avenues and structuring arguments through an iterative dialogue, the final conceptual choices, the interpretation of results, all scientific assertions, derivations, analyses, and the ultimate articulation of the theory remain under the direct intellectual ownership, conceptual guidance, and editorial control of the author. The AI system is not credited as a co-author as the origination of LFT and the responsibility for its scientific validity rest solely with the human author. This work aims to demonstrate a model of AI-assisted theoretical physics exploration.

Appendix A Derivation of the Logical-Strain Metric

This appendix derives the conformity operators L_I, L_N, L_E of Sec. ?? and computes $\mathcal{D}$ for the states used in the main text.

A.1 Single qubit in its PLB (Z-basis)

Write $\rho = \frac{1}{2}(\mathbb{I} + \vec{r}\cdot\vec{\sigma})$ with Bloch vector $\vec{r} = (r_x, r_y, r_z)$, $|\vec{r}| \leq 1$. Projectors in the PLB are $\hat{P}_{0,1} = |0,1\rangle\langle 0,1|$ with $P_0 = (1 + r_z)/2,\ P_1 = (1 - r_z)/2$.

Identity L_I. For one qubit the multi-qubit definition collapses to $L_I = \langle Z\rangle^2 = r_z^2$.

Non-Contradiction L_N. Here $N = 1$, so $\mathcal{P}_{\text{local}} = \text{Tr}\rho^2 = \frac{1}{2}(1+|\vec{r}|^2)$. With $\mathcal{P}_{\min} = 1/2$ (Sec. ??), $L_N = (\mathcal{P}_{\text{local}} - \mathcal{P}_{\min})/(1 - \mathcal{P}_{\min}))equals 1 for pure states and 0 for the maximally mixed state.$

Excluded Middle L_E. Always $L_E = 1$ because $\text{Tr}\rho = 1$.

Strain. $\mathcal{D}(\rho) = 1 - \min(r_z^2, L_N, 1) = 1 - r_z^2 = \sin^2\theta$, so $|0\rangle$ and $|1\rangle$ have zero strain, whereas $|+\rangle$ and $|-\rangle$ have $\mathcal{D} = 1$.

A.2 Two qubits: Bell outcomes evaluated in the PLB

The experiment of Sec. 4.1 measures in $M' = \{|00\rangle, |\Psi^+\rangle, |\Psi^-\rangle, |11\rangle\}$. Logical strain, however, is still evaluated in the underlying two-qubit PLB—*the computational Z-basis* $\{|00\rangle, |01\rangle, |10\rangle, |11\rangle\}$. Table 3 lists the resulting L_I, L_N, and $\mathcal{D}$.

Table 3: Logical strain of Bell-basis *measurement outcomes* evaluated in the computational PLB.

Outcome state	L_I	L_N	$\mathcal{D}$
$\|00\rangle$	1	1	0
$\|\Psi^+\rangle$	0	0	1
$\|\Psi^-\rangle$	0	0	1
$\|11\rangle$	1	1	0

Identity. For $|00\rangle$ and $|11\rangle$, $\langle Z_{1,2}\rangle = \pm 1 \Rightarrow L_I = 1$; for the Bell states the single-qubit averages vanish, while $\langle Z_1 Z_2\rangle = \pm 1$, so $L_I = \min(0, 1) = 0$.

Non-Contradiction. Product states have local purity 1 ($L_N = 1$); maximally entangled Bell states give local purity 1/2 ($L_N = 0$).

A.3 General N-qubit product states

For a product state $\rho = \bigotimes_{k=1}^{N} \rho_k$ in the computational PLB,

$$L_I = \min_k \langle Z_k\rangle^2, \qquad L_N = L_E = 1, \quad \Rightarrow \quad \mathcal{D} = 1 - \min_k \langle Z_k\rangle^2.$$

Thus a single qubit in superposition ($\langle Z_k\rangle = 0$) drives the global strain to unity, motivating collapse toward a fully definite Z-product state.

A.4 Continuous-variable outline

Choosing the coherent-state set $\{|\alpha\rangle\}$ as a PLB candidate, preliminary analysis suggests $\mathcal{D}(|\alpha\rangle) = 0$ and $\mathcal{D}(|n\rangle) = 1$ for Fock states $|n \geq 1\rangle$. A full continuous-variable treatment is deferred to future work.

These derivations underpin the strain values employed in Sec. 4 and in the shot-budget (Table 4).

Appendix B Derivation of the One-Qubit Collapse Law

This appendix shows how the first–order ordinary differential equation

$$\dot{\theta} \;=\; -\sqrt{\alpha_L \gamma_L}\,\sin 2\theta, \tag{4}$$

used in Sec. 3.3, follows from the Logical-Field equation

$$\Box\,\Phi_L = \alpha_L\big[D(\mathbf{x}) - \langle D\rangle\big] \quad (\text{Eq.}\,3).$$

B.1 Logical strain for a single qubit

In the PLB (Z-basis) a pure state has Bloch coordinates $\vec{r} = (\sin\theta\cos\phi, \sin\theta\sin\phi, \cos\theta)$. Section A.1 showed that its logical strain is

$$D(\theta) = \mathcal{D}(\theta) = \sin^2\theta.$$

Because D depends only on the polar angle, so will $\Phi_L = \Phi_L(\theta, t)$.

B.2 Overdamped information dynamics

We adopt an "overdamped" ansatz: the rate of change of a state coordinate equals a mobility μ times the component of the logical force in that direction,

$$\dot{\theta} = \mu\,F_\theta, \qquad F_\theta = -\frac{\partial}{\partial\theta}V_L, \tag{B.1}$$

analogous to gradient-flow dynamics in classical thermodynamics. With $V_L = \kappa D$ (Definition **??**) and $D(\theta) = \sin^2\theta$,

$$F_\theta = -\kappa\frac{\partial}{\partial\theta}\sin^2\theta = -2\kappa\sin\theta\cos\theta = -\kappa\sin 2\theta.$$

B.3 Fixing the mobility

In the information manifold underlying LFT there is no *a priori* mass scale, so mobility must be built from the available constants α_L (units s^{-2}) and κ (units J). Writing E_{ref} for the reference energy, the dimensionless coupling is $\gamma_L = \kappa/E_{\mathrm{ref}}$. The simplest choice that yields correct units for $\dot{\theta}$ is

$$\mu = \frac{\sqrt{\alpha_L}}{\sqrt{\kappa E_{\mathrm{ref}}}} = \frac{\sqrt{\alpha_L}}{\kappa}\sqrt{\gamma_L}. \tag{B.2}$$

B.4 Resulting equation of motion

Substituting F_θ and (B.2) into (B.1) gives

$$\dot{\theta} = -\frac{\sqrt{\alpha_L}}{\kappa}\sqrt{\gamma_L}\,\kappa \sin 2\theta = -\sqrt{\alpha_L \gamma_L}\,\sin 2\theta,$$

which is Eq. (4) in the main text.

B.5 Collapse time

Linearising near $\theta = \pi/2$ ($\sin 2\theta \approx -2\delta\theta$) one finds

$$\dot{\delta\theta} = 2\sqrt{\alpha_L \gamma_L}\,\delta\theta \implies \delta\theta(t) = \delta\theta(0)\,e^{\,2\sqrt{\alpha_L\gamma_L}\,t},$$

so the deterministic collapse time is

$$\tau_c = \frac{1}{2\sqrt{\alpha_L \gamma_L}} \quad \text{(Eq. 5)}.$$

Equation (4) thus follows directly from the Logical Field dynamics once (i) strain is expressed in angular coordinates and (ii) overdamped mobility is chosen to match the available α_L–κ scale. The resulting trajectories are plotted in Fig. 2.

Appendix C Shot-Budget Analysis and Reproducibility

This appendix lists the numerical shot counts and SPAM tolerances that underpin Sec. 4.2, and it documents exactly how to recreate every figure and table.

C.1 Bell-basis shot budget

For each coupling γ_L the single-channel deviation

$$\Delta P = P_{\mathrm{LFT}}(\Psi^+) - 0.50,$$
$$P_{\mathrm{LFT}}(\Psi^+) = \frac{e^{-\gamma_L}}{1 + e^{-\gamma_L}},$$

yields a 5σ shot requirement

$$N \;=\; \frac{25\,p(1-p)}{\Delta P^2} \quad (p = 0.50), \qquad \varepsilon_{\mathrm{SPAM}}^{\max} = |\Delta P|/2.$$

Table 4: Required shots N and SPAM ceiling $\varepsilon_{\mathrm{SPAM}}^{\max}$ for a 5σ detection of ΔP.

γ_L	$P_{\mathrm{LFT}}(\Psi^+)$	ΔP	Shots N	$\varepsilon_{\mathrm{SPAM}}^{\max}$
0.005	0.498750	-1.25×10^{-3}	4.00×10^{6}	0.00063
0.010	0.497503	-2.50×10^{-3}	1.00×10^{6}	0.00125
0.020	0.495050	-4.95×10^{-3}	2.55×10^{5}	0.00248
0.050	0.487503	-1.25×10^{-2}	4.00×10^{4}	0.00625

These numbers match the curves in Fig. 3 and the benchmark histogram, Fig. 4.

C.2 Reproduction instructions

All plots and tables can be regenerated in a free Google Colab environment:

(1) Open the notebook `code/LFT_simulations.ipynb`[1] in Colab.

(2) Run the `Setup` cell to install `numpy` and `matplotlib`.

(3) Execute the remaining cells in sequence: *Single-qubit collapse*, *Two-qubit probability sweep*, *Shot-budget table*, *Tunnelling suppression*.

(4) Generated PNGs appear in `/content` and are copied to `figures/` via a final shell command.

(5) Compile the LaTeX project locally or on Overleaf—no manual edits are required if file names remain unchanged.

The calculations in Table 4 are fully deterministic; no Monte-Carlo sampling is involved.

Appendix D Comparative Analysis of Logic Field Theory with Other Foundational Frameworks

Logic Field Theory (LFT), as developed in this work, proposes a novel ontological foundation for physical reality based on the primacy of logical constraints. To situate LFT within the broader landscape of foundational physics and interpretations of quantum mechanics, this appendix provides a comparative analysis. Table 5 summarizes key distinctions across several frameworks concerning their core ontological commitments, mechanisms for quantum measurement and state evolution, and empirical testability.

LFT's central thesis is that physical reality Ω emerges from a set of potential information states S filtered by an operator $\mathcal{L}$ representing the three fundamental laws of logic (3FLL). This filtering occurs within a Preferred Logical Frame (C_{PLF}). Deviations from perfect logical conformity are quantified by Logical Strain D, which gives rise to a Logical Potential $V_L = \kappa D$. This potential, mediated by a Logical Field Φ_L, governs deterministic dynamics and yields a modified Born rule for outcome probabilities: $P_k \propto |\langle\varphi_k|\psi\rangle|^2 e^{-\gamma_L D_k}$, where $\gamma_L = \kappa/E_{\text{ref}}$ is a fundamental LFT constant. This framework aims to provide a deterministic and ontologically minimalist explanation for quantum phenomena, leading to falsifiable predictions.

The following table (Table 5) contrasts LFT with prominent theories and interpretations.

This comparative analysis highlights LFT's unique approach. By elevating logical laws to an active ontological role, LFT seeks to provide a deterministic and causally complete underpinning for quantum mechanics. Its distinctiveness lies in its specific mechanisms involving the Preferred Logical Frame (C_{PLF}), Logical Strain (D), the Logical Potential (V_L) and Field (Φ_L), and the resulting LFT-Modified Born Rule. These constructs lead to empirically falsifiable predictions, chiefly the potential for deviations from standard quantum probabilities quantified by the LFT parameter γ_L. This positions LFT not merely as an interpretation but as a candidate foundational theory with new physical content, aiming to resolve long-standing conceptual issues in quantum theory by grounding them in the primacy of logical consistency.

[1] Replace the dummy link with the final GitHub or Drive URL, e.g. `https://colab.research.google.com/drive/15YxcSUcTuANeolUaYpd_x2a3V8wx_KcM?usp=sharing`.

Table 5: Comparative Summary of Logic Field Theory (LFT) and Other Foundational Theories/Interpretations.

Aspect	**Copenhagen Int.**	**Many-Worlds (MWI)**	**Logic Field Theory (LFT) (This Work)**	**Pilot-Wave (Bohm)**
Ontology	Classical world fundamental; Ψ often epistemic. Observer cut.	Universal Ψ is real; all branches exist.	Info states S fundamental; Logic (3FLL) prescriptive; C_{PLF} real; Φ_L real. $\Omega = \mathcal{L}(S)$ derived.	Particles with definite positions; Ψ is real guiding field.
Wavefunction Ψ	Knowledge/probs; collapses.	Real, never collapses, describes multiverse.	Potential info in S. Effective collapse via logical filtering.	Real, physical "pilot wave"; no collapse.
Measurement/ Collapse	Axiomatic, probabilistic collapse by measurement.	No collapse; measurement = branching.	Deterministic dynamics (V_L, Φ_L) yield $P_k \propto \lvert\langle\varphi_k\vert\psi\rangle\rvert^2 e^{-\gamma_L D_k}$. Observer-independent.	Effective collapse; particles follow one trajectory.
Determinism	Indeterministic (collapse).	Deterministic (universal Ψ). Apparent chance from branching.	Underlying dynamics deterministic. Probs from logical filtering.	Fully deterministic.
Non-Locality	"Spooky action."	Inherent in universal Ψ.	From global logical consistency in S.	Explicit via quantum potential.
New Entities/ Principles	Observer cut; collapse postulate.	Many unobservable universes.	C_{PLF}; $\kappa, E_{\text{ref}}, \gamma_L$; Φ_L; D; L_i. Primacy of Logic.	Hidden positions; pilot wave.
Falsifiability	Core tenets hard to falsify.	Very difficult (other worlds inaccessible).	Born rule deviations $(e^{-\gamma_L D_k})$, testable via $\gamma_L \neq 0$.	Empirically like QM.
Role of Logic	Reasoning tool.	Applies in each branch.	Ontologically primary; constrains reality.	Reasoning tool.

Aspect	**Spontaneous Collapse (GRW/CSL)**	**Relational QM (RQM)**	**QBism**	**String Theory**
Ontology	Ψ real; physical stochastic collapse.	Properties relational; no absolute state.	Ψ is agent's subjective beliefs.	Strings/branes in higher-D; spacetime dynamic. Landscape.
Wavefunction Ψ	Real, physical field.	Relational info.	Agent's beliefs.	String/brane states.
Measurement/ Collapse	Spontaneous stochastic hits.	Relational fact actualization.	Bayesian update of beliefs.	Inherits QM issues.
Determinism	Stochastic.	Facts definite relationally.	Belief evolution probabilistic.	Underlying laws deterministic.
Non-Locality	Can be non-local.	Correlations of relational facts.	Correlated beliefs.	String/brane interactions.
New Entities/ Principles	Stochastic terms in Schröd. eq.; new constants.	Primacy of relations.	Primacy of agent's experience.	Extra-D, strings, SUSY. Many params.
Falsifiability	Predicts deviations (heating), testable.	Philosophical; hard to distinguish from QM.	Focus on agent beliefs; fewer new physical predictions.	Direct tests hard; landscape problem.
Role of Logic	Reasoning tool.	Applies to relational statements.	Tool for agent's reasoning.	Math consistency key.

Appendix E Objections and Responses

This appendix addresses anticipated and common objections to Logic Field Theory (LFT), reflecting the formalism and postulates presented in this work. Each objection is followed by a concise response aimed at clarifying LFT's positions, demonstrating its internal coherence, and underscoring its commitment to empirical falsifiability.

E.1 Foundational and Ontological Objections

Objection: "Logic is merely epistemic or linguistic, not ontological."

Response: LFT fundamentally challenges this traditional view by positing that the three fundamental laws of logic (3FLL: Identity, Non-Contradiction, Excluded Middle) are prescriptive, ontological constraints on what can exist or manifest as physical reality (Axiom 2.1). LFT asserts that no state can stably exist if it inherently violates these principles. These laws act as foundational filters on the space of potential information states S, determining which configurations $\Omega = \mathcal{L}(S)$ are actualizable. This is analogous to how physical principles like conservation laws constrain possible physical processes, without necessarily being "forces" in a mechanistic sense. LFT makes this ontological role of logic operational via the Logical Strain D and its consequences, such as the LFT-Modified Born Rule.

Objection: "This theory sounds metaphysical, not like physics."

Response: While LFT's foundational axioms (e.g., Primacy of Logic, Preferred Logical Frame) are deeply philosophical, the theory built upon them generates concrete, mathematical, and empirically falsifiable predictions, as detailed in Section 4. Specifically, the LFT-Modified Born Rule predicts deviations from standard quantum probabilities quantified by the measurable parameter γ_L. Foundational physics often interfaces with metaphysics when addressing "why" questions about the nature of reality. LFT aims to provide a framework where such deep questions lead to testable physical consequences.

Objection: "The Preferred Logical Frame ($C_{\mathbf{PLF}}$) is a strong, unmotivated assumption that could break established physical symmetries like Lorentz invariance."

Response: LFT acknowledges the postulate of a C_{PLF} (Axiom 2.4) as a significant element of its current formulation. Its primary motivation is to provide a concrete, universal reference against which Logical Strain D can be unambiguously defined and calculated, making LFT's predictions operationally meaningful and testable. Without such a frame, strain related to concepts like "definiteness of property" would be entirely basis-dependent. LFT views C_{PLF} not necessarily as a preferred frame in spacetime, but as a fundamental structuring principle within the abstract information space S. Its deeper origin is posited to arise from underlying information-theoretic constraints or emergent stability criteria. The relationship between an abstract C_{PLF} and observed spacetime symmetries is a critical area for future LFT research. For the present formulation, C_{PLF} serves as the necessary scaffold for quantifying logical conformity.

E.2 On Logical Strain, Conformity Operators, and New Constants

Objection: "The definitions for the Logical Conformity Operators (L_I, L_N, L_E) and the resulting Logical Strain D seem arbitrary or constructed merely to fit desired outcomes."

Response: The translation of abstract logical laws into concrete quantum mechanical operators is a core theoretical step in LFT. The forms proposed in Section **??** are LFT's current operationalization of these laws within the context of C_{PLF}. L_I (definiteness via variance), L_N (consistency with local PLF properties via local purities for composite systems), and L_E (completeness) are constructed to reflect these logical principles. The definition $D = 1 - \min\{L_I, L_N, L_E\}$ embodies the idea that maximal violation of any single law suffices for maximal strain. These definitions are not arbitrary but are motivated by the logical principles and yield a consistent, calculable framework leading to testable predictions. Their deeper derivation from first principles of logic and information remains an area of LFT development.

Objection: "Common quantum states like superpositions (e.g., $|+\rangle$) are labeled as 'high-strain'. This seems counterintuitive given their ubiquity."

Response: LFT does not prohibit such superpositions; it aims to explain their characteristic behavior. A state like $|+\rangle$ having maximal Logical Strain ($D = 1$) relative to a Z-basis C_{PLF} (due to its indefinite Z-property, $L_I = 0$) signifies a high Logical Potential $V_L = \kappa D$. Such states are not "forbidden" but are dynamically driven towards lower strain configurations and are less probable to manifest as stable outcomes if they retain high strain (per the LFT-Modified Born Rule). "High-strain" thus reflects an inherent ontological tension with C_{PLF}, explaining the observed "fragility" of superpositions and their tendency to resolve into eigenstates upon measurement in the relevant basis.

Objection: "LFT introduces new fundamental constants ($\kappa, E_{\mathbf{ref}}, \gamma_L$). Doesn't this add unneeded complexity or free parameters?"

Response: The introduction of new fundamental constants often accompanies new physical principles (e.g., G, h, c). LFT proposes that if logic ontologically shapes reality, this influence should be characterized by physical scales. κ (Logical Strain Energy Coefficient) and E_{ref} (Reference Energy Scale) are these posited scales, with their dimensionless ratio $\gamma_L = \kappa/E_{\text{ref}}$ directly quantifying the strength of LFT's empirical deviations from standard QM. The crucial point is that γ_L is experimentally testable. A confirmed non-zero γ_L would establish its physical reality, justifying the introduction of these constants by the theory's increased explanatory and predictive power.

E.3 On Predictions and Experimental Feasibility

Objection: "There is currently no experimental proof that logic directly affects quantum outcomes beyond what standard QM predicts."

Response: This is accurate. Standard Quantum Mechanics successfully describes all known experimental outcomes within its established domain. LFT views this not as a barrier, but as the context for its novel predictions. LFT forecasts specific, quantifiable deviations from standard QM, particularly in the Born rule, under conditions of engineered, differential Logical Strain (as detailed in Section **??**). The LFT framework is constructed to be empirically falsifiable via the search for a non-zero LFT parameter γ_L. The proposed experiments are designed precisely to seek such proof.

Objection: "The predicted LFT deviations are likely too subtle to be experimentally detectable."

Response: The magnitude of LFT's predicted deviations depends on the value of γ_L. If γ_L is very small, detection will indeed require high-precision experiments and large datasets (see Appendix **??**). However, LFT identifies specific experimental regimes (outcomes with differing D values) where deviations should be maximized. Modern quantum experimental platforms possess remarkable precision, making searches for even small new effects feasible. A null result from such experiments would provide a stringent upper bound on γ_L, which is itself a valuable scientific outcome.

E.4 On LFT's Relation to Standard Quantum Theory

Objection: "Is LFT just adding constraints post hoc to force determinism or explain collapse?"

Response: The logical constraints in LFT are axiomatically foundational (Axiom 2.1), not retrofitted. The theory begins with the premise that only logically coherent configurations (low D in C_{PLF}) can stably manifest. The ensuing deterministic dynamics (via V_L, F_L, Φ_L) and the LFT-Modified Born Rule are consequences derived from this premise. Determinism in LFT is an outcome of the proposed logical structure of reality, not an ad hoc imposition. LFT aims to provide an ontological *explanation* for quantum phenomena, including collapse and probabilities.

Objection: "Why hasn't standard quantum theory needed these LFT concepts before?"

Response: Standard Quantum Mechanics is an exceptionally successful operational framework. However, it largely postulates, rather than derives, key features like the collapse of the wavefunction and the Born rule. LFT attempts to address these deeper "why" questions by proposing an underlying ontological layer based on logic. QM treats measurement as a somewhat black-boxed process; LFT proposes that logical consistency within C_{PLF} is a key selection principle occurring within that process. LFT aims to embed QM's mathematical machinery within a constraining logical framework that refines outcome probabilities.

Objection: "Isn't LFT just another interpretation of quantum mechanics?"

Response: LFT aspires to be more than an interpretation. Interpretations typically offer different ontological or epistemological perspectives on the existing mathematical formalism of QM without altering its empirical predictions. LFT, by introducing new postulates (e.g., C_{PLF}), new fundamental constants $(\kappa, E_{\mathrm{ref}}, \gamma_L)$, specific mechanisms for evaluating logical strain (D via L_i), a dynamic potential (V_L), and importantly, a modified predictive rule (the LFT-Modified Born Rule), makes empirically distinct, falsifiable predictions that can differ from standard QM (if $\gamma_L \neq 0$). It is proposed as a foundational theory from which standard QM might emerge as a limiting case.

Objection: "It seems LFT replaces probability with logic."

Response: LFT does not eliminate probability but seeks to provide an ontological grounding for it. It replaces the axiomatic Born rule with an emergent probability distribution (the LFT-Modified Born Rule) that is shaped by both standard quantum amplitudes ($|\langle\varphi_k|\psi\rangle|^2$) *and* logical strain ($D(|\varphi_k\rangle, C_{\mathrm{PLF}})$) via the factor $e^{-\gamma_L D}$. In low-strain regimes, or if γ_L is very small, LFT's predictions converge with standard quantum statistics. In specifically engineered high-strain regimes, LFT predicts deviations where logic demonstrably modulates probabilities. Probability in LFT becomes a consequence of the interplay between quantum potentiality and logical admissibility.

E.5 Scope and Broader Implications

Objection: "Is LFT reintroducing hidden variables?"

Response: LFT introduces no hidden variables in the traditional sense (e.g., pre-determined particle positions as in Bohmian mechanics). The information space S consists of *potential* configurations. The Preferred Logical Frame C_{PLF} and the Logical Field Φ_L are new structural elements of the theory, not hidden properties of particles. LFT's determinism (at the level of Φ_L dynamics) arises from its posited laws governing information and logic, not from pre-existing, unknown values of standard observables.

Objection: "What is the practical value of LFT?"

Response: If empirically confirmed ($\gamma_L \neq 0$), LFT's primary value would be a fundamental advancement in our understanding of reality, quantum mechanics, and the role of logic in the physical world. Potential practical implications, though more speculative, could include:

1. Guiding principles for the stability and design of complex quantum systems (e.g., quantum computers), where managing "logical strain" might become relevant.

2. New perspectives on physics in extreme regimes (early universe, black holes), where logical consistency constraints might play a significant role in state selection or singularity avoidance.

The immediate value lies in its potential to resolve foundational puzzles and its testable predictions.

Objection: "LFT currently doesn't account for relativity or the Standard Model."

Response: This is correct. The present formulation of LFT focuses on foundational quantum mechanics and the origin of quantum probabilities. Its integration with Special/General Relativity and the Standard Model of particle physics represents a significant program for future research (as outlined in Section **??**). Key challenges include understanding the relationship between the abstract C_{PLF} and spacetime structure (and Lorentz invariance), and how logical constraints might apply to quantum fields. LFT is proposed as a deeper ontological layer that might eventually provide principles from which the structure of these established theories could be better understood or even derived.

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