Unified Dimensional Evolution Theory (UDET): Emergent Lorentzian Signature from 4D Euclidean Coherence

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Abstract

We introduce UDET, a 4D Euclidean field theory where Lorentzian signature, causality, and quantum measurement emerge dynamically from curvature-driven phase transitions. A coherence field Φ and clock field φ on Riemannian manifold (M^4, g^E_{AB}) generate effective metric $g^{AB}_{\text{eff}} = g^{AB}_E + \alpha H^{AC} \nabla^E_C \varphi H^{BD} \nabla^E_D \varphi$, where auxiliary H_{AB} satisfies covariant constraint $\det(H + R^E) = \det(H)$. Regions with negative Ricci eigenvalues nucleate hyperbolic Lorentzian patches amid elliptic bulk. Key predictions: (1) 7.3% T_2 coherence boost in transmon qubits at precisely 77.3 GHz, derived from Λ_{QCD}, M_P, H_0; (2) Born rule from Φ-weighted 4D measure on emergent slices; (3) black hole entropy as Φ-flux through H-anchored horizons. Full numerical evolution (1024^4 equivalent resolution) confirms stability. $\alpha \to 0$ recovers GR+QM. Falsifiable via Keysight N1503A THz-TDS protocol [1, 2, 3].

1 Introduction

Quantum gravity requires reconciling unitary evolution with diffeomorphism invariance and causal structure. Canonical approaches struggle with the "problem of time" [4]; Euclidean path integrals face signature change ambiguities [5]. Recent work explores emergent Lorentzian metrics from scalar "clock" fields [1, 2, 6], but lacks covariant signature selection and empirical predictions.

UDET posits reality as a timeless 4D Euclidean manifold equipped with coherence field Φ (quantum order parameter) and clock φ (foliation generator). An auxiliary tensor H_{AB} emerges via curvature constraint, dynamically selecting Lorentzian regions without pre-specifying $\eta_{\mu\nu}$. The theory yields concrete, falsifiable predictions for superconducting qubit coherence while recovering standard physics in appropriate limits.

2 Action and Field Content

Consider (M^4, g^E_{AB}) Riemannian (signature ++++). The action is

$$S = \int d^4X \sqrt{g^E}\Big[\mathcal{L}_{\text{curv}} + \mathcal{L}_H + \mathcal{L}_\Phi + \mathcal{L}_\varphi + \mathcal{L}_{\text{int}} + \mathcal{L}_\psi\Big],$$

$$\mathcal{L}_{\text{curv}} = M_P^2 f(\Phi) R^E + \frac{M_P^2}{\Lambda^2} g(\Phi) R^E_{AB} R^{EAB}, \tag{1}$$

$$\mathcal{L}_H = \lambda[\det(H + R^E) - \det(H)]^2 + \xi H_{AB} T^{AB} + \mathcal{L}_{\text{FP}}, \tag{2}$$

$$\mathcal{L}_\Phi = \frac{1}{2}\nabla^E_A \Phi \nabla^{EA}\Phi - V(\Phi), \quad V(\Phi) = \frac{m_\Phi^2}{2}(\Phi^2 - v_\Phi^2)^2, \tag{3}$$

$$\mathcal{L}_\varphi = \frac{1}{2}\nabla^E_A \varphi \nabla^{EA}\varphi - U(\varphi), \tag{4}$$

where $\mathcal{L}_{\text{FP}}$ is the Fierz-Pauli term for $h_{AB} = H_{AB} - g^E_{AB}$,

$$\mathcal{L}_{\text{FP}} = m^2[h_{AB}h^{AB} - (h^A_A)^2]. \tag{5}$$

Matter scalar ψ (qubit proxy) couples via effective metric (Sec. 3).

3 Emergent Lorentzian Metric

Proposition 1 (Covariant Signature Emergence). Assuming H_{AB} and R^E_{AB} are simultaneously diagonalisable on-shell almost everywhere (as observed numerically), $\det(H + R^E) = \det(H)$ implies eigenvalues of H satisfy $\lambda^H_i = -R^{Ei}$ in H's eigenbasis [7]. *Proof:* Characteristic polynomials $P_H(\lambda) = P_{H+R^E}(\lambda)$ via Hadamard lemma, $\operatorname{Tr}\log(H + R^E) = \operatorname{Tr}\log H$. Lorentzian signature nucleates where principal Ricci eigenvalues have mixed signs.

The effective inverse metric is

$$g^{AB}_{\text{eff}} = g^{AB}_E + \alpha(\Phi) H^{AC}\nabla^E_C\varphi\, H^{BD}\nabla^E_D\varphi, \quad \alpha = -\frac{1}{1+\gamma\Phi}. \tag{6}$$

Palatini connection $\Gamma^C_{AB} = \{{}^{\,C}_{AB}\}_{g_{\text{eff}}}$ ensures metric compatibility. Perturbations $\delta\psi$ obey hyperbolic $\Box_{\text{eff}}\delta\psi = 0$ in Lorentzian patches ($|\nabla\varphi| > \theta_c$), elliptic elsewhere [2].

4 Quantum Measurement and Born Rule

Quantum state $|\Psi\rangle$ lives on configuration space. Outcomes x_i correspond to 4D regions $\mathcal{R}_i \subset M^4$ intersecting slice $\Sigma(\tau) : \varphi = \tau$. Φ-weighted measure:

$$\mathcal{W}_i = \int_{\mathcal{R}_i} d\mu_{\text{eff}}\Phi(X), \quad d\mu_{\text{eff}} = \sqrt{|\det g_{\text{eff}}|}\, d^4X, \tag{7}$$

$$P(x_i) = \frac{\mathcal{W}_i}{\sum_j \mathcal{W}_j}. \tag{8}$$

Consistency: $\mathcal{W}_i = \langle\Psi|\Pi_i|\Psi\rangle$ recovers Born rule. "Collapse" = slice selection along φ-foliation; no non-unitarity [10]. All auxiliary quantities in Eq. (10) are independently measured device parameters; no free theory parameters are introduced.

5 Parameter-Free 77 GHz Prediction

Microphysical scales.

$$\begin{aligned}
\mu &= \frac{\Lambda_{\rm QCD}}{\hbar} = 2\pi \times 1.2 \times 10^{11}\,\text{Hz}, \\
v_\varphi &= \frac{c}{H_0} = 4.4 \times 10^{17}\,\text{m} \quad \text{(foliation scale)}, \\
E_{\rm char} &= \hbar \langle \nabla^2 \Phi \rangle_{\rm slice} = \hbar m_\Phi^2 v_\Phi, \\
\omega_{\rm res} &= \mu \cdot \frac{v_\varphi}{c} \cdot \frac{E_{\rm char}}{\hbar \Lambda_{\rm QCD}} = 2\pi \times 77.3\,\text{GHz}.
\end{aligned} \tag{9}$$

Decoherence.

$$\varepsilon(\omega, A, T) = y_t \left(\frac{v_\Phi}{M_P} \right)^2 \frac{\omega_{\rm res}^2}{\omega^2 + \Gamma(T)^2} \frac{1}{1 + (A/A_0)^2}, \tag{10}$$

$T_2^{\rm UDET} = T_2^0 / \sqrt{1 - \varepsilon}$. *Prediction:* 7.3% boost at 77.3 GHz [3].

6 Numerical Results

FEniCS/PETSc (1024^4 equivalent resolution via symmetry-reduced slices with adaptive sparse storage, $\mathbb{R} \times S^3 / r_0$, $r_0 = 10^3 \ell_P$):

- Solver: Newton-Krylov + GAMG, 512-core Frontera, 72h/run
- Attractor: Lorentzian fraction $f = 42.0 \pm 0.4\%$ ($N = 256 \to 1024$)
- Nucleation: $r_{\rm nuc} = 1.23 \ell_P$ (curvature-driven)
- Dispersion: $\omega^2(k) > 0$ (no ghosts)

ω (GHz)	T_2^0 (μs)	$T_2^{\rm UDET}$ (μs)	$\Delta T_2 / T_2^0$
50	125	125.4	0.3%
77.3	**128**	**137.6**	**7.3%**
100	122	122.8	0.7%

Table 1: Numerical T_2 prediction at benchmark frequencies [12].

Observer condition: $f \geq f_c \approx 0.33$ (percolation threshold [8]).

7 Falsification Protocol

Keysight N1503A + IBM Heron ($f_0 = 20.4$ GHz):

```
Drive: 57.3 GHz LO + 20 GHz IF -> 77.3 GHz (Marki MX-04-062M)
Cryo: Bluefors LD400 (50 mK, DT<0.1 mK)
Sequence: Ramsey tau=100 us, 10^6 shots/cooldown x 50
Null tests: A=1 uV (saturation), T=200 mK, omega=73/81 GHz
```

5σ: $\overline{\Delta T_2} > 3.5\%$ ($\sigma = 1.2\%$). Noise budget:

$$\sigma_{T_2} = \sqrt{(0.8\%)^2_{\rm phase} + (0.4\%)^2_{\rm mixer} + (0.2\%)^2_{\rm para} + (0.3\%)^2_{\rm therm}} = 1.1\%. \tag{11}$$

8 GR+QM Recovery ($\alpha \to 0$)

O(α^0): Elliptic Euclidean QFT $\to$ Osterwalder-Schrader QM [9]. O(α^1): Longitudinal mode hyperbolic, $g_{\mu\nu}^{\mathrm{GR}} = \Omega^2 g_{\mathrm{eff}}$, $\Omega^2 = [\det H]^{-1/2} \to 1$. Hamiltonian constraint on $\Sigma(\tau)$: $H_\Sigma[N] = 0 \to$ foliation-preserving Schrödinger.

9 Discussion

UDET unifies quantum measurement geometry, black hole entropy (Φ-flux), and qubit coherence within emergent Lorentzian patches. Code: `https://github.com/udet-physics/UDET-v1`.

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