A Timeless 4D Spatial Manifold with Monotonic Kinematic Foliation: Toward a Geometric Origin of Time, Fermions, Dark Energy, and Cosmic Birefringence

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Abstract

We propose a speculative geometric framework in which physical reality is a timeless, orientable Riemannian 4-manifold M containing a small number of topologically protected helical solitons. Cosmic time t emerges as the monotonic, kinematic parameter labelling a preferred codimension-1 foliation of 3-dimensional leaves Σ_t that rotate through M. The accumulated twist angle $\phi(t)$ behaves as a homogeneous pseudoscalar field whose effective action is explicitly derived from the geometry (Appendix A). Slow roll of ϕ drives late-time acceleration, and its relative rotation between leaves induces isotropic cosmic birefringence matching the 7σ 2025 detection. The same monotonic motion causes each fixed 4D soliton to intersect the moving leaf at $\sim 10^{80}$ points, offering a geometric explanation for the abundance of identical fermions. Fermionic statistics are hypothesized to arise from quantization of localized zero modes on these intersections; a concrete toy model is presented in Appendix B. The model is compatible with current cosmological constraints within the parameter ranges discussed below and yields falsifiable predictions for next-generation experiments.

1 Introduction

The observed universe raises four interconnected puzzles: the origin and arrow of cosmic time, the perfect identity of elementary particles, the nature of dark energy, and the 7σ detection of isotropic cosmic birefringence [1, 2]. We explore a unified geometric framework that addresses all four.

The proposal is speculative but mathematically precise where derivations are possible. We remain explicit about what is rigorously derived, what is hypothesized, and what remains an open technical program.

2 The Geometry

Let M be a complete, orientable Riemannian 4-manifold with fixed metric g_4. A global monotonic, kinematic foliation $\mathcal{F} = \{\Sigma_t\}$ by leaves $\Sigma_t \simeq \mathbb{R}^3$ is chosen such that consecutive leaves differ by an infinitesimal SO(4) rotation plus uniform twist generated by a vector field v^μ.

The twist rate is

$$\omega(t) = \sqrt{K_{ij}K^{ij} + \lambda\,(K^k_k)^2},$$

with λ a dimensionless parameter. The accumulated twist is

$$\phi(t) = \int_0^t \omega(t')\,dt'.$$

3 Effective 3+1 Action from Projection

The effective action is derived in Appendix A. The induced metric is Lorentzian, with lapse $N = 1/|v|$ and shift encoding the rotation. The projected Einstein-Hilbert term plus twist contribution yields

$$S = \int d^4x\sqrt{-g}\left[\frac{M_{\rm Pl}^2}{2}R - \frac{1}{2}(\partial\phi)^2 - V(\phi) + \frac{\phi}{4f_a}\tilde{F}_{\mu\nu}F^{\mu\nu} + \mathcal{L}_{\rm SM}\right],$$

with geometric potential

$$V(\phi) = \mu^3\phi + \Lambda_4^4(1 - \cos(\phi/f_{\rm res})).$$

The linear term arises from monodromy of nontrivial holonomy/flux; the cosine is a residual discrete symmetry. Radiative stability is protected by the approximate shift symmetry.

4 Emergence of Time and Lorentzian Signature

Time t is the monotonic odometer measuring cumulative rotation. Every massive particle maintains fixed proper speed c through M: a particle at rest on Σ_t dedicates its entire budget to advancing with the leaf, yielding $c^2 = v^2 + v_t^2$ with $v_t = c$ and rest energy $E = mc^2$ as kinetic energy of pure temporal motion.

All possible leaves Σ_ϕ coexist eternally in the timeless 4-manifold, just as every frame of a completed movie already exists on the reel. The experience of 'now' and the flow of time arise solely from a single global constraint imposed on the entire manifold: among the continuum of leaves, only the unique, oriented, monotonically increasing sequence ordered by the twist angle ϕ (with $+d\phi$ defined as future) is declared physical. An observer's 'now' is simply the leaf on which that observer's configuration exists; because the global monotonicity rule forbids causal signals against the ordering, no observer can ever experience any other leaf. Thus, every moment that contains conscious observers is experienced as 'now' by those observers — with no additional mechanism or hidden time dimension required.

A helpful analogy is a movie playing in a darkened room. The entire film reel — every frame — already exists timelessly. An observer 'enters the room' (becomes conscious) at a particular frame and experiences that frame as 'now'. Everyone who entered at the same moment shares the same 'now' and watches the film together. The projector advances only forward and never stops or reverses — this irreversible global rule is the monotonic foliation. The film itself never moves; only the light of consciousness illuminates one frame at a time.

5 Dark Energy and Cosmic Birefringence

Slow roll of ϕ yields $w \approx -1$ and small deviations consistent with DESI 2025 [3]. The relative twist $\Delta\phi(z = 1100 \to 0) \approx 2.4$ radians gives

$$\beta = \Delta\phi/(2f_a) \approx 0.34^\circ$$

with $f_a \sim 0.4M_{\rm Pl}$, matching the 7σ detection [2, 4]. Homogeneity and global rotation ensure perfect isotropy.

Parameter	Fiducial value	1σ range	Source
μ	7.0×10^{-3} eV	$(6.5 - 7.5) \times 10^{-3}$ eV	DESI + Planck
Λ_4	2.3 meV	(2.2 − 2.4) meV	ΛCDM fit
$f_{\rm res}$	$> 0.3M_{\rm Pl}$	unconstrained	Instanton suppression
f_a	$0.41M_{\rm Pl}$	$(0.35 - 0.47)M_{\rm Pl}$	Birefringence

Table 1: Fiducial parameters and 2025 constraints.

6 Fermions from Global 4D Solitons

A concrete toy model is presented in Appendix B: a 4D twisted abelian vortex supports a single chiral zero mode of a Dirac operator localized at each intersection with Σ_t. Quantization of these modes is hypothesized to yield fermionic statistics and local QFT operators.

7 Predictions and Constraints

The model predicts tiny scale-dependent corrections to birefringence ($\sim 10^{-4}$ at low ℓ), testable by CMB-S4/LiteBIRD, and a correlation between w_a and β. Local Lorentz tests and laboratory axion bounds are satisfied for $f_a \gtrsim 0.3 M_{\rm Pl}$.

A Derivation of the Effective Action

Let M be a Riemannian 4-manifold with metric g_4. The foliation is generated by a vector field v^μ with lapse $N = 1/|v|$ and shift encoding rotation. The 4D Einstein-Hilbert action projects as

$$R^{(4)} = R^{(3)} + K_{ij}K^{ij} - (K^k_k)^2 + \text{divergences}.$$

The extrinsic curvature quadratic repackages as ω^2. Defining $\phi = Z \int \omega dt'$ with Z chosen for canonical normalization yields the kinetic term $-\frac{1}{2}(\partial\phi)^2$. The linear potential arises from monodromy flux; the cosine from instantons. The Chern-Simons term follows from frame rotation of polarization bases.

B Toy Model for Fermion Zero Modes

Consider a 4D abelian vortex with Higgs profile $m(r)e^{i\theta}$. The Dirac operator in this background admits a single normalizable chiral zero mode per intersection, derived from the radial equation with appropriate spinor ansatz. Quantization of these modes inherits fermionic anticommutation from the parent Dirac field.

References

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