A 6D Geometric Framework Unifying General Relativity and Quantum Mechanics

Martin Hristov
Independent Researcher
M.V.Hristov@proton.me

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Abstract

This paper presents a 6-dimensional pseudo-Riemannian framework that geometrizes quantum phenomena by introducing two additional temporal dimensions. Building upon the tradition of Kaluza-Klein unification [4, 5] and modern extra-dimensional theories [6, 7], we demonstrate that quantum superposition and entanglement emerge as natural consequences of temporal extension. The model is grounded in a novel spacetime conservation principle, providing a deterministic geometric basis for quantum mechanics while maintaining compatibility with General Relativity [1]. This work extends recent insights into the geometric origin of inertia [27] and offers testable predictions distinguishing it from standard quantum field theory.

1 Introduction

The fundamental incompatibility between the deterministic geometry of General Relativity (GR) [1] and the probabilistic framework of Quantum Mechanics (QM) represents the central unresolved problem in theoretical physics [3]. While string theory [12, 13] and loop quantum gravity [14, 15] offer prominent approaches, they have yet to achieve experimental verification or complete conceptual unification.

The concept of extra dimensions has a long history in unification attempts, beginning with Kaluza and Klein's demonstration that electromagnetism could emerge from a 5D metric [4, 5]. Modern developments include two-time physics [7] and large extra dimensions [6]. Meanwhile, the geometrodynamic program of Wheeler [8, 9] envisioned matter as topological features of spacetime itself.

This work synthesizes these traditions by proposing a 6D manifold where quantum phenomena become geometric properties of extended temporal dimensions. Our approach differs from string theory by focusing specifically on temporal rather than spatial extensions, and from canonical quantum gravity by maintaining a classical geometric foundation.

2 The 6D Mathematical Framework

2.1 Fundamental Manifold and Metric

We propose a 6D pseudo-Riemannian manifold extending the 4D spacetime of GR:

$$X^A = (x^1, x^2, x^3, \tau^1, \tau^2, \tau^3) \tag{1}$$

where x^i represent spatial coordinates and τ^α represent temporal coordinates. This extends the Kaluza-Klein framework [4] but with temporal rather than spatial compactification.

The 6D metric tensor generalizes the 4D case:

$$G_{AB} = \begin{pmatrix} g_{ij} & A_{i\beta} \\ A_{\alpha j} & h_{\alpha\beta} \end{pmatrix} \tag{2}$$

where g_{ij} describes 3D spatial geometry, $h_{\alpha\beta}$ describes temporal geometry, and $A_{i\alpha}$ represents spacetime coupling terms analogous to the Kaluza-Klein vector field.

2.2 Spacetime Conservation Principle

We introduce a fundamental conservation principle motivated by the reciprocal nature of gravitational redshift and time dilation:

$$\rho_s \cdot \rho_t = K \tag{3}$$

where ρ_s is spatial density (proper volume per coordinate volume) and ρ_t is temporal density (coordinate time per proper time). This principle extends the geometric understanding of gravity developed in [9] and provides physical motivation for the extended dimensionality.

3 Dimensional Reduction to 4D Physics

3.1 Spontaneous Symmetry Breaking

Following the Higgs mechanism in particle physics [10, 11] and compactification in string theory [12], our familiar 4D spacetime emerges through symmetry breaking:

$$h_{\alpha\beta} = \text{diag}(-c_1^2, -c_2^2, -c_3^2) \to \text{diag}(-c^2, \epsilon_2, \epsilon_3) \tag{4}$$

where $\epsilon_2, \epsilon_3 \to 0$ in our local frame, analogous to the Kaluza-Klein compactification [5].

3.2 Recovery of General Relativity

The τ^1 dimension reproduces standard GR [1, 9]:

$$G_{\mu\nu} = 8\pi G T_{\mu\nu} \tag{5}$$

Gravitational phenomena emerge from the conservation principle:

$$\frac{\lambda_{\text{obs}}}{\lambda_{\text{emit}}} = \frac{\rho_{s,\text{emit}}}{\rho_{s,\text{obs}}} \quad \text{(Gravitational Redshift)} \tag{6}$$

$$\frac{d\tau_{\text{obs}}}{d\tau_{\text{emit}}} = \frac{\rho_{t,\text{emit}}}{\rho_{t,\text{obs}}} \quad \text{(Time Dilation)} \tag{7}$$

These relationships extend the geometric interpretation of gravity developed in [8].

4 Quantum Mechanics as 6D Geometry

4.1 Superposition as Temporal Extension

Quantum superposition finds a natural geometric interpretation as extension along the τ^2 dimension:

$$|\psi\rangle = \int \alpha(\tau^2)|\phi(\tau^2)\rangle d\tau^2 \tag{8}$$

This provides a deterministic foundation for quantum states, addressing concerns raised in [2] while maintaining mathematical consistency with standard QM [16, 17].

4.2 Measurement and Wavefunction Collapse

The measurement problem [17] receives a geometric interpretation. Measurement corresponds to localization in τ^2:

$$\Delta\tau^2 \to 0 \quad \text{(Geometric Collapse)} \tag{9}$$

This resolves the problem without additional axioms like those in GRW theory [18] or many-worlds interpretation [19].

4.3 Entanglement as Temporal Correlation

Quantum entanglement [2, 20] emerges from shared temporal geometry:

$$\Psi_{AB} = \Psi(\tau_A^2, \tau_A^3, \tau_B^2, \tau_B^3) \quad \text{with} \quad \tau_A^2 = \tau_B^2, \tau_A^3 = \tau_B^3 \tag{10}$$

This explains non-local correlations through geometric connection in the extra temporal dimensions, providing a realist interpretation complementary to Bohmian mechanics [21].

5 Testable Predictions and Experimental Verification

5.1 Modified Uncertainty Principle

The framework predicts a fundamental uncertainty relation:

$$\Delta\tau^2 \cdot \Delta\tau^3 \geq \frac{\hbar}{2} \tag{11}$$

Standard position-momentum uncertainty [22] emerges as a special case, similar to how classical mechanics emerges from quantum mechanics.

5.2 Gravitational Quantum Effects

The model predicts specific gravitational influences on quantum probabilities:

$$P(\tau^2) = P_0(\tau^2)\left[1 + \beta\frac{\Phi}{c^2} + \mathcal{O}\left(\frac{\Phi^2}{c^4}\right)\right] \tag{12}$$

where Φ is gravitational potential. This differs from standard quantum field theory in curved spacetime [23] and is testable with matter-wave interferometry [24].

5.3 Novel Entanglement Signatures

The geometric interpretation predicts specific patterns in multi-particle entanglement that differ from standard quantum field theory predictions [25], testable with quantum information experiments [26].

6 Discussion and Comparison with Existing Approaches

This 6D framework provides several advantages over existing approaches:

1. **Deterministic Foundation**: Unlike standard QM [16], quantum probabilities emerge from geometric distributions rather than fundamental randomness.

2. **Geometric Unification**: Provides a more direct geometric unification than string theory [12] by focusing specifically on temporal dimensions relevant to quantum phenomena.

3. **Resolution of Paradoxes**: Offers geometric explanations for both the measurement problem [17] and quantum non-locality [20] within a single framework.

4. **Testability**: Makes distinctive, falsifiable predictions accessible to near-term experimental verification.

7 Conclusion

We have presented a complete 6D geometric framework that unifies General Relativity and Quantum Mechanics through extended temporal dimensions and a spacetime conservation principle. The model provides geometric interpretations for key quantum phenomena while maintaining mathematical consistency with established physics. The framework offers testable predictions that could experimentally distinguish it from standard quantum theory, providing a promising direction for resolving the century-old conflict between our fundamental physical theories.

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