A Higher-Dimensional Interpretation of Quantum Entanglement and Its Extension to a High-Dimensional Schrödinger Equation

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Conflict of Interest

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Abstract

Quantum entanglement, wherein a measurement on one particle instantaneously determines the spin state of another, challenges the locality and causality principles in four-dimensional spacetime. I hypothesize that two entangled electrons are unified as a single higher-dimensional object across compactified extra dimensions (5th to 11th dimensions). Embedding the entangled wavefunction

$$\psi(x_1, x_2) = (1/\sqrt{2})\ [|\uparrow\rangle_1|\downarrow\rangle_2 \pm |\downarrow\rangle_1|\uparrow\rangle_2]$$

into an extended configuration space $X = (x_1, x_2, y_1, y_2)$ with a delta-function constraint $\delta(y_1 - y_2)$, I interpret entanglement not as nonlocal influence, but as a manifestation of geometric unity in higher dimensions. I further develop a higher-dimensional Schrödinger equation to describe the dynamics:

$$i\hbar\, \partial\Psi(x_1, x_2, y, t)/\partial t = \left(-\hbar^2/2m_1\, \nabla^2_{x_1} - \hbar^2/2m_2\, \nabla^2_{x_2} - \hbar^2/2m_y\, \nabla^2_{y} + V(x_1, x_2, y) \right) \Psi(x_1, x_2, y, t)$$

My model offers a geometrical reinterpretation of quantum entanglement as projections of a single coherent higher-dimensional entity and suggests new pathways for understanding quantum foundations and spacetime structure.

Keywords: Quantum Entanglement; Higher-Dimensional Physics; M-Theory; Compactified Dimensions; Nonlocality; Wavefunction Projection; Dimensional Identity

Introduction

Quantum entanglement presents a fundamental challenge to our understanding of causality and locality. When two entangled electrons are separated in space, a measurement on one instantaneously determines the spin state of the other. Einstein famously referred to this as "spooky action at a distance" [1]. In four-dimensional spacetime, this behavior seems to defy relativistic constraints. However, recent theoretical frameworks allow us to reconsider this phenomenon within the context of higher dimensions.

In this hypothesis, the particles in quantum entanglement are spatially separated in four-dimensional space yet can share spin information instantly due to their unified identity in higher dimensions. This reframing posits that the observed nonlocality stems from a compactified geometric overlap in extra dimensions, providing a novel explanation that avoids superluminal signaling.

Hypothesis

I hypothesize that the two entangled electrons are, in higher-dimensional space (specifically from the 5th to 11th dimension), not distinct particles but manifestations of a single higher-dimensional entity. In this view, the "instantaneous" correlation is not mediated across space but is simply a reflection of a unified change in the same object, viewed from different projections into our four-dimensional spacetime.

Interpretation and Analogy

Consider an ant walking on a hose: to the ant, two points on the hose may seem far apart along the surface, but in the higher dimension of the hose's circular cross-section, they are connected. Similarly, two entangled particles may be spatially distant in 4D, but adjacent—or identical—in a higher-dimensional manifold. Thus, the change is singular and not duplicated; what changes is the observer's frame and the projection of that higher-dimensional reality.

Mathematical Suggestion

The entangled wavefunction in standard quantum mechanics is:

$$\psi(x_1, x_2) = (1/\sqrt{2})\, [|\uparrow\rangle_1 |\downarrow\rangle_2 \pm |\downarrow\rangle_1 |\uparrow\rangle_2]$$

This hypothesis embeds it into a higher-dimensional configuration space $X = (x_1, x_2, y_1, y_2)$:

$$\Psi(X) = \psi_4(x_1, x_2) \otimes \delta(y_1 - y_2)$$

Here, y_1 and y_2 are compact extra-dimensional coordinates, and the delta function enforces geometric identity. The corresponding Lagrangian is:

$$L(\Psi) = \int d^n y_1\, d^n y_2\, \delta(y_1 - y_2)\, \Psi^*(x_1, x_2, y_1, y_2)\, \hat{H}\, \Psi(x_1, x_2, y_1, y_2)$$

where $\hat{H}$ is a higher-dimensional Hamiltonian. The delta correlation implies that while particles appear separated in 4D, they remain unified in higher dimensions.

High-Dimensional Schrödinger Equation Extension

Normally, the two-particle Schrödinger equation in 4D spacetime is:

$$i\hbar\, \partial\psi(x_1, x_2, t)/\partial t = \hat{H}_4\, \psi(x_1, x_2, t)$$

where x_1 and x_2 are the spatial coordinates of each particle and $\hat{H}_4$ represents the standard 4D Hamiltonian (kinetic + potential energy).

Extending to higher dimensions, each particle additionally has compactified coordinates y_1, y_2, leading to a total configuration space:

$$X = (x_1, x_2, y_1, y_2)$$

The high-dimensional Schrödinger equation becomes:

$$i\hbar\, \partial\Psi(X,t)/\partial t = \hat{H}\_high\, \Psi(X,t)$$

where $\Psi(X,t) = \Psi(x_1, x_2, y_1, y_2, t)$.

The high-dimensional Hamiltonian structure is:

$$\hat{H}\_high = \hat{H}\_x + \hat{H}\_y + \hat{H}\_V$$

with

$\hat{H}\_x = -(\hbar^2/2m_1)\, \nabla^2\_\{x_1\} - (\hbar^2/2m_2)\, \nabla^2\_\{x_2\}$

$\hat{H}\_y = -(\hbar^2/2m_1)\, \nabla^2\_\{y_1\} - (\hbar^2/2m_2)\, \nabla^2\_\{y_2\}$

$\hat{H}\_V = V(x_1, x_2, y_1, y_2)$

Applying the constraint $y_1 = y_2 = y$, the wavefunction simplifies to:

$\Psi(x_1, x_2, y_1, y_2, t) = \Psi(x_1, x_2, y, y, t)$

and the Schrödinger equation reduces to:

$i\hbar\, \partial\Psi(x_1, x_2, y, t)/\partial t = (-\hbar^2/2m_1\, \nabla^2\_\{x_1\} - \hbar^2/2m_2\, \nabla^2\_\{x_2\} - \hbar^2/2m\_y\, \nabla^2\_\{y\} + V(x_1, x_2, y))\, \Psi(x_1, x_2, y, t)$

where m_y is an effective mass associated with the compact dimension.

Relation to Theories

The hypothesis supports and extends:

- ER=EPR conjecture: entangled particles are connected by non-traversable wormholes [2]
- AdS/CFT correspondence: duality between high-dimensional gravity and boundary field theory [3]
- M-theory and string theory structures [4][5]
- The use of compactified dimensions to address hierarchy problems [6]

Discussion

This geometric identity model offers an intuitive and physically plausible basis for entanglement. Unlike interpretations rooted in information theory, it explains entanglement without invoking superluminal signaling. Instead, entangled particles share identity in hidden dimensions. This perspective opens avenues for indirect experimental tests, especially in conditions with high curvature or energy.

Though presently speculative, this model suggests potential observable implications:

- Deviations in entanglement correlation functions under high curvature or energy.
- Quantum simulations of delta-correlated compact dimensions.
- Modulations in Bell test experiments conditioned on geometric embedding.

Testing this hypothesis would require indirect evidence, possibly through the behavior of entangled systems under extreme conditions, or via advanced simulations of compactified geometry effects. If future high-energy experiments or quantum gravity models reveal deviations that fit this framework, it could provide insight into the deep structure of spacetime and entanglement.

Furthermore, the incorporation of compactified dimensions introduces testable frameworks if deviations from standard quantum behavior can be observed under extreme physical conditions, such as near black holes or within high-energy particle collisions. While speculative, this hypothesis can stimulate further theoretical work, particularly in unifying geometric approaches in string theory with quantum informational models.

Conclusion

I propose that entangled particles are unified in higher-dimensional space, explaining instantaneous spin correlation without violating causality. This framework offers a geometric reinterpretation of quantum nonlocality and invites future exploration in both theory and experiment.

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