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Ichiro Tsukamoto *

Posted Date: 27 April 2025

doi: 10.20944/preprints202504.1961.v1

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# Quantum Entanglement as a Manifestation of Higher-Dimensional Unification

**Ichiro Tsukamoto**

Tsukamoto Orthopedic Clinic, Marutani building 1F, 28 Hanashiba-Cho, Nara City, Nara, 630-8266, Nara, Japan; ichirottt1980@gmail.com

**Abstract:** This paper proposes a hypothesis in which two entangled particles, while spatially separated in four-dimensional spacetime, can instantaneously share spin information because they occupy the same location—or are the same object—in higher-dimensional space. The model suggests that quantum entanglement arises not from superluminal communication, but from a deeper geometric identity in extra dimensions. The entangled wavefunction is expressed as: $\Psi(X) = \psi_4(x_1, x_2) \otimes \delta(y_1 - y_2)$ with \(y₁, y₂\) representing coordinates in compactified higher dimensions. An effective Lagrangian formulation is introduced: $L(\Psi) = \int d^n y_1\, d^n y_2\, \delta(y_1 - y_2)\, \Psi^* \hat{H} \Psi$ This framework parallels D-brane physics and noncommutative geometry, and aligns with the ER=EPR conjecture. Observable consequences may include deviations in Bell-test correlations under extreme conditions, suggesting a new geometrical lens for quantum entanglement.

**Keywords:** quantum entanglement; higher-dimensional physics; M-theory; compactified dimensions; nonlocality; wavefunction projection; dimensional identity

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## Introduction

Quantum entanglement challenges our understanding of locality and causality. When two entangled particles are measured, the spin of one appears to determine the spin of the other instantaneously—even across vast distances. Einstein, Podolsky, and Rosen (1935) famously criticized this phenomenon as incomplete physics [1]. Though Bell's theorem and experimental evidence support quantum predictions, the deeper mechanism behind entanglement remains open to interpretation.

In this hypothesis, particles A and B 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.

## 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.

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## 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.

## Conclusions

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.

**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.

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