

A Physical Origin of Quantum Entanglement

Explanatory Summary and Mathematical Formalism of BFUT-P68

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The Persistence of the Measurement Problem

Precision: Quantum entanglement is confirmed to extraordinary precision (e.g., Bell-inequality violations, 2022 Nobel Prize).

Predictability: Standard Quantum Mechanics predicts outcomes perfectly via the Born rule.

The Void: QM offers no physical consensus on what entanglement actually is, defining it only by mathematical non-separability.

The Interpretational Divide

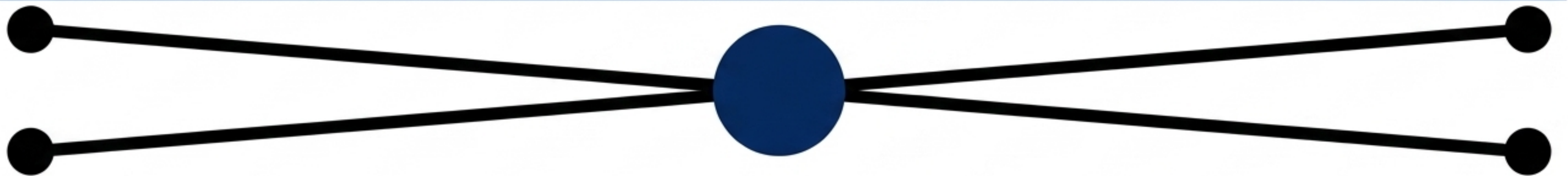
Is entanglement a mysterious non-local connection actively maintained across space ('spooky action at a distance')?

Or does it demand a completely new physical origin that preserves local realism?

The Paradigm Shift: A Shared Substrate

Deformation Event

Quantum entanglement originates from the joint formation history of a pair of condensations in a universal physical substrate.



Two particles become entangled when they emerge from a single, shared deformation event. They are not independent objects requiring separate specification. They remain two aspects of one continuous physical configuration.

Formalism I: The Governing Field Equation

Entanglement behavior emerges naturally from the strict linearity of the Sparticle substrate's governing field dynamics prior to wave function collapse.

$$g^{\mu\nu}\nabla_\mu\nabla_\nu(\delta\Psi) - 3\rho_sc^2\delta\Psi = \kappa\nabla^2\Psi_{matter}$$

$\delta\Psi$:	Carrier perturbation (distributed physical state)	c :	Substrate propagation speed
ρ_s :	Intrinsic equilibrium density (5.9×10^{-27} kg/m ³)	κ :	Source-to-substrate coupling coefficient
		Ψ_{matter} :	Matter configuration

This continuous, linear, covariant equation (F1-cov) governs all substrate interactions prior to the irreversible threshold of physical wave function collapse.

Formalism II: Deriving the Tensor Product Structure

Standard QM Postulate

Mathematical Axiom: The joint state of two distinct particles is postulated mathematically as a tensor product.

$$\Psi_{AB} = \Psi_A \otimes \Psi_B$$

Status: Treated as an unexplained foundational rule.



P68 Physical Derivation

Physical Mechanism: Because the substrate's governing field equation (F1-cov) is strictly linear, a single deformation event that bifurcates into two propagating condensations maintains linear superposition.

Conclusion: The tensor product structure is a direct mathematical consequence of substrate field linearity. It is an inherited geometric property, not a disconnected mathematical axiom.

Formalism III: Topological Circulation & Half-Integer Spin

Principle: Bell correlation functions rely on the underlying spin-statistics of the particles. P68 utilizes the topological circulation structure derived from substrate embedding geometry.

$$L_{\min} = \hbar/2 = \frac{1}{2}m_{eff}c\ell_{\text{model}}$$

The topological phase winding of the embedded condensation requires two full frame rotations (720 degrees) to return to its original configuration. This physical geometry establishes the **half-integer spin baseline** fundamentally necessary for the formulation of Bell states.



Formalism IV: Bell Correlation & The Tsirelson Bound

Standard Classical Limit (Local Hidden Variables): $S \leq 2$

The CHSH Parameter Limit (Tsirelson Bound): $S \leq 2\sqrt{2}$

- P68 reproduces the exact numerical form of the Bell correlation function without invoking superluminal signaling.
- The Tsirelson bound ($2\sqrt{2}$) is achieved naturally because measurement correlations were fixed at the exact moment of joint formation.
- Measurement merely reveals pre-established, topologically linked substrate correlations, entirely circumventing the classical limit without violating the strict substrate speed limit (c).

Diagnostic Comparison: Standard QM vs. The Substrate Model

	Standard Interpretation	BFUT P68 Substrate Model
Nature of the State	Purely mathematical non-separability in Hilbert space.	A single, continuous physical substrate configuration.
The Measurement Effect	Instantaneous, non-local wave function collapse across space.	Local revelation of physical correlations permanently fixed at the joint formation event.
Information & Speed Limit	Apparent superluminal interaction (spooky action).	Strictly constrained by c . No information is transferred between particles during measurement.

Addressing Theoretical Objections

Q: Is a shared-origin account merely a restatement of local hidden-variable theories, which have already been definitively excluded by Bell's Theorem?

A: **No.** Classical hidden variables incorrectly assume two completely **independent** particles carrying localized, separate data lists. P68 proposes that the particles never became mathematically or physically independent. They remain a **single, extended substrate topology**. Bell's theorem brilliantly excludes local independent variables; **it does not, and mathematically cannot, exclude a single, spatially distributed, continuous physical configuration.**

Falsifiable Predictions of the P68 Framework

1

Physical Entanglement Degradation

Decoherence is not purely mathematical. It is a physical, monotonic function of the degree to which substrate deformations remain jointly sourced.

2

Environmental Decoherence Mechanics

Environmental decoherence physically represents independent substrate interactions actively decomposing the jointly sourced topology. It is a continuous, graded process governed by coupling strength.

3

The Absolute Speed Limit

No confirmed experimental protocol will ever demonstrate controllable, superluminal transfer of usable information. Entanglement is an inherited correlation, not an active communication channel, and remains strictly bounded by c .

Conclusions: A Non-Mysterious Origin

BFUT-P68 replaces “spooky action” with strict mechanical continuity, establishing a physical origin for Quantum Entanglement.

Mathematical Derivation	Topological Correlation	Strict Local Realism
The standard tensor product structure is derived physically and inevitably from substrate field linearity, replacing an unexplained axiom.	Bell correlations and exact Tsirelson bounds are reproduced seamlessly via the topological circulation history (half-integer spin) of embedded condensations.	Total compliance with the strict substrate speed limit (c) is maintained. Correlations are inherited at formation, requiring no superluminal signaling during measurement.