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A Vortex-Based Interpretation of Quantum Entanglement: Bridging Classical Intuition and Quantum Reality

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Abstract

Quantum entanglement represents one of the most profound and counterintuitive phenomena in modern physics, challenging our classical understanding of locality and causality. While the mathematical formalism of quantum mechanics accurately predicts entanglement correlations, the lack of a physically intuitive mechanism has led to numerous interpretational difficulties and philosophical debates. This article presents a comprehensive analysis of existing interpretations of quantum entanglement, from the Copenhagen interpretation to many-worlds and hidden variable theories, highlighting their limitations and motivating a novel vortex-based interpretation grounded in the hydrodynamic behavior of a superfluid vacuum, drawing upon the author's published work on electron, quark, and gravitational force dynamics. This vortex model provides a physically intuitive and causally consistent explanation for nonlocal correlations without invoking superluminal signaling, offering a bridge between classical physics and quantum mechanics. The proposed interpretation suggests that entangled particles are surface manifestations of deeper, coherent vortex structures within a continuous vacuum medium, analogous to connected vortices in a fluid system. This framework not only resolves the conceptual difficulties associated with "spooky action at a distance" but also provides a foundation for understanding quantum phenomena through classical hydrodynamic principles.

Keywords

Quantum Entanglement, Vortex Theory, Superfluid Vacuum, Nonlocality, Copenhagen Interpretation, Many-Worlds, Hidden Variables, Hydrodynamic Analogy

1. Introduction

Quantum entanglement stands as one of the most remarkable and perplexing phenomena in the realm of quantum mechanics, fundamentally challenging our classical intuitions about the nature of reality, locality, and causality. First brought to prominence through the famous Einstein-Podolsky-Rosen (EPR) paradox in 1935 [1], entanglement describes a quantum mechanical phenomenon where the quantum states of two or more particles become correlated in such a way that the quantum state of each particle cannot be described independently, even when separated by vast distances. This phenomenon has been experimentally verified countless times and forms the foundation of emerging technologies such as quantum computing, quantum cryptography, and quantum teleportation [2].

The profound implications of quantum entanglement extend far beyond its technological applications. At its core, entanglement challenges the principle of local realism—the idea that physical processes occurring at one location do not depend on the properties of objects at other locations and that objects have definite properties independent of observation [3]. When two particles become entangled, measurements performed on one particle appear to instantaneously influence the state of its partner, regardless of the spatial separation between them. This apparent "spooky action at a distance," as Einstein famously termed it, seems to violate the fundamental principle that no information can travel faster than the speed of light [4].

The mathematical formalism of quantum mechanics, while extraordinarily successful in predicting the statistical outcomes of entanglement experiments, provides no clear physical mechanism to explain how these correlations arise or are maintained. This gap between mathematical description and physical understanding has given rise to numerous interpretational frameworks, each attempting to reconcile the quantum mechanical predictions with our understanding of physical reality [5].

Despite decades of theoretical development and experimental verification, the fundamental question remains: What is the physical mechanism underlying quantum entanglement? The violation of Bell's inequalities in numerous experiments has definitively ruled out local hidden variable theories, confirming that quantum mechanics cannot be explained by classical concepts of local realism [6]. However, this experimental confirmation has simultaneously deepened the conceptual mystery.

Recent developments in our understanding of the quantum vacuum suggest a potential avenue for resolving this conceptual impasse. The quantum vacuum, far from being empty space, is now understood to be a dynamic medium filled with virtual particle pairs and zero-point energy fluctuations [7]. Building upon this foundation, we propose a novel interpretation of quantum entanglement based on vortex dynamics within a superfluid vacuum, drawing upon the author's extensive published work [8]-[10].

2. The Problem with Current Interpretations

2.1. The Copenhagen Interpretation

The Copenhagen interpretation, developed by Niels Bohr and Werner Heisenberg [11] [12], represents the orthodox view that dominated physics for much of the 20th century. This interpretation embraces fundamental indeterminacy and rejects the notion that quantum objects possess definite properties independent of measurement. While pragmatically successful, it faces the measurement problem and provides no clear physical mechanism for wave function collapse.

2.2. The Many-Worlds Interpretation

The Many-Worlds Interpretation, proposed by Hugh Everett III [13], eliminates wave function collapse by postulating that all possible outcomes occur in parallel branches of reality [14] [15]. While mathematically elegant, it requires an ontologically expensive multiverse and faces the preferred basis problem.

2.3. Hidden Variable Theories

Hidden variable theories attempt to restore classical determinism by postulating additional variables that determine measurement outcomes [16]. However, Bell's theorem [3] and subsequent experiments [6] [17]-[19] have definitively ruled out local hidden variable theories. Nonlocal alternatives like Bohmian mechanics maintain realism but violate locality.

2.4. The Need for a New Approach

Each existing interpretation faces significant conceptual challenges. The Copenhagen interpretation avoids providing a physical mechanism, many-worlds requires an expensive multiverse, and hidden variable theories either violate locality or are ruled out by experiments. This suggests the need for a fundamentally new approach.

3. The Vortex-Based Interpretation: A Hydrodynamic Solution

3.1. Theoretical Foundation: The Superfluid Vacuum

The vortex-based interpretation rests on the hypothesis that the quantum vacuum behaves as a superfluid medium—a continuous, frictionless substrate capable of sustaining self-organizing vortex structures that give rise to matter, fields, and forces. Within this framework, space itself is dynamic, characterized by density fluctuations and quantized circulation patterns rather than empty void.

This view aligns with quantum field theory, which describes the vacuum as a seething sea of virtual particle-antiparticle pairs and zero-point fluctuations that never truly vanish, even at absolute zero. Phenomena such as the Casimir effect, Lamb shift, and vacuum birefringence further confirm that the vacuum possesses measurable physical properties—pressure, polarization, and elasticity—suggesting a real, energetic continuum rather than an abstract background [7] [20].

In this superfluid model, vortices represent quantized excitations of the vacuum field. Their stability and interactions account for the apparent discreteness of particles, while their underlying fluid nature explains the continuity of quantum wave behavior. This duality between localized structure and delocalized flow provides a natural bridge between quantum mechanics and classical hydrodynamics, eliminating the need for probabilistic interpretations by grounding them in a deterministic fluid dynamics of the vacuum.

3.2. Particles as Vortex Structures

The interpretation builds upon the author's published framework demonstrating that fundamental particles can be understood as stable vortex structures within the superfluid vacuum:

Electron Vortex Model: In "Electron Shape and Structure: A New Vortex Theory" [8], the electron is modeled as a frictionless vortex with conserved momentum, formed from condensed vacuum energy. This model successfully predicts the electron's mass, charge, spin, and wave-particle duality through hydrodynamic principles.

Quark Vortex Model: The extension to quarks [10] demonstrates that these fundamental constituents can be understood as superfluid vortices formed during the Quark Epoch following the Big Bang, explaining color charge, confinement, and the strong force.

Gravitational Vortex Model: The gravitational force [9] arises from large-scale vortex structures that curve the superfluid vacuum, providing a physical mechanism for Einstein's geometric description while maintaining consistency with both Newtonian and relativistic gravity.

3.3. The Hydrodynamic Analogy

To understand quantum entanglement in this framework, consider a concrete analogy: a flat plate pushed through a swimming pool creates two counter-rotating vortices at its ends. On the surface, these appear as separate structures, but beneath the surface, they are connected by continuous flow patterns forming a unified hydrodynamic system [21] [22] (**Figure 1**).

This analogy captures the essential features of quantum entanglement. Entangled particles correspond to surface vortices—appearing separate when observed individually but actually connected by invisible flow patterns in the underlying superfluid vacuum. The correlations arise not from communication between particles, but from their being part of a single, coherent vortex system.

3.4. Entanglement as Vortex Coherence

In the vortex-based interpretation, quantum entanglement arises when particles are created as part of a coherent vortex system within the superfluid vacuum. When particles are created in an entangled state, they form a "vortex dipole" structure—observable manifestations of a deeper, unified vortex structure embedded in the vacuum medium.

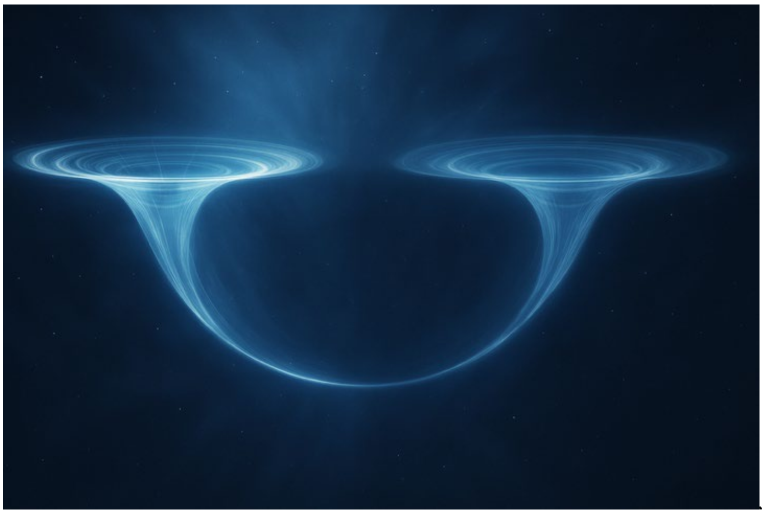

Figure 1. Visualize two counter-rotating quantum vortices emerging from a shared superfluid field, forming a continuous bridge beneath the surface—a hydrodynamic analogy of quantum entanglement. The image should show fluid-like motion, coherent blue light patterns, and a sense of unity beneath apparent separation, illustrating how two vortices share one invisible flow in the vacuum.

The phase coherence of this vortex structure is maintained by the superfluid properties of the vacuum. In superfluids, vortices can persist indefinitely without dissipation [23] [24], and their topological properties ensure that connections between different parts remain stable over arbitrary distances and time periods.

Conservation Laws and Instantaneous Correlations: Conservation laws governing entangled systems are naturally incorporated through the topological properties of vortex structures [25] [26]. When a measurement perturbs one part of an entangled vortex system, the entire system responds instantaneously to maintain its topological and conservation properties. This response represents the natural tendency of the vortex system to maintain coherent structure rather than transmission of information.

3.4.1. Bell's Theorem and the Vortex Model

Bell's Theorem is one of the most significant milestones in the foundations of quantum mechanics. It demonstrates that no theory based on local hidden variables can reproduce the statistical predictions of quantum entanglement as described by quantum mechanics. This result, supported by a multitude of experiments, implies that any realistic theory of entanglement must either abandon locality, realism, or both.

In the standard interpretation, the violation of Bell inequalities is often taken as evidence for nonlocal behavior in nature—what Einstein famously called "spooky action at a distance." However, this notion introduces deep conceptual tensions with the framework of special relativity and lacks a clear physical mechanism [3].

The vortex-based interpretation offers an alternative resolution. In this framework, entangled particles are not isolated systems but are two endpoints of a shared, continuous vortex structure embedded in a superfluid-like vacuum. The vacuum field acts as a physically real and connected medium that supports instantaneous phase coherence across spatial separations, not through signal transmission, but through topological unity.

When one part of an entangled pair is measured, the resulting change is interpreted not as a signal to the distant partner, but as a global readjustment of the shared vortex structure. This preserves causality, since the adjustment occurs within a single extended physical system—the coherent vacuum field—rather than between two spatially distinct and independent particles.

As a result, the vortex model reproduces the quantum mechanical violations of Bell inequalities, such as those in the CHSH form [3], without invoking superluminal influences or abandoning realism. The correlations arise from phase-locked structures maintained by the vacuum's topological properties, which constrain the degrees of freedom available to the system as a whole.

Furthermore, entanglement entropy in this framework gains a physical interpretation: it reflects the amount of vacuum phase information shared between vortex poles. The von Neumann entropy of a subsystem corresponds to the deformation or constraint imposed on the global phase field. This bridges the formalism of quantum information theory with a hydrodynamic and topological physical model.

In this way, the vortex interpretation not only explains why Bell inequalities are violated but also offers a mechanism rooted in coherent field dynamics, thereby restoring physical intuition and preserving compatibility with relativistic causality.

3.4.2. Mathematical Framework of Vortex Entanglement

To formalize the vortex-based interpretation of entanglement, we begin by modeling each particle as a phase-coherent vortex structure embedded in the superfluid vacuum. Let the wavefunction of each vortex be expressed in polar form:

$$\Psi_i(\mathbf{r}_i,t) = A_i(\mathbf{r}_i,t)\exp\left[\frac{(iS_i(r_i,t)}{\hbar}\right]$$

where A_i is the amplitude and S_i is the phase (or action) of the vortex structure. The local velocity of the vacuum field surrounding each vortex is then given by:

$$\mathbf{v}_i = \frac{1}{m}\nabla S_i$$

For two entangled vortices, the total system cannot be expressed as a simple tensor product. Instead, the full wavefunction must include a non-separable shared phase component Slink induced by the vortex-mediated vacuum bridge:

$$\Psi_{12}(\mathbf{r}_1,\mathbf{r}_2,t) = A(\mathbf{r}_1,\mathbf{r}_2,t)\cdot\exp\left[\frac{i}{\hbar}(S_1+S_2+S_{link})\right]$$

Since vortex circulation in the superfluid vacuum is quantized according to

$$\Gamma = n\frac{ih}{m}$$

the shared phase S_{link} must obey discrete topological constraints. This implies that entanglement corresponds to the synchronization of quantized circulation modes between vortices. Hence, Planck's constant represents not merely a quantum of action but the fundamental circulation quantum of the vacuum itself.

The linking phase term encodes the nonlocal coherence imposed by the continuous vacuum field. This implies that changes in one vortex affect the global phase structure, producing immediate but causal adjustments in the second vortex via conservation laws—not information transfer.

The dynamics of S_{link} can be modeled using a quantum Hamilton-Jacobi equation:

$$\frac{\partial S_{link}}{\partial t} + \frac{1}{2m}\left(\nabla S_{link}\right)^2 + V_{vac}\left(\mathbf{r}_1, \mathbf{r}_2\right) = 0$$

where V_{vac} is the vacuum potential arising from topological and energetic constraints of the vortex system.

Angular momentum conservation across the vortex system imposes:

$$L_{\text{total}} = L_1 + L_2 + L_{\text{field}} = \text{constant}$$

This framework maintains quantum correlations without superluminal signaling by interpreting entanglement as the continuous deformation of a single coherent field, not the interaction of discrete entities.

3.5. Advantages of the Vortex Model

The vortex-based interpretation offers a number of compelling advantages that make it a promising alternative to traditional quantum interpretations. By grounding entanglement in the physical behavior of vortices within a superfluid vacuum, the model provides a clear and intuitive visualization of quantum correlations that are otherwise abstract and counterintuitive. The hydrodynamic analogy allows for a tangible understanding of how entangled particles remain connected through coherent flow structures in the vacuum, offering a framework that retains mathematical rigor while enhancing conceptual accessibility.

One of the most significant benefits of this approach is its causal consistency. Rather than requiring information to propagate instantaneously between distant particles, the model accounts for observed correlations through pre-existing phase continuity and topological constraints within the vacuum field. This resolves the apparent conflict between quantum nonlocality and relativistic limitations on signal propagation.

Furthermore, the vortex framework brings together particles, forces, and entanglement into a unified picture governed by the same underlying principles. This coherence simplifies the conceptual landscape of quantum theory and opens the door to integrated explanations of diverse physical phenomena.

The model also leads to clear, testable predictions. These include the influence of entanglement on vacuum properties, potential correlations between entanglement stability and topological features such as winding number or vorticity, and specific ways in which gravitational fields might modulate quantum coherence.

Finally, the interpretation remains compatible with standard quantum predictions. It reproduces the expected violations of Bell inequalities and offers a natural, physically meaningful way to interpret entanglement entropy in terms of vacuum phase structure. This compatibility with both theoretical results and experimental data, combined with the model's explanatory power, positions the vortex interpretation as a strong candidate for advancing our understanding of the quantum world.

3.6. Connection to the Unified Vortex Theory

The phenomenon of entanglement constitutes the microscopic manifestation of the same vacuum coherence that, at macroscopic scales, gives rise to gravitation and spacetime curvature. Within the Unified Vortex Theory, both effects emerge as complementary expressions of the fundamental tendency of the vacuum to preserve phase coherence, continuity, and topological order. The superfluid vacuum behaves as a dynamic medium where energy, momentum, and information circulate through quantized vortex flows, binding all phenomena—quantum and cosmic—within one continuous hydrodynamic framework.

At the quantum level, entanglement corresponds to the synchronization of vortex oscillations across distinct regions of the vacuum. The shared phase field, which sustains quantum correlation, represents the fine-scale manifestation of the same topological coherence that stabilizes larger vortex structures such as particles, atoms, and ultimately celestial systems. Thus, the S_{link} term in the entangled wavefunction reflects a localized instance of the universal phase continuity that governs the entire vacuum field.

At macroscopic and cosmological scales, gravitational curvature emerges as the geometrical imprint of this same coherence principle operating collectively across an immense ensemble of vortices. Matter concentrations generate pressure gradients and curvature in the vacuum analogous to the way coherent vortices distort the local flow field of a superfluid. Hence, the Einsteinian curvature of spacetime can be viewed as the large-scale hydrodynamic consequence of the same vacuum mechanics responsible for quantum entanglement at microscopic scales.

This unified description implies that quantum correlation and gravitational attraction are not fundamentally distinct phenomena, but two aspects of one self-organizing process governed by the conservation of circulation and phase. Entanglement describes the *informational* coherence of the vacuum, while gravity expresses its *geometric* coherence. Together, they form a dual expression of the same underlying law of vortex continuity.

Furthermore, this correspondence bridges the gap between the quantum and cosmological domains: the microcosmic vortex link connecting entangled particles finds its macrocosmic counterpart in the coherent vortex structures that organize galaxies and cosmic filaments. The same equations describing quantized circulation and phase locking at the quantum level, when scaled by vacuum density and energy distribution, yield the continuum equations governing large-scale gravitational flows.

In this view, the Omniom vacuum field acts as a universal superfluid substrate through which all interactions—electromagnetic, gravitational, strong, and weak—arise from variations in vortex density, circulation, and phase alignment. Quantum entanglement therefore represents the smallest-scale resonance of this universal coherence, providing the missing bridge between quantum mechanics and general relativity.

This unified framework eliminates the conceptual separation between fields and particles, waves and matter, locality and nonlocality. It portrays the universe as a single living continuum—a hierarchical network of vortices resonantly coupled through the Omniom vacuum. Entanglement, gravitation, and cosmic evolution thus become different scales of one coherent process: the perpetual self-organization of the vacuum into structures of energy, information, and consciousness.

4. Implications and Future Directions

4.1. Quantum Technology Applications

The vortex model suggests new and potentially transformative approaches to quantum technologies. Certain entangled states, particularly those characterized by higher topological charge, may exhibit intrinsic resistance to environmental decoherence due to the topological stability of vortex structures. This opens the possibility for topologically protected quantum computing architectures, in which information is encoded not in fragile quantum states, but in robust vortex configurations that are less sensitive to local disturbances.

Such an approach could lead to the development of fault-tolerant quantum processors where qubits are stabilized by the topological coherence of the underlying vacuum field. Additionally, the vortex-based framework implies that the strength and persistence of entanglement may be enhanced by engineering specific flow geometries within the vacuum, offering a new design parameter for quantum circuits and entanglement-based protocols.

In the realm of quantum communication, the model suggests that long-range entanglement could be maintained more effectively through vacuum-mediated vortex links, potentially enabling ultra-stable quantum networks. Vortex phase coherence across macroscopic distances may also facilitate new protocols for entanglement distribution and quantum key exchange, where security and signal integrity are maintained by the global conservation properties of the vortex system.

Furthermore, the ability to manipulate topological features in the vacuum field—such as vorticity, helicity, or winding number—may lead to novel methods of encoding, transmitting, and decoding quantum information in both terrestrial and space-based applications.

4.2. Cosmological Implications

If fundamental particles are vortex structures formed during the Big Bang, this would have left observable signatures in the large-scale structure of the universe and in the anisotropies of the cosmic microwave background (CMB). Such signatures might manifest as preferred alignment patterns, residual vorticity imprints, or correlations in polarization data that reflect early vacuum phase configurations.

The vortex model also offers new insights into the nature of dark matter and dark energy. Dark matter could be understood as a population of stable, large-scale vortex structures in the superfluid vacuum that interact gravitationally but remain undetectable via electromagnetic interactions due to their non-radiating nature. Their persistence and invisibility would be natural consequences of the topological stability of such vortices and their insulation from decoherence or decay.

Dark energy, on the other hand, may arise from the large-scale tension and energy density of the vacuum itself. In this view, the observed accelerated expansion of the universe is not driven by an exotic scalar field or cosmological constant, but by the elastic properties and dynamic pressure of the vortex-rich superfluid vacuum. The vacuum behaves as a medium with negative pressure, wherein large-scale coherent flows and circulation patterns store energy that manifests as a repulsive gravitational effect.

Additionally, the formation and evolution of galaxies, filaments, and voids may be influenced by underlying vacuum vorticity fields. The vortex interpretation suggests that structure formation is not merely the result of gravitational collapse of point particles, but a hydrodynamic process shaped by the coherence and dynamics of vacuum flow fields established in the earliest moments of cosmic evolution.

This framework provides an opportunity to reinterpret inflation, baryogenesis, and the arrow of time in terms of vortex generation, dissipation, and symmetry breaking in the primordial vacuum.

4.3. Experimental Predictions

The vortex model predicts measurable modifications in vacuum properties in the presence of entangled particles, potentially detectable through precision measurements of vacuum birefringence, phase-shift interferometry, or variations in the Casimir effect under controlled quantum correlation conditions. Such deviations would signal a coupling between the entangled system and the vacuum field structure, providing direct evidence for the physical substrate of entanglement.

The model also anticipates specific relationships between entanglement stability and topological charge. Entangled vortex pairs with higher quantized circulation or more complex knot-like configurations may exhibit enhanced resistance to decoherence due to their intrinsic topological protection. Experimental verification of this could be pursued through comparisons of entanglement lifetimes across different topologically encoded quantum states.

Furthermore, gravitational effects on entanglement correlations—traditionally neglected in standard quantum mechanics—are predicted to influence the phase alignment and coherence of vacuum-linked vortex systems. Slight but systematic variations in entanglement fidelity or Bell inequality violation strength under gravitational gradients, such as those achievable in satellite- based quantum optics experiments, would offer a test of the model's coupling between vortex coherence and spacetime curvature.

In particular, the model reproduces the expected statistical violations of Bell inequalities. Entangled vortex pairs exhibit correlations that violate the CHSH inequality, exceeding the classical bound of 2 and approaching the quantum (Tsirelson) bound of $2\sqrt{2}$. This bound can be naturally correlated with vortex interactions if each vortex effectively couples through four coherent interaction lines, since the CHSH inequality itself is constructed from four correlation terms; the quantum maximum $2\sqrt{2}$ then reflects the optimal coherent superposition of these four channels under geometric and phase constraints. Moreover, the shared vacuum-field structure provides a natural interpretation of entanglement entropy: the von Neumann entropy of the reduced density matrix associated with a single vortex reflects information encoded in the global phase structure of the coupled system, becoming nonzero precisely when the vortex pair is entangled. This establishes a direct bridge between topological vortex coherence and conventional quantum-information measures.

Additionally, the model suggests new experimental tests involving vacuum tuning: by altering environmental factors such as vacuum boundary conditions, temperature, or electromagnetic field strengths, one may induce detectable shifts in entanglement properties. Such experiments would provide critical evidence for the underlying fluidic nature of the vacuum and the physical structure of the entangled connection.

4.4. Integration with Vortex-Based Gravitation and Cosmology

The holographic nature of spacetime information can be reinterpreted as a large-scale manifestation of vacuum entanglement. In this framework, the entire cosmos behaves as a coherent field of vortical structures within the superfluid vacuum, where every region retains phase and topological correlations with every other region. These correlations, established during the primordial stages of the universe, constitute the foundation of nonlocal information continuity across cosmic scales.

From the perspective of the Unified Vortex Theory, the holographic principle emerges naturally: information encoded on the boundary of a system corresponds to the total vorticity and circulation within it. Each quantized vortex in the vacuum stores angular momentum and phase data that, collectively, form the informational surface of spacetime. Thus, the apparent "projection" of information on a two-dimensional boundary is the hydrodynamic imprint of the vacuum's internal circulation patterns.

During the early universe, massive coherent vortex formations coupled different regions of the vacuum through entangled flow fields. These primordial vortices acted as cosmic conduits of phase coherence, linking distant regions long before causal communication was possible under relativistic constraints. As the universe expanded, these correlations were stretched across cosmic distances, leaving behind subtle imprints observable today in the anisotropies of the cosmic microwave background (CMB) and the filamentary structure of galactic superclusters.

Gravitation, in this view, is not a distinct fundamental force but a macroscopic expression of vacuum coherence, arising from large-scale curvature in the superfluid field. Matter acts as a concentrated vortex core that curves the surrounding vacuum flow, while quantum entanglement represents the microscopic version of the same phenomenon — curvature of the phase field rather than the density field. Both obey the same underlying hydrodynamic law of vortex continuity.

This correspondence between quantum entanglement and gravitational connectivity implies that spacetime itself is the emergent geometry of a vast network of coherent vortex links. Just as entangled particles remain phase-correlated through the vacuum, celestial bodies and galaxies remain gravitationally connected through large-scale coherent flow structures. The gravitational field, therefore, can be regarded as the collective entanglement of matter through the Omniom vacuum [27].

In this integrated framework, dark matter can be understood as non-radiating, stable vortex formations within the vacuum—massive enough to generate gravitational influence but invisible to electromagnetic detection due to their phase-locked neutrality. Similarly, dark energy arises from the tension and negative pressure of large-scale vortex circulation within the Omniom field, driving the universe's accelerated expansion through vacuum elasticity rather than an external cosmological constant.

This model unifies quantum entanglement, gravitation, and cosmological evolution into a single continuum of vortex coherence. It suggests that the same principles governing the correlation of subatomic vortices extend seamlessly to galactic and intergalactic scales, where the universe itself behaves as a self-entangled superfluid system—a cosmic hologram sustained by the coherence of the vacuum.

5. Conclusions

The vortex-based interpretation of quantum entanglement offers a fundamentally new approach that provides both mathematical rigor and physical intuition while resolving conceptual difficulties of previous interpretations. By grounding quantum correlations in vortex dynamics within a superfluid vacuum, this interpretation explains how correlations can be maintained over arbitrary distances without violating causality.

The interpretation addresses major weaknesses of existing approaches: unlike Copenhagen, it provides a concrete physical mechanism; unlike many-worlds, it requires no expensive multiverse; unlike hidden variable theories, it maintains locality through vacuum continuity. The model's integration with the author's published work on particle physics and gravity suggests a unified understanding of fundamental physics.

The vortex-based interpretation represents a return to the classical ideal of physics as the study of concrete, visualizable phenomena governed by comprehensible physical laws. By showing that quantum mechanics can be understood through familiar classical concepts, this interpretation suggests that the divide between classical and quantum physics may be less fundamental than previously thought.

Future research should focus on developing the mathematical formalism in greater detail, conducting experimental tests of the predicted vacuum modifications, and exploring technological applications based on topological protection of vortex connections. The success of this approach could lead to new insights into the fundamental nature of reality and practical advances in quantum technology.

The Vortex-Based Interpretation of Quantum Entanglement completes a continuum that extends from subatomic particle structure to cosmic-scale coherence, forming a comprehensive framework where all forces and quantum phenomena derive from the same hydrodynamic substrate—the Omniom vacuum field.

This unified perspective suggests that the same principles governing vortex coherence at the quantum scale also dictate the emergence of structure, order, and information throughout the universe, thus providing a coherent bridge between physics, cosmology, and consciousness.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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