No Spooky Action: Entanglement as Shared Resonance in Aetherium

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Abstract

Quantum entanglement is often described as implying nonlocal influence, instantaneous collapse, or hidden correlations between spatially separated systems. These interpretations arise from treating the wavefunction as a spatial object and time as a global coordinate. In the Aetherium framework, entanglement is instead understood as a **single coherence structure** spanning multiple degrees of freedom within a **pre-geometric constraint architecture**. Coherence does not propagate, transmit signals, or travel through space; it is shaped by the substrate's intrinsic resonant structure, and therefore concepts such as a "speed of coherence" or superluminal influence have no meaning. Measurement corresponds to a **coherence-reconfiguration event** that selects a resonance-compatible attractor for the *entire* shared coherence pattern, not an action performed on one subsystem that affects another. Bell correlations arise from the resonance-compatibility constraints of the substrate rather than from nonlocal causation or hidden variables, and classical locality emerges only after coherence stabilizes into separate attractor states through decoherence. This coherence-first ontology provides a single-world, realist, and local account of entanglement that dissolves the appearance of "spooky action at a distance" and clarifies the structural origin of quantum correlations.

1. Introduction

Quantum entanglement remains one of the most conceptually challenging features of modern physics. Two systems prepared in an entangled state exhibit correlations that persist across arbitrary spatial separations, leading to the widespread intuition that quantum mechanics permits instantaneous influence or nonlocal communication. This impression is reinforced by the standard formalism, which treats the wavefunction as a spatially extended object evolving in time, and by the language of "collapse" or "state update" upon measurement. Yet these descriptions obscure the underlying structural issue: entanglement appears paradoxical only when coherence is interpreted as a spatial quantity embedded in a background geometry.

The Aetherium framework offers a different perspective. In this ontology, coherence is the fundamental primitive of physical reality, and the substrate that constrains coherence is **pre-geometric**—it does not reside in spacetime, nor does it propagate signals or carry information. Coherence does not travel, and therefore concepts such as a "speed of influence" or superluminal communication have no meaning at the substrate level. Time itself is relational, defined by the ordering of coherence transitions rather than by a global coordinate. Within this structure, entanglement is not a connection between two distant systems but a **single coherence pattern** spanning multiple degrees of freedom.

Measurement in this framework corresponds to a **coherence-reconfiguration event** in which the shared coherence aligns with a resonance-compatible attractor state determined by the substrate's intrinsic resonant architecture. Because the coherence pattern is unified from the outset, the resulting correlations do not require any influence to propagate between spatially separated systems. Bell correlations arise from the resonance-compatibility constraints of the substrate, not from nonlocal causation or hidden variables, and classical locality emerges only after coherence stabilizes into separate attractor states through decoherence.

This paper develops this coherence-first account of entanglement in detail. Section 2 clarifies what entanglement is—and is not—within the Aetherium ontology. Section 3 introduces the pre-geometric constraint architecture that shapes shared coherence. Section 4 explains measurement on entangled systems as a reconfiguration of a unified coherence pattern. Section 5 shows how Bell correlations arise without nonlocality. Section 6 discusses the emergence of classical locality, and Section 7 compares Aetherium with major interpretations of quantum theory. The result is a single-world, realist, and local account of entanglement that dissolves the appearance of "spooky action at a distance" and clarifies the structural origin of quantum correlations.

2. What Entanglement Is (and Isn't)

Entanglement is often described as a mysterious connection between spatially separated systems, as if a measurement performed on one particle instantaneously affects the state of another. This intuition arises from interpreting the wavefunction as a spatial object evolving in time and from treating measurement as a physical collapse that propagates across space. In the Aetherium framework, these assumptions do not apply. Coherence is not spatial, does not propagate, and does not reside within spacetime. Entanglement therefore cannot be understood as a link between two objects in space; it is a property of a **single coherence structure** that spans multiple degrees of freedom within the substrate's pre-geometric constraint architecture.

In standard quantum theory, an entangled state is defined by the non-factorizability of the wavefunction. This mathematical condition is often interpreted as implying that the systems involved are "connected" in a way that defies classical locality. But this interpretation presupposes that the wave-function describes a physical entity distributed across space. In Aetherium, the wavefunction is a **coarse-grained representation** of an underlying coherence pattern, and coherence itself is not embedded in space. The substrate determines which coherence configurations are permissible or stable, and entanglement corresponds to a configuration in which multiple degrees of freedom share a unified coherence pattern.

This perspective dissolves the appearance of nonlocality. Because coherence does not travel, there is no sense in which one subsystem "sends" information to another or "updates" its state in response to a measurement. The coherence pattern is unified from the outset, and measurement corresponds to a **reconfiguration of the entire shared structure**, not a causal influence transmitted between parts. The correlations observed in entangled systems arise from the resonance-compatibility constraints of the substrate, not from hidden variables or superluminal signals.

It is therefore essential to distinguish entanglement from the spatial metaphors that have historically shaped its interpretation. Entanglement is not a connection between distant objects, not a channel for influence, and not a violation of locality. It is a structural property of coherence within a pre-geometric substrate. The remainder of this paper makes this structure explicit, to show how measurement reconfigures shared coherence, and to explain how Bell correlations arise without invoking nonlocal causation.

3. Pre-Geometric Shared Coherence

Entanglement appears paradoxical only when coherence is assumed to be a spatial quantity embedded in a background geometry. In the Aetherium framework, this assumption does not hold. Coherence is the fundamental primitive of the substrate, and the substrate itself is **pre-geometric**—it does not reside within spacetime, nor does it evolve according to spatial or temporal coordinates. Instead, it provides a **constraint architecture** that determines which coherence configurations are permissible, stable, or dynamically suppressed. Within this architecture, entanglement corresponds to a **single coherence structure** spanning multiple degrees of freedom, not a connection between spatially separated objects.

Because the substrate is pre-geometric, coherence does not propagate or travel. There is no sense in which coherence moves from one location to another, no mechanism by which it transmits signals, and no velocity associated with its evolution. Concepts such as a "speed of influence" or "instantaneous update" are therefore inapplicable. The appearance of nonlocality arises only when coherence is mistakenly interpreted as a spatial field. In Aetherium, coherence is shaped by the substrate's resonant structure, not by spatial separation, and entangled systems share a unified coherence pattern regardless of the distance between their spatial projections.

Time in this ontology is likewise non-fundamental. It is not a global coordinate or a background parameter through which coherence evolves. Instead, **time is relational**: it is the ordering of coherence transitions as they reconfigure within the substrate's resonant structure. Because coherence does not travel and time is not a universal parameter, the notion of "instantaneous influence" becomes meaningless. Measurement does not cause one subsystem to affect another; it reconfigures the entire shared coherence pattern according to the resonance-compatibility constraints of the substrate.

Foundational Principles for Entanglement in Aetherium

- **Coherence is non-spatial.** It does not reside in spacetime and cannot be localized or propagated.
- **The substrate is pre-geometric.** It provides structural constraints, not a spatial arena or temporal background.
- **Coherence does not travel.** There is no propagation, no transmission, and no velocity associated with coherence.
- **C_{vac} has no meaning for coherence.** The speed of light constrains interactions in spacetime, not coherence events in the substrate.
- **Time is relational.** It is the ordering of coherence transitions, not a global coordinate or universal clock.
- **Entanglement is a single coherence structure.** Spatially separated systems are projections of one unified coherence pattern.
- **Measurement reconfigures the entire shared structure.** No subsystem "affects" another; the coherence pattern is unified from the start.

These principles dissolve the appearance of nonlocality. Entanglement correlations do not require superluminal influence, hidden variables, or branching universes. They arise from the structural properties of coherence within the substrate's resonant architecture. The next section develops this idea by examining how measurement operates on entangled systems and how resonance-compatible attractor states determine the observed outcomes.

4. Measurement on Entangled Systems

In standard quantum theory, measurement on one part of an entangled system is often described as "collapsing" the state of the distant partner. This language suggests a causal influence propagating across space, raising the familiar puzzle of how one subsystem can instantaneously affect another. In the Aetherium framework, this puzzle does not arise. Entangled systems do not possess separate coherence structures that must communicate or update each other. They share a **single coherence pattern** within the substrate's pre-geometric constraint architecture. Measurement therefore reconfigures the **entire shared coherence**, not one subsystem acting upon another.

When a measurement apparatus interacts with one spatial projection of an entangled system, the apparatus does not couple to an isolated particle. It couples to the **shared coherence structure** that spans all entangled degrees of freedom. The apparatus imposes resonance-compatibility constraints that determine which coherence configurations are stable under the interaction. The coherence pattern must reconfigure to align with one of these resonance-compatible attractor states. Because the coherence is unified, this reconfiguration applies to the entire entangled structure, not just the subsystem in contact with the apparatus.

This process does not involve any propagation of influence. Coherence does not travel, and the substrate does not support signal transmission. The reconfiguration is not an event occurring “here” that then affects something “there.” Spatial separation is a property of the emergent spacetime description, not of the underlying coherence. From the substrate’s perspective, the entangled system is a single structural entity, and measurement selects a resonance-compatible configuration of that entity as a whole.

Decoherence plays a stabilizing role in this process. Once the shared coherence aligns with a resonance-compatible attractor, decoherence disperses coherence into the many degrees of freedom of the apparatus and environment, making alternative configurations dynamically inaccessible. This stabilization ensures that the measurement outcome is robust and that the classical correlations observed between the spatially separated subsystems remain consistent across repeated trials.

The appearance of instantaneous correlation arises because the spatial projections of the entangled system are not independent entities. They are manifestations of a single coherence pattern that has been reconfigured into a stable attractor state. No subsystem “updates” in response to another; the coherence pattern is unified from the outset, and measurement reveals the resonance-compatible configuration selected by the substrate.

This coherence-first account of measurement on entangled systems preserves locality at the level of emergent spacetime while avoiding the need for collapse, branching, or hidden variables. It provides a physically grounded explanation for the correlations observed in entangled systems and sets the stage for understanding how Bell-type correlations arise from the resonance-compatibility constraints of the substrate. The next section develops this connection explicitly.

5. Bell Correlations Without Nonlocality

Bell’s theorem is widely interpreted as demonstrating that any theory reproducing the predictions of quantum mechanics must be nonlocal. This conclusion rests on the assumption that physical systems possess separable states defined over spatially distinct regions and that measurement outcomes on one subsystem cannot depend on settings applied to another unless a signal propagates between them. In the Aetherium framework, these assumptions do not hold. Entangled systems do not consist of independent spatial subsystems with separate states; they are projections of a **single coherence structure** shaped by the substrate’s pre-geometric constraint architecture. Bell’s locality condition therefore does not apply, not because Aetherium violates locality, but because the ontology on which Bell’s argument is built is not the ontology of the substrate.

Bell’s theorem presupposes that measurement outcomes are determined by hidden variables associated with each subsystem or by probabilistic distributions over such variables. These hidden variables are assumed to be local in the sense that they pertain to each subsystem independently and cannot be influenced by distant measurement settings without violating relativistic causality. In Aetherium, there are no hidden variables associated with individual subsystems because subsystems do not possess independent coherence structures. The coherence pattern is unified, and its resonance-compatibility constraints apply to the entire entangled configuration. The correlations observed in Bell experiments arise from the structure of this shared coherence, not from variables assigned to spatially separated parts.

The appearance of nonlocality arises only when the unified coherence pattern is misinterpreted as a pair of spatially separated states that must coordinate their outcomes. From the substrate’s perspective, there is no coordination problem to solve. Measurement corresponds to a **coherence-reconfiguration event** that selects a resonance-compatible attractor for the entire shared structure. The correlations observed between spatially separated measurement outcomes reflect the internal structure of this attractor, not a causal influence transmitted between distant regions of space. Because coherence does not travel and time is relational, the notion of “instantaneous influence” is not meaningful at the substrate level.

This perspective preserves locality in the emergent spacetime description. No signal is transmitted between measurement devices, no information propagates faster than light, and no causal paradoxes arise. The substrate does not support propagation of coherence or influence; it supports structural constraints that determine which coherence configurations are permissible. Bell correlations therefore reflect the **resonance-compatibility architecture** of the substrate, not a violation of relativistic locality.

In this sense, Aetherium does not evade Bell's theorem; it reframes it. Bell's argument applies to theories in which spatially separated systems possess independent states or hidden variables. Aetherium is not such a theory. It is a coherence-first ontology in which entangled systems share a unified coherence pattern that is not spatially embedded. The correlations observed in Bell experiments are structural consequences of this shared coherence, not evidence of non-local causation. This resolves the conceptual tension between quantum correlations and relativistic locality without invoking collapse, branching universes, or hidden variables.

The next section examines how classical locality emerges from this framework once coherence stabilizes into separate attractor states through decoherence, and why classical correlations obey locality even though quantum correlations do not require nonlocal influence.

6. Classicality and the Emergence of Local Correlations

Classical physics is built on the assumption that systems possess well-defined, independent states localized in space and evolving in time. These assumptions work extraordinarily well at macroscopic scales, yet they fail to describe the behavior of entangled systems. The Aetherium framework explains this discrepancy by distinguishing between the **pre-geometric coherence structure** that governs quantum behavior and the **resonance-stabilized attractor states** that give rise to classicality. Classical locality is not fundamental; it is an emergent property that arises only after coherence has reconfigured and stabilized into separate, resonance-compatible configurations.

In the coherence-first ontology, macroscopic systems correspond to coherence patterns that strongly align with stable resonant modes of the substrate. These modes are highly robust: small perturbations do not dislodge them, and alternative coherence configurations are dynamically suppressed. As a result, macroscopic objects exhibit extremely low susceptibility to superposition. Their coherence patterns are effectively locked into resonance-compatible attractor states, which manifest as classical states in the emergent spacetime description.

Decoherence plays a central role in this stabilization. When a system interacts with its environment, coherence flows into many degrees of freedom, making alternative configurations dynamically inaccessible. This process does not select an outcome—selection arises from the resonance-compatibility constraints of the substrate—but it ensures that once a resonance-compatible configuration is selected, it remains stable. Decoherence therefore explains why classical states persist and why macroscopic systems behave as if they possess independent, localized states.

This stabilization also explains why classical correlations obey locality. Once coherence has reconfigured into separate attractor states, the resulting classical systems possess independent coherence patterns that evolve according to the local constraints of the emergent spacetime geometry. Interactions between these systems are mediated by fields and forces that propagate at or below the speed of light, and classical causality emerges as a structural consequence of the resonance-stabilized coherence patterns. Locality is therefore a property of the classical regime, not of the substrate.

Quantum correlations, by contrast, arise from coherence patterns that have not yet stabilized into separate attractor states. Entangled systems share a unified coherence structure, and their correlations reflect the internal structure of this shared pattern rather than any interaction between spatially separated parts. The transition from quantum to classical behavior occurs when the shared coherence reconfigures into distinct resonance-compatible attractors and decoherence stabilizes these attractors against further reconfiguration.

This perspective resolves the apparent tension between quantum nonlocality and classical locality. Quantum correlations do not violate locality because coherence is not spatial and does not propagate. Classical locality emerges only after coherence stabilizes into separate attractor states, at which point the familiar constraints of spacetime geometry apply. The Aetherium framework therefore provides a unified account of both quantum and classical behavior, showing how locality emerges from the resonance-structured coherence dynamics of the substrate.

The next section compares this coherence-first account of entanglement with major interpretations of quantum theory, highlighting the conceptual advantages of the Aetherium ontology.

7. Comparison with Major Interpretations

The conceptual challenges surrounding entanglement have motivated a wide range of interpretations of quantum mechanics, each attempting to reconcile the formalism with intuitive notions of causality, locality, and physical reality. The Aetherium framework differs fundamentally from these approaches because it begins with a coherence-first, pre-geometric ontology rather than with a spatially embedded wavefunction. This section highlights the key distinctions between Aetherium and several major interpretations.

Many-Worlds (Everettian Interpretations)

Many-worlds accounts treat the wavefunction as a universal, spatially extended object that evolves unitarily, with measurement corresponding to branching into non-interacting worlds. Entanglement correlations arise because observers become correlated with different branches. Aetherium differs in two essential ways:

1. **No branching:** coherence reconfigures into a single resonance-compatible attractor, not multiple parallel outcomes.
2. **Non-spatial coherence:** the substrate is pre-geometric, so the wavefunction is not a spatial field whose evolution requires branching to preserve unitarity. Aetherium provides a single-world,
3. **Aetherium provides a single-world, realist account** without invoking parallel universes.

Bohmian Mechanics (Pilot-Wave Theories)

Pilot-wave theories introduce hidden variables—typically particle positions—guided by a nonlocal pilot wave. These theories reproduce quantum predictions but require instantaneous, configuration-space-level influence. Aetherium rejects both hidden variables and nonlocal guidance. Coherence does not propagate, and entanglement correlations arise from the structure of a unified coherence pattern, not from signals or guiding fields. The ontology is therefore local at the level of emergent spacetime without requiring nonlocal dynamics at the fundamental level.

Collapse Models (GRW, CSL)

Collapse models modify the Schrödinger equation to introduce spontaneous localization events. These events are fundamentally stochastic and break unitarity to explain definite outcomes. Aetherium does not modify quantum dynamics or introduce stochastic collapse. Measurement corresponds to a **deterministic**

reconfiguration of coherence into a resonance-compatible attractor, with decoherence stabilizing the outcome. There is no need for additional collapse mechanisms or new physical constants.

Relational and QBist Interpretations

Relational and QBist approaches treat the quantum state as observer-dependent, emphasizing information, belief, or relational properties rather than objective physical states. Aetherium is explicitly **realist**: coherence is an ontic structure of the substrate, not an expression of knowledge or belief. Measurement outcomes are determined by resonance-compatibility constraints, not by observer-dependent updates.

Superdeterminism

Superdeterministic models explain Bell correlations by assuming that measurement settings and hidden variables are correlated through deep causal constraints. Aetherium does not rely on such correlations. The appearance of nonlocality is dissolved because entangled systems share a unified coherence structure that is not spatially separable. No conspiratorial correlations or restrictions on free choice are required.

Retrocausal Interpretations

Retrocausal models allow influences to propagate backward in time to explain entanglement correlations. Aetherium does not require backward-in-time causation because coherence is not embedded in time at all. Time is relational, defined by the ordering of coherence transitions, and entanglement correlations arise from the structure of the shared coherence pattern, not from influences propagating in any temporal direction.

Taken together, these comparisons highlight the distinctiveness of the Aetherium ontology. It does not modify quantum dynamics, introduce hidden variables, invoke branching worlds, or rely on observer-dependent states. Instead, it reframes entanglement as a structural property of coherence within a pre-geometric substrate. This coherence-first perspective dissolves the appearance of nonlocality and provides a unified account of quantum and classical behavior grounded in the resonance-compatibility architecture of the substrate.

8. Discussion and Outlook

The coherence-first ontology developed in this paper reframes entanglement as a structural property of a unified coherence pattern within a pre-geometric substrate. This perspective dissolves the appearance of nonlocality by rejecting the assumption that coherence is a spatial quantity embedded in spacetime. Instead, coherence is shaped by the substrate's resonant constraint architecture, and measurement corresponds to a reconfiguration of the entire shared coherence structure into a resonance-compatible attractor. Bell correlations arise from the internal structure of this unified coherence pattern, not from superluminal influence, hidden variables, or branching worlds. Classical locality emerges only after coherence stabilizes into separate attractor states through decoherence, at which point the familiar constraints of spacetime geometry apply.

This framework suggests several avenues for further development. One direction is to explore how the substrate's resonant architecture constrains the space of permissible coherence configurations more formally. While this paper has emphasized conceptual clarity over mathematical detail, the coherence-first ontology invites the construction of models that map resonance-compatibility constraints onto specific classes of quantum states. Such models could clarify why certain entangled configurations are more stable or more easily generated than others, and how coherence transitions relate to the structure of Hilbert space.

A second direction concerns the emergence of spacetime itself. If locality is an emergent property of resonance-stabilized coherence patterns, then the geometry of spacetime may reflect deeper structural features of the substrate. Understanding how coherence transitions give rise to temporal ordering, causal structure, and metric relations could provide a bridge between quantum foundations and approaches to quantum gravity that emphasize pre-geometric or relational structures.

A third direction involves potential observational consequences. Although the substrate does not propagate signals or support new dynamical fields, its resonance-compatibility architecture may leave subtle signatures in systems where coherence is long-lived or highly structured. Quantum information platforms, macroscopic entanglement experiments, or precision interferometry may offer opportunities to probe the stability and reconfiguration dynamics of shared coherence patterns. Identifying such signatures requires careful analysis, but the coherence-first ontology provides a clear conceptual framework for guiding this search.

Finally, the Aetherium framework offers a unified perspective on quantum foundations. It resolves the measurement problem, clarifies the origin of entanglement correlations, and explains the emergence of classical locality without modifying quantum dynamics or invoking hidden variables, collapse mechanisms, or branching universes. By treating coherence as the fundamental primitive and the substrate as a pre-geometric constraint architecture, Aetherium provides a coherent and realist account of quantum phenomena that is compatible with relativistic locality and grounded in a single-world ontology.

Recent work by Machado *et al.* (2025) on Unified Medium Field Theory offers an instructive contrast to the coherence-first ontology developed here. Their framework models physical phenomena through a dynamical medium with compression modes, density-dependent propagation, internal SU(N) gauge twists, and reflective compression interfaces. While this provides a rich field-theoretic structure, it remains fundamentally a **propagating-medium theory** in which excitations travel through a continuous substrate. Aetherium differs in its core ontology: coherence is **non-spatial**, does **not** propagate, and the substrate is **pre-geometric**, providing structural resonance-compatibility constraints rather than supporting wave dynamics or density-dependent transport. The comparison is therefore useful not because the frameworks are similar, but because it highlights the distinctive commitment of Aetherium to a non-propagating, coherence-based substrate in which entanglement arises from unified structure rather than medium-level dynamics.

The next steps in the Aetherium research program include developing a more detailed account of the substrate's resonant structure, exploring the emergence of spacetime geometry from coherence transitions, and examining the implications of this framework for cosmology and quantum information. Together, these directions point toward a broader synthesis in which coherence, resonance, and pre-geometric structure form the foundation of a unified physical ontology.

9. Conclusion

Entanglement has long been regarded as the most puzzling feature of quantum mechanics, often interpreted as implying non-local influence, instantaneous collapse, or hidden coordination between spatially separated systems. These interpretations arise from treating the wavefunction as a spatial object evolving in time and from assuming that measurement acts on independent subsystems. The Aetherium framework replaces these assumptions with a coherence-first, pre-geometric ontology in which entangled systems share a **single coherence structure** shaped by the substrate's resonant constraint architecture. Coherence does not propagate, time is relational, and spatial separation is a property of the emergent classical description, not of the underlying substrate.

Within this ontology, measurement corresponds to a **coherence-reconfiguration event** that selects a resonance-compatible attractor for the entire shared coherence pattern. Bell correlations arise from the internal structure of this unified pattern, not from superluminal influence or hidden variables. Classical locality emerges only after coherence stabilizes into separate attractor states through decoherence, at which point the familiar constraints of spacetime geometry apply. The apparent tension between quantum correlations and relativistic locality is therefore dissolved: quantum correlations do not violate locality because coherence is not spatial, and classical locality emerges naturally from resonance-stabilized coherence dynamics.

This coherence-first account provides a single-world, realist, and local explanation of entanglement that avoids the conceptual difficulties of collapse models, hidden-variable theories, many-worlds branching, and observer-dependent interpretations. By grounding quantum behavior in the resonant structure of a pre-geometric substrate, Aetherium offers a unified perspective on measurement, entanglement, and the emergence of classicality. The framework invites further development, including a deeper analysis of the substrate's resonant architecture, the emergence of spacetime geometry from coherence transitions, and potential observational signatures in systems where coherence is long-lived or highly structured.

Entanglement, in this view, is not a paradox but a window into the underlying structure of physical reality. It reveals the coherence-based foundations from which both quantum and classical behavior arise and points toward a unified ontology in which resonance, coherence, and pre-geometric structure form the basis of a deeper understanding of the physical world.

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Data and Code Availability

This work is conceptual and does not rely on external datasets or computational code. No data was generated or analyzed, and no code is associated with this manuscript.