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Topological Interpretation of Quantum Collapse and Entanglement

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Abstract

This work proposes a reinterpretation of wave function collapse as the result of a geometric intersection between our space-time universe and a higher-dimensional reality, here referred to as the bulk. In this framework, time in the bulk does not unfold as a sequence of moments but exists instead as a static and extended dimension, one in which all possible states of subatomic particles are present simultaneously.

By contrast, in our universe time is experienced in a strictly one-dimensional, point-like manner and we access only a single instant at once, giving rise to the perception of a flowing sequence. From this perspective what we perceive as the collapse of the wave function may arise from the interaction between our unidimensional timeline and this timeless multidimensional reality. Rather than a process of selection among alternatives, the collapse would be the result of our space-time intersecting a pre-existing landscape of possibilities, effectively slicing through the bulk and revealing a single outcome from an already complete set of quantum configurations.

Within the same framework, quantum entanglement emerges as a co-intersection in the bulk. Even when particles appear distant within our universe, they remain correlated because their states are rooted in the same geometric anchor point of the higher-dimensional domain.

1 Introduction

Quantum mechanics has profoundly revolutionized our understanding of physical reality introducing concepts such as state superposition, entanglement and intrinsic probability. Among its most radical interpretative challenges stands the collapse of the wave function: when and how does a quantum particle "choose" a defined state among the many possible ones described by its wave function?

Many quantum phenomena, including nonlocality, indeterminacy and the apparent retrocausal effects observed in delayed-choice experiments suggest that our universe may not be a closed and self-sufficient system. Rather, it might constitute a subset or projection of a broader framework referred to as a containing universe, which encompasses and governs its fundamental dynamics.

In this framework, it's hypothesized that our universe is a space-time subset embedded within a hyperdimensional reality that does not follow time as a sequence of moments but as a complete structural dimension already entirely existent. This idea is not new but finds resonance in several recent scientific and philosophical proposals, including:

- The Block Universe Theory (Rietdijk–Putnam, Ellis), according to which past, present, and future coexist simultaneously as a fixed four-dimensional structure;
- Julian Barbour's theories, which propose the abolition of time as a flow, interpreting it instead as a relationship between static configurations ("time capsules");
- Loop Quantum Gravity and Relational Quantum Mechanics models (Rovelli), which reject an absolute notion of time, describing reality as a network of relations between events without a privileged temporal order;
- Roger Penrose's ideas on consciousness and collapse as a gravitational phenomenon rooted in a deeper level of reality;
- Brane cosmology (Randall-Sundrum), where our universe is a "membrane" within a higher-dimensional hyperspace, suggesting that what we observe may be only a partial "shadow" of a richer dynamic.

These perspectives share a common intuition: time, as we experience it (entropic and directional), may not be a fundamental property of reality but rather a local perception of a global structure that contains it as a simple coordinate.

In this context quantum collapse could represent the point of intersection between our limited perspective and the extended temporal dimension of the containing universe. The particle does not "choose" a state but rather manifests only at the point where our space-time trajectory intersects with the higher underlying structure.

2 Theoretical Background

2.1 Standard recap: unitary evolution, Born and measurement (Lüders)

The starting point is the unitary Schrödinger dynamics, the Born rule for measurement statistics and the Lüders state-update rule. We will refer to these throughout.

$$i\hbar\,\partial_t|\psi(t)\rangle = \hat{H}|\psi(t)\rangle, \qquad P(a_n) = \langle\psi(t)|\Pi_n|\psi(t)\rangle, \qquad |\psi(t)\rangle \xrightarrow{a_n} \frac{\Pi_n|\psi(t)\rangle}{\sqrt{\langle\psi(t)|\Pi_n|\psi(t)\rangle}} \tag{1}$$

2.2 "Extra-temporal" intersection: from heuristic notation to a linear map

In the text above we had the heuristic arrow

$$\psi(x,t) \xrightarrow[\text{intersection with } U_5]{T_5=\tau} \delta(x-x_0)$$

Two issues arise: (i) the δ was not given a physical normalization; (ii) the operator realizing the "projection" was missing.

The slice defined by $T_5 = \tau(t)$ is a limiting case:

$$K(t,T_5) = \delta\big(T_5 - \tau(t)\big) \;\Rightarrow\; (\Pi_t\Psi)(x) = \Psi\big(x,\tau(t)\big).$$

According to the standard formulation, a position measurement with outcome x_0 localizes the wave function as

$$|\psi\rangle \xrightarrow{x_0} \delta(x-x_0)$$

Here $\delta(x-x_0)$ must be understood as the limit of normalized Gaussians. We replace the ideal eigenstate $|x_0\rangle$ by the physical state

$$|x_0,\sigma\rangle, \qquad \langle x|x_0,\sigma\rangle = \frac{1}{(\pi\sigma^2)^{1/4}}\exp\left[-\frac{(x-x_0)^2}{2\sigma^2}\right]$$

with $\lim_{\sigma\to 0}|x_0,\sigma\rangle = |x_0\rangle$ in the sense of distributions.

Minimal formal proposal:

- Bulk space U_5 with extra coordinate T_5.
- Define a projection/integration operator $\Pi_t : L^2(\mathbb{R}^3 \times \mathbb{R}_{T_5}) \to L^2(\mathbb{R}^3)$:

  $$(\Pi_t\Psi)(x) = \int_{\mathbb{R}} K(t,T_5)\,\Psi(x,T_5)\,dT_5$$

  with kernel K such that $\int |K(t,T_5)|\,dT_5 < \infty$ and ideally $\int |K(t,T_5)|^2\,dT_5 = 1$ to preserve norms (or make explicit the loss of norm).

- The “section” at $T_5 = \tau$ is a limiting case:

$$K(t, T_5) = \delta(T_5 - \tau(t)) \quad \Rightarrow \quad (\Pi_t \Psi)(x) = \Psi(x, \tau(t))$$

- The localization (“collapse”) is expressed in Lüders form in the position basis:

$$\psi(x,t) \xrightarrow[\text{outcome } x_0]{} \frac{\langle x_0|\psi(t)\rangle}{\sqrt{|\psi(x_0,t)|^2}} \, |x_0\rangle$$

- To avoid δ-states, use a Gaussian with instrumental variance σ^2:

$$\Pi_{x_0}^{(\sigma)} = \int dx \, \frac{e^{-\frac{(x-x_0)^2}{2\sigma^2}}}{\sqrt{2\pi}\sigma} \, |x\rangle\langle x|$$

2.3 Wave Function Collapse

In the standard formalism of quantum mechanics the state of a system is described by a wave function: ψ, which evolves deterministically according to the Schrödinger equation. At the moment of measurement this function appears to collapse into one of its possible eigenstates with a probability defined by the Born rule.

This phenomenon has sparked intense debate since the early days of the theory as the act of observation seems to play a physically determining role, a feature absent from classical laws.

2.4 Main Interpretations

- **Copenhagen Interpretation (Niels Bohr, Werner Heisenberg)** Proposes that the wave function does not describe physical reality itself but only our knowledge of the system. Collapse occurs upon measurement making reality effective only at the moment of observation. It does not precisely define what constitutes a “measurement,” nor when collapse physically occurs.

- **Many-Worlds Interpretation (Everett)** Denies the existence of collapse: all possible outcomes of the wave function are realized in parallel universes. The observer "splits" into as many quantum copies as there are possibilities. This view eliminates collapse but introduces a potentially unfalsifiable multiverse.

- **Decoherence Theory** It proposes that interaction with the environment (such as photons or air molecules) causes a loss of coherence between superposed states, thereby making them effectively non-interfering. Decoherence fails to account for why a specific outcome is realized instead of another, as it lacks an underlying physical mechanism that would explain the collapse.

- **Objective Collapse (GRW, Penrose)** Objective collapse models modify the Schrödinger equation by adding a stochastic term so that collapse is posited as a real physical process, either spontaneous or induced by gravity. Theories such as Penrose's suggest that the self-gravitation of superposed states triggers a spontaneous breakdown of coherence

2.5 The Nature of Time in Modern Theories

In classical Newtonian physics time was considered a uniform and absolute flow experienced identically by all observers. This view was profoundly altered with Einstein's theory of relativity which redefined time as a component of a four-dimensional space-time continuum, comparable in status to spatial dimensions. As a result, simultaneity ceased to be an absolute concept and became dependent on the observer's frame of reference, a shift that continues to challenge our intuitive understanding of temporal order.

From this conception two fundamental interpretations arise:

- **Dynamic Present (Presentism)** The present is real, the past no longer exists and the future does not yet exist. This aligns with our everyday intuition.
- **Block Universe** Everything that has happened, is happening and will happen coexists simultaneously within a 4D structure. Time does not "flow" but is "traversed" by consciousness.

This second view is compatible with the hypothesis that our experience of time is merely a section of a broader structure, potentially navigable by external entities or higher-dimensional frameworks.

2.6 Higher-Dimensional Spaces and Containing Universes

Speculative theories in theoretical physics, such as string theory and brane cosmology, predict the existence of extra dimensions, some of which may contain our own universe as a "membrane" (brane) embedded within a larger space (bulk). We will use the term bulk refers to the hyperdimensional space that contains our observable universe, conceptually distinct from the "brane" on which our space-time reality unfolds. The brane represents the familiar four-dimensional structure of our universe but the bulk may go further, containing extra dimensions and possibly hosting physical or geometric features that, from our limited perspective, we simply cannot access.

In certain models brane collisions or vibrations may produce observable energy in our universe and these kinds of multidimensional models suggest that our universe might not be on its own after all, it could be part of a bigger structure.

3 Proposed Hypothesis: Extra-temporal intersection and quantum collapse

3.1 Traditional Modeling of Quantum Collapse

In the standard formalism of quantum mechanics, a particle is described by a quantum state $|\psi\rangle$, which evolves in time according to the Schrödinger equation:

$$i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle = \hat{H}|\psi(t)\rangle$$

When a measurement takes place it's generally assumed that the wave function no longer evolves smoothly, but instead collapses instantly into one of its possible outcomes. The likelihood of each outcome is given by the Born rule, which connects the mathematical description to what is actually observed:

$$P(a_n) = |\langle a_n|\psi\rangle|^2$$

and the system's state transitions from:

$$|\psi(t)\rangle \xrightarrow{a_n} \frac{\Pi_n|\psi(t)\rangle}{\sqrt{\langle\psi(t)|\Pi_n|\psi(t)\rangle}}$$

where $|a_n\rangle$ is the eigenstate corresponding to the eigenvalue a_n, that is, the observed result. This transition is not dynamically described but is introduced as a postulate of the formalism.

3.2 Description of the Hypothesis

In the model proposed here collapse might not be a random 'choice' or a break in quantum dynamics but rather the geometric result of an intersection between our 4D universe, where time is experienced as a single unidimensional flow, and a higher structure in which all quantum outcomes exist as part of a complete physical framework. This transition can be expressed as:

$$\psi(x,t) \xrightarrow[\text{intersection with } U_5]{T_5 = \tau(t)} \delta(x - x_0)$$

where $\psi(x,t)$ is the wave function in our universe, T_5 is the extended temporal coordinate of the bulk, τ is the point of intersection, and $\delta(x - x_0)$ represents the observable manifestation of the unique outcome projected into our reality.

Measurement does not cause the collapse but reflects it: what appears to us as an event of quantum localization is the projection of a geometric interaction with a higher structure where all possible outcomes are already "arranged" along the extended T_5 dimension.

This hypothesis suggests that the collapse of the wave function does not result from an act of observation internal to our universe but from a geometric and structural interaction between our space-time universe U_4 (three spatial dimensions plus time) and a higher-dimensional containing universe U_5 (or beyond), in which time behaves as an extended dimension rather than as a sequence of events.

In this context:

- Our universe U_4 is sequential: we experience time as a flow from past to future.
- The containing universe U_5 is atemporal in experiential terms: all temporal coordinates coexist as a fixed structure, comparable to a "map of time."

The interaction between U_4 and U_5 occurs at localized points of intersection, which we can interpret as "moments of observability" for us: each intersection selects a single quantum outcome, making it the only one visible along our timeline.

3.3 Conceptual Formalization

In this scenario all quantum possibilities are real and geometrically distributed within the bulk universe, which represents their complete set of possible states. When a region of this bulk intersects with our local space-time section (U_4), only a single observable projection is generated, corresponding to the point at which the particle "appears" in our universe. So it's not really a matter of random choice but simply a limitation imposed by the geometry of the intersection: only what intersects with our space-time can show up in our reality. The other possibilities are still there, existing within the bulk but they stay out of reach from our point of view.

3.4 Geometric Representation of Quantum Collapse

This section provides an initial attempt to formally represent the hypothesis of quantum collapse as a geometric effect of intersection between manifolds of different dimensionalities.

Let $U_5 = (x, y, z, t, T_5)$ be a five-dimensional space-time manifold with an extended temporal coordinate T_5, and let $U_4 = (x, y, z, t)$ denote its observable four-dimensional section, where time t is locally perceived as a sequence.

The wave function $\psi(x, t)$ can be regarded as the projection of an extended function $\Psi(x, T_5)$ defined on U_5. Collapse occurs at point (x_0, t_0) if and only if

$$\Psi(x, T_5) \xrightarrow[T_5=\tau(t)]{} \delta(x - x_0), \qquad t = \pi_T(\tau(t))$$

where τ is the selected value of the bulk coordinate and $\delta(x - x_0)$ is the Dirac delta distribution indicating the observed localization within U_4.

As discussed in Sec. 2.2, the Dirac delta must be interpreted as the limit of normalized Gaussians and the localization corresponds not to the non-normalizable state $|x_0\rangle$, but to the physical packet

$$|x_0,\sigma\rangle, \qquad \langle x|x_0,\sigma\rangle = \frac{1}{(\pi\sigma^2)^{1/4}} \exp\left[-\frac{(x-x_0)^2}{2\sigma^2}\right]$$

with $\lim_{\sigma\to 0} |x_0,\sigma\rangle = |x_0\rangle$ in the sense of distributions. This ensures proper normalization and avoids distributional pathologies while preserving the operational meaning of collapse in the position basis.

The intersection can be described by a projection operator or map $\pi : U_5 \to U_4$, consistent with the kernel formalism of Sec. 2.2:

$$\pi[\Psi(x,T_5)] = \psi(x,t) \in U_4, \qquad T_5 = \tau(t), \;\; t = \pi_T(\tau(t))$$

This construction suggests that collapse is not an intrinsic operation of the quantum system but rather the effect of restricting observability to a specific section of the higher-dimensional manifold.

Future developments might involve a more rigorous formulation, for example using fiber bundles and section operators, and introducing a metric to investigate how the curvature of the bulk could influence the distribution and frequency of observable events.

3.5 Conceptual Representation

Before a direct intersection occurs between our universe (brane U_4) and the higher structure of the bulk, it is plausible to imagine that our reality is already capable of perceiving, indirectly, the presence and influence of the multiplicity of possible states contained within the bulk.

This situation can be intuitively represented by the image of a stretched sheet that curves slightly under the influence of a sphere placed beneath it. In this analogy, the sphere does not represent a single physical object but the totality of simultaneous configurations of the particle within the higher-dimensional domain. Even without direct contact, the curvature of the sheet, which corresponds to the deformation of our space-time brane, illustrates how quantum effects such as nonlocality and apparent retrocausality might already emerge before the actual intersection takes place.

In this sense, the interference patterns seen in experiments like the double-slit one might be understood as visible traces of the internal consistency of the broader geometric structure within the bulk.

Imagine:

- Our universe as a curved sheet extending through time (a temporal trajectory);

- The containing universe as a larger volume, with coordinates (x, y, z, t, T_5);
- A point of intersection between the sheet and the volume determines the unique observable point among the infinite possibilities of the wave function.

This visualization is compatible with brane models, but it introduces a "semi-deterministic" dynamic of collapse: each observation constitutes a slice of the hyperspace upon our sheet of reality.

3.6 Interpretative Implications

1. **Reduction of observer dependence**: observation doesn't cause the outcome, it simply captures what happens at the point of geometric intersection between our world and a deeper structure;
2. **Superposition as structural latency**: quantum states coexist potentially until the intersection occurs;
3. **Compatibility with relativistic determinism**: since time in the higher domain is static, "collapsed" events are determined within the structure, though they appear random from our frame of reference.

In the end, what we perceive as a determined reality may simply arise from the structural limits of our own space-time section. All the possible states are out there in some higher-dimensional space, we just happen to encounter one when our reality crosses its path. From this perspective, observation is not a subjective or spontaneous act but the result of a geometric constraint. Our experience of time might reflect a particular trajectory through a domain where all possible outcomes already coexist.

Quantum collapse might not be local but rather the effect of a geometric filter, showing us only the outcome that intersects with our timeline while the rest stay real but unreachable, scattered across temporal regions beyond our reach.

Once an intersection occurs between our brane (U_4) and the extended temporal dimension of the bulk (U_5), our temporal trajectory becomes constrained to a coherent path within the bulk's structure. This anchoring determines not only the point of particle observability but also the local temporal orientation in which subsequent events will manifest in our universe.

3.6.1 Double-slit: step-by-step derivation

A mathematical formalization is proposed for the behavior of the wave function $\Psi(x, T_5)$, applied to the double-slit experiment, in light of the multidimensional intersection hypothesis with the bulk.

In the higher domain (bulk), the wave function $\Psi(x, T_5)$ represents a continuous superposition of states along the extended temporal dimension T_5. The observable wave function on our brane U_4 can be seen as the result of an integral projection of $\Psi(x, T_5)$ shaped by a kernel $K(t, T_5)$ that captures the interaction between the two structures.

The kernel $K(t, T_5)$ acts as a projection operator selecting the specific temporal instant t of our reality from the extended T_5 domain of the bulk. This integral representation suggests that our universe does not perceive a single state at once, but rather integrates multiple possibilities from the higher dimension before any collapse becomes definite.

In the case of the double-slit experiment, let us assume that the wave function in the bulk can be represented as a continuous superposition of possible states:

$$\Psi(x, T_5) = \sum_n c_n \, e^{ik_n x - i\omega_n T_5}$$

Applying the projection operator Π_t to Ψ yields:

$$\psi(x, t) = \int_{\mathbb{R}} dT_5 \, \Psi(x, T_5) \, K(t, T_5) = \sum_n c_n e^{ik_n x} \int_{\mathbb{R}} dT_5 \, K(t, T_5) \, e^{-i\omega_n T_5}$$

We identify the temporal weight for each mode as:

$$A_n(t) = \int_{\mathbb{R}} K(t, T_5) \, e^{-i\omega_n T_5} \, dT_5 \;=\; \widehat{K}(t, \omega_n)$$

Definition.

$$\widehat{K}(t, \omega) \;:=\; \int_{\mathbb{R}} K(t, T_5) \, e^{-i\omega T_5} \, dT_5.$$

Here $A_n(t)$ is literally the Fourier transform of the kernel $K(t, \cdot)$ evaluated at frequency ω_n. In this notation, $K(t, \cdot)$ means that t is held fixed and the kernel is viewed as a function of the bulk variable T_5 alone, which is the variable being Fourier transformed.

Thus the observed state takes the form:

$$\psi(x, t) = \sum_n c_n \, A_n(t) \, e^{ik_n x}$$

This formulation shows how the projection of the multidimensional wave function onto the plane of our brane can generate interference patterns such as those observed in the double-slit experiment. In this framework, the interference does not arise from the physical passage of the particle through both slits simultaneously, but from an "informational curvature" of the brane induced by the superposition of possibilities within the bulk.

Consistency conditions.

- **Norm preservation:** For pure states, require

$$\sum_n |c_n|^2 \, |A_n(t)|^2 = 1$$

for all t, or renormalize ψ after applying Π_t. This corresponds to the requirement

$$\int_{\mathbb{R}} |K(t, T_5)|^2 \, dT_5 = 1 \quad \forall t$$

- **Controlled support:** Choose $K(t, T_5)$ with finite width (e.g. Gaussian) instead of an ideal $\delta(T_5 - \tau(t))$ — here δ is to be understood as the limit of normalized Gaussians

$$\delta(y) = \lim_{\sigma \to 0} \frac{1}{\sqrt{2\pi}\sigma} e^{-y^2/(2\sigma^2)}$$

3.6.2 Entanglement: rigorous derivation

We extend the projection formalism to bipartite systems, where the bulk wave function encodes correlations between two spatially separated subsystems A and B.

In the higher-dimensional domain (bulk), the joint wave function $\Psi_{AB}(x_A, x_B, T_5)$ represents a continuous superposition of product states along the extended temporal coordinate T_5. The joint state observed in our brane U_4 is obtained by projecting the bulk state through the same operator Π_t that acts in dimension T_5.

Let the bulk bipartite state be expressed as:

$$\Psi_{AB}(x_A, x_B, T_5) = \sum_{ij} c_{ij} \, e^{i(k_i^A x_A + k_j^B x_B)} e^{-i\omega_{ij} T_5}$$

Applying the projection operator Π_t yields:

$$\begin{aligned}
\psi_{AB}(x_A, x_B, t) &= \int_{\mathbb{R}} dT_5 \, \Psi_{AB}(x_A, x_B, T_5) \, K(t, T_5) \\
&= \sum_{ij} c_{ij} e^{i(k_i^A x_A + k_j^B x_B)} \int_{\mathbb{R}} dT_5 \, K(t, T_5) \, e^{-i\omega_{ij} T_5}
\end{aligned}$$

We define the bipartite temporal weights as:

$$A_{ij}(t) = \int_{\mathbb{R}} K(t, T_5) \, e^{-i\omega_{ij} T_5} \, dT_5 \;=\; \widehat{K}(t, \omega_{ij}).$$

Here $A_{ij}(t)$ is literally the Fourier transform of the kernel $K(t,\cdot)$ evaluated at frequency ω_{ij}. As before, $K(t,\cdot)$ indicates that t is fixed and the kernel is regarded as a function of the bulk coordinate T_5 only, so that the Fourier transform acts on T_5.

The observed bipartite state is thus:

$$\psi_{AB}(x_A, x_B, t) = \sum_{ij} c_{ij}\, A_{ij}(t)\, e^{i(k_i^A x_A + k_j^B x_B)}$$

Interpretation. In this picture what appears in U_4 as "instantaneous" nonlocal correlations between A and B is simply the restriction of a *local* joint state in U_5. The temporal kernel K encodes the slicing of the bulk time T_5 into the observed time t and may attenuate or phase-shift specific frequency components ω_{ij}, thereby modifying the observed correlations.

Consistency conditions.

- **Norm preservation:** For pure bipartite states, require

  $$\sum_{ij} |c_{ij}|^2\, |A_{ij}(t)|^2 = 1$$

  for all t, or renormalize after projection. Equivalently,

  $$\int_{\mathbb{R}} |K(t, T_5)|^2\, dT_5 = 1 \quad \forall t$$

- **Controlled support:** As in the single-particle case, replace ideal $\delta(T_5 - \tau(t))$ with a Gaussian of width σ, corresponding to the states

  $$\langle x|x_0, \sigma\rangle = \frac{1}{(\pi\sigma^2)^{1/4}} \exp\left[-\frac{(x-x_0)^2}{2\sigma^2}\right]$$

3.7 Verifiability and Limitations

Even if the hypothesis can't yet be tested in the usual ways it might still open doors offering new angles on how we interpret quantum phenomena:

- New avenues for reinterpreting experiments such as delayed choice, entanglement, and weak measurements.
- A speculative framework to correlate quantum collapse with the perception of time (e.g., in neuroscience and consciousness studies).

To bring the hypothesis closer to a scientific framework it would be useful to attempt:

- Mathematical simulations of projection models from U_5 to U_4.
- Analysis of whether the intersection can be represented as a geometric transition state between manifolds.
- Exploration of analogies with already formalized theories (brane models, loop quantum gravity, etc.).

4 Theoretical consequences and comparison with other interpretations

4.1 Reformulation of Collapse as a Geometric Event

The collapse of the wave function is not an intrinsic phenomenon of our universe, nor an act caused by an observer, but rather the effect of a structural intersection between our space-time and a higher domain in which time and states coexist statically.

This marks a fundamental change in perspective on the structure of reality:

- Quantum superposition is not unstable or indeterminate, but latent until the intersection occurs;
- Collapse might just be the moment our own timeline intersects with a deeper structure and the particle shows up exactly where that meeting happens.

This perspective offers a more expansive view of how observable phenomena relate to the broader structure of the cosmos and it may also provide useful insights in discussions about consciousness and the nature of perceived reality.

4.2 Parallels and Differences with Existing Interpretations

The proposed hypothesis can be better understood when compared with some of the major existing interpretations of quantum mechanics.

Copenhagen interpretation. Collapse is usually conceived as occurring at the moment of measurement with reality being defined by the observer. In contrast, the present hypothesis removes the subjective role where collapse is not caused by observation but is the structural result of an intersection with a higher domain.

Many-Worlds interpretation. According to Everett, all possible outcomes are realized in parallel universes. This model differs in that only one possibility manifests within our universe determined by the intersection with the containing structure, rather than by a branching of realities.

Decoherence theory. Decoherence explains the apparent loss of superposition through environmental interactions. The present hypothesis suggests that collapse is not a simple loss of coherence but the emergence of a definite outcome from a supra-universal structure.

Objective collapse models (GRW, Penrose). These theories modify the Schrödinger equation by introducing new stochastic or gravitational terms. In this model approach the dynamics of Schrödinger remain unaltered and collapse arises instead from an external geometric effect.

Brane theories. In these models our universe is a membrane within a higher-dimensional hyperspace and physical effects may result from interactions between branes. The proposed hypothesis shares this higher-dimensional perspective but shifts the focus and the intersection is not a physical collision but a conceptual and ontological overlap between structures.

4.3 Implications for Measurement and Nonlocality

The hypothesis of extra-temporal intersection suggests that:

- Quantum measurement does not "choose" among possible outcomes, but reveals the one already selected by the geometry of the intersection;
- This could reframe quantum nonlocality (e.g., entanglement) as part of a higher-order unity: two entangled particles share the same "intersection point" within the containing domain and therefore manifest coherently even when spatially separated in our universe.

In this context, the coherence between separated events would reflect a single common topology at the higher level, rather than an instantaneous influence at a distance.

4.4 Emerging and Cosmological Aspects

If the hypothesis were true, several fascinating implications could follow:

- The full set of quantum possibilities truly exists but becomes visible only when "sliced" by our space-time structure;
- What we see as the universe could just be a 4D slice of something bigger, maybe a 5D (or higher) reality we can't directly access;
- Events we perceive as "random" are, in fact, given the geometrically pre-selected points of intersection.

This perspective also opens the possibility of rethinking the origin of the universe not as a single event, such as the Big Bang, but rather as the progressive emergence of intersection sections between higher-order universes.

4.5 Deepening: Quantum Entanglement as a Topological Co-Intersection

Entanglement is one of the most fascinating and mysterious phenomena in quantum mechanics: two (or more) particles, once entangled, remain correlated in such a way that measuring the state of one instantaneously determines the state of the other, even when they are separated by arbitrarily large spatial distances. This phenomenon led Einstein to refer to it as "spooky action at a distance," an expression highlighting what appeared to be a nonlocal influence that seemed incompatible with the principles of relativity.

Within the framework of extra-temporal intersection, a new geometric interpretation is proposed:

- Entangled particles are not connected within our space-time U_4 but instead share the same geometric section (anchor point) within the containing universe U_5;
- In other words, their wave functions are co-localized along the same topological intersection structure, and for this reason they manifest coherently within our observable reality;
- The "instantaneous communication" is merely an illusion resulting from our linear perception of time. In the static hypersurface of the bulk, the two particles are already connected: no information needs to travel.

This interpretation suggests that entangled particles are geometric projections of a single, nonlocal entity embedded in the bulk, much like two distant points on a flat sheet that are physically adjacent once the sheet is folded in higher dimensions.

Implications:

- It explains the coherence between distant measurements without violating relativistic causality;
- This suggests that quantum entanglement isn't a case of action at a distance but rather the result of a shared anchor point in a higher-dimensional structure;
- This opens the door to new approaches for modeling entanglement, including the use of fiber structures or topological folds in higher-dimensional geometry.

5 Critical discussion and epistemological limitations

5.1 Experimental Limitations and Non-Falsifiability

Experiments like delayed-choice quantum erasers and Bell tests might offer an indirect way to explore the predictive aspects of this hypothesis. While these experiments cannot directly confirm the existence of the bulk, unexpected deviations from standard predictions could be seen as indirect support for the multidimensional intersection hypothesis.

One of the fundamental criteria for assessing the robustness of a scientific theory is falsifiability: the possibility of empirically verifying it through experiments. The hypothesis of extra-temporal intersection presents a significant limitation in this respect:

- At present, no conceived experiment could directly confirm or refute the existence of a containing universe in which time is a static dimension;
- There is no complete mathematical formulation that quantitatively predicts collapse as a geometric projection in a way that would clearly distinguish it from the predictions of standard quantum mechanics.

This hypothesis remains a speculative and interpretive proposal that expands the framework of ideas without yet providing predictions that can be tested.

5.2 Formal and Theoretical Challenges

Despite its explanatory potential, the hypothesis raises several significant theoretical questions:

- **What type of geometry or mathematical structure would describe the containing domain U_5?** Is it comparable to a differentiable manifold? To a fiber structure? Or should it be conceived as an abstract topological set?
- **How are the projection rules between universes defined?** The intersection between manifolds of different dimensionality requires a rigorous mathematical description (for example, using pullbacks or section operators), which is currently only sketched.
- **What is the relationship between quantum probability and the geometric structure of the intersection?** It would be necessary to explain how the Born rule emerges from such geometry, an aspect that remains unresolved.

Without at least tentative answers to these questions, the hypothesis risks remaining within the domain of metaphysics rather than entering the field of theoretical physics.

5.3 Semantic Ambiguity and Anthropocentric Risk

Another key concern lies in the language used to present the hypothesis. Despite its conceptual depth, some of the terminology might invite interpretations that lean too heavily toward philosophy or anthropocentrism:

- The term "intersection" implies a geometric visualization but could erroneously evoke a causal dynamic, whereas here it refers to atemporal structural relationships.
- The concept of a "containing universe" risks being perceived as a theological or mythological transposition (e.g., the idea of an "elsewhere" governing our world), unless accompanied by formal rigor.

For this reason it will be essential, in future developments, to refine the technical terminology and avoid interpretative ambiguities, particularly for an academic audience.

5.4 Comparison with the Principle of Simplicity (Occam's Razor)

The hypothesis introduces additional elements, such as a hyperdimensional universe and an intersection dynamic, that are not strictly necessary to explain the observed phenomena from an operational standpoint. According to the principle of parsimony (Occam's Razor), this may make the hypothesis less competitive than other interpretations, unless the following conditions are met:

- It offers a clear explanatory advantage, such as improved understanding of paradoxes like the delayed-choice quantum eraser or Bell's theorem.
- It produces new testable predictions that distinguish this hypothesis from existing interpretations.

5.5 Philosophical Value and Evolutionary Potential

Despite the discussed limitations, the hypothesis retains significant heuristic value and it offers a new interpretative framework for quantum collapse and the concept of time. In this sense, it can be regarded as:

- An intermediate interpretative framework, useful for future unifications between quantum mechanics and relativity.
- A foundation for developing hybrid models in which geometric concepts drawn from string theory, quantum gravity or quantum computing could inspire more concrete mathematical formulations.

6 Conclusion

The hypothesis of extra-temporal intersection arises as an attempt to address one of the most controversial questions in theoretical physics: the underlying nature of quantum collapse. It responds to the limitations of prevailing interpretations which range from observer-centric approaches to multiverse theories, often lacking a foundational mechanism. As an alternative, it proposes a geometric and structural perspective that seeks to move beyond the dichotomy between determinism and probability.

The central idea is that our universe is not an isolated system but a section immersed in a higher reality in which time is a fully extended dimension and not merely a local flow. In this context the apparent quantum "choice" we observe is not the result of a sudden collapse but the necessary manifestation of an intersection between two structural realities: one dynamic and perceived (ours) and one static and complete (the bulk).

This work is not intended as a fully developed theory but as a heuristic framework designed to stimulate further theoretical development. Its current value lies in opening a new interpretative space where geometry, topology and ontology intersect to suggest that quantum reality may not be random but instead structured in ways that remain largely hidden from our view.

The aim of this paper is therefore twofold:

1. to propose an alternative and coherent vision of quantum collapse;
2. to stimulate broader reflection on the role of our universe as an observable portion of a broader, a-temporal reality. If this contribution can inspire future developments (whether theoretical, philosophical or conceptual) it will have achieved its goal.

A possible future theoretical-experimental roadmap could include:

- Mathematical simulations of interactions between branes and the bulk.
- Conceptual experiments to assess the internal coherence of the hypothesis.
- Interdisciplinary explorations in philosophy of science and neuroscience, investigating possible connections with the conscious perception of time.
- Detailed analysis of delayed-choice experiments and Bell tests to explore indirect implications.

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