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Unveiling the Fifth Dimension: A Novel Approach to Quantum Mechanics

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Abstract: This paper presents a new theoretical framework that reimagines time as a two-dimensional manifold, encompassing two orthogonal dimensions: foretime, which represents traditional linear time, and sidetime, a continuum of parallel states akin to quantum superposition. This unified five-dimensional model incorporates key aspects of both the Copenhagen and Many-Worlds interpretations, reimagining particles as clouds of interconnected, tangible "clones." Each clone represents a unique eigenstate, collectively manifesting as a waveform distributed across sidetime rather than existing as a singular entity in traditional time. This framework challenges conventional views on quantum measurement by proposing that measurement arises not from wave function collapse, but from an interaction between the observer's limited three-dimensional perspective and a fundamentally five-dimensional quantum event—termed 3-5 duality. This reinterpretation unifies conflicting interpretations of observation and measurement, offering potential resolutions to several longstanding quantum paradoxes without invoking external decoherence mechanisms. Through a re-examination of experimental evidence within this five-dimensional context, Strip Theory provides fresh insights into foundational quantum phenomena, harmonising divergent interpretations and offering solutions to enduring paradoxes in quantum mechanics. This framework offers a transformative approach to quantum mechanics by harmonizing diverse interpretations within a unified five-dimensional model, potentially advancing our understanding of quantum measurement, coherence, and the classical-quantum boundary.

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1. Introduction

This paper introduces Strip Theory, a five-dimensional framework in which time includes two orthogonal dimensions—foretime and sidetime—to address persistent quantum phenomena that continue to challenge our understanding. Quantum mechanics (QM) faces foundational issues, such as wave-particle duality and superposition, that defy classical interpretations and remain unresolved in frameworks like Copenhagen and Many-Worlds, which often clash with classical notions of determinism and causality.

Strip Theory proposes that these persistent issues arise from an incomplete understanding of time. While General Relativity (GR) [[1]] presents time as dynamic and relative, many QM interpretations rely on a fixed, universal measure of time [[2]] but, even so, most interpretations rely on a simple, clock-based measure of time—which may oversimplify its true nature, particularly in the quantum realm. Building on the mathematical structure of QM and the role of complex numbers, Strip Theory suggests that time itself may be two-dimensional, supporting a five-dimensional model of reality that harmonizes QM with classical determinism and even resolves philosophical issues like free will and the grandfather paradox.

This expanded perspective offers a unified approach to QM interpretations by embedding quantum phenomena within a dual-temporal framework. With the foundational principles of Strip Theory established, this paper explores its implications for other interpretations—such as Copenhagen and Many Worlds—paving the way for a cohesive understanding of both classical and quantum domains. While this work is primarily theoretical, it establishes the foundation for future

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exploration of experimental implications and falsifiability that may address longstanding challenges in quantum mechanics.

2. Discussion

2.1. Thought Experiment

2.1.1. To examine the fundamental nature of time, consider a thought experiment modelling the universe as a sequence of discrete states or "snapshots," (f_1, f_2, f_3, … f_n). Each snapshot f_i represents the complete state of the universe at a distinct moment t, with $t_i < t_{i+1}$ for all i, and a finite time interval $\Delta t = t_{i+1} - t_i$ between consecutive states. The change between two snapshots f_i and f_j ($j > i$) is represented by the difference in their respective states, $\Delta f_{ij} = f_j - f_i$. For any $n > 1$, $\Delta f_{1n} = f_n - f_1$ represents the cumulative change between t_1 and t_n, and it follows that as n increases, both the time interval $\Delta t = t_n - t_1$ and the magnitude of the observed change Δf_{1n} grow, suggesting a correlation between the passage of time and the degree of cumulative change.

This experiment aligns with Aristotle's view that time is a measure of change [[3]] and Rovelli's notion [[4]] that time emerges relationally between events. Time is thus interpreted as a dimension representing *sequential* change, where causally linked events (f_1 leading to f_2, then f_3, …) unfold in order.

2.1.2. Building on this, consider the quantum superposition principle, where a system exists in multiple states simultaneously. This superposition can be seen as alternate, parallel evolutions of a particle, coexisting along independent temporal pathways. Thus, superposition reflects parallel change, where different potential outcomes unfold concurrently along distinct temporal pathways. Instead of representing probabilistic ambiguity in a single path, superposition can be viewed as representing multiple, parallel evolutions of a system.

Imagine a series of parallel snapshots at a specific moment, f_i, each representing a distinct potential outcome (s_a, or s_b, or s_c …), that coexist simultaneously. This set constitutes a superposition of states at f_i, offering a fresh perspective on quantum superposition. Mathematically, this requires an additional time-like dimension *s*—a *possibility* dimension—orthogonal to *f*, representing parallel change. Each outcome f_{1i} is then a function of both *s* and *f*, i.e., $f_{1i} = s(f_1,s_i)$. This additional dimension aligns with Many Worlds Interpretations (MWI), which hold that all possible states coexist in parallel. The set $\{s_i\}$ represents the possible outcomes within this parallel dimension.

2.1.3. Thus, time can be reconceptualized as a two-dimensional plane of change, (f,s), wherein all outcomes of every event, $s(f_1,s_i)$, coexist within the possibility dimension s, and subsequently evolve through the sequential time dimension f. This dual-dimensional model provides a novel mathematical framework for QM, providing insights into the interplay between determinism and superposition. The proposed model can be expressed as a tensor product space:

$$H = H_f \otimes H_s \quad (1)$$

Where H_f represents the Hilbert space of states evolving in sequential time *f*, and H_s represents the Hilbert space of states evolving in parallel time *s*. The tensor product structure, equation (1), signifies that sequential and parallel evolutions are interwoven within a temporal *plane*, rather than being independent in two isolated time dimensions. The state of the universe at any moment is described by a vector $|\Psi(f,s)\rangle$, allowing for a rigorous mathematical treatment of both sequential and parallel evolution.

We define *sidetime* as a physically real dimension of time, encoding parallel quantum outcomes, that is orthogonal to normal time, or *foretime,* which governs sequential causality. Sidetime enables multiple outcomes to coexist and produce interference – which manifests as superpositions in foretime, aligning with observable phenomena without violating causality. This framework yields the same measurable results as traditional QM but resolves ambiguities in superposition and the complexities of MWI, offering a clearer, more consistent description of quantum phenomena.

2.1.4. Many perplexing anomalies in QM, such as wave-particle duality and the vacuum catastrophe, may stem from the standard assumption that time is inherently one-dimensional. Notably, Itzhak Bars' two-time physics [[5]] introduces an extra temporal dimension to unify forces, and Stephen Hawking's imaginary time [[6]] avoids singularities. Yet, both adhere to traditional notions of a sequential, clock-based, time progression, without fully exploring a two-dimensional temporal framework for QM.

2.1.5. In the Copenhagen interpretation [[7]], superposition is seen as probabilistic and collapses upon measurement to yield one outcome. In contrast, MWI [[8]] posits that all outcomes occur in separate universes. This new framework introduces a unified model where all potential outcomes coexist within a five-dimensional reality, integrating both perspectives. This model introduces a time-like possibility dimension (s) as a novel paradigm in our understanding of QM. This additional dimension can be rigorously defined within a five-dimensional manifold M_5, where:

$$M_5 = \mathbb{R}^3 \times f \times s \qquad (2)$$

Where $\mathbb{R}^3$ represents the three spatial dimensions, f is conventional time, and s is a time-like possibility dimension orthogonal to f. This allows for all potential quantum states to coexist in a unified structure, accommodating both probabilistic outcomes and multiplicity without requiring separate universes or collapse mechanisms.

2.1.6 In this framework, each possible outcome of every event exists concurrently in sidetime, integrated with the boundless spatial dimensions. Sidetime thus forms a complete, unbounded entity for the entire universe at every moment of foretime. If sidetime encompasses all potential outcomes as a complete whole, then foretime must also be unbounded and fully extant. This conception implies that every moment in foretime forms part of a larger temporal structure coexisting with infinite parallel possibilities. This has philosophical implications, particularly for the grandfather paradox [[9]] and free will [[10]].

For example, in the grandfather paradox, any attempt to alter one's history would result in many alternate outcomes existing in parallel, preserving one's existence in one of these outcomes and thereby preventing any actual change to personal history. Regarding free will, while all possible futures exist in sidetime, this model allows for free will by letting conscious choices determine which outcome in sidetime is realised sequentially. Thus, free will remains intact as our choices navigate pre-existing possibilities. This two-dimensional temporal model addresses both philosophical challenges and provides a foundation for further exploration of QM's nature.

2.2. Two-Dimensional Time

2.2.1. If time is indeed a two-dimensional plane of change, equations involving time must be adapted accordingly. In a general four-dimensional equation: F(t,x,y,z), we can formally expand the one-dimensional temporal component t, into two orthogonal dimensions: foretime (f), representing the sequential component of time and sidetime (s), representing the parallel component. This yields:

$$F(t,x,y,z) \rightarrow F(f,s,x,y,z) \qquad (3)$$

The extended function now operates in five dimensions instead of four.

2.2.2. In classical physics and relativity, the deterministic nature of events precludes the necessity of considering multiple simultaneous outcomes, rendering sidetime irrelevant. Consequently, there is no need to modify these frameworks to accommodate an additional temporal dimension. In contrast, QM involves the superposition of states—a concept that aligns well with sidetime. Therefore, it is logical to reformulate QM within a framework that incorporates both sidetime and foretime. However, QM has been extensively tested and consistently validated, which suggests that sidetime may already be implicitly incorporated within the existing framework.

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2.3. Complex Numbers

2.3.1. Complex numbers are fundamental to the mathematical formulation of QM, yet the reason for their necessity remains elusive—an issue that even troubled Schrödinger. In his correspondence with Lorentz on June 6, 1926, Schrödinger expressed discomfort with complex numbers, believing that the wave function should represent a physically real entity, which led him to question their necessity.

2.3.2. Despite these challenges, QM relies on complex numbers to describe and predict the behaviours of quantum systems. The wave function, denoted as $\psi(x,t)$, is typically a complex-valued function. This complex nature is not arbitrary; it allows the wave function to encode both amplitude and phase, both crucial for interference and superposition. Thus, the complex formalism is not merely a convenient tool, but a necessary aspect of how QM models the world. The question that arises is: why is this necessity so profound?

2.3.3. Complex numbers also introduce a crucial dimensionality aspect. In a complex Hilbert space, complex numbers are one-dimensional ($\dim_{\mathbb{C}}(\mathbb{C}) = 1$). However, in a real numbered Hilbert space, they require two dimensions ($\dim_{\mathbb{R}}(\mathbb{C}) = 2$). This dimensional discrepancy raises important questions about how we interpret QM. Typically, QM is expressed in a four-dimensional complex Hilbert space. However, reinterpreting QM within a real Hilbert space implies an intrinsic five-dimensional framework to account for the full representation of complex numbers.

2.3.4. To explore the implications of time as a two-dimensional entity, I treat time as a complex plane. In this framework, foretime corresponds to the real axis, while sidetime is represented on the imaginary axis. However, sidetime is not literally imaginary; it is only represented by complex numbers. This representation integrates both sequential and parallel time components within a unified structure.

2.3.5. A two-dimensional temporal coordinate (f,is), can be represented as (f+is) transforming the general function (3) as follows:

$$F(t,x,y,z) \rightarrow F(f,s,x,y,z) \rightarrow F((f+is),x,y,z) \qquad (4)$$

This transformation still introduces a parallel time component into the general equation, suggesting a five-dimensional structure, but appears to be four-dimensional. Although QM equations may be four-dimensional when expressed in a complex Hilbert space, this inclusion of sidetime hints at a five-dimensional reality. For example:

Take a basis state: $\psi = e^{ipx/\hbar}$

Simplify with $p = \hbar$: $\psi = e^{ix}$

From Euler: $\psi = \cos(x)+i\sin(x)$

This decomposition reveals the structure of the temporal plane, where *cos(x)* and *isin(x)* represent coordinates, which implicitly suggests an additional dimension. Using Euler's formula within a complex Hilbert space allows inherently five-dimensional QM functions to be expressed in a seemingly four-dimensional form. Reinterpreting *cos(x)+isin(x)* as the coordinate *(cos(x),sin(x))* on the temporal plane suggests that the wave function may contain information about this unrecognized time dimension. A parallel time dimension may not be explicitly recognized in traditional formulations, but it seems to play a crucial role in the underlying structure of QM.

2.3.6. Erwin Schrödinger faced significant difficulties formulating his wave equation within a four-dimensional framework and adopted complex numbers to fully capture the quantum behaviour of particles—effectively introducing an implicit fifth dimension. The mathematical construct of a complex Hilbert space maintains the theory's apparent four-dimensionality, but obscures the true dimensionality of QM.

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2.3.7. A more suitable approach is to continue using two-dimensional complex numbers to represent the phase and amplitude, but do so within a real, five-dimensional Hilbert space – where the extra dimension gives the Schrödinger equation room to breathe, so to speak. Since QM implicitly operates in a five-dimensional framework anyway, Strip Theory simply makes this dimensionality explicit and, using a complex representation of time, it preserves QM's structure without fundamental changes.

The extra dimension is also essential for expressing the probabilistic nature of Schrödinger's equation. Sidetime, as introduced in Strip Theory, thus becomes indispensable for capturing the complex and probabilistic components inherent to quantum mechanics. The phase aspect is governed by foretime, while the probabilistic nature of quantum mechanics is encoded in sidetime. This five-dimensional framework is not an arbitrary extension; it formalises an inherent aspect of QM that has always been implicitly present, recognising the true dimensional structure underlying QM's mathematical and conceptual foundations.

2.3.8. The invisibility of temporal dimensions to human perception stems from our sensory limitations. Human perception is limited to three spatial dimensions in a continuously evolving present, while the universe operates in at least five dimensions. This dimensional discrepancy, referred to as dimensional 3-5 duality, highlights the need to rethink our approach to interpreting QM.

3. Strip Theory: A Five-Dimensional Framework for Quantum Phenomena

This section introduces the fundamental principles of Strip Theory, a novel theoretical framework proposing a five-dimensional model to elucidate quantum phenomena.

3.1. Postulates

- *Postulate 1:* Time, *T*, is conceptualised as a two-dimensional manifold $T = (f,s)$, where *foretime (f)*, is the sequential component of time, aligning with the traditional, linear concept of time progression, and *sidetime (s)*, is an orthogonal *possibility* dimension that represents parallel potential outcomes existing concurrently, supporting quantum superposition. These dimensions combine with the spatial dimensions, to form a five-dimensional manifold for local events, referred to as a *strip*[11]: $s = (x,f,s)$, that encompasses all possible histories of an event. The totality of all events and their evolution over all time is termed the *universal strip*[12].

- *Postulate 2:* All possible histories of an event coexist within a strip. In sidetime, all possible outcomes that can occur are realised. However, observers, who exist in a dimensional *3-5 duality*, traverse foretime *(f)* and perceive only a single history, while their potential actions and outcomes, invisible to the observer, unfold across sidetime *(s)*. Thus, while only one timeline is observed, other possible histories continue to exist within sidetime.

3.2. The Schrödinger Equation

The interaction between *f* and *s* is analysed here using a dimensionally extended Schrödinger equation:

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$$i\hbar(\partial\Psi(x,f,s))/\partial f = \hat{H}\Psi(x,f,s) \quad (5)$$

Where the Hamiltonian operator $\hat{H}$ governs the evolution of the system and the state vector Ψ, is dependent on both *f* and *s*. Strip Theory extends the Schrödinger equation to incorporate sidetime dynamically, forming a two-dimensional temporal manifold that allows potential outcomes to be considered as real, rather than nebulous superpositions. However, this extension does not alter the fundamental equations used in quantum mechanics. Upon measurement, sidetime effectively becomes "frozen" for an observer, becoming a non-zero constant. This allows the wavefunction to be factorized into the product of two functions:

$$\Psi(x,f,s) = \Psi(x,f) \cdot \xi(s). \quad (6)$$

Where ξ is a function of sidetime alone. Substituting this into the extended equation:

$$i\hbar(\partial(\Psi(x,f) \cdot \xi(s))/\partial f = \hat{H}(\Psi(x,f) \cdot \xi(s)) \quad (7)$$

Since ξ is a constant independent from *f* it can be factored out, yielding:

$$i\hbar((\partial\Psi(x,f))/\partial f) \cdot \xi(s) = \hat{H}\Psi(x,f) \cdot \xi(s) \quad (8)$$

As $\xi(s)$ is a non-zero constant, we can divide both sides by $\xi(s)$ leading to:

$$i\hbar(\partial\Psi(x,f))/\partial f = \hat{H}\Psi(x,f) \quad (9)$$

In this way, the extended five-dimensional framework naturally reverts to traditional three-dimensional quantum mechanics in the absence of sidetime dynamics that occurs upon observation. The extended equation is deployed in the five-dimensional universe, and the standard equation is used in the three-dimensional observed universe.

3.3. Quantum Clones

3.3.1. In accordance with postulate 2, all possible histories of an event are real, exist in sidetime (s) and evolve in foretime (f), represented by a wavefunction $\Psi(x,f,s)$. Each individual history is denoted as a clone, φ_j, with all such clones equally real and unprivileged. A quantum clone is a distinct instantiation of a particle within sidetime, representing a unique eigenstate or possible outcome of a quantum event. Collectively, these clones form a five-dimensional wavicle—a cloud-like structure encompassing all possible quantum states of a particle. The term particle may loosely refer to either wavicle or clone, depending on context.

3.3.2. When a particle is created, the associated wavicle consists of a superposition, or a cloud[13], of quantum clones representing all potential outcomes of the event:

$$\Psi(x,f,s) = \sum_j c_j\varphi_j(x,f) \quad (10)$$

Where $\varphi_j(x,f)$ is the state of the j^{th} clone, and c_j are the probability amplitudes of these states. The wavicle evolves in foretime as a wave packet, while each clone propagates along its unique path, or timeline, in sidetime. Upon measurement, a single clone is observed, manifesting as the entire particle from the observer's limited three-dimensional perspective.

3.3.3. Clones exist within a wavicle in the same three-dimensional space, and their behaviour resembles multiplexing, where multiple signals are modulated onto a single carrier wave. The wavicle's wavefunction serves as the carrier wave, encoding all potential quantum states. Each clone corresponds to a modulated signal, representing a single eigenstate. During measurement, the process selects a single clone—or a coherent combination of clones—with dimensional reduction producing the observed state.

3.3.4. Clones within a discrete wavicle can overlap and produce interference owing to their intrinsic identity as quantum manifestations of the same particle. It occurs because the clones represent different quantum states of a single underlying entity, forming a coherent superposition. In contrast, the clones of distinct particles, described by independent wavefunctions, do not interfere with each other.

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For example, two distinct electrons will experience electrostatic repulsion, preventing significant wavefunction overlap, and they do not form a coherent superposition. Conversely, in a single-particle double-slit experiment, a single electron's wavefunction coherently splits into clones along different paths, resulting in path superposition. Upon recombination, this superposition produces the interference pattern due to the overlap of the wavefunction's own quantum states across paths. This dual nature arises naturally from the clonal structure of wavicles, resolving the wave-particle duality by unifying both behaviours within the same framework.

3.3.5. Upon measurement, any permissible eigenstate of a particle can be observed. All possible outcomes of a quantum measurement must be accounted for, so a wavicle contains distinct clones corresponding to every possible outcome of the wavefunction. Each clone represents a unique eigenstate configuration, encapsulating all possible measurement outcomes within the structure of the wavicle.

3.3.6. The clonal interpretation of quantum mechanics suggests that phenomena like quantum tunnelling and entanglement arise from sidetime dynamics. For example: With Quantum tunnelling, clonal interference can amplify energy momentarily, allowing a clone to overcome classically forbidden barriers. Also, with entanglement clonal ensembles across sidetime naturally preserve coherence, explaining non-local correlations without faster-than-light communication. By framing quantum phenomena in terms of clones and wavicles, Strip Theory provides a coherent and intuitive explanation for superposition, interference, and measurement, integrating these behaviours into a unified five-dimensional model.

3.4. Wave-Particle Duality

3.4.1. Wave-particle duality, a central concept in quantum mechanics, describes how particles like photons and electrons exhibit both wave-like and particle-like behaviour [[14]]. In Strip Theory, this duality is explained through the wavicle, a structure comprising a cloud of clones—distinct instances of the same quantum entity. Upon measurement, a dimensional reduction occurs, reducing the five-dimensional state to three dimensions, which isolates a specific clone φ_j and manifests particle-like properties. Conversely, the wave-like nature arises from the collective behaviour and interference of all clones within the wavicle's sidetime structure.

3.4.2. In Strip Theory, wave-particle duality naturally emerges from the clonal structure of wavicles. The particle-like behaviour corresponds to the detection of individual clones φ_j, while the wave-like behaviour arises from the collective, superpositional properties of the entire cloud of clones distributed across sidetime. This framework resolves the duality by suggesting that both wave and particle properties are intrinsic to the system. For example, in the photoelectric effect, the experimental setup isolates specific clones, demonstrating particle-like behaviour. In the double-slit experiment, however, the wave-like features of the entire wavicle emerge, reflecting the coherence across clones.

3.4.3. In Strip Theory, quantization occurs within the individual clones of a wavicle, rather than at the particle level. Each clone, as a discrete quantum instance, inherits quantized attributes such as energy levels, representing possible eigenstates of the particle's wavefunction. This reframes quantization as a property of the collective clone ensemble within sidetime, rather than an isolated particle. This perspective naturally explains phenomena like interference and quantum tunneling, where superpositional interactions among quantized clones give rise to observed effects. The quantized energy states of a wavicle, governed by sidetime dynamics, naturally align with traditional particle-level quantization in scenarios where sidetime's influence is indistinguishable from standard quantum mechanics predictions.

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3.5. Timelines

3.5.1. A strip exists within the 5-brane: the full five-dimensional structure in Strip Theory, encompassing space, foretime, and sidetime, where all quantum outcomes coexist and interact continuously. Observations take place in the 3-brane: the three-dimensional space we experience, composed of three spatial dimensions that change over foretime, presenting classical outcomes as our perceived reality.

3.5.2. A timeline is defined as the trajectory of an individual clone (or observer) through a 5-brane strip. Each quantum clone φ_j evolves along its own distinct timeline τ_j, represented as a path within the 5-brane. The state of each clone at any given moment is expressed by the quantum state vector $|\varphi_j(f,s)\rangle$. Each timeline τ_j corresponds to a unique realization of the particle's evolution through the five-dimensional strip s = (x,f,s). These timelines evolve according to the extended Schrödinger equation, where $|\varphi_j(f,s)\rangle$ depends on both temporal dimensions, enhancing the potential for continuous coherence across outcomes.

3.5.3. Interference phenomena occur when two or more clones, φ_j, φ_k, … progressing along different timelines t_j, t_k, … intersect at shared coordinates in (x,f). At such intersections, quantum states can superpose, yielding a total wavefunction for the intersecting clones as:

$$\Psi_{total}(x,f) = \sum_j c_j \varphi_j(x,f,s) \quad (11)$$

Where c_j are complex coefficients representing the probability amplitudes of the respective clones. The interference pattern is derived from the probability distribution:

$$P(x,f) = |\Psi_{total}(x,f)|^2 = |\sum_j c_j \varphi_j(x,f,s)|^2 \quad (12)$$

Where constructive or destructive interference occurs based on phase alignment between overlapping clones—mirroring the principles underlying Feynman's path integral formulation in standard quantum mechanics.

3.5.4. A timeline (τ_j) encapsulates a clone's (or an observer's) individual history as it unfolds across both temporal dimensions. In Strip Theory, timelines bear analogy to the multiple universes of MWI but differ fundamentally by preserving coherence within sidetime, rather than creating isolation. Consequently, each timeline represents a distinct, consistent historical trajectory from the perspective of the observer or clone within the continuous sidetime structure, aligning quantum potentialities with classical outcomes.

3.6. Vacuum Catastrophe

3.6.1. The vacuum catastrophe, which refers to the vast discrepancy between the predicted and observed vacuum energy density, arises in Quantum Field Theory (QFT) when integrating over all quantum field fluctuations. QFT predicts that the zero-point energies of these fluctuations contribute to the cosmological constant Λ, but results in theoretical values that exceed observed values by 120 orders of magnitude.

3.6.2. In Strip Theory, sidetime provides an alternate perspective on this summation process. Each quantum fluctuation—corresponding to a possible vacuum state or timeline—is treated not as an isolated event, but as part of a continuous sidetime manifold. Within sidetime, all possible states coexist in parallel, forming a dense, unobservable 'cloud' of timelines. Thus, the standard QFT summation can be interpreted as integrating over not just a single timeline but across the entire sidetime continuum, implicitly including the energy contributions of every possible vacuum fluctuation across sidetime.

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3.6.3. Mathematically, this interpretation suggests that the calculated vacuum energy $e_{calculated}$ accounts for an extensive sidetime structure, leading to an accumulation of energy contributions that are far larger than the energy observed within any single timeline. The observed energy $e_{observed}$, in contrast, represents the zero-point energy specific to an observer's single timeline and does not encompass the additional energy from unobserved timelines within sidetime.

3.6.4. The measurement of zero-point energy within a vacuum yields a value specific to the vacuum as it exists within the observer's singular timeline t_j. In contrast, when QFT equations—within the context of the 5-brane framework—are used to calculate vacuum energy, these calculations take into account contributions from all possible timelines. Hence, the energy value (e) is dependent on the framework used:

Observed: $e = e_j$ for one j
Calculated: $e = \Sigma e_j$ for all j

This discrepancy between single-timeline observations and multi-timeline calculations explains the massive difference—up to 120 orders of magnitude—between the predicted and observed vacuum energies.

3.6.5. To quantify this huge difference, Strip Theory introduces the sidetime ratio S_r, defined as the ratio between the calculated vacuum energy across all timelines and the observed vacuum energy in a single timeline:

$$S_r = e_{calculated} \,/\, e_{observed} \approx 10^{120} \qquad (13)$$

This ratio, S_r, representing the calculated energy across all sidetime timelines relative to a single timeline, offers a potential resolution to this longstanding problem, aligning the theoretical predictions with observed values.

3.6.6. Additionally, this ratio provides an approximate upper bound on the number of parallel timelines that a given particle or quantum state can occupy, with each clone existing in a distinct yet concurrent timeline. Since the clonal timelines of each particle are concurrent with those of other particles, this also suggests the existence of approximately S_r parallel timelines. Although vast, this number represents a reasonable upper bound on the potential "size" of sidetime, encapsulating the extent of possibilities in this additional temporal dimension.

3.7. Forces of Nature

3.7.1. In classical physics, forces like gravity, electromagnetism, and the strong and weak nuclear forces operate within well-defined spatial and temporal boundaries. Strip Theory introduces a five-dimensional framework, encompassing sidetime and foretime, which raises questions about how these forces extend across these dimensions.

3.7.2. In Strip Theory, forces are constrained to act within the present moment of a specific timeline. This constraint preserves causality and prevents inconsistencies with observed phenomena. If forces like gravity or electromagnetism operated across sidetime or non-sequentially through foretime, non-local interactions would disrupt the balance of energy and momentum within a timeline. For example, an electron with a rest mass of 9.11×10^{-31} kg9.11 x 10^{-31} could have up to 10^{120} clones, yielding a total mass of approximately 10^{90} kg. If gravity acted across sidetime, this mass accumulation would collapse the electron into a black hole. Similarly, forces like electromagnetism, which are finely tuned to interact at specific scales, would introduce catastrophic instabilities if extended across timelines.

3.7.3. To preserve physical consistency, Strip Theory posits that the influence of gravity, electromagnetism, and nuclear forces act within individual timelines and do not propagate through sidetime or across foretime. These forces operate sequentially within foretime and remain spatially

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localised within the present moment of a timeline, ensuring that cause precedes effect and causality is maintained. This localisation aligns with observational evidence and avoids contradictions inherent in extending forces across dimensions beyond the four dimensions of classical physics.

3.7.4. By constraining the operation of forces to individual timelines Strip Theory integrates seamlessly with classical observations of force interactions, such as gravitational attraction or electromagnetic fields. The framework avoids introducing inconsistencies with experimental results while allowing sidetime to influence quantum phenomena independently of classical forces.

3.8. Nonlocality

3.8.1. The Einstein-Podolsky-Rosen (EPR) paradox was devised to demonstrate that QM might be incomplete [[15]]. In the Bohm version of the EPR experiment, a spin -1/2 particle pair is prepared in a singlet state, which decays into two spatially separated, entangled particles, A and B, with opposite spins +1/2 (↑) and -1/2 (↓). If the spin of particle A is measured and found to be ↑, then particle B spin must necessarily be ↓ to preserve the total spin of the system. This instant determination of B's spin upon measurement of A's spin implies that information about A's measurement outcome is transmitted to B faster than the speed of light, which violates the principle of locality.

3.8.2. In Strip Theory, this nonlocality is treated differently. Particles A and B are interpreted as ensembles of entangled clones, each with defined spin states in parallel timelines. Consider two such entangled pairs, (A↑,B↓) in timeline t_1, and (A↓,B↑) in timeline t_2. Upon measurement, the observer chooses timeline t_1 or t_2, but the spin states are embedded in the system, so no information instantly propagates between particles. Measurement reveals the spin configuration embedded in the intersected timeline, preserving locality within the universal 5-brane framework – without spooky action at a distance. Non-locality only appears in the observer's limited 3-brane framework.

3.9. Time

In QM, time it is treated as a fixed, universal parameter that flows uniformly across spacetime. In contrast, GR treats time within a spacetime geometry that varies based on the observer's frame of reference and the local curvature caused by mass/energy. Strip Theory proposes a unified framework by integrating these two seemingly incompatible perspectives. Time possesses both absolute and relative aspects depending on whether we consider the higher-dimensional 5-brane or the lower-dimensional 3-brane. In the 5-brane structure, time is universal and fully extant, i.e., all time exists at once in a kind of "simultaneous now," where past, present, and future are all equally real. Conversely, in the 3-brane framework, time is a relative phenomenon that emerges from the observer's movement along a specific timeline. Effects like time dilation are shaped by the curvature of spacetime, in accordance with general relativity, and is perceived differently by observers depending on their motion and gravitational environment.

3.10. Decoherence

3.10.1. In conventional quantum mechanics, decoherence explains how classicality emerges from quantum superpositions. Through environmental entanglement, a system's coherence decays, leading to a reduced density matrix for the system, defined as $\rho S = TrE(\rho SE)$ where $\rho SE = \rho S \otimes \rho E$ represents the combined system-environment state. This tracing-out process removes coherence between the system and environment by suppressing off-diagonal elements of ϱS, which represent coherence between superposed states. Decoherence aligns the system into a "preferred basis" corresponding to classical outcomes, a critical feature in interpretations like MWI, where each branch forms a distinct classical "world" without interference between different outcomes.

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3.10.2. Strip Theory diverges from this standard view by introducing sidetime, an additional temporal dimension where all potential quantum outcomes are continuously defined as part of a five-dimensional wavefunction, $\Psi(x,f,s)$, where foretime (f) governs sequential events along observable timelines and sidetime (s) encodes parallel outcomes, representing a continuum of coexisting possibilities. Unlike traditional decoherence, where coherence decays through environmental entanglement, Strip Theory posits that sidetime continuity inherently preserves coherence because it represents a continuous, self-contained dimension where all quantum states remain dynamically coupled. This eliminates the need for external interactions, as coherence is maintained within the intrinsic dynamics of sidetime due to the seamless coupling of quantum states across the continuous sidetime manifold.

3.10.3. In this framework, sidetime acts as a unifying field, linking clones—the quantum manifestations of a particle—into a cohesive wavefunction. Coherence naturally emerges from continuous interactions among clones, akin to the flow of currents in a stream. Each clone influences the next, maintaining quantum information and phase relationships throughout sidetime. This internal coupling ensures that coherence is preserved without requiring external environmental factors. Coherence in sidetime is preserved through smooth wavefunction evolution, with no interaction with external systems and governed by $\partial\Psi(x,f,s)/\partial s = -i\hat{H}_s\Psi(x,f,s)$, where $\hat{H}_s$ governs sidetime evolution by encapsulating phase continuity across states. Phase divergence, described by $\Delta\phi(s)$, accounts for coherence reduction between sidetime currents, leading to classicality as divergence increases.

3.10.4. While sidetime continuity supports coherence, certain pathways within sidetime may gradually diverge in phase. This divergence reduces coherence across specific currents, leading to the emergence of distinct classical outcomes. As some pathways in sidetime become more pronounced, the system evolves towards a stable quantum state that aligns with observed classical phenomena. This process seamlessly transitions quantum possibilities into classical realities without invoking traditional decoherence.

3.10.5. The observer's interaction with sidetime is an active process, with free will playing a critical role in selecting a specific outcome. Within the sidetime framework, free will serves as the mechanism by which an observer navigates the continuum of coexisting possibilities, reducing the five-dimensional wavefunction $\Psi(x,f,s)$ to a three-dimensional classical outcome. This selection aligns the observer's foretime trajectory with a chosen sidetime pathway, producing a cohesive experience. This process is intrinsically tied to the sensory apparatus, which acts as a conduit for dimensional reduction. By interacting with sidetime currents, the sensory system narrows the observer's engagement with the five-dimensional structure into a single timeline, creating the illusion of classicality and integrating sensory input with the quantum state to collapse multiple pathways into a coherent foretime-aligned experience.

3.10.6. Strip Theory predicts that sidetime dynamics may produce detectable deviations from traditional decoherence. For instance, interference patterns may persist in systems with minimal environmental coupling, such as in ultra-cold or high-vacuum conditions. Observing such residual coherence, distinguishable from standard environmental effects, could indicate sidetime's role in sustaining quantum states beyond conventional decoherence predictions.

3.11. Multiple Locations

3.11.1. In conventional QM, the state of a particle is described by a wavefunction $\psi(x,t)$, representing the probability amplitude of finding the particle at position x at time t. A non-zero probability amplitude at multiple locations is often seen as the particle existing simultaneously in different positions—or teleporting between them, challenging classical notions of locality and realism. Strip Theory reinterprets the wavefunction as a cloud of clones propagating across

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timelines in sidetime. In this view, a "particle" does not exist in multiple locations simultaneously but is instead represented by its clones, each occupying a unique position along parallel sidetime trajectories. The probability amplitude at a given location reflects contributions from clones already present at that position in their respective timelines.

3.11.2. This clonal framework resolves apparent violations of locality. For example, a particle observed at two locations within a short time interval is understood as the observation of two different clones. Apparent teleportation does not involve a single particle traversing space instantaneously but arises from clones already distributed across space via sidetime propagation. Strip Theory redefines the concept of multiple locations as an emergent property of sidetime dynamics. This reinterpretation preserves locality while aligning with experimental observations, offering a coherent alternative to classical interpretations of quantum mechanics.

3.12. Quantum Tunneling

3.12.1. Quantum tunnelling, where particles penetrate classically forbidden barriers, is traditionally explained by a wavefunction's non-zero amplitude beyond the barrier. Strip Theory offers an alternative mechanism, attributing tunnelling to interference between clones within sidetime. Clones propagate along separate timelines but may intersect in foretime, where constructive interference temporarily amplifies the clone's energy, enabling it to overcome the barrier.

3.12.2. Whilst this amplification is governed by the uncertainty principle ($\Delta T \Delta E \geq \hbar/2$), the energy is framed as borrowed from sidetime – rather than uncertainty principle itself. Total energy conservation is maintained across sidetime, with amplification in one timeline offset by reductions in others. As clones move past their intersection, interference dissipates and, effectively, returns the energy.

3.13. Virtual Particles

3.13.1. In quantum field theory (QFT), virtual particles are central to explaining phenomena such as the Lamb shift, vacuum polarization, and the Casimir effect. In quantum electrodynamics (QED), they are described as transient entities that mediate interactions by temporarily violating energy conservation, justified by the time-energy uncertainty principle. However, this interpretation raises conceptual challenges, including conflicts with classical expectations of particle trajectories and the physical reality of virtual particles.

3.13.2. Strip Theory reinterprets virtual particles as real clones existing in sidetime. These clones interact dynamically within the sidetime framework, remaining imperceptible to observers constrained to spacetime. For example, the emission and absorption of virtual photons occur as interactions between photon and electron clones in sidetime. This resolves the paradox of photon trajectories, replacing them with clonal dynamics that conform to classical expectations of straight-line behaviour.

3.13.3. Unlike conventional interpretations, Strip Theory eliminates the need for energy borrowing. Clonal interference within sidetime redistributes energy while maintaining conservation laws. The vacuum, traditionally seen as nearly empty, is reimagined as a densely populated medium filled with clones. These clones interact through interference patterns, generating zero-point energy and other measurable effects. This reinterpretation transforms the vacuum into a dynamic structure within sidetime, providing a coherent explanation for the energetic contributions of the vacuum. By treating virtual particles as tangible entities within sidetime, Strip Theory resolves ambiguities in QFT and aligns with experimental observations. This framework offers a unified and grounded understanding of virtual particles and the quantum vacuum.

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4. Sidetime and Other Frameworks

The introduction of sidetime in Strip Theory presents a profound shift in how temporal evolution is conceptualized in quantum mechanics. Sidetime offers a richer framework for understanding the branching of quantum states and the coexistence of multiple outcomes. This additional temporal dimension reshapes existing frameworks by altering the treatment of time, superposition, and causality within a five-dimensional context, which can extend and improve other interpretations:

4.1. Copenhagen Interpretation

4.1.1. In the Copenhagen interpretation, certain aspects remain unclear. In von Neumann's exposition [[16]], for example, an isolated quantum system is described by a complex state function, ψ, which evolves according to two distinct processes:

- Process 1: In a system where $c_j = \langle \varphi_j \mid \psi \rangle$, with wavefunctions φ_j representing all possible outcomes of measuring ψ—described as a *superposition* of states—an observation causes a *discontinuous change* in ψ, reducing it to a particular state φ_j with a probability given by the Born rule: $|(\psi, \varphi_j)|^2$.

- Process 2: In a deterministic way, ψ evolves according to the Schrödinger equation, $(ih/2\pi)\partial\psi/\partial t = H\psi$ where H is the Hamiltonian operator. When measured, a *cut* occurs and the *wavefunction collapses* with probability given by process 1.

Where the phrases in *italics* remain unqualified.

4.1.2. Within the Strip Theory framework, Process 2 is interpreted as the unobserved evolution of a five-dimensional strip over foretime. In Process 1, superposition corresponds to the distribution of possible outcomes (clones) across sidetime. Discontinuous change and cut are interpreted as the dimensional reduction that occurs upon measurement, rendering wavefunction collapse as the 3-brane observation of a 5-brane event. Strip Theory thereby provides a more rigorous framework for the Copenhagen interpretation which clarifies previously unqualified properties.

4.2. Pilot Wave Theories

4.2.1. In Pilot Wave theories, like the de Broglie-Bohm model [[17]], particles follow deterministic paths guided by hidden variables. Non-locality in these theories arises due to the hidden variables influencing particle motion even across separated regions. Strip Theory reinterprets this, embedding hidden variables within sidetime, allowing particle paths to evolve deterministically through sidetime without non-local effects (see §3.8).

4.2.2. Hidden variables are reinterpreted as sidetime parameters, where a particle's trajectory, $\gamma_j(f,s)$, evolves deterministically. Here, foretime dictates the progression of observables, while sidetime enables branching and alternative paths. A particle's position, is influenced by a pilot wave evolving through the coupled dynamics:

$$\partial x(f,s)/\partial f = v(f,s) \quad (14)$$

$$i\hbar(\partial\Psi(f,s))/\partial f = \hat{H}_f \Psi(f,s) \quad (15)$$

$$i\hbar(\partial\Psi(f,s))/\partial s = \hat{H}_s \Psi(f,s) \quad (16)$$

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Where *v(f,s)* is the particle's velocity, and $\hat{H}_f$ and $\hat{H}_s$ are Hamiltonians governing wavefunction evolution in foretime and sidetime, respectively. By localising hidden variables within the sidetime dimension, Strip Theory establishes a deterministic, five-dimensional structure where particle and wave interactions unfold coherently without requiring non-local forces. This local, realistic approach preserves Pilot Wave Theory's conceptual foundation, but attributes hidden variables to sidetime rather than to instantaneous action at a distance, thus integrating determinism and realism within a coherent five-dimensional framework.

4.3. Relational Quantum Mechanics

4.3.1. Relational Quantum Mechanics (RQM) [[18]] posits that quantum states are observer-dependent, meaning they are not absolute but contingent on the information available to a specific observer. The state of a system reflects the relational information between observer and system, allowing different observers to assign different quantum states to the same system based on their individual interactions.

4.3.2. Strip Theory aligns with this relational approach, embedding observers in a five-dimensional framework. Each observer's experience is a three-dimensional projection of this higher-dimensional structure, meaning that their perception of quantum states is inherently relational, based on their unique path through foretime and sidetime. Observers experience the five-dimensional reality from distinct perspectives defined by their positions within a given strip. Consequently, quantum states in Strip Theory evolve relative to the observer's specific trajectory $\gamma_j(f,s)$ in five-dimensional space, linking the wavefunction $\Psi(f,s)$ to the observer's position in foretime and sidetime.

4.3.3. Strip Theory thus upholds RQM's principles, embedding the observer's unique viewpoint within its framework. Quantum states are inherently relational, evolving based on the observer's path through foretime and sidetime, allowing multiple valid quantum descriptions by different observers according to their distinct positions in the five-dimensional structure.

4.4. Many Worlds Theories

The Many-Worlds Interpretation [[19]] (MWI) and Everettian Quantum Mechanics (EQM) posit that all possible outcomes of a quantum measurement occur in distinct, non-interacting branches of reality remaining isolated due to decoherence, which prevents interference between branches. Strip Theory offers an alternative perspective, situating these outcomes within a unified sidetime structure that preserves coherence and interaction across timelines. This distinction is considered in several key areas:

4.4.1. Branching: Branching In MWI, quantum states split into isolated branches, creating a separate "world" for each outcome. In Strip Theory, this branching occurs as the evolution of distinct timelines within sidetime, rather than separate universes. Each timeline represents a coherent clonal trajectory within the five-dimensional structure: $\Psi(f,s) = \sum c_j \varphi_j(f,s)$, where $\varphi_j(f,s)$ corresponds to a clone's state, and c_j are probability amplitudes. Timelines in sidetime allow outcomes to coexist while retaining potential for interference, distinguishing Strip Theory from MWI's strict isolation of branches.

4.4.2. Decoherence: In EQM, as outlined by David Wallace [[20]] and others, explains why observers experience one outcome per measurement, isolating identities along branches and making branching irreversible. However, Adlam [[21]], among others, explores alternatives to decoherence. Strip Theory offers an alternative by situating outcomes in connected timelines within sidetime (s), achieving classicality through sidetime continuity and dimensional reduction upon observation, rather than decoherence. Sidetime continuity permits natural interference between timelines, as discussed in §3.10, making separate decoherence mechanisms unnecessary.

4.4.3. Time: EQM suggests that time evolves independently in each branch, prompting debate over whether time is global or relational. This aligns with Hugh Everett's view of time as branch-dependent. Emily Adlam further examines whether cross-branch interference could indicate an interdependent temporal framework, challenging the conventional "branch-independent" time notion. As discussed in §3.9, Strip Theory regards time as universal within the 5-brane but emerges as relative in the 3-brane.

4.4.4. Identity: MWI raises questions about the persistence of identity across branches. Wallace argues that identity remains continuous within a branch but diverges between branches. In Strip Theory, identity is treated as continuous within timelines in sidetime, where an observer's actions are mirrored by alternate versions along parallel paths. Interactions with others occur through "shared" timelines, but individual choices lead to divergence. Coherence within sidetime ensures a seamless transition to an alternate clone of the departed individual, preserving the continuity of identity. While our identity remains persistent, interactions with others are fractured. This framework avoids the rigid compartmentalisation of identity seen in MWI, offering a more fluid interpretation of observer trajectories.

5. Conclusion

Strip Theory extends time to include foretime and sidetime, addressing foundational issues in quantum mechanics. This dual-temporal structure enables continuous coherence within sidetime, bypassing traditional decoherence mechanisms and bridging quantum phenomena with classical emergence. By integrating deterministic evolution and probabilistic outcomes, Strip Theory aligns observer-relative quantum states with consistent identities, resolving limitations of branching models like MWI.

Strip Theory suggests testable predictions, such as prolonged coherence in cryogenic or ultra-high-vacuum environments and deviations in interference patterns detectable by high-precision interferometers. These pathways for empirical validation could distinguish Strip Theory from conventional frameworks and provide opportunities to explore sidetime's role in quantum phenomena, despite the challenges of direct experimental validation.

While sidetime raises questions about reconciling its implications with current time tests, it is proposed as a complementary framework that enriches existing theories. Future experiments could validate sidetime's role, advancing our understanding of quantum coherence and harmonizing interpretations of quantum reality.

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