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Time: A Three-Directional Dimension II

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Abstract: *This essay explores a refined framework for conceptualizing time as a three-directional construct with orthogonal axes, emphasizing the distinct role of the* θτ-plane *in causality, potentiality, and the probabilistic evolution of events. Building on prior theories of multi-directional time, this model delineates how temporal axes interact within a six-directional spatio-temporal continuum (3S + 3T) to address the immutability of the past, the fleeting nature of the present, and the probabilistic dynamics of the future. The discussion extends to the mathematical representation of events and their clustering within the future cone, highlighting how probabilities are distributed and realised. This approach also investigates the influence of gravitational effects and disturbances on temporal axes, offering insights into how potentialities may be reshaped without deterministic constraints. By synthesizing concepts from relativity, probability, and three-dimensional time, this model provides a structured, yet flexible framework for interpreting the interconnected nature of time, space, and events. It invites further investigation into its implications for retro-causality, temporal disturbances, and the broader dynamics of the universe.*

Keywords:3S + 3T, causality, probability, gravity, quantum mechanics,

INTRODUCTION

Just as Space is represented by the three axes x, y, and z, Time can be assigned a similar structure [1]. The presented model conceptualises time as a dimension on its own, with three spacelike orthogonal axes [2]. In conventional understanding, time does not have a negative direction in the same sense that spatial dimensions possess positive and negative domains. Yet, classical mechanics and certain interpretations of quantum mechanics allow for a bidirectional time arrow. The argumentation is, however, predominantly driven by mathematical reasoning: it is not only by changing the sign of a term in an equation that time-reversal becomes a reality. The present model firmly adheres to a unidirectional framework that aligns with our intuitive experience of causal flow. Contrary to traditional physics, viewing time as a single, linear, and scalar dimension – flowing from past to future, lacking any inherent directional complexity – this model offers a more nuanced approach, as well as a possible explanation of Einstein's "Spooky Action on a Distance" (Muchow 2025).

The aim of this essay is to explore both philosophical and scientific implications the proposed model implies, relating to the apparent simplicity of Space. The characterization of the two additional temporal axes, θ and τ, as well as the plane they span orthogonal to the conventional flow of time, offers a novel perspective for analysing phenomena that transcend linear temporality. These axes, forming a plane orthogonal to the perceptive time axis, may influence temporal degrees of freedom, subtly interfering with upcoming events and potentially freeing them from the constraints of linear progression. This approach calls for a reconsideration of foundational concepts such as causality, probability, potentiality, and feedback, offering fresh insights into their roles within a multidirectional temporal 3S + 3T continuum. The declared objective of this essay is to expand the actual vision of time into a three-directional dimension of its own.

Structure of the Dimension Time

Assigning Temporal Axes

Building on the conceptual framework introduced above, this section examines the non-interacting properties of the three temporal axes within the Time coordinate system, envisioned as a 3D grid of events. Distinct characteristics are attributed to the t-and θ-axis, facilitating an exploration of possible interrelations between events and their outcomes. The characteristics of the τ-axis, however, are still unclear. In order to deepen our understanding of all three axes and their interplay within the presented framework, further mathematical considerations will be necessary.

The Cause-and-Effect Axis t represents the perceptual flow of time, ensuring causality through a unidirectional progression of events, proceeding logically and sequentially along this axis, where each event is influenced by prior ones, and in turn influences those that follow [3].

The axes θ and τ are thought to be orthogonal to one another and to t, forming a projection plane for events contained in the future cone. Their origin is anchored in t in the point t_0, which represents the floating present. In itself, the θ-axis may be considered as the origin of branching possibilities, where each moment offers multiple potential pathways. These pathways are spread out into the plane where they could manifest due to a variety of factors – choices, randomness, or quantum uncertainty – each leading to a different spread of possible event-outcomes. Still under investigation is the role of the τ-axis; it is hypothesized to constrain the spread of potential events within the future cone. One of its particularities might reveal possible temporal connections across the $\theta\tau$-plane, related to higher-order patterns.

More on the "Spatial" Structure of Time

As depicted in a previous essay, the described axes are conceived being orthogonal to one another [4]. In this system, the perceptual flow of time remains unidirectional along t, while the $\theta\tau$-plane co-evolves with t. Figure 1 illustrates this relationship, showing the synchronous shifting $\theta\tau$-plane, maintaining its orthogonality to t, as it progresses from t_0 to t_1, with t_0 always considered as the present, i.e. t_1 will be the future t_0, and so forth.

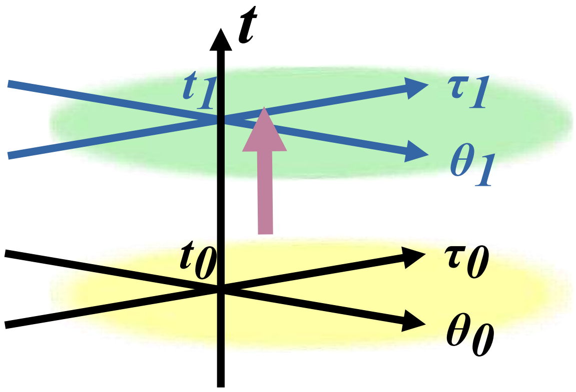


Figure 1: Synchronous shifting of the $\theta\tau$-plane as t progresses from t_0 to t_1

The passage from t_0 to t_1, … , is thought to happen in a Planck-time interval. Thus, the present is seen as a dynamic gap with Planck-time duration, enabling the transition of events between the apexes of the future and past hyperboloids in the temporal coordinate system. This concept of a gap was introduced previously (Muchow 2020). It marks the transition of events from the future, imagined as the upward hyperboloid containing all potential events, and the past, visualised as the downward hyperboloid, encompassing all realised events. As *t* progresses, the gap shifts along the t-axis, continuously bridging the potentiality of the future cone and the realisation of the past cone at each Planck-time increment. This dynamic ensures that the "*now*" is an essential concept, as the present remains distinct, separating the unchangeable past from the realm of future possibilities, at the same time introducing the quantification of time.

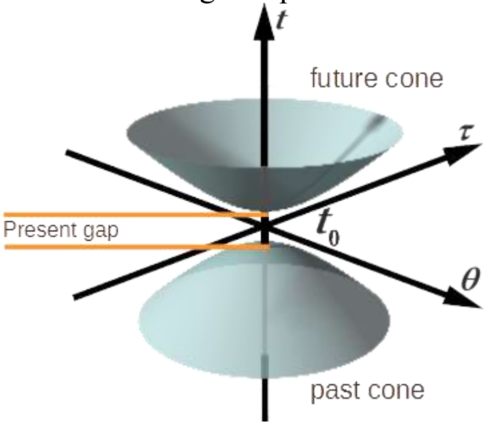


Figure 2: Past and future cones showing the time axes and the "gap" at t_0

The time-coordinates are considered as a three-directional framework, a space-like grid containing all events in the dimension Time, however with distinct particularities. Contrary to Space, where the intercept of the x, y, and z axes is generally considered as a static origin, the origin of the temporal grid t_0 is floating dynamically due to the passing of events along *t*. Thus, the three-directionality of the Time dimension becomes only apparent through the dynamic progression of events along the *t*-axis. However, there are distinct features of reference: the perceptual time axis is the primordial "*pillar*" of Time. On it are registered all realised events within a Planck-time instant, contributing to the creation of a history. Anchored in t_0, the $\theta\tau$-plane functions primarily as the interface between future and past. As pointed out earlier, it may also function as the projection plane for events contained in the future cone. The future and past cones contain all possible and realised events, respectively. Whereas the future cone is dynamic, with probable events continuously weighed and filtered on approaching the apex, the immutable past cone accommodates all events that occurred. The nature and potential characteristics of the realm beyond these cones parallel questions asked about regions outside light cones, offering an intriguing avenue for future research.

Events and Causality

Events and Causal Independence

Space without objects does not exist. A similar statement can be made about time: time without events does not exist. Without events, there will be no "flow" of time [5]. This perspective aligns with relational theories of spacetime, where space and time derive meaning only in relation to objects or events. [6]. However, while time flow is often conceptualized as the incremental occurrence of events, in certain physical theories—such as relativity—time can be treated as independent of events, though it will always depend on events within the spacetime continuum.

In classical physics, an event is a point in spacetime, localized by its position x, y, z, and its scalar position in Time. This classical definition works well within the confines of Newtonian physics or even special relativity. However, it proves insufficient when extended to a three-directional time dimension, where an event cannot be described by a time scalar. The involved interactions, especially in the $\theta\tau$-plane, introduce new dimensions of potentiality and influence.

Through this lens, an event at the outcome of a cause can't be seen in a deterministic way; it is shaped by the probability of its realisation. Consider an event E1 at time $t = 0$ that causes event E2 at time $t = 1$: the nature of E1 depends probabilistically on the conditions of E1. In the proposed framework, E1 ($t = 0$, $\theta = m$, $\tau = r$) could branch into E2a ($t = 1$, $\theta = n$, $\tau = u$) or E2b ($t = 1$, $\theta = -p$, $\tau = v$), and even into other states, reflecting the multiple, potential paths an event can take toward realisation.
It is important to notice that events on the $\theta\tau$-plane are imagined as weighted projections of the cumulated probable events from the future cone. Yet, they follow the same criterium of causal independence which is valid for the *t*-axis [7]. Thus, although the processes in the $\theta\tau$-plane parallel the weighing and filtering process in the future cone, it allows a realising event to take a different path. The characteristics of the θ axis as the basis of branching possibilities render the $\theta\tau$-plane a place of non-deterministic action, enhancing or diminishing the probability of realising events. In a way, it is in the $\theta\tau$-plane that events can take an apparently improbable path, augmenting the possibility that not always the most probable event will happen. A possible direct influence of the τ-axis on events is not yet determined.

The lack of direct interaction of the time axes, and especially the $\theta\tau$-plane's singular interaction with *t* at the present t_0 means that causality is maintained through the causal flow of events on *t*. Any event realised in *t* has no direct causal influence on the $\theta\tau$-plane. However, as mentioned, an event's realisation may be influenced by coincidences in the $\theta\tau$-plane.

Probabilistic Causality and Filtering Across Axes

Causality becomes philosophically more complex when introducing multiple axes of time, questioning how we interpret it in light of the presented system. However, observational results following cause-and-effect sequences do not change because of the introduction of a new model for time. It must be considered that Time, being three-directional, is not a new virtue of time—the simple recognition of an existing multi-directionality does not imply new observations or changes in the well-documented process of cause and effect.

Building on the probabilistic nature of causality in this model, upcoming events within the future cone and their projections on the $\theta\tau$-plane are influenced by their proximity to the present gap. The likelihood of an event realising increases as the present moment nears, a phenomenon that manifests differently in each of the domains, while occurrences in the $\theta\tau$-plane may lead to unexpected outcomes [8].

Feynman's idea of multiple possible events and their convergence toward the most probable outcome illustrate well the probabilistic nature of causality [9]. According to him, while a multitude of possible outcomes exists, the most probable events dominate as they converge, increasing their likelihood of realization. This concept proves central to understanding how causality unfolds in the three-dimensional time model.

Building on this idea, the concept "Zeitstrang", or time strand, was introduced (Muchow 2020). It represents a fabric of potential timelines that converge as they approach the present gap, with each timeline initially following its own potential trajectory. However, as these trajectories near the present gap, they merge into a single strand, with only the most probable event passing through the gap to join the past cone.

This process emphasizes the filtering mechanism that occurs as the gap progresses forward in time:

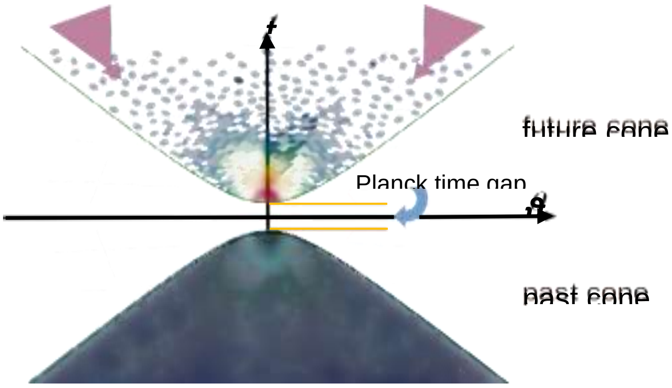


Figure 3: Probabilistic filtering of events close to the apex of the future cone
In the figure, the pink arrows indicate the "gathering" of events – for simplicity, only the t and θ axes are shown. The filtering process is unique for each axis; in the $\theta\tau$-plane similar filtering occurs, according to possible futures, and independent of the t-axis. The likelihood of events converges near the present gap, with the highest-probability outcomes concentrated at the base of the future cone. At each moment – talking in Planck-time length – one event will jump the gap and become part of the past cone.

Understanding probabilistic causality within each temporal axis is possible taking into account foundational nonlinear interactions. These interactions govern how potential events evolve, based on initial conditions, their proximity to the present gap, and the inherent probabilistic rules of the individual axes. For instance, a small fluctuation near the present gap could amplify through nonlinear dynamics, significantly affecting the probability distribution of future events [10]. This allows for unexpected outcomes, in addition to the possible, and unpredictable contributions stemming from occurrences in the $\theta\tau$-plane, aligning with the nondeterministic nature of this model [11].

However, one might still want to think about how these filters work across time, keeping in mind that causality on one axis does not bleed over into another axis. A feedback mechanism within the probabilistic filtering process could yet be imagined, leading to emergent behaviours that transcend individual axes. Given that each axis is independent, the probabilistic filtering process within each axis and within the $\theta\tau$-plane may create conditions that, when combined, lead to complex interactions. This distinction highlights how the axes retain their individual causal structures, as their aggregate behaviour can give rise to new emergent properties [12]. Thus, iterative filtering along one axis could create conditions that ripple through the system, manifesting as consistent patterns or unexpected configurations [13]. These emergent dynamics highlight the complexity and interdependence within probabilistic systems, providing insights into the broader implications of multidimensional time.

Mathematical Framework of Multidimensional Time

Nonlinear Interactions, Relational Time , and Cross-Axis Probabilities

In mathematical terms the filtering process of events in this three-dimensional time model can be described using a Gaussian distribution, where the probability density at time t converges to a peak at the most probable event [14]:

$$\rho(E,t) = \frac{1}{\sqrt{2\pi\sigma^2(t)}} \exp\left(-\frac{(E - E_{\mathrm{mp}}(t))^2}{2\sigma^2(t)}\right)$$

where $E_{\mathrm{mp}}(t)$ denotes the most probable event at time t; $\sigma(t)$ is assumed to decrease monotonically with time, reflecting a progressive narrowing of the probability distribution around the most probable event. This reflects how probabilities become more certain as time progresses.
The dynamics of causality in this model can be formalized by a system of coupled differential equations [Prigogine (1997), López & Valdano (2020)]. The rates of change of probabilities along each temporal axis are then given by:

$$\frac{dP_t}{dt} = f(P_t, G_t), \quad \frac{dP_\theta}{d\theta} = g(P_\theta, G_\theta), \quad \frac{dP_\tau}{d\tau} = h(P_\tau, G_\tau)$$

where P_t, P_θ, and P_τ represent the probabilities of events along the respective axes, while G_t, G_θ, and G_τ describe their governing constraints or boundary conditions specific to each axis. These equations capture the dynamic evolution of probabilities within each temporal dimension, enabling an analysis of how events probabilistically cluster over time. Solutions to this system could reveal intricate feedback loops or emergent patterns, offering profound insights into the multidimensional nature of time. Such solutions would help illuminate how time's interdependent axes contribute to the nonlinear evolution of events and their probabilistic relationships. Understanding these emergent patterns could provide a deeper grasp of the intricate feedback mechanisms that govern temporal dynamics across multiple dimensions. [15]

The present model also allows the introduction of cross-axis dependencies, reflecting the interactions between events in the θ- and τ-axes. These interactions give rise to nonlinear dependencies, where the evolution of one axis depends not only on its own state but also on the state of the other [16]. Specifically, one can write:

$\frac{d\theta}{dt} = f_1(\theta,\tau) \cdot \frac{d\tau}{dt}$, and
$\frac{d\tau}{dt} = f_2(\tau,\ \theta) \cdot \frac{d\theta}{dt}$

where f_1 and f_2 are nonlinear functions governing the progression of events along each axis, and $\frac{d\theta}{dt}$ describes how θ evolves with respect to t; $\frac{d\tau}{dt}$, on the other hand, represents the rate of change of τ with respect to t. The functions depend not only on the current state of the respective axis but also on the state of the other axis. This interdependence would allow events in θ to influence the progression of events in τ and vice versa. Nonlinear terms may account for complex relationships, such as feedback loops or interaction terms that create non-proportional relationships between the axes. Thus, the influence of θ on τ might not be direct, but could depend on the relative timing between events on them.

Further, the relational time between axes could be represented as a time-delay function that adjusts how an event on one axis affects the other. This time-delay could introduce a lag or a leading effect depending on the particularities of the system. This effect may be most conveniently described with the equation:

$\tau = g(\theta, \Delta t)$
where g is a nonlinear function that depends on the relational time between the axes, and Δt accounting for time shifts or temporal delays [17].

Events on the θ-axis could influence events on the τ-axis based on their temporal proximity and relational time. Such interactions are governed by a probability density function, reflecting the nonlinear nature of their relationship. For instance, an event at θ_1 could increase the likelihood of a corresponding event at τ_2 if the system's conditions align with specific relational time dynamics [18]. This probabilistic approach maintains the model's flexibility, while emphasizing the interconnectedness of the temporal dimensions and their influence on each other. A probability density function for such an interaction might be:

$P(\tau|\theta) = h(\theta,\tau)$

where $h(\theta,\tau)$ is a nonlinear probability distribution that specifies the likelihood of an event on the τ-axis, given the state of the θ-axis. This equation emphasizes the dynamic relationship between the axes, with events in one axis influencing the other in a probabilistic manner.

Coupled Differential Equations and Emergent Behaviour

However, such probabilistic descriptions are useful, but would benefit from a more rigorous mathematical formalisation. Introducing a system of coupled differential equations allows for a more stringent representation of how temporal interactions evolve, emphasizing the interplay between axes. These equations can describe how the evolution of one temporal axis influences and is influenced by the other:

$\frac{d\theta}{dt} = f_1(\theta) + \alpha \cdot g(\tau,\theta)$ equation(1)
$\frac{d\tau}{dt} = f_2(\tau) + \beta \cdot h(\theta,\ \tau)$ equation(2)

Equation (1): The rate of change of θ with respect to t is determined by the function $f_1(\theta)$, which depends solely on θ. The term $\alpha \cdot g(\tau, \theta)$ introduces a dependence on both τ and θ, and α is a proportionality constant modifying the contribution of this interaction [19].

Equation (2): The rate of change of τ with respect to t is determined by the function $f_2(\tau)$, which depends solely on τ. The term $\beta \cdot h(\theta, \tau)$ introduces a dependence on both θ and τ, and β is a proportionality constant modifying the contribution of this interaction (Lorenz, 1963).

These equations describe a coupled system where the evolution of θ and τ with respect to t depends both on the intrinsic dynamics of $f_1(\theta)$, $f_2(\tau)$, and on interactions mediated by g and h. In this system α and β are constants that control the strength of interaction between the axes, whereas $g(\tau,\theta)$ and $h(\theta,\tau)$ are the nonlinear terms that represent the influence of one axis on the other.

These feedback mechanisms arise from the interplay between the nonlinear terms $g(\tau,\theta)$ and $h(\theta,\tau)$, which allow for mutual influence between the axes. For instance, a significant change in θ might trigger a cascade effect in τ, altering its trajectory in ways that were not directly predictable from the initial state of the system. Over time, such interactions could stabilize into patterns or cycles, or alternatively, lead to highly sensitive and chaotic dynamics depending on the boundary conditions.
Emergent behaviour in this context refers to phenomena that arise from the collective interactions of the axes but cannot be solely explained by their individual equations. This could manifest as synchronized oscillations between θ and τ, the formation of temporal attractors where certain states recur, or the emergence of entirely new modes of progression that reflect the system's intrinsic complexity [20].

Such emergent phenomena underscore the richness of a multi-directional temporal framework, offering insights into how complex systems—whether physical, biological, or cosmological—operate within this model. They also offer new perspectives on causality, highlighting how feedback loops and interdependencies between axes can reveal intricate patterns of cause and effect within the system.

Potentiality and the Wave Function

The Wave Function and Gaussian Wave Packet

The foundation of quantum physics is based on the work of Einstein, Heisenberg, Schrödinger, Planck, and other eminent physicists of the past century. However, their perception of spacetime only contains one time scalar. In the present model, time is conceptualized as a dimension with three orthogonal directions: t, θ, and τ. Consequently, the wave function, as traditionally defined, must be re-examined to incorporate this extended temporal structure.

Thus, based on the present model, the wave function becomes $\psi(t, \theta, \tau)$, where the total probability P of finding a particle within a region of this three-dimensional "time space" would be:
$P(t, \theta, \tau) = |\psi(t, \theta, \tau)|^2$

The wave function $\psi(t, \theta, \tau)$ typically encodes the state of the system across the three temporal directions. For instance, it could exhibit symmetry around $t = \theta = \tau = 0$, implying equal contributions from positive and negative values of each temporal axis. This symmetry suggests a balanced distribution across the temporal directions, indicating a stationary or equilibrium state where no axis is privileged. What is more, the modulus squared ensures that the probability of observing a particle is always bounded between zero and one, more precisely expressed as: $0 \leq P \leq 1$ [21].

Given that the wave function $\psi(t, \theta, \tau)$ is complex-valued, its modulus squared is used to derive the probability density, calculated as:

$|\psi(t, \theta, \tau)|^2 = \psi^*(t, \theta, \tau) \cdot \psi(t, \theta, \tau)$
where, $\psi^*(t, \theta, \tau)$ is the complex conjugate of the wavefunction, obtained by reversing the sign of its imaginary part, i.e., if $\psi = a+ib$, then $\psi* = a-ib$, where a and b are real numbers. The result of this multiplication is a real, non-negative value. In quantum mechanics, $|\psi(t, \theta, \tau)|^2$ represents the probability density of locating a particle within a particular configuration in the temporal space defined by t, θ, and τ [22].

This probabilistic interpretation extends traditional quantum interpretations, introducing a temporal "landscape" where the particle's state exists in a superposition across all three temporal directions.
A localized particle in classical "spacetime" is described as a Gaussian wave packet. This description attributes a spread of position and momentum to the particle. In the present, extended model, the wave packet $\psi(t, \theta, \tau)$ evolves within the "temporal space" defined by the axes t, θ, and τ [23].
A general form of the wave function for a Gaussian wave packet in this framework can be written as:

$$\psi(t,\theta,\tau) = A\exp\left(-\frac{(t-t_0)^2}{4\sigma_t^2} - \frac{(\theta-\theta_0)^2}{4\sigma_\theta^2} - \frac{(\tau-\tau_0)^2}{4\sigma_\tau^2} + i(k_t t + k_\theta\theta + k_\tau\tau)\right)$$

where:
- A is the normalisation constant.
- t_0, θ_0 , τ_0 are the coinciding zero positions in this coordinate system.
- σ_t, σ_θ, σ_τ are the widths of the wave packet along each axis, representing temporal uncertainty.
- k_t, k_θ, k_τ are the temporal "frequencies" analogous to wave numbers in space, connected to energy contributions along each axis.

The modulus squared of the wave function gives the probability density:

$$P(t,\theta,\tau) = |\psi(t,\theta,\tau)|^2 = A^2\exp\left(-\frac{(t-t_0)^2}{2\sigma_t^2} - \frac{(\theta-\theta_0)^2}{2\sigma_\theta^2} - \frac{(\tau-\tau_0)^2}{2\sigma_\tau^2}\right).$$

This distribution highlights the localization of the particle centred in t_0, θ_0, and τ_0, with the widths σ_t, σ_θ, and σ_τ., dictating the uncertainty in the temporal coordinates.

Wave Packet Evolution and Temporal Dynamics
In the traditional spacetime framework, Gaussian wave packets evolve and disperse over time due to the interplay between position and momentum [24]. In the three-directional time model, the wave packet evolves simultaneously across the independent axes t, θ, and τ, reflecting the extended temporal structure The evolution of the wave function can be described by a Schrödinger-like equation adapted using three time directions [25]:

$$i\hbar\frac{\partial\psi}{\partial t} = \hat{H}\psi, \quad i\hbar\frac{\partial\psi}{\partial\theta} = \hat{H}\psi, \quad i\hbar\frac{\partial\psi}{\partial\tau} = \hat{H}\psi.$$

where $\hat{H}(t, \theta, \tau)$ represents a generalized Hamiltonian operator that incorporates contributions from all three temporal directions. The structure of the wave function $\psi(t, \theta, \tau)$ suggests a probabilistic distribution of "temporal locations." Here, particles exist in a state of temporal superposition, where uncertainties across the axes influence the shape and behaviour of the wave packet.
To fully describe the evolution of the wave packet within the extended temporal structure, it is essential to ensure that the wave function remains properly normalized [26]. The requirement of normalization not only preserves the probabilistic interpretation of the wave function but also subtly links the axes probabilistically while maintaining their fundamental independence.

Normalization and Physical Interpretation
The normalization of the wave function is an essential requirement that ensures the total probability across the temporal axes equals unity. This constraint guarantees the consistency of probabilistic interpretations, as the total probability of the particle within the three-directional temporal space must remain unity [25]:

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}|\psi(t,\theta,\tau)|^2\,dt\,d\theta\,d\tau = 1.$$

This normalisation inherently links the temporal axes, as the probabilities along θ and τ contribute to the total probability, just as t does. While no cyclic processes exist within the axes, the probabilistic "entanglement" arising from the shared wave function introduces subtle correlations between them, potentially influencing the system's evolution [26].

Furthermore, uncertainties along each axis could give rise to *temporal interference patterns*, analogous to spatial interference in quantum mechanics [27]. These patterns, arising from the interplay of temporal uncertainties, may reveal yet undiscovered dynamical effects, providing new insights into the behaviour of systems within this model.

Exploring Multi-Temporal Phenomena in Physics
This model introduces speculative, yet profound conceptual extensions, as it also offers concrete avenues for exploration. Advanced experimental techniques, such as ultra-cold atomic systems or precision interferometry, might reveal subtle effects stemming from multi-temporal interference. These could manifest as deviations in coherence times, unexpected correlations, or novel interference patterns within temporal observables [28]. Moreover, the model raises questions about the reconciliation of causality and quantum non-locality, providing a fresh framework for understanding phenomena that challenge traditional interpretations of time and space. Beyond experimental insights, the conceptual implications resonate with broader attempts to unify quantum mechanics and relativistic theories, where additional dimensions often emerge as natural extensions of physical law [29].

Three-dimensional Time and Gravity
The interplay between time and gravity is well-documented in the framework of general relativity, where mass and energy curve spacetime. As the classical four-dimensional spacetime is expanded into the three-directional time model, the addition of two independent temporal axes – θ and τ – introduces new dimensions of time. In this extended model, gravity's influence extends beyond spatial curvature, affecting the probabilistic structure of events along the temporal axes.

The temporal axes (*t, θ, τ*) and the spatial axes (x, y, z) are intricately intertwined, forming a continuum different from the classical, Einsteinian four-"dimensional" spacetime concept based on the principles of relativity. In the presented model, both the causal structure of events, and the probabilities of their outcomes are influenced by gravity. Time and space are not independent constructs, but part of the multi-dimensional framework 3S + 3T, where the flow of time, the curvature of space, and the probability of events are all interconnected [32].

It is expected that the curvature of space around massive objects and gravitational waves cause alterations in the additional temporal axes θ and τ, and in the perceived axis of time t. For the latter, gravitational disturbances are not expected to affect its cause-and-effect chain, since it functions simply as a registrar of events that unfold according to their specific probabilities. However, gravitational waves can influence the sequence and relative likelihood of potential outcomes in the θτ-plane. The resonance effect between gravitational waves and this plane can either contract or expand the distribution of probabilities within it, redistributing events into a narrower or broader range of possible outcomes. This would significantly change the probability of specific, expected events [33].

Thus, in a three-directional time system, gravity not only warps space but also potentially influences the cause -and effect axis *t*, but the dynamic evolution of events in the *θτ*-plane as well:

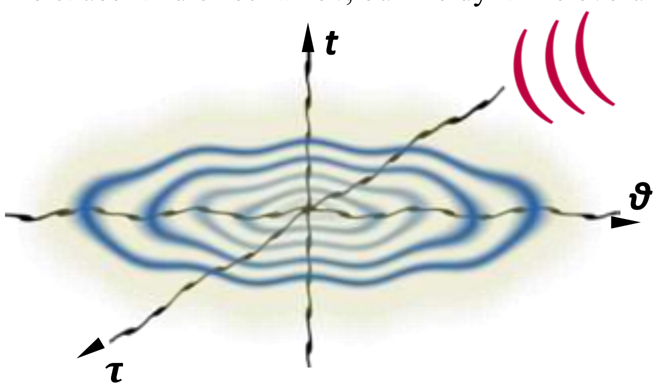
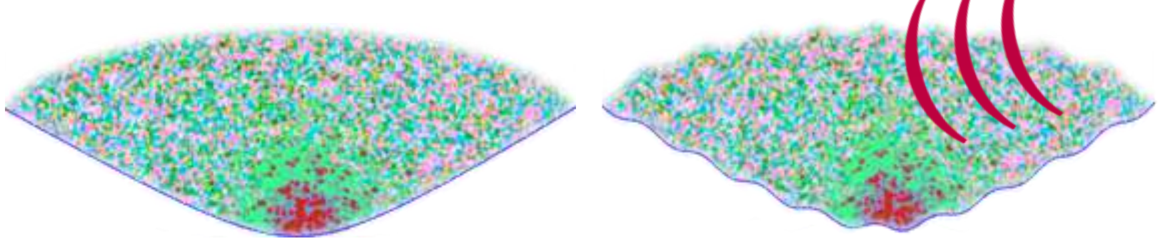


Figure 4: Warping of the *θτ*-plane and the future cone through gravitational waves

As illustrated in the figure below, gravitational effects may also warp the future cone, altering the relative probabilities and sequential order of potential events there. This suggests that potentiality is not fixed: gravitational influences can modify the range of outcomes, reshaping event-probabilities close to the apex of the future cone. The effect of gravity on the past cone may be considered negligible, since it hosts events that belong to the history of the universe and thus is immutable.



unperturbed future cone gravitational waves passing

Figure 5: Perturbation of the future cone by gravitational waves

The influence of gravity on both space and time underscores the hypothesis that events within the future cone are not deterministically but probabilistically distributed. Gravitational disturbances, such as those caused by waves, potentially modify the likelihood of event outcomes. Just as gravitational waves distort classical spacetime, their disturbances also ripple through the temporal axes, affecting the probability distribution of potential events and how their spatial coordinates are realised. It is to bear in mind that gravitational effects – given that gravity is the weakest of the fundamental forces – will be very small and thus extremely difficult to detect.

CONCLUSION

The model of a probabilistic three-directional time dimension with orthogonal axes of t, θ, and τ, introduces a novel approach to understanding the flow of time, causality, and the potentiality of future events. By expanding the concept of time beyond a single axis, it will be possible to better account for the multifaceted nature of temporal dynamics, where the past remains immutable, the present is a fleeting moment of action, and the future is shaped by probabilities. Causality is considered in a very rigorous manner, following the well-grounded cause-effect model, explicitly excluding retro-causality, in alignment with the fundamental principles of physics [34].

Although the mathematical arguments of this model remain in their early stages, they provide a promising avenue for further research in the domain of Time – and in consequence in quantum mechanical considerations [35].

Further, the interaction of the temporal axes with gravity opens up a different perspective on the fabric of our universe. The possibility of gravity to interact with the three time axes shows how gravity not only influences the rate of time but also shapes the potential event outcomes in the $\theta\tau$-plane. Gravitational waves, causing disturbances in the 3S + 3T continuum, may also alter the probability distribution within the future cone, underscoring the interconnectedness of space, time, and causality [36].

As Time is mostly an unknown phenomenon, it is evident that many of the presented subjects are speculative [37]. Given that this model is completely built on probabilistic events, it is to expect that following up this temporal model will not only have an impact on theoretical – and probably also on experimental – physics but also on philosophy. Looking into the future, the model invites further exploration and refinement in multiple areas, as depicted above. Ultimately, this multi-axial approach to time provides a fresh perspective on our understanding of the universe.

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