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Theory of the Four-Dimensional Electromagnetic Universe: Derivation of the Energy-Time Uncertainty Principle for Temporal Waves and Their Stability

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Abstract

In this paper, we derive a specific form of the energy-time uncertainty principle as it applies to Temporal Waves (TWs) in the context of the Four-Dimensional Electromagnetic Universe (4DEU) Theory, providing further evidence of the stability of TWs from the beginning and throughout the four-dimensional (4D) universe's expansion. In this model, the universe is proposed to exist in four real spatial dimensions, with the fourth dimension, which we perceive as time, along which the cause of the 4D universe's expansion acts. TWs play a fundamental role in the formation and expansion of the 4D universe, with this expansion being caused by their radiation pressure. In this work, we derive the specific form of the uncertainty principle for TWs, demonstrating that the product of the uncertainties in the TW energy and privileged time is not merely constrained by a lower bound, as in the canonical uncertainty principle, but is exactly equal to h/4. In contrast to the canonical uncertainty principle, where the product of uncertainties is greater than or equal to h/4π, in the case of TWs this product equals precisely h/4, indicating a unique relationship in the 4DEU theory. Our findings also confirm the stability of TWs from the beginning and throughout every phase of the 4D universe's expansion, ensuring their persistence over time. This paper offers further mathematical evidence supporting the stability of TWs and strengthens the foundational principles of the Theory of the Four-Dimensional Electromagnetic Universe.

Keywords: Energy-Time Uncertainty Principle, Bohr-Wigner Formulation, Temporal Wave, Theory of the Four-Dimensional Electromagnetic Universe, Privileged Quantities

1. Introduction

The investigation of fundamental cosmic principles has recently led to the development of new theoretical models that attempt to address unresolved questions about the universe's structure and evolution. One such model is the Theory of the Four-Dimensional Electromagnetic Universe (4DEU theory), which posits that the universe exists as a four-dimensional hypersphere, with four real spatial dimensions, where the fourth dimension is perceived as time in the three-dimensional (3D) part of the universe in which we live. In this framework, the radius of the 4D universe corresponds to the dimension that we perceive as time [1].

In the 4DEU theory, privileged time and privileged space are defined as time and space measured with respect to a reference system centered on the Big Bang event, which in this theory represents the centre of the 4D universe, thus establishing it as a 'privileged' reference frame [1]. Moreover, privileged time and privileged space correspond exactly to proper time and proper space as defined in the theory of Relativity [2].

A central aspect of this theory is the existence of Temporal Waves (TWs), stationary electromagnetic waves oscillating along the fourth dimension. These TWs play a crucial role in determining the universe's structure, driving its expansion, and potentially explaining phenomena such as dark energy and the generation of mass. According to the 4DEU theory, at the beginning of the universe's formation, four initial TWs were generated from the quantum vacuum that has always existed [3]. These waves required a certain temporal duration, governed by the energy-time uncertainty principle, to transition from 'virtual' to 'real entities. The application of the Bohr-Wigner uncertainty relation further confirmed the stability of these initial TWs (chapter 3.4.3 in [4]). As the universe expanded, the wavelengths of the TWs increased, and the effects of the uncertainty principle at macroscopic scales disappeared.

The Bohr-Wigner uncertainty relation is given by:

$$\Delta U \cdot \Delta t \approx h \tag{1}$$

This approach confirmed that the four initial TWs were stable and that their energy-time uncertainty relation allowed their transformation into real entities.

This paper focuses on deriving a specific form of the energy-time uncertainty principle as it applies to TWs within the 4DEU theory, providing further evidence of the stability of TWs throughout the 4D universe's evolution, building upon previous published analyses.

The principle developed here shows that the product of the uncertainties in TW energy and privileged time is not merely constrained by a lower bound, as in conventional quantum mechanics, but is precisely equal to a constant value, h/4, different from the canonical $h/4\pi$.This result reflects the unique interdependence between the radius of the 4D universe, TW energy, and privileged time within the framework of this theory.

Furthermore, we demonstrate rigorously the stability of TWs across different stages of the 4D universe's expansion, utilizing both (i) the energy-time uncertainty principle for TWs, derived in this work, and (ii) the Bohr-Wigner formulation. Together, these principles provide strong evidence that TWs remain stable throughout the universe's evolution, ensuring their persistent influence in the creation and continued expansion of the 4D universe.

By deriving and analysing this uncertainty principle, this work further supports the core tenets of the 4DEU theory and offers deeper insights into the interconnected roles of energy, time, and cosmic expansion.

2. Results

2.1 Derivation of the Uncertainty Principle for TWs

In the 4DEU theory, the minimum uncertainty for the radius of the 4D universe is given by $\Delta R = l_{pl}$, the Planck length, which represents the smallest possible measurable length. Since the radius of the universe R_t is related to time through the equation 1 in [1]:

$$t = \frac{R_t}{c} \quad (2)$$

The minimum uncertainty in privileged time Δt, associated with this minimal radius, is:

$$\Delta t = \frac{\Delta R_t}{c} = \frac{l_{pl}}{c} \quad (3)$$

This represents the smallest possible uncertainty in time, corresponding to the minimal measurable length l_{pl}, also known as the space quantum in 4DEU theory.

The energy of a TW is inversely proportional to the radius of the universe R_t and is given by Eq.10 in [1]:

$$U_{tw} = \frac{hc}{4R_t} \quad (4)$$

Where U_{tw} is the energy of a TW when the radius of the 4D universe equals R_t, and h is Planck's constant.

By defining the minimum 4D universe radius through the Planck length, we set a minimum granularity in 4D space, representing the smallest measurable unit for this radius. This limitation not only constrains the spatial measure of the radius but also establishes a lower bound for the energy of TWs, given their inverse relation to the radius of the universe. This lower energy limitation contributes to the stability of TWs throughout the entire expansion of the 4D universe, ensuring that TW energy never falls below a threshold, even as the radius approaches the minimum Planck length. This constancy provides TWs with the robustness needed to fulfil their fundamental role in maintaining the structure and expansion of the 4D universe.

Given that the minimum uncertainty in the 4D universe radius is $\Delta R = l_{pl}$, the minimum uncertainty in energy becomes:

$$\Delta U_{tw} = \frac{hc}{4\Delta R} = \frac{hc}{4l_{pl}} \quad (5)$$

Now, calculating the product of the minimum uncertainties for energy and time, we substitute the values for ΔU_{tw} and Δt:

$$\Delta U_{tw} \cdot \Delta t = \frac{hc}{4l_{pl}} \cdot \frac{l_{pl}}{c} \quad (6)$$

Where l_{pl} is the Planck length.

And simplifying we obtain the uncertainty principle for TWs:

$$\Delta U_{tw} \cdot \Delta t = \frac{h}{4} \quad (7)$$

Thus, the product of the minimal uncertainty in energy and the minimal uncertainty in time for TWs is exactly $\frac{h}{4}$.

2.2 Analysis of the Equality in the Uncertainty Principle for TWs

In the 4DEU theory, both privileged time t and the energy of TWs are directly tied to the radius of the universe R_t. Specifically:

- Time t is proportional to R_t, with $t = \frac{R_t}{c}$.
- The energy U_{tw} is inversely proportional to R_t, with $U_{tw} = \frac{hc}{4R_t}$.

This means that both quantities, time and TWs energy, are governed by the same physical parameter, the radius of the 4D universe. Thus, the product of their uncertainties is necessarily tightly linked. Since both Δt and ΔU_{tw} are functions of R_t, they cannot vary independently of one another. This leads to the conclusion that the product of the uncertainties is always equal to a fixed value, specifically $\frac{h}{4}$.

Thus, in the 4DEU theory, the product of the uncertainties is not simply bound by a lower limit (as expressed by ≥) but is always exactly equal to $\frac{h}{4}$. This tight relationship between time and energy necessitates the use of the equality symbol "=" in the uncertainty principle for TWs.

In contrast to the traditional uncertainty principle, which implies a lower bound (≥), the derivation for TWs in the 4D universe establishes an exact equality in the product of energy and time uncertainties. This result is based on the assumption that the 4D radius (a measure tied to the fourth dimension, perceived as time) simultaneously determines both the TWs energy and their privileged time. In this model, therefore, the close interdependence between the 4D universe radius and the TWs implies that the energy and time uncertainties cannot vary independently. The strict equality relation is an intrinsic property of the TWs, suggesting that in the context of the 4D universe, the uncertainty constraint is "saturated" exactly at $\frac{h}{4}$, rather than merely bounded as in the canonical principle.

2.3 Mathematical Proof of the Stability of Temporal Waves

From the uncertainty relation for energy ΔU_{tw} in terms of the uncertainty in radius ΔR_t:

$$\Delta U_{tw} = \frac{hc}{4\Delta R_t} \quad (8)$$

and the expression for time uncertainty:

$$\Delta t = \frac{\Delta R_t}{c} \quad (9)$$

we substitute both into the uncertainty principle equation:

$$\frac{hc}{4\Delta R_t} \cdot \frac{\Delta R_t}{c} = \frac{h}{4} \quad (10)$$

Now, simplifying, we obtain:

$$\frac{h}{4} = \frac{h}{4}$$

From which:
1=1

This confirms that the uncertainty in time Δt and the uncertainty in energy ΔU_{tw} are always perfectly balanced, ensuring the stability of Temporal Waves throughout the expansion of the universe.

The stability of TWs during the expansion of the 4D universe results from the fact that the energy-time uncertainty relation for TWs remains invariant despite variations in the 4D radius. In this model, the expansion itself does not alter the equality relation, as both energy and time uncertainties are governed by the same physical variable: the radius of the 4D universe. In other words, as the radius increases with expansion, the strict proportional dependence between energy and time uncertainties preserves the stability of TWs, ensuring that they consistently play their role across all evolutionary phases of the 4D universe.

The obtain equality 1=1 simply demonstrates that the energy-time uncertainty principle is both satisfied and consistent. As the universe continues to expand, the lifespan of the TWs increases in direct proportion to the radius of the 4D universe (our privileged time), ensuring that TWs remain stable throughout its expansion. Thus, the relationship between the uncertainty in energy and time ensures the stability of TWs from the earliest stages of the universe to its future evolution. This stability is in accordance with the energy-time uncertainty principle derived here, which applies universally to all times and radii of the 4D universe.

3. Discussion

In this paper we derive a specific form of the energy-time uncertainty principle that applies to Temporal Waves within the framework of the 4DEU theory. By demonstrating that the product of the uncertainties in TW energy and privileged/proper time is always exactly equal to h/4, this work establishes a fundamental distinction between the behaviour of TWs and the uncertainty principles observed in conventional quantum mechanics. This precise equality arises from the inherent interdependence between the radius of the 4D universe, TW energy, and time, as predicted by the 4DEU theory.

Additionally, the stability of TWs throughout all stages of the universe's expansion has been confirmed. Using both the derived energy-time uncertainty principle and the Bohr-Wigner formulation, here we have shown that TWs remain stable as the 4D universe expands, from its earliest stages up to the present day and into the future. This stability ensures the continuous presence and influence of TWs, which are fundamental to the 4DEU theory's explanation of the creation and evolution of the 4D universe.

These findings reinforce the theoretical foundations of the 4DEU theory and provide deeper insights into the relationships between time, energy, and the expansion of the 4D universe. The results of this work confirm the persistence and stability of TWs over cosmic privileged time.

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