

Theory of the Four-dimensional Electromagnetic Universe, Part I:
A Real Hyperspherical Four-Dimensional Universe Can Explain the Equations $E = hf$ and $E = m_0c^2$, as Well as the
Wave-Particle Duality of Electromagnetic Waves.

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ABSTRACT

This work postulates ([Postulate 1](#)) that the real universe is a true four-dimensional hypersphere (4D), with three spatial dimensions and a fourth dimension that we perceive as time. Therefore, a real (not an imaginary as in *Minkowski* spacetime), four-dimensional spacetime, whose radius is a real time dimension that expands at the speed of light in vacuum, “ c ”. This postulate allows the definition of a privileged reference system centered on the Big Bang event, with coordinates (0,0,0,0), representing the centre of the 4D universe. I refer to time and space measured with respect to this system as privileged time and space. Another postulate ([Postulate 2](#)) posits that all physical phenomena occurring along the real temporal dimension of the 4D universe are perceived and measured in the three-dimensional (3D) spatial part of the 4D universe, where we live, differently from their actual nature. For instance, the expansion of the time dimension is not perceived as a spatial expansion (an increase in the separation between two bodies) but as “the flow of time,” and the energy developed along the temporal dimension is perceived as mass.

This [second postulate](#), in analogy with the holographic principle (3D information encoded on a surface), is termed “[restricted holographic principle](#)”, since it encodes only the information related to the time dimension of the 4D universe in its 3D spatial part.

In this work, based on these two postulates and their corollaries, I derive the quantum equation, or Planck equation, of the energy of electromagnetic waves, $E=hf$. This derivation demonstrates that it is the sum of the spatial and temporal components of the energy in the real four-dimensional spacetime.

Applying the restricted holographic principle, I find that the temporal component of the energy of an electromagnetic wave, appearing as mass in the 3D portion of the 4D universe, imparts particle properties, while the wave properties are attributed to the spatial component. This explains the dual behaviour (wave/particle) of electromagnetic waves in the 3D spatial part of the 4D universe.

Another consequence of these postulates is that in the 4D universe, there are no physical objects, that is, entities with mass, but only electromagnetic waves whose temporal component manifests as mass within the 3D portion of the 4D universe. This theoretical result gives rise to the name of the theory: The Theory of the Four-dimensional Electromagnetic Universe.

Moreover, if these electromagnetic waves are only temporal, the equivalence $hf_t = m_0c^2$ is obtained, where f_t is the frequency of these only temporal electromagnetic waves.

Other important deductions are that the physical quantities, such as acceleration and the associated fields, force (including gravity), and work, have physical significance only in the 3D portion of the 4D universe where we live.

Finally, since mass exists only in the spatial (3D) portion, this part can be considered as a hyperspherical shell (3D) of the 4D universe that, not exerting gravity on itself, leads to the intriguing deduction that all the mass presents in its 3D part cannot slow down the expansion of the 4D universe.

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1. INTRODUCTION

Albert Einstein's theory of relativity overturned the absolutist Newtonian axioms concerning space and time, fundamentally relying on a singular postulate, kept valid also in this study, that has never been contradicted by experiments or physical evidence: the invariance of the speed of light, or more broadly, the speed of electromagnetic waves (EMWs) in vacuum. The absence of a privileged reference frame, such as the luminiferous ether for the speed of light, has led to concepts, now extensively demonstrated, like relativistic mass (even though today this notion has been largely superseded by the term "relativistic energy" (Roche, 2005)), the mass-energy equivalence ($E = m_0c^2$), relative time dilation, and relative length contraction.

This study postulates the existence of a privileged reference system (see [Chapter 2, postulate 1](#)) and that the actual universe is a genuine four-spatial-dimensional hypersphere (three spatial and a fourth dimension perceived as time). Thus, the real universe constitutes a four-dimensional (4D) spacetime, not an imaginary one like *Minkowski* spacetime. The time dimension, which represents its radius, expands at the speed of light in vacuum " c ". The coordinates of the privileged reference system have origin in the Big Bang event, representing the centre of the 4D universe. I will henceforth denote as privileged time and space those referring to the aforementioned coordinate system.

Acknowledging the existence of a real time dimension raises the question of why it is not visible. Having admitted that it is also expanding, I cannot assume that it is rolled on itself as in the Kaluza-Klein theory (Klein, 1926) or subsequent theories up to M-theory (Witten, 1995). To address this, a second postulate, termed the *restricted holographic principle* (postulate 2), is proposed. According to this principle, any physical phenomenon occurring partially or entirely along the time dimension of the 4D universe must be perceived and measured in the 3D part of the 4D universe where we live. This perception occurs in a qualitatively different yet quantitatively proportional manner, ensuring coherence with the phenomenon itself.

In this work, I preferred to use postulates (or axioms), which are statements taken as true without the need for proof, rather than simple hypotheses. This choice allows me to focus directly on the consequences of these postulates, without the necessity of proving their validity.

Additionally, to avoid misunderstandings, I will use the term *mass* to refer to the *proper mass*, also known as *invariant mass* or *rest mass*.

2. POSTULATE 1 (On the Truly 4D Universe)

The real universe is a four-dimensional hypersphere (4D), not a *Minkowski* spacetime, with four spatial dimensions of which one appears to us as the dimension of time, representing its radius, also expanding. The expansion speed of the time dimension of the 4D universe is constant and equal to " c ".

$$c = \frac{dR_t}{dt} \rightarrow dt = \frac{dR_t}{c} \rightarrow dR_t = cdt \quad (1)$$

Where " c ", the speed of light in vacuum, is postulated to be the expansion speed of the 4D universe, and R_t is the radius of the 4D universe at privileged time t (i.e., the privileged time elapsed after the Big Bang).

2.1. Corollary 1 of postulate 1

It follows from postulate 1 that the expansion of the 3D portion of the real four-dimensional (4D) universe is caused primarily by the expansion of its temporal dimension. Consequently, the cause of the expansion of the entire 4D universe acts along the time dimension.

2.2. Corollary 2 of postulate 1

The expansion of the temporal dimension (postulate 1) implies that physical objects, stationary relatively to the 3D part of 4D universe, move in a privileged sense with the expansion of the temporal dimension at speed " c " ([Eq.1](#)).

2.3. Considerations on postulate 1

The [Eq.1](#) tells us that time and space are the same entity and that " c " represents a constant of proportionality that serves exclusively to convert the two different units of measurement historically used for them.

It's crucial to note that this postulate doesn't imply that we and everything we know are four-dimensional (that is obvious), but that we exist solely in the three-dimensional part of a universe that is actually composed of four dimensions, all spatial. One of these four spatial dimensions is perceived/measured by us and our three-dimensional equipment as time.

2.4. Definition of a privileged reference system

Based on postulate 1, it is possible to define as privileged reference system having coordinate origin at the Big Bang event, then of coordinates (0;0;0;0), representing the centre of the 4D universe. By determining these two privileged quantities (time and space), it is possible calculate all the derived quantities which, in turn, will also be privileged (speed, acceleration, force, etc.). It is noteworthy that in 4D

universe postulated here, not being a *Minkowski* spacetime, the distance between two points requires the classical *Pythagoras* theorem in which the coordinate time, being a real dimension and not imaginary (the imaginary unit “*i*” does not appear), it is not subtracted from the spatial coordinates.

Therefore, the distance d in 4D spacetime between a coordinate event $A(x, y, z, t)$ and the coordinate event $A'(x', y', z', t')$ can be computed as follows:

$$d_{AA'}^2 = (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 + (c\Delta t)^2$$

While, in a *Minkowski* spacetime it would be obtained as:

$$d_{AA'}^2 = (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 + (ic\Delta t)^2$$

From which, developing the square of the imaginary unit “*i*”, I get:

$$d_{AA'}^2 = (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 - (c\Delta t)^2$$

Instead, the relative time is that measured by "physical" clocks existing in the 3D component of the 4D universe, that is, oscillating phenomena (EMWs, heartbeat, atomic clocks etc.). It is "relative", that is measured relative to a physical clock placed in the 3D portion of the 4D universe. It expands or shortens according to:

- Special relativity, that is based on the relative speed of the clock used to measure it.
- General relativity, that is based on the gravitational field or the accelerated reference system in which the clock is located.

Relative time is unrelated to the time dimension of 4D universe.

Henceforth, all mentioned physical quantities must be understood as privileged, referring to the privileged reference system, unless otherwise specified. It is crucial to note that the measurement of privileged time occurs along the time axis and not through a physical clock.

3. POSTULATE 2

(Restricted Holographic Principle)

Any physical phenomenon, with its physical quantities that measure and characterize it, which occurs partially or totally along the time dimension must be perceived and measured in the 3D part of the 4D universe, where we live, in a qualitatively different but quantitatively proportional way, always coherently with the phenomenon itself.

In analogy with the holographic principle, where 3D information is encoded on a surface (Hooft, 1993; Susskind & Witten; Susskind L. , 1995), I call this postulated *restricted holographic principle* because the information relating to everything that happens only along the time

dimension of the 4D universe. It is “restricted” because encoded, that is a kind of projection, onto 3D portion of the 4D universe. Consequently, the 3D component of the 4D universe of all physical phenomena is perceived and measured for what it really is.

3.1. Corollary 1 to postulate 2

The expansion of the temporal dimension, unable to be perceived as a spatial expansion, in order to maintain the 'coherence' mentioned in [postulate 2](#), is perceived as the flow of time.

[Corollary 1 to postulate 1](#) states that there is no stationary element in respect to the privileged reference frame and that, therefore, there is always a temporal movement due to expansion.

It follows that the energy linked to the expansion of the time dimension, to maintain the mentioned "coherence" stated in [postulate 2](#), appear as mass, which indeed is a form of energy, in 3D part of the 4D, universe where we live.

I define “temporal wave” (TW) an electromagnetic wave that oscillates only along the time dimension and does not present components in the 3D space of the 4D Universe.

In summary, this corollary states that:

- a) The expansion along the time dimension appears to us as the flow of time.
- b) The temporal energy component of a generic spatiotemporal electromagnetic wave appears in the 3D part of the 4D universe as mass.
- c) Here, I define waves that oscillate only along the time dimension as 'temporal waves' (TW).

3.2. Corollary 2 to postulate 2

[Corollary 1 to postulate 2](#) states that mass is nothing more than the energy carried by the temporal component of an EMW moving in the 4D universe with wavelength given by the *de Broglie's* formula ($\lambda = h/p$) (De Broglie, 1925). It follows from this that in the 4D universe there are no physical objects, that is, entities with mass, but merely electromagnetic waves whose temporal component manifests as mass within the 3D portion of the 4D universe.

4. PRIVILEGED SPACE-TIME VELOCITY AND ITS COMPONENTS

In the 4D real universe, nothing remains stationary with respect to the reference system centered on the Big Bang event, except for the point-event where the Big Bang itself occurred. In fact, due to the expansion of the temporal dimension, everything in existence moves away from the origin of the privileged reference system with a speed of

“ c ”. This privileged movement into the spatiotemporal (ST) 4D universe is referred as spacetime speed (v_{ST}). It consists of three spatial components, collectively indicated as v_s , which, for simplicity, correspond to one of the three spatial axes (v_{sx}, v_{sy} or v_{sz}) and only one temporal component, v_t . The time component of the ST velocity measures the rate of expansion of the time dimension which, according to [Eq.1](#), is always equal to “ c ”.

4.1. Time component of the spatiotemporal velocity

By virtue of [postulate 1](#) and [Eq.1](#), it is evident that the magnitude of the temporal component v_t of the spacetime velocity vector is given by the following formula:

$$v_t = \frac{dR}{dt} = \frac{c dt}{dt} = c \quad (2)$$

Where, the temporal component, v_t , of the spatiotemporal speed, v_{ST} , is always equal to “ c ”.

4.2. Space component of the spatiotemporal velocity

The magnitude of the spatial component v_s of the spacetime velocity is given by the classical formula of the instantaneous speed which must always be $\leq c$:

$$v_s = \frac{dS}{dt} \leq c \quad (3)$$

4.3. Privileged spacetime (ST) velocity

The spacetime velocity vector is expressed as:

$$\vec{v}_{ST} = v_s \vec{s} + v_t \vec{t} \quad (4)$$

Where \vec{s} is the unitary vector of a spatial axis (for example x), \vec{t} is the unit vector of the temporal axis (t).

Note that the imaginary unit i is not used, since the temporal dimension has been postulated to be a real dimension. Through the theorem of Pythagoras, I can obtain the magnitude of this speed:

$$v_{ST} = \sqrt{v_s^2 + v_t^2} \quad (5)$$

From which:

$$v_{ST} = \sqrt{\frac{(dS)^2}{(dt)^2} + \frac{c^2 (dt)^2}{(dt)^2}} = \sqrt{\frac{(dS)^2}{(dt)^2} + c^2}$$

Then:

$$v_{ST} = \sqrt{v_s^2 + c^2} \quad (6)$$

Since the maximum spatial speed is also equal to “ c ”, from [Eq.6](#), obtains that the spacetime speed is always less than or equal to:

$$v_{ST} \leq c\sqrt{2} \quad (7)$$

Where “ c ” is the speed of light in vacuum, representing the speed along the time dimension always equal to “ c ” ([Eq.2](#)), v_s is the spatial component of the spacetime velocity vector v_{ST} composed of the individual components x , y and z .

As examples, using [Eq.6](#), I determine the spacetime velocities for the 3 possible cases.

4.3.1. CASE 1: ST velocity of electromagnetic waves

In this case we mean the EMWs that we observe in the 3D part of the 4D universe. Therefore, using [Eq.6](#), I can calculate magnitudes of the temporal component of the v_{ST} of a generic EMW. Since, light and EMWs in vacuum move in space always and at speed “ c ” (which is a postulate of Einstein’s theory of relativity and never disproved), v_s is obviously equal to “ c ”. Thus:

$$v_{s(EMW)} = c \quad (8)$$

Using [Eq.8](#), it follows that the magnitude of their ST speed is equal to:

$$v_{ST(EMW)} = \sqrt{v_s^2 + c^2} = \sqrt{c^2 + c^2} = c\sqrt{2} \quad (9)$$

In other words, by postulating the existence of a real 4th temporal dimension ([Postulate 1](#)) of 4D universe, EMWs move at a faster rate than “ c ”, the speed of light in the 3D portion of 4D universe.

Moreover, since the two spatial and temporal components are both equal to “ c ” in magnitude, the angle between the spatiotemporal velocity vector of a generic EMW and the spatial axis is always equal to 45° or $\frac{\pi}{4}$ radians. This is outlined in [Figure 1](#).

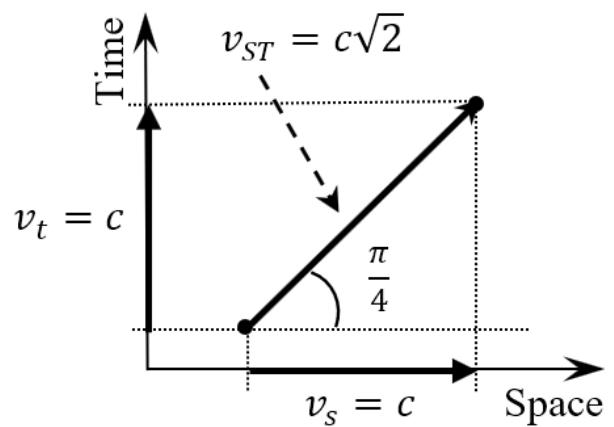


FIG. 1 — Projection of an EMW moving in spacetime on the spatial and temporal axes. Since the 2 spatial and temporal components are in magnitude both equal to “ c ”, the angle between the spacetime velocity vector of the generic EMW and the spatial dimension is always equal to 45° or $\frac{\pi}{4}$ rad.

4.3.2. CASE 2: ST velocity of a body stationary in space, that is at privileged spatial speed $v_s=0$

In this case, the magnitude of the ST velocity is equal to:

$$v_{ST(\text{station.body})} = \sqrt{v_s^2 + c^2} = \sqrt{0 + c^2} = c$$

Thus, from [Eq.6](#), the space-time vector for a body that is stationary with respect to 3D space, is reduced to the temporal component alone:

$$\vec{v}_{ST} = c\vec{t}$$

In other words, the stationary body relative to 3D space moves at spatiotemporal speed equal to “ c ” along the time dimension, following its expansion.

4.3.3. CASE 3: ST velocity of a body moving in 3D space at privileged spatial speed equal to a fraction of “ c ”

In this example let η be a fraction of the number 1. For it, the spatiotemporal speed magnitude is equal to:

$$v_{ST(\eta c)} = \sqrt{v_s^2 + c^2} = \sqrt{\eta^2 c^2 + c^2} = \sqrt{c^2(\eta^2 + 1)}$$

Then:

$$v_{ST(\eta c)} = c\sqrt{(\eta^2 + 1)}$$

Thus, in this third case the spacetime vector is as follows:

$$\vec{v}_{ST(\eta c)} = c\sqrt{(\eta^2 + 1)}\vec{s} + c\vec{t}$$

This is outlined in [Figure 2](#).

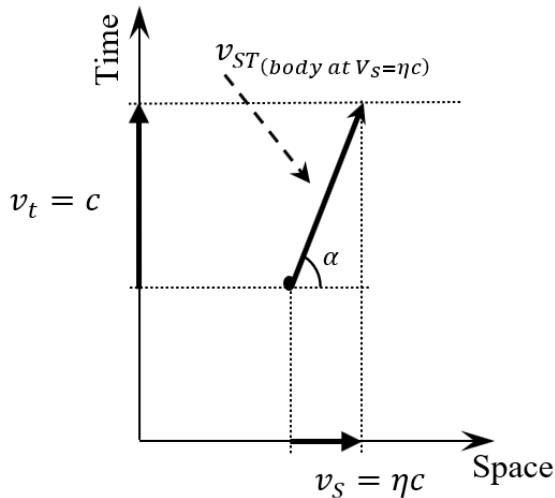


FIG. 2 — Spacetime components of a body moving in 3D space at the spatial speed of ηc . The magnitude of its ST speed is: $v_{ST(\eta c)} = c\sqrt{\eta^2 + 1}$.

Note that the alpha angle in [Figure 2](#), can vary from 90° (stationary body), to 45° (spacetime velocity vector of the EMW).

In summary, from [postulate 1](#) and as stated in [Eq.2](#), there is that the time speed magnitude “ v_t ” is always equal “ c ”, while from [Eq.3](#) the spatial speed magnitude “ v_s ” always results $\leq c$, so that the spacetime speed is always $\leq c\sqrt{2}$. In summary, there is that:

$$v_{ST} \leq c\sqrt{2} \quad (10)$$

Thus, the spacetime speed of the EMWs is not “ c ”, but $c\sqrt{2}$. This privileged speed is the maximum possible in the 4D universe.

4.4. Composition of spacetime velocity (ST)

If one wants to compare two privileged ST velocities, one relative to the other, then a relative velocity will be obtained. Consequently, the *Lorentz* transformation will need to be applied (Rao, 1988) without γ factor. The resulting vector is given by the following equation:

$$\vec{v}'_{ST} + \vec{v}_{ST} = \vec{v}_{Res} = \left\{ \frac{v'_x + v_x}{\left(1 + \frac{v'_x v_x}{c^2}\right)}; \frac{v'_y + v_y}{\left(1 + \frac{v'_y v_y}{c^2}\right)}; \frac{v'_z + v_z}{\left(1 + \frac{v'_z v_z}{c^2}\right)}; c \right\} \quad (11)$$

Where $\vec{v}_{st} = \{v_x; v_y; v_z; c\}$, $\vec{v}'_{st} = \{v'_x; v'_y; v'_z; c\}$ and \vec{v}_{Res} = Space-time velocity resulting vector from vector sum $\vec{v}' + \vec{v}$. Note that magnitude of spatial component of $v_s = \sqrt{(v_x)^2 + (v_y)^2 + (v_z)^2}$ and $v'_s = \sqrt{(v'_x)^2 + (v'_y)^2 + (v'_z)^2}$ must be always $\leq c$. Based on [Eq.10](#), the magnitude of the resulting vector will be always $\leq c\sqrt{2}$.

$$v_{Res} = \sqrt{\left[\frac{v'_x + v_x}{\left(1 + \frac{v'_x v_x}{c^2}\right)}\right]^2 + \left[\frac{v'_y + v_y}{\left(1 + \frac{v'_y v_y}{c^2}\right)}\right]^2 + \left[\frac{v'_z + v_z}{\left(1 + \frac{v'_z v_z}{c^2}\right)}\right]^2 + c^2} \leq c\sqrt{2}$$

5. WAVE-PARTICLE DUALITY OF LIGHT AND ELECTROMAGNETIC WAVES

In this chapter, based on the two postulates and correlated corollaries above, it will be shown that:

- 1) The energy of EMWs, determined using privileged quantities, can be considered as classical kinetic energy.
- 2) The spatial component of EMWs is responsible for their wave behaviour which is associated with half of their overall kinetic energy.
- 3) The temporal component of EMWs, on the other hand, is responsible for their corpuscular behaviour since it corresponds to a mass ([corollary 1 to](#)

[postulate 2](#)) equivalent to the remaining half of its total kinetic energy.

5.1. Wavelength, frequency and momentum of a generic electromagnetic wave moving in 4D spacetime.

Consider an EMW moving in real 4D having a wavelength spacetime λ_{ST} .

As shown in [Figure 3](#), the wavelength of the spatial component is equal to the wavelength of the temporal component, and both are equal to:

$$\lambda_s = \lambda_t = \lambda_{ST} \cos\left(\frac{\pi}{4}\right) = \frac{\lambda_{ST}}{\sqrt{2}} \quad (12)$$

At the same time, by the theorem of *Pythagoras* obtains that:

$$\lambda_{ST} = \sqrt{\lambda_s^2 + \lambda_t^2} = \sqrt{2\lambda_s^2} = \lambda_s\sqrt{2} = \lambda_t\sqrt{2} \quad (13)$$

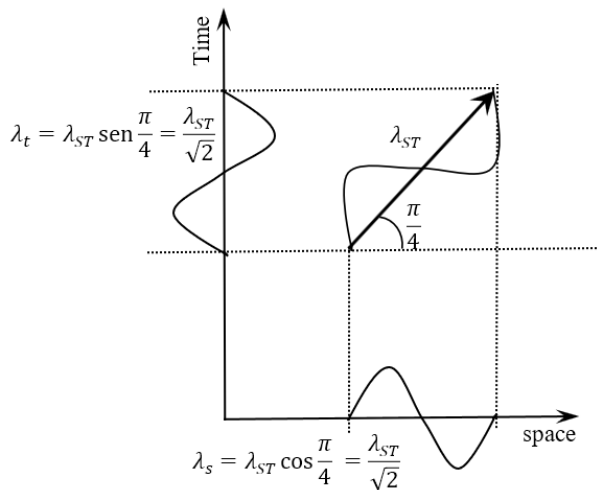


FIG. 3 — Projection on spatial and temporal axes of an EMW moving in spacetime. $\lambda_{ST}, \lambda_s, \lambda_t$ are the wavelengths of the spatiotemporal EMW and its spatial and temporal components.

From Figure 3, it is easy to infer that all the periods (T_{ST}, T_s and T_t) are equal because a complete cycle always occurs at the same time. This is true since in this theory, the elapsed time corresponds to the variation of the radius of the real 4D universe. Consequently, all frequencies (f_{ST}, f_s and f_t) are equal to each other because they correspond to the reciprocal of the period T ($f = \frac{1}{T}$).

That is:

$$f_{ST} = f_t = f_s \quad (14)$$

more specifically I have that:

$$f_{ST} = f_t \quad (15)$$

It is always valid (data not shown), for all spacetime EMWs that represent everything that really exists within the 4D real universe ([Corollary 2 to postulate 2](#)).

Instead:

$$f_{ST} = f_s \quad (16)$$

And

$$f_s = f_t \quad (17)$$

Are valid only if $f_s \neq 0$.

In other words, excluding the case $f_s = 0$, the spatiotemporal frequency f_{ST} of a generic EMW of the 4D universe is equal to the frequency of its spatial (f_s) and temporal (f_t) components, while their wavelengths differ.

Because in the three-dimensional part of 4D universe it is known that $\lambda_s f_s = c$, being from the [Eq.12](#) $\lambda_s = \lambda_t$ and [Eq.16](#) and [Eq.17](#) $f_{ST} = f_t = f_s$, follows that:

$$\lambda_s f_s = \lambda_t f_t = \lambda_s f_{ST} = \lambda_t f_{ST} = c \quad (18)$$

If $f_s \neq 0$

Substituting into [Eq.18](#), to λ_s or λ_t , the [Eq.12](#) ($\lambda_s = \lambda_t = \frac{\lambda_{ST}}{\sqrt{2}}$), I get:

$$\frac{\lambda_{ST}}{\sqrt{2}} f_{ST} = c$$

From which:

$$\lambda_{ST} f_{ST} = c\sqrt{2} \quad (19)$$

That is, for an EMW, the product between ST wavelength and ST frequency is equal to $c\sqrt{2}$, which, indeed, is the maximum ST speed.

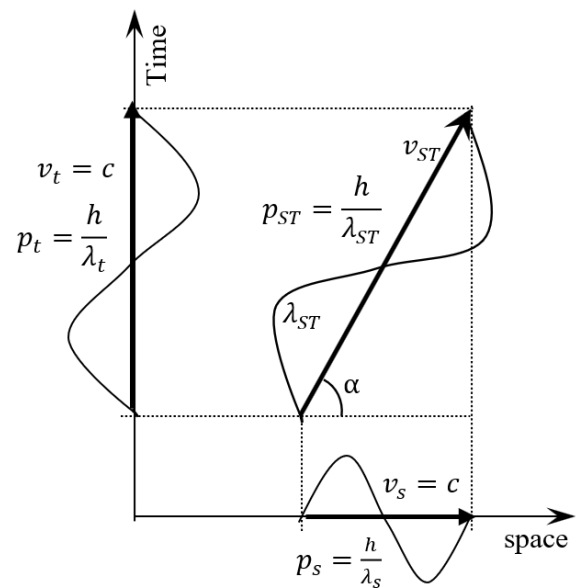


FIG. 4 — Momentum spacetime components of a generic EMW moving in the 4D universe.

The spatiotemporal momentum of a generic EMW is equal to the following equation (see also Figure 4 above):

$$p_{ST} = \sqrt{p_s^2 + p_t^2} \quad (20)$$

From [Eq.20](#), and being $p_s = p_t$, it is easy to demonstrate that for an electromagnetic wave the magnitude of the spatiotemporal momentum is equal to:

$$p_{ST} = \sqrt{2p_s^2} = p_s\sqrt{2}$$

And then:

$$p_s = \frac{p_{ST}}{\sqrt{2}} \quad (21)$$

Where p_{ST} , p_s and p_t are, respectively, the magnitudes of the spatiotemporal, spatial and temporal momentum of a generic EMW.

According to the *De Broglie* hypothesis (De Broglie, 1925) and the corollary 2 to the postulate 2, I find that a spatial momentum p_s is associated with a spatial wavelength given by $\lambda_s = \frac{h}{p_s}$ from which I have:

$$p_s = \frac{h}{\lambda_s} \quad (22)$$

By substituting p_s from [Eq.22](#) in p_s of [Eq.21](#), I have:

$$p_{ST} = \frac{h\sqrt{2}}{\lambda_s} \quad (23)$$

The energy of EMWs, determined using privileged quantities, can be considered as classical kinetic energy.

The classical kinetic energy (E) is expressed by the equation:

$$E = \frac{1}{2}pv \quad (24)$$

Recalling that in the real spacetime the speed of EMWs is $c\sqrt{2}$ ([Eq.9](#)), it is calculate the kinetic energy of an EMW in the 4D universe by replacing the [Eq.23](#) into [Eq.24](#):

$$E_{ST} = \frac{1}{2}p_{ST}c\sqrt{2} = \frac{1}{2}\frac{h\sqrt{2}}{\lambda_s}c\sqrt{2} = \frac{1}{2}\frac{h(\sqrt{2})^2c}{\lambda_s} = \frac{1}{2}\frac{h2c}{\lambda_s}$$

From which:

$$E_{ST} = \frac{hc}{\lambda_s} \quad (25)$$

And recalling from [Eq.18](#) that $\lambda_s = \frac{c}{f_s}$, obtains:

$$E_{ST} = \frac{hf_s c}{c}$$

Simplifying we obtain the known quantum equation for the total energy of an EMW:

$$E_{ST} = hf_s \quad (26)$$

Where E_{ST} is the energy of an EMW in 4D universe, h is Planck's constant, and f_s is the frequency of an EMW.

6. DETERMINATION OF THE ANGLE BETWEEN THE ST VELOCITY VECTOR AND AN ARBITRARY SPATIAL AXIS

As stated in [corollary 2 to the postulate 2](#), in the 4D universe there are only EMWs with wavelength given by the *de Broglie's* formula ($\lambda = h/p$) (De Broglie, 1925). They have of a temporal component that appears as mass of wavelength λ_t , and the spatial one that appears as a material wave of wavelength λ_s . This is outlined in [figure 5](#).

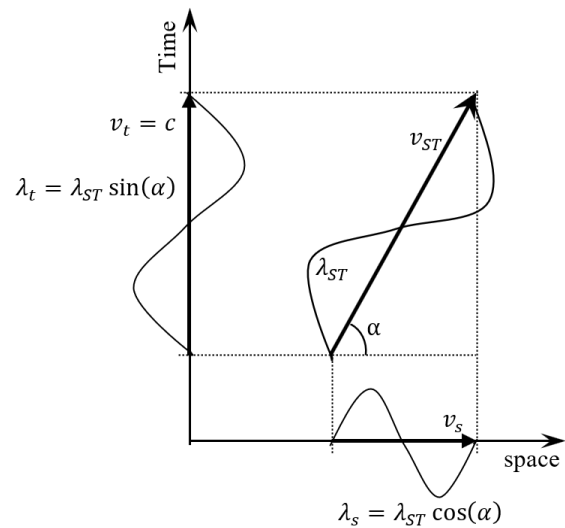


FIG. 5 — Projection on the spatial and temporal axes of a generic spatiotemporal EMW having wavelength and spacetime speeds equal to λ_{ST} , and v_{ST} , respectively. In this case, the wave represents a moving body in the 3D component of the 4D universe, so the α angle is less than 90° (Body stationary in 3D space) and greater than 45° (light in 3D spatial component of the 4D universe).

Applying to our case the commonly called "wave formula" $v = \lambda f$, where v is the wave speed, λ and f are, respectively, the wavelength and frequency, obtains:

$$\lambda_t = \frac{c}{f_t} \quad (27)$$

$$\lambda_s = \frac{v_s}{f_s} \quad (28)$$

Knowing from [Eq.18](#) that $f_t = f_s$, and by replacing it in [Eq.28](#), obtains:

$$\lambda_s = \frac{v_s}{f_t} \quad (29)$$

Formulas for calculating wavelengths based on the alpha angle are those shown in [Figure 5](#). Joining them to [Eq.27](#) and [Eq.28](#) obtains:

$$\lambda_t = \lambda_{ST} \sin(\alpha) = \frac{c}{f_t} \quad (30)$$

And

$$\lambda_s = \lambda_{ST} \cos(\alpha) = \frac{v_s}{f_t} \quad (31)$$

By dividing [Eq.31](#) by [Eq.30](#), the following result is obtained:

$$\frac{\lambda_{ST} \cos(\alpha)}{\lambda_{ST} \sin(\alpha)} = \frac{v_s f_t}{f_t c}$$

From which:

$$v_s = c \frac{\cos(\alpha)}{\sin(\alpha)} = c \cot(\alpha) \quad (32)$$

Finally, I get the alpha angle in radians:

$$\alpha = \tan^{-1}\left(\frac{c}{v_s}\right) \quad (33)$$

Where: $\frac{\pi}{4} \leq \alpha \leq \frac{\pi}{2}$

7. ENERGY OF A GENERIC ELECTROMAGNETIC WAVE MOVING ONLY ALONG THE TIME DIMENSION OF THE 4D UNIVERSE

[Corollary 1 to postulate 2](#) states that what appears as mass in the 3D part of the 4D universe is nothing more than the temporal component of an EMW moving in the real 4D universe. Below I analyse the case of EMWs that move only along the time dimension, previously defined as temporal waves (TWs).

The wavelength of these TWs can be calculated by generalizing the *de Broglie's* equation (De Broglie, 1925) and referring only to the time dimension.

Thus:

$$\lambda_t = \frac{h}{p_t} \rightarrow p_t = \frac{h}{\lambda_t} \quad (34)$$

Being $\lambda_t = \frac{c}{f_t}$, then the equation above turns into:

$$p_t = \frac{hf_t}{c} \quad (35)$$

Where h is the *Planck's* constant, “ c ” is the speed of light in vacuum, while λ_t , f_t and p_t are, respectively, the wavelength, frequency, and momentum of the temporal component of an EMW moving in 4D universe.

For a body of mass m_0 , the classical formula of momentum is:

$$p = m_0 v$$

Since the EMVs always move along the temporal dimension at speed “ c ”, then [Eq.35](#) becomes:

$$m_0 c = \frac{hf_t}{c}$$

From which:

$$m_0 c^2 = hf_t \quad (36)$$

Where h is the *Planck's* constant, “ c ” is the speed of light in vacuum, m_0 is the mass and f_t is frequency of a TW.

The above equivalence is the mathematical expression that correlates the energy of a TW with what it appears to us in the 3D portion of the 4D Universe: the mass (at rest).

8. SPATIOTEMPORAL KINETIC ENERGY OF A BODY HAVING MASS EQUAL TO m_0 , MOVING IN 3D SPACE AT “ V_s ” PRIVILEGED SPATIAL SPEED

Spatiotemporal kinetic energy of a body having mass “ m_0 ” is given by the following equation:

$$dK_{ST} = \frac{1}{2} d(P_{ST} v_{ST}) = \frac{1}{2} (P_{ST} dv_{ST} + v_{ST} dP_{ST}) \quad (37)$$

It is known that:

$$P_s = m_0 v_s$$

And

$$P_t = m_0 c$$

Replacing both the previous equations in [Eq. 20](#), obtains:

$$p_{ST} = m_0 \sqrt{v_s^2 + c^2} \quad (38)$$

and differentiating obtains:

$$dp_{ST} = \frac{m_0 v_s}{\sqrt{v_s^2 + c^2}} dv_s \quad (39)$$

Differentiating, the [Eq.6](#) transform into:

$$dv_{ST} = d\left(\sqrt{v_s^2 + c^2}\right) = \frac{v_s}{\sqrt{v_s^2 + c^2}} dv_s \quad (40)$$

Replacing the previous equations ([Eq.38](#), [40](#), [20](#) and [39](#)) in [Eq.37](#), gives:

$$dK_{ST} = \frac{1}{2} m_0 \sqrt{v_s^2 + c^2} \frac{v_s}{\sqrt{v_s^2 + c^2}} dv_s + \frac{1}{2} \sqrt{v_s^2 + c^2} \frac{m_0 v_s}{\sqrt{v_s^2 + c^2}} dv_s$$

And simplifying:

$$dK_{ST} = m_0 v_s dv_s$$

And integrating the previous equation:

$$\int dK_{ST} = m_0 \int v_s dv_s$$

Obtains:

$$K_{ST} = \frac{1}{2} m_0 v_s^2 + C \quad (41)$$

It is possible to calculate the constant C knowing that, when $v_s = 0$, the energy of a body is equal to that of its mass ([corollary 1 to postulate 2](#)).

Thus:

$$m_0c^2 = 0 + C$$

And, by rearranging, obtains the constant “C”:

$$C = m_0c^2$$

Finally, by replacing C in [Eq.41](#), obtains the sought-after equation:

$$K_{ST} = \frac{1}{2}m_0v_s^2 + m_0c^2 \quad (42)$$

9. DISCUSSION

From postulates 1 and 2 and their corollaries (chapters [2](#) and [3](#)), states that the real universe is a true 4D hypersphere, with three spatial dimensions and a fourth dimension that appears to us as time. In addition, these postulates states that in the real 4D universe, everything is in motion due to the expansion of the time dimension at speed “c”. Therefore, there is no stationary state, except the point-event where the Big Bang itself took place.

In the 4D real universe, the maximum ST speed (v_{ST}) is equal to $c\sqrt{2}$ ([Eq.9](#)). In addition, within the 4D universe, there are no physical objects—entities with mass. Instead, there are only electromagnetic waves (EMWs), whose temporal component manifests as mass within the 3D portion of the 4D universe.

In this work, I do not describe any method for measuring the privileged quantities. However, the results presented here are essentially independent of their measurement. Indeed, they provide information about the possible actual nature of some phenomena as they manifest in the 3D part of the 4D universe in which we live.

In the context of how measure privileged quantities, I think that the concept of rest mass could be useful. In fact, it is important to note that the mass remains constant with respect to any chosen reference systems. Furthermore, the mass of an object is an intrinsic quantity of the object itself and does not depend on its speed or acceleration. For these reasons, it is also named as *invariant mass*, *intrinsic mass*, or *proper mass*.

Thus, I think that the measure of the mass could be exploited to go back, at least indirectly, to the privileged reference system.

Starting from classical equations, but utilising privileged quantities, it is possible to derive the relativistic energy equation (Planck equation) for EMWs (Halliday & Resnick, 1981).

According to postulate 2, the temporal energy component of an EMW is not detectable by our sensors in the 3D part of the 4D universe for what it truly is—an electromagnetic

wave. Instead, it is perceived as mass, imparting particle-like properties. In other words, the classical kinetic energy of the temporal wave component of electromagnetic radiation, as already foreshadowed in [section 3.1](#), is not perceptible as such within the 3D part of the 4D universe. Still, it cannot vanish due to the energy conservation principle and is consequently perceived as mass.

Finally, in [chapter 7](#), I analyse a generic EMW moving only along the time dimension (here named TW) of the 4D universe. From these analyses, I derive equation [Eq.36](#), which relates the temporal frequency of this TW to the mass as it appears in the 3D part of the 4D universe, that is:

$$m_0c^2 = hf_t$$

The above equivalence is the mathematical expression, resulting from corollary 2 of postulate 2, that correlates the (rest) mass of a body with the energy of the corresponding TW.

9.1. Considerations on privileged physical quantities Acceleration, Force, and Work.

The spatiotemporal acceleration vector ($\overrightarrow{a_{ST}}$), like that of the spatiotemporal velocity ($\overrightarrow{v_{ST}}$), has two components: the spatial (3D) and the temporal one. However, the temporal component is always zero since there is no variation in ST speed, as it is always equal to “c” ([Postulate 1](#) and [Eq.1](#)). Therefore, privileged acceleration is a phenomenon that develops exclusively in the 3D portion of the 4D universe. Consequently, all privileged physical quantities derived from acceleration, such as force and work, lack of the temporal component. In other words, acceleration, force, work, and all privileged physical quantities derived from them are phenomena that occur solely in the 3D portion of the 4D universe, where we live.

9.2. The total mass contained in the spatial part of the 4D universe cannot slow down the expansion of the 4D universe.

As reported in the previous chapter, even the gravitational force (Gravity) must be a physical quantity existing only in the spatial part of the 4D universe. This can also be inferred from the fact that mass or that related to the particle component of light ([Chapter 5](#)) exists as such, mass, only in the 3D portion of the 4D universe. Therefore, we can consider the 3D portion as a hyperspherical shell of the 4D universe within which (the temporal dimension) there is no mass.

Gauss's theorem for the gravitational field states that if there is no mass inside a closed surface, such as a spherical shell, the total gravitational field passing through that

surface is zero. This means that the mass contained within the shell will not exert any gravitational attraction on itself. Furthermore, the theorem of the spherical shell asserts that all the mass of a homogeneous spherical shell acts as if it were concentrated at its geometric centre. Additionally, if a test mass " m " is located within the spherical shell, i.e., at a distance " r " from the centre of the sphere equal to its radius " R ", which mean that $r = R$, then the net gravitational force due to the spherical shell on the test mass " m " will be zero. In other words, a uniformly distributed mass in a spherical shell does not exert a net gravitational attraction on itself.

Extending these theorems to the 4D universe and considering the 3D universe as a hyperspherical shell of matter of the 4D universe, it is possible to conclude that **all the mass in the 3D universe**, not exerting gravity on itself, **cannot slow down the expansion of the 4D universe**. However, a local inhomogeneity in mass density in the 3D part of the 4D universe has led to the aggregation of masses into stellar, galactic, and cluster structures.

This paper marks represent the first part of a new cosmological theory—**The Theory of the Four-dimensional Electromagnetic Universe**. It is founded on the concept of a truly 4D universe and the existence of a privileged reference frame centered in the Big Bang event. Based on three additional postulates, the second part of this new theory attempts to explain the primary cause of the 4D universe expansion, that is what really could be the dark energy (Work in progress).

Summarising:

- a) In the 4D universe there are only EMWs that move at a spacetime speed (v_{ST}) between c and $c\sqrt{2}$. The vector \vec{v}_{ST} consists of a temporal component having a constant magnitude equal to " c " and a spatial one with magnitude $\leq c$.
- b) The temporal component of the spatiotemporal energy appears as mass in 3D part of 4D universe, where we live.
- c) The wave-like behaviour of what we observe as EMWs in the 3D part of the 4D universe, is due to their spatial component which accounts for half of their overall energy.
- d) The particle-like behaviour of what we observe as EMWs in the 3D part of the 4D universe, is attributed to their temporal component which corresponds to the remaining half of their total spatiotemporal energy. It is important to note that this mass is not a rest mass since photons/ EMWs are always in motion through the 3D space at speed " c ".

- e) Another consequence of the two postulates and corollaries stated here is that, like mass, acceleration and the associated fields, as well as the physical quantities derived from it (such as force and work), exist only in the 3D part of the 4D universe. Therefore, the 3D universe can be considered as a mass hyperspherical shell of the 4D universe which, not exerting gravity on itself, cannot decelerate the expansion of the 4D universe.

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