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Tachyons and *i*ions in Theoretical Particle Physics

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Abstract *Super-luminous* particles, such as the Tachyon, should be seen as a possibility for further advancement of our understanding of how the universe or even the Multiverse functions. Due to the particle's imaginary mass and the lack of detection, Tachyons have been identified as a 'hypothetical' or 'exotic' particle. This classification is not based upon their Quantum Spin. This new class of particle, "imaginary ions" or "*i*ions", consists of all particles associated with a imaginary Quantum Spin, such as the Tachyon and its corresponding anti-particle. This document will discuss and break down the classification of Tachyons as well as the numerous components of these magnificent particles while also traveling down into the rabbit hole of the quantum mechanical universe to the exotic branches of the physical realm.

Keywords: *exotic physics, tachyons, quantum spin,* iions, *epistemological concepts*

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1. Introduction to *i*ions

Tachyons[1] and other particles that are noted to have a imaginary mass fall under the *i*ion category, this implies that each particle within this group have a imaginary quantum spin. Since the spin of a particle is dependent on the mass of the particle, similar to how the angular momentum is dependent on the mass in classical mechanics, the presence of *i* is known.

From analyzing the pattern of mass and velocity of different particles, it can be said that particles with an imaginary mass can travel at *super-luminous* velocities, similar to how massless particles travel at the speed of light. Therefore it can be noted that '*i*ions' should be an independent classification of particles, rather than be lumped together with exotic or hypothetical particles.

The word "ion" refers to a charged particle whether the charge is positive or negative. The reason for the term "ion" in this scenario is simply because they have a charge, they might not have a conventional charge, but they still have one, *i*ions have a imaginary charge, an imaginary mass and even a imaginary quantum spin. With so much complexity it is a given to why the full classification of these types of particles should be "imaginary ions".

1.1. Quantum Spin

The 'spin' of a particle, such as a Electron or Proton, is described as the representation of total angular momentum all the way down to the sub-atomic level. It is the most common way to classify particles into categories. For example, Fermions, such as all six Quarks, have a half integer spin like $\frac{1}{2}$ and $\frac{3}{2}$, while Bosons, such as Photons and Gluons, have full integer spins like 0 and 1. Most particles have either a full or half integer spin, but because of the exotic nature of a *i*ion, neither type applies. Instead a new type of spin matrix will be calculated to accommodate for the complexity of *i*ions.

1.1.1. Spin Vectors

All particles contain spin vectors that are associated with their quantum spin number, this determines a lot of different attributes of the particle. Each vector on each of the axes has either a positive or negative aspect, the 'right', 'up', and 'in' are all positive aspects of their own respective axes, while 'left', 'down', and 'out' are the opposite aspects of their respective axes, The x-axis spin vectors are 'left' $\left(\left|x;-\right\rangle\right)$ and 'right' $\left(\left|x;+\right\rangle\right)$, the y-axis spin vectors[2] are 'up' $\left(\left|y;+\right\rangle\right)$ and 'down' $\left(\left|y;-\right\rangle\right)$, and the z-axis vectors are 'in' $\left(\left|z;+\right\rangle\right)$ and 'out' $\left(\left|z;-\right\rangle\right)$. Each one of these vectors are expressed with an equation. [1]

$$\left|x;+\right\rangle = \left|r\right\rangle = \frac{1}{\sqrt{2}}\left|z;+\right\rangle + \frac{1}{\sqrt{2}}\left|z;-\right\rangle \quad (1)$$

$$\left|x;-\right\rangle = \left|l\right\rangle = \frac{1}{\sqrt{2}}\left|z;+\right\rangle - \frac{1}{\sqrt{2}}\left|z;-\right\rangle \quad (2)$$

$$\left|y;+\right\rangle = \left|u\right\rangle = \frac{1}{\sqrt{2}}\left|z;+\right\rangle + \frac{i}{\sqrt{2}}\left|z;-\right\rangle \quad (3)$$

$$\left|y;-\right\rangle = \left|d\right\rangle = \frac{1}{\sqrt{2}}\left|z;+\right\rangle - \frac{i}{\sqrt{2}}\left|z;-\right\rangle \quad (4)$$

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[1] The word "Tachyon' originates from the Greek word ταχύ□& (tachýs) meaning rapid or swift.

[2] Note: the *i* present in the y-axis spin vectors are not spin vectors themselves they are $\sqrt{-1}$

$$|z;+\rangle = |i\rangle = \frac{1}{\sqrt{2}}|x;+\rangle + \frac{1}{\sqrt{2}}|x;-\rangle \quad (5)$$

$$|z;-\rangle = |o\rangle = \frac{1}{\sqrt{2}}|x;+\rangle - \frac{1}{\sqrt{2}}|x;-\rangle. \quad (6)$$

The two vectors that are specific to *i*ions are:

$$|i;+\rangle = |f\rangle = \frac{i}{\sqrt{2}}|y;+\rangle + \frac{i}{\sqrt{2}}|y;-\rangle \quad (7)$$

$$|i;-\rangle = |p\rangle = \frac{i}{\sqrt{2}}|y;+\rangle - \frac{i}{\sqrt{2}}|y;-\rangle. \quad (8)$$

The 'past', $|i;-\rangle$, and 'future', $|i;+\rangle$, spin vectors represent the fourth dimensional component, of a imaginary ion. This axis can be thought of more of an imaginary, *i*, axis, since it can not be physically represented without context[3]. The pattern of mathematical charge is also applied in this pair of vectors, with 'future' symbolizing positive and 'past' symbolizing the negative.

Of the generic six spin vectors, the only vectors that can be applied to these particular particles is the 'past' and 'future' vectors. This is because *i*ions can only exist on the *i*-axis rather than any of the three spatial axes.

1.1.2. Spin Matrices

Spin matrices are the final step to classifying a particle, via spin. There are differences and similarities between different particles' spin matrices and the particles themselves. An example of a difference would include the size of the spin matrix, for a Fermion with a $\frac{1}{2}$ quantum spin value, the size of each of the matrices are 2 x 2 but for a Boson with a spin of 1 the size of the matrices are 3 x 3. A common similarity is that for each `real' particle there are three separate spin matrices for each of the three axes.

Unfortunately, *i*ions have it a little differently. Due to the nature of the velocity of a *i*ion, the values of the x, y, and z axes make no difference at all. That is the reason for the *i*-axis, and with this axis there is a matrix to go with both the positive and the negative aspects.

$$S_{|i;+\rangle} = \frac{\hbar i}{\sqrt{2}}\begin{pmatrix} i & 0 \end{pmatrix} \quad (9)$$

$$S_{|i;-\rangle} = \frac{\hbar i}{\sqrt{2}}\begin{pmatrix} 0 & i \end{pmatrix}. \quad (10)$$

One of the major differences between these types of matrices and the matrices for non-complex particles, other than the massive amount of complexity present, is the number of matrices that are used to describe them. As discussed previously, the three spatial axes are irrelevant to these particles so only one is needed for the *i*-axis. These matrices can also describe all *i*ions by determining if the corresponding vector is either positive or negative. The anti-particle counterpart of a Tachyon would be classified as a *i*ion but would have a positively based spin vector and in turn it would be associated with a positively based spin matrix.

[3] Now this does not mean that either vector relates to time itself, it is more of an extra-dimensional approach to the nomenclature of the vectors.

2. Tachyons

Tachyons are hypothetical particles that can travel at *super-luminous* speeds. One of the fundamental features of a Tachyon is that as the particle's energy decreases the velocity increases, this will also be discussed in a later section.

One of the most significant features of this particle is the quantum spin, as described in the previous section the Tachyon has a spin of *i*, this is different, to say the least, compared to 'normal' particles.

Another one of the specifications are its mass, which is very unique. Its mass is the square root of negative one, $\sqrt{-1}$. This raises the question, how can a particle contain a imaginary mass?

2.1. Velocity - Energy Relations

The concept of Tachyons seem to defy the basic logic in regards to the relationship between velocity and energy. For example, as a Tachyon loses its energy, its velocity literary skyrockets to infinity. But when the energy increases, the velocity decreases down towards its minimum velocity, the speed of light. The equation [2] used for this is,

$$E = \frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}. \quad (11)$$

Mathematically, once a Tachyon has reached a energy level of zero, the velocity becomes infinite. The significance of this relation is that almost all particles, Fermions and Bosons alike, experience a linear relationship with their velocity and energy. This is where, as a particle gains energy, it gains velocity.

2.2.1. Lorentz Contraction

The Lorentz - Fitzgerald Contraction is the "reduction in the observed length of an object moving in that direction with high velocity relative to the value" of initial length "that is obtained when the object is at rest in the observer's frame of reference". [3]

The equation used for such a concept is,

$$l = l_0\sqrt{\left(1-\frac{v^2}{c^2}\right)}. \quad (12)$$

This concept is relevant due to the nature of Tachyons, specifically their extremely high velocity, and it also shows just how significant the difference in optical length is between light-speed particles and faster-thanlight speed particles. To demonstrate this, the substitution of the velocity component of the equation to the speed of light. So it reads:

$$0 = l_0\sqrt{\left(1-\frac{c^2}{c^2}\right)}. \quad (13)$$

This means that there is no reduction in optical length, for the square-root of zero is, well zero. But for the maximum reduction of a *i*ion, the velocity component needs to be infinity. Now the original equation reads:

$$\infty = l_0 \sqrt{\left(1 - \frac{\infty^2}{c^2}\right)}. \quad (14)$$

In this instance, the reduction is complete, to where it is entirely unseen by everything and everyone. This might also help in explaining the widely accepted theory of Tachyons traveling against the gradient of time.

2.2. Energy States

Energy states can be best described using the Electron as an example, a Electron energy state is distinguished by the different layers of the Electron cloud, the higher an Electron is in the Cloud, the higher the energy state is and therefore the more energy an Electron has. An Electron has three main energy states [1]: a vacuum state $|0\rangle$, a ground state $|k\rangle$, and a excited state $|\Psi\rangle$. The vacuum state being the lowest and the excited state being the highest. This concept of energy states can also be applied to Tachyons and *i*ions in general. Now a faster-than-light particle has two essential states of being based on velocity, light-based and FTL[4]-based. This can transition into two energy states, one where the particle is traveling at light speed $|\tau_\Psi\rangle$, and another for when it breaks the light barrier $|\tau_k\rangle$. The concept of ground and excited states are still existent, but there is a minor difference. The energy value is lower past the light barrier, while the highest energy value is at the speed of light.

3. Particle Emission

The probability of such a event occurring is $\frac{1}{\infty}$, but when a Tachyon does emit from the chaos, it exists at all times before the initial point of origin, given by the fourth spin vector pair. As mentioned before, particles that exhibit an imaginary mass are subject to an unprecedented instability within both Standard Model (SM) and Super-symmetry (SUSY). On the contrary to that belief, this imaginary mass originate from a plausible source.

As shown, scalar fields such as the Higgs Field, carry an imaginary masses, this intertwined with both the Gravitational and Electromagnetic force carriers, could raise the possibility that Tachyons play a larger role in the universe.

The Axion particle that leaves the process as the Tachyon forms is due to the interaction between Gravitons and Photons present. Axions are one of the rare scalar particles that interact with both of these components. The scalar component is important because it releases the ‘real’ scalar part of the field, while the ‘complex’ part moves on to become the mass and charge of the Tachyon.

[4] “FTL” is the acronym for Faster Than Light

3.1. Conservation of Mass and Charge

On the several parameters in regards to Feynman Diagrams, on of the most important is that both mass and charge, among other things, need to be conserved. This is so that the physical laws are preserved. For example, an object cannot be spontaneously created, the matter that makes the object must come from somewhere.

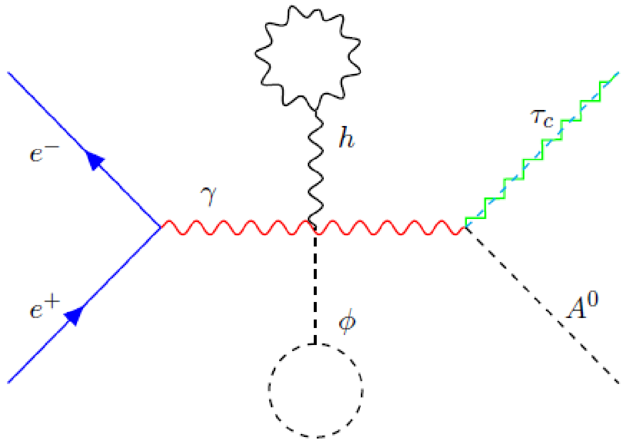

Figure 1. A particle scattering diagram, that describes Tachyons in the terms of the product of different particles interacting. These particles include an Electron and Positron, a Photon, γ, a Graviton with its respective field, h [4], a scalar field, φ an Axion, A^0, and finally the Tachyon, which is denoted as τ_c.

This can be demonstrated in Figure 1, by noting that Photons and Gravitons are both virtually massless and charge-less, therefore the excess particle has to be without mass or charge, and on top of that, the particle needs to interact with both of these force carriers. With this, the list for possible candidates has been significantly reduced to either Axions or Axionlike particles.

An Axion can be defined as a “so-called pseudo-Goldstone Boson, a particle proposed to explain the lack of violation of CP-symmetry...”, CP represents Charge-Parity, which is a quantum number with the value of either 1 or -1, but the symmetry of the quantum number is broken when weak nuclear force is being applied, “...in certain string interactions predicted by quantum chromodynamics and also required by string theory.” [3] it also goes on to state that “The Axion would have no charge and a tiny mass (little more than $1\mu eV/c^2$).” This statement follows the previously mentioned conserved process.

The other conserved process is towards the Tachyon itself. The mass and charge are both of a complex nature, in that they are imaginary values but also because they are very complicated concepts. These values originate from the scalar field that is fused with both the Photon and Graviton vector paths. A scalar field contains both a complex mass and charge.

3.2. Scalar Field Interactions

One of the main factors of the Tachyon emission model proposed above is the interaction with a scalar field, as seen in Figure 1. To put it simply a scalar field is a field that only has a scalar value, where it has a magnitude whether it is charge or mass, but these types of fields do not have a direction that corresponds with that magnitude, unlike gravitational fields where there is a magnitude as well as a direction. The scalar field contains both the favorable mass value and charge value that is necessary for the formation of a Tachyon. Although due to the nature of gravity in relation with both mass and energy, both of these variables from the scalar field assimilate with the newly formed Tachyon, this assimilation produces a Axion or Axion-like particle. In the last phase of emission, the mass and charge of the new particle become *i*, from the scalar field and the particle begins to show its true complexity in both a mathematical and physical sense.

4. Particle Symmetry

In order to preserve the "universe's way of life" every particle must have a antiparticle so that there is a constant balance. Every positive has a negative, every electron have a positron, and so on. This symmetry can be present with regards to Tachyons, as it was briey mentioned in a above section the spin matrices also reect this concept on all four axes, so this raises the question of, what is the nature of a polar opposite of a Tachyon? The thought of this is actually quite intriguing, reason being is that since a Tachyon is positively based *i*ion and its velocity is faster than light, would the anti-Tachyon be something of equal absurdity, perhaps even "Slower-than-Zero"? Although this is seemingly impossible, it is the physical barrier that is the polar opposite of FTL, it is also the physical equivalent to the negative half of the *i*-axis. Another interesting fact that can relate the topic of seemingly impossible velocities would be, how it is said that if an object were to travel as the speed of light the object in question would be in a state at which time has apparently stopped, and, as discussed above, an object that travels faster than light can be in a state at which time is owing backwards. Using this logic and the knowledge of the physical barriers of velocity, one can question if it is possible to have such as particle that can travel at STZ[5] velocities.

5. Conclusion

All in all, the Tachyon as well as its class of *i*ions are among the most dificult particles in the quantum soup to understand. From its velocity trend to its spin matrix, every aspect of *i*ions are of an entirely new level of complexity. Tachyons, and any other particle with similar complexity, should be classified by their respective spin matrices just as every other particle is. Unfortunately, Tachyons are labeled under terms such as hypothetical and exotic, which is entirely understandable, but there is a more accurate title to give these types of particles and that is "imaginary ions", or *i*ions.

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[5] "STZ" is the acronym for Slower than Zero.