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CHIRAL FIELD IDEAS FOR A THEORY OF MATTER

IDEAS DE CAMPO QUIRAL PARA UNA TEORÍA DE LA MATERIA

H. Torres-Silva[1]

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RESUMEN

En este trabajo, para el desarrollo de una teoría unificada de campos electromagnéticos y gravitacionales se usa un método quiral. Los fotones que satisfacen las ecuaciones de Maxwell, para una onda electromagnética se consideran como componentes físicos básicos. El objetivo de esta teoría es unificar el fenómeno de la invarianza relativística, mecánica de onda y la creación del par electrón positrón, con las ecuaciones de Maxwell, para obtener una teoría de la materia totalmente electromagnética. Considerando esta teoría se discuten algunos aspectos de los sistemas GPS (Global Positioning Systems).

Palabras clave: Potencial quiral, teoría de la materia, onda-partícula.

ABSTRACT

In this paper, a chiral approach is used for developing a unified theory of electromagnetic and gravity fields. The photons which satisfy Maxwell's equations for an electromagnetic wave are taken as the basic physical components. The goal of the theory is to unify the phenomena of relativistic invariance, wave mechanics and pair creation with Maxwell's equation to obtain an electromagnetic field theory of matter. With this theory some aspects of GPS (Global Positioning Systems) systems are discussed.

Keywords: Chiral potential, matter theory, wave-particle.

INTRODUCTION

A chiral approach is suggested for developing a unified theory of electromagnetic and gravity fields. Photons which satisfy Maxwell's equations for an electromagnetic wave are taken as the basic physical component. The extent of the photon in its direction of travel permits a part of the photon to modify the geodetic of another part.

A photon with a self disturbed orbit, for which a centroid can be defined, has the key property by which matter differs from light. Matter has a speed which is less than that of light. The centroid of the orbit has a speed which is less than the speed of the photon which travels with the speed of light. We refer to this chiral approach as the electromagnetic field theory of matter.

Chiral approach means that our Universe is observable area of basic space-time where temporal coordinate is positive and all particles bear positive masses (energies). The mirror Universe is an area of the basic space-time, where from viewpoint of regular observer temporal coordinate is negative and all particles bear negative masses. Also, from viewpoint of our-world observer the mirror Universe is a world with reverse flow of time, where particles travel from future into past in respect to us. The two worlds are separated with the membrane - an area of space-time inhabited by light-like particles that travel along light-like right or left-handed (isotropic-chiral) spirals.

The goal of the theory is to unify the phenomena of relativistic invariance, wave mechanics and pair creation with Maxwell's equation for electromagnetic waves. Section 2 enumerates advantages of an electromagnetic field theory of matter. Section 3 considers how the de Broglie relation and the Schrodinger equation might be derived from Maxwell's wave equation. Section 4 treats the relation between electromagnetic and inertial energy. Section 5 comments on parity failure in weak interactions. Appendix A derives an application on GPS satellites using chiral potential.

1 Instituto de Alta Investigación. Universidad de Tarapacá. Antofagasta Nº 1520. Arica, Chile. E-mail: htorres@uta.cl

ADVANTAGES OF AN ELECTROMAGNETIC FIELD THEORY OF MATTER

An electromagnetic field theory should not be confused with an electric charge theory of matter which is not relativistically invariant [1]. An electromagnetic field, however, is relativistically invariant from the start.

One simplicity is that special relativity is not a separate hypothesis. The Lorentz contraction of electromagnetic fields was realised before special relativity. If matter is composed only of electromagnetic fields then matter is automatically Lorentz invariant. In particular, matter cannot exceed the speed of light.

Another area of simplicity is pair creation where two electromagnetic fields (photons) produce an electron and a positron. If the particles are electromagnetic fields, then pair creation is like the transformation of electromagnetic field from one state of motion to another. We suggest since masses are unique that this should be thought of as the construction of a quantized state of the EM wave (i.e. standing wave a de Broglie type phase relation) [2]. The distinction between matter and antimatter would then be sought as a natural law of conservation of a property inherent in the separate initial photon and divided between the particles. Such a difference is inherent the photon polarization. For example, the photons can have right- and left-handedness.

It should be further noted that a fast electron is like an EM wave having a transverse EM field with equal electric magnetic field energies. Also the momentum of fast particles, like EM waves, is the energy divided by c.

The uncertainty principle of quantum mechanics would also be more consistent with an electromagnetic theory of matter. That is, particles which have an inherent wave nature would be expected and not a surprise. Also, quantized absorption of EM energy would not be viewed as a charge accelerated by an electric field but a merging of two EM waves. The merged EM fields would have the required frequency and wavelength to be the quantized wave of the electron in the final state.

The appearance of the fine structure constant, $\alpha = e^2/hc$, in the ratio of the masses of fundamental particles would be expected and not a coincidence as in the ratio of the mass of the π meson and the electron.

The development of an EM field theory of matter requires the accomplishment of at least two objectives, namely (i) predict the Coulomb force between electron and positron (etc.), and (ii) derive the Schrodinger equation from Maxwell's equation for an electromagnetic wave. We suggest approaches to these objectives in the next sections.

DERIVATION OF THE PARTICLE WAVELENGTH FROM CHIRAL POTENTIAL WAVES

We start with the potential vector equation.

Assuming $e^{j\omega t}$ time dependence, Maxwell's time-harmonic equations [2] for isotropic, homogeneous, linear media (without charges) are

$$\nabla \times \boldsymbol{E} = -j\omega_0 \boldsymbol{B} \tag{1}$$

$$\nabla \times \boldsymbol{H} = j\omega_0 \boldsymbol{D} \tag{2}$$

$$\nabla \bullet \boldsymbol{B} = 0 \tag{3}$$

$$\nabla \bullet \boldsymbol{D} = 0 \tag{4}$$

Chirality is introduced into the theory by defining the following constitutive relations to describe the isotropic chiral medium [3]

$$\boldsymbol{D} = \varepsilon \boldsymbol{E} + \varepsilon T \nabla \times \boldsymbol{E} \tag{5}$$

$$\boldsymbol{B} = \mu \boldsymbol{H} + \mu \nabla \times \boldsymbol{H} \tag{6}$$

Where the chirality factor indicates the degree of chirality of the medium, and the ε y μ are permittivity and permeability of the chiral medium, respectively. Since $\boldsymbol{D}$ and $\boldsymbol{E}$ are polar vectors and $\boldsymbol{B}$ and $\boldsymbol{H}$ are axial vectors, it follows that ε and μ are true scalars and T is a pseudo scalar factor. This means that when the axes of a right-handed Cartesian coordinate system are reversed to form a left-handed Cartesian coordinate system, T changes in sign whereas ε and μ remain unchanged.

Since ∇•B = 0 always, this conditions will hold identically if $\boldsymbol{B}$ is expressed as the curl of a vector potential $\boldsymbol{A}$ since the divergence of the curl of a vector is identically zero. Thus

$$\boldsymbol{B} = \nabla \times \boldsymbol{A} \tag{7}$$

And $\boldsymbol{A}$ must be perpendicular to both ∇ and $\boldsymbol{B}$ and lie in ∇ and ∇ x $\boldsymbol{B}$ plane. However, $\boldsymbol{A}$ is not unique since only its components perpendicular to ∇ contribute to the cross product. Therefore, ∇ • $\boldsymbol{A}$, the component of

$\boldsymbol{A}$ parallel to ∇, must be specified. The curl equation for $\boldsymbol{E}$, as in Equation, and Equation give ∇ x $(E + j\omega\boldsymbol{A}) = 0$ where the quantity in parentheses should be parallel to ∇ and the curl of the gradient of a scalar function ϕ is identically zero; so the general integral of the above equation is

$$\boldsymbol{E} + j\omega_0 \boldsymbol{A} = -\nabla\phi \tag{8}$$

Substituting Equation into Equation we obtain

$$\nabla\times\boldsymbol{A} = \mu\boldsymbol{H} + \mu T\nabla\times\boldsymbol{H} = \boldsymbol{B} \tag{9}$$

Substituting Equation and Equation into Equation gives

$$\nabla\times\nabla\times\boldsymbol{A} + j\frac{\omega_0\mu\varepsilon T}{1-k_o^2T^2}\nabla\times\boldsymbol{E} = j\frac{\omega_0\mu\varepsilon}{1-k_o^2T^2}\boldsymbol{E} - \frac{\omega_0{}^2\mu\varepsilon T}{1-k_o^2T^2}\boldsymbol{B},$$

with $k_0T = \omega_0 T/c$. Placing the value of ∇x$\boldsymbol{E}$ from equation into the above equation, using the vector identity ∇ x ∇ x $\boldsymbol{A}$ = ∇ (∇ • $\boldsymbol{A}$) – $\nabla^2\boldsymbol{A}$ and equation (8) enables us to write the above equation as

$$\nabla^2\boldsymbol{A} + \frac{k_0^2}{1-k_0^2T^2}\boldsymbol{A} + 2\frac{\omega_0^2\mu\varepsilon T}{1-k_0^2T^2}(\nabla\times\boldsymbol{A}) = \nabla\left(\nabla\bullet\boldsymbol{A} - j\frac{\omega_0^2\mu\varepsilon T\phi}{1-k_0^2T^2}\right) \tag{10}$$

Here ∇ • $\boldsymbol{A}$ is arbitrary, so in order to specify ∇ • $\boldsymbol{A}$, for unique $\boldsymbol{A}$, we may define a chiral Lorentz gauge

$$\nabla\bullet\boldsymbol{A} = j\frac{\omega_0\mu\varepsilon\phi}{1-k_0^2T^2} \tag{11}$$

And eliminate the term in parentheses. Then Equation will be simplified to

$$\nabla^2\boldsymbol{A} + \frac{k_0^2}{1-k_0^2T^2}\boldsymbol{A} + 2\frac{\omega_0^2\mu\varepsilon T}{1-k_o^2T^2}(\nabla\times\boldsymbol{A}) = 0 \tag{12}$$

The solution of the potential vector equation can be solved as follows:

Let

$$\nabla\times\boldsymbol{A} = \begin{pmatrix} \hat{x} & \hat{y} & \hat{z} \\ ik_x & 0 & ik_z \\ A_x & A_y & A_z \end{pmatrix}$$

$$= \hat{x}(-ik\cos\theta A_y) - - \hat{y}(ik\sin\theta A_z - ik\cos\theta A_x) + \hat{z}(ik\sin\theta A_y) \tag{13}$$

so equation (12) is expressed as

$$\begin{pmatrix} -k^2(1-k_0^2T^2)+k_0^2 & -2ik_0^2kT\cos\theta & 0 \\ 2ik_0^2kT\cos\theta & -k^2(1-k_0^2T^2)+k_0^2 & -2ik_0^2kT\cos\theta \\ 0 & 2ik_0^2kT\sin\theta & -k^2(1-k_0^2T^2)+k_0^2 \end{pmatrix}\begin{pmatrix} A_x \\ A_y \\ A_z \end{pmatrix} = 0$$

The solution of the determinant is

$$k^2(1-k_0^2T^2) = k_0^2 = \omega_0^2/c^2 \Rightarrow k = \pm k_0/\sqrt{1-k_0^2T^2} \tag{14}$$

for the longitudinal field, and

$$\left\{-k^2(1-k_0^2T^2)+k_0^2\right\}^2 - 4k_0^2T^2(\sin^2\theta+\cos^2\theta) = 0$$
$$\Rightarrow k = k_0/(1\pm k_0T) \tag{15}$$

for the transverse fields.

Our approach to deriving the Schrodinger equation from Maxwell's equation starts with the assumption that an electron is an electromagnetic ware travelling in a circular orbit in the observer's rest frame. We suggest that the orbit is a geodetic in a space-time curved by the photon's own electromagnetic energy.

We note that the model of the self- trapped wave must look like an electron to observers in all inertial frames. The observer at rest only sees the static Coulomb field. The moving observer, with speed u, sees (i) some magnetic field from the current associated with the charged particle, and (ii) (the wave-motion of the particle with a wave-length $\lambda_m = h/mu$. For the observer whose speed relative to the circulating photon approaches the velocity of light, the photon appears as a photon. This is appropriate since the electric and magnetic fields of a fast electron become transverse as its speed approaches c.

From equation (14), where $k = \pm k_0/\sqrt{1-k_0^2T^2}$, if we make $k = \omega/c$, $k_0T = \omega_0 T/c \equiv u/c$ then particle momentum is consistent with the photon model. The observer with speed u in the usual theory of special relativity notes that the electron has energy [3].

$$E = \frac{m_0 c^2}{\sqrt{1-\beta^2}} \tag{16}$$

where $\beta = u/c = \omega_0 T/c$, and momentum

$$p = \frac{m_0 u}{\sqrt{1-\beta^2}} \tag{17}$$

From equations (16) and (17) as v approaches c and the rest mass becomes a small part of the energy

$$p \approx E / c \tag{18}$$

In special relativity the frequency transforms as the energy and this is the correct expression for the momentum of a photon. The momentum of a photon in the rest frame is effectively zero because the geodetic closes on itself.

We will try to illustrate how the photon frequency can lead to the appropriate particle wavelength for all inertial observers. For the observer at rest with respect to the circulating photon. The field appears static, the period is infinite, the frequency is zero, and the wavelength infinite. At high speed we will show that the photon's wavelength in the observer's frame is consistent with the quantum mechanical expression for the corresponding particle. We relate the photon energy $h\nu_0$ to the rest mass of the electron m_0 using the special relativity relation $E=mc^2$, by.

$$h\nu_0 = m_0 c^2 = \hbar\omega_0 \tag{19}$$

and inverting equation (19)

$$h / m_0 c = c / \nu = \lambda_0 \tag{20}$$

In the limit of $u \to c$ the matter wavelength is the wavelength associated with the photon reduced by the usual special relativity Lorentz contraction factor $\sqrt{1-\beta^2}$.

Then using equations (20), (19) and (16) in order we obtain

$$\lambda_m = \lambda_0 \sqrt{1-\beta^2} = c / \nu_0 \sqrt{1-\beta^2} = \frac{hc}{mc^2} = \frac{hc}{E} \tag{21}$$

This result is the same as obtained from the theory of the electron for v - c using Equation (17)

$$\lambda_m = \frac{h}{p} = \frac{hc^2}{E\nu} \approx \frac{hc}{E} \tag{22}$$

More generally, for any value of u from equations (19) and (21)

$$p = \frac{h\nu u}{c^2} \tag{23}$$

where $h\nu = E = mc^2 = m_0 c^2 / \sqrt{1-\beta^2}$. Defining a wavelength related to the particle

$$\lambda_m = \frac{h}{p} = \frac{c^2}{u\nu} = \lambda \frac{c}{u} = \lambda_0 \frac{c}{u}\sqrt{1-\beta^2} \tag{24}$$

In terms of frequencies from equation (24)

$$\nu_m = \nu \frac{u}{c} \tag{25}$$

We interpret this result as follows. The electron has intrinsically the frequency of its parent photon. The observer going by at the speed of light sees the circulating wave stretched out to its limit and associates the full frequency, ν, with the particle frequency.

The observer moving more slowly passes the nodes in the EM wave more slowly and interprets this as a lower frequency, $\nu_m < \nu$. The observer at rest sees no change and concludes $\nu_m = 0$. These frequencies are consistent with the de Broglie wavelength for matter.

The Schrodinger equation describes the wave motion of the centroid of a photon which is a solution of Maxwell's wave equations in a distorted space time.

A word is in order about the problem of interference patterns of scattered electrons such as produced by the diffraction by two slits in a barrier. Margenau [4] considers the difficulties of this problem. He concludes that there are no known interactions that can explain how an electron can go through one slit and be appropriately scattered by the other.

An electromagnetic field which acts like a particle, may possible avoid this dilemma by either (i) the electric and magnetic field goings partly through each slit, or (ii) having a scattering which differs from known interactions because of the fluctuating EM field properties of the electron such as in our photon model. We think that the second possibility is the correct explanation.

RELATION BETWEEN ELECTROMAGNETIC AND INERTIAL ENERGY

In this section we relate the photon electromagnetic and the elementary charge electric field energies with the inertial and gravitational energies.

When an electron positron pair is created we distinguish two changes in energy: (i) the electromagnetic field energy of the photons is transformed into the electric field of the pair, and (ii) the transformed photon which we recognise as a particle has inertia with respect to the cosmology. By special relativity the inertial energy per unit mass is c^2. The inertial mass relates to the electrical energy of the charge by $m^2 = e^2/r$. Now a more detailed discussion of the effect of the cosmology on inertia and the gravitational red shift are required to clarify the distinctions between the four types of energy.

We assume, following E Mach, that the inertia depends on the cosmology. That is, we take inertial energy equal to the negative of the cosmological gravitational potential. From general relativity, then, we assume

$$mc^2 - \frac{m2MG}{R} = 0 \Leftrightarrow k_0^2 T^2 = \frac{u^2}{c^2} \qquad (26)$$

where M is the total mass of the universe (~10^{56} *gm*), R is the radius of the universe (~10^{28} *cm*) and G is the gravitational constant (0,67*x*10-8 *dynecm*^{2}/*gm*^{2}) [5-7].

Consequently, in pair creation, the inertial energy gained is cancelled exactly by the loss of gravitational potential energy. We note that equation (11) is independent of m.

We have assumed c^2 to be invariant and hence the gravitational potential energy per unit mass must also be independent of location in the cosmology. This is consistent with the assumption that every location in the cosmology senses the expansion of the cosmology in the same way and that there is no distinguished location in the cosmology.

The next important hypothesis is that the photon energy does not change as it moves through the cosmology. This concept must be distinguished from the dependence of frequency on the local gravitational potential. We use a subscript i to correspond to initial value, i.e. hv_i is the photon energy when it is emitted by an atom or produced as a result of pair annihilation. Now *hv*; depends on the gravitational potential at the location where it is emitted since for atomic radiation $hv_i \alpha e^4 m_i / h^2$ and for pair radiation $hv_i = m_i c^2$. In this way we see that $hv_i \alpha m_i$, and both depend in the same way on the gravitational potential. This is consistent with general relativity [7]. In particular it agrees with the gravitational red shift. For example, a photon radiated from the sun has energy $hv_s \alpha m_s$, and the corresponding atom on the earth has the transition energy $hv_e \alpha m_e$; v_s is to the red of v_e as given by general relativity because the masses are related by

$$m_e = m_s \sqrt{1 - \frac{2\Delta\phi}{c^2}} \qquad (27)$$

where $\Delta\phi$. is the difference in the gravitational potential energy per unit mass.

Thus the photon energy hv_s has not changed energy during its travel from sun to earth.

This is the justification for the assumption that the photon energy does not change as it moves through the cosmology.

We now return to the relation between the electrical energy and inertial energy and compare both with the photon energy. The subscripts relating to location in the gravity field are retained

$$h\nu_i = m_i c^2 = e^2 / r_i \qquad (28)$$

and we must subscript the particle radius for consistency. Thus photons which are produced by annihilation can only receate the correct amount of energy where the gravitational potential is the same as at point of origin. The problem can be solved by special relativity. There are four energies with significant differences. A photon can be transformed into an electron and both photon and electron have equal and positive energy. The photon energy does not change as it traverses the cosmology. The particle energy depends on the local cosmological metric. No net gravitational energy is produced by the creation of the particle since the gain of inertial energy is just cancelled by the loss in gravitational energy.

As a particle traverses space the inertial energy is always equal to the electrical energy of the particle and the inertial energy is always cancelled by the gravity energy.

PARITY

The photon model of the electron has a natural explanation of the failure of reflection symmetry (parity) in weal interactions. Wigner [8] has given a phenomenological discussion of the implication of the $C_0\beta$ decay experiment in which the spin of the β is determined to be opposite to its momentum. He points that the mirror image of an electron is a positron.

We invoke the polarization of the photons the electron positron pair. We assume that one particle has right-handed polarization photon and the other a left- handed one. Thus, the particles are mirror images as required. In fact, it is the difference in handedness which distinguishes two charge states.

APPENDIX A: RELATIVISTIC EFFECTS ON CLOCKS ABOARD GPS SATELLITES

Consider a clock aboard a satellite orbiting the Earth, such as a Global Positioning System (GPS) transmitter. There are two major relativistic influences upon its rate of timekeeping: a special relativistic correction for its orbital speed and a general relativistic correction for its orbital altitude. Both of these effects can be treated at an introductory level, making for an appealing application of relativity to everyday life.

First, as observed by an earthbound receiver, the transmitting clock is subject to time dilation due to its orbital speed. From our results of chiral potential, (14), a clock aboard a spaceship traveling at speed u runs slow (compared to a stationary clock) by a factor of [9]

$$\frac{1}{\gamma} = \sqrt{1-\frac{u^2}{c^2}} = \sqrt{1-\beta^2} \approx 1-\frac{u^2}{2c^2} \tag{A1}$$

provided $u << c$, as would be the case for a satellite. Thus when one second of proper time elapses, the moving clock loses $u^2/2c^2 = K/E_0$ seconds, where K and E_0 are the kinetic and rest energies of the clock, respectively. Second, a clock at the higher gravitational potential of orbit runs faster than a surface clock. The gravitational potential energy of a body of mass m in Earth's gravity is $U = mV$, where $V = -Gm_E/r$ is Earth's gravitational potential (at distance r from the center of the Earth of mass m_E). In the case of a photon, we replace m by E/c^2, where $E = hf$ is the photon's energy.

If the photon travels downward in Earth's gravitational field, it therefore loses potential energy of $(hf/c^2)\Delta V$ and gains an equal amount of kinetic energy $h\Delta f$. We thereby deduce that the falling photon is gravitationally blue-shifted by

$$\Delta f = f\,\frac{\Delta f}{c^2} \tag{A2}$$

(This expression can also be straightforwardly deduced [10] using the equivalence principle to treat Earth's downward gravitational field as an upward accelerating frame, and then calculating the Doppler shift in the light between emission high up and observation low down in this moving frame.) If the clock's ticking is synchronized to a light wave, the orbiting clock will be observed at Earth's surface to be ticking faster due to this gravitational frequency shift. Therefore, when one second of Earth time elapses, the clock at high altitude gains $\Delta V/c^2 = \Delta U/E_0$ seconds, where U is the gravitational potential energy of the clock.

The sum of the two relativistic effects can be compactly expressed as

$$\frac{\Delta t}{\tau} = \frac{K-U}{E_0} \tag{A3}$$

where Δt is the time lost by the orbiting clock when a time interval τ elapses on the surface-bound clock.

Here $K-U$ is the Lagrangian of the orbiting clock where the reference level for the gravitational potential energy is chosen to lie at Earth's surface.

As a concrete example, let's calculate the size of these two effects for a GPS satellite, located at an altitude of r = 26,580 km, about four times Earth's radius of r_E = 6380 km. From Newton's second law, we have

$$a = \frac{F}{m} \Rightarrow \frac{v^2}{r} = \frac{Gm_E}{r^2} \Rightarrow v^2 = \frac{gr_E^2}{r} \tag{A4}$$

where Earth's surface gravitational fieldis $g = Gm_E / r_E^2$ = 9.8 m/s2. Hence the fractional time loss due to the satellite's orbital speed is $-gr_E^2 / 2c^2$ per second, or –7.2 μs/day. Meanwhile, the general relativistic fractional time gain due to the satellite's altitude is

$$\frac{\Delta V}{c^2} = \frac{1}{c^2}\left[-\frac{Gm_E}{r} + \frac{Gm_E}{r_E}\right] = \frac{gr_E}{c^2}(1 - \frac{r_E}{r}) \quad \text{(A5)}$$

which works out to be +45.6 μs/day. Notice that the gravitational effect is more than six times larger than the speed effect: the dominant GPS correction is general, not special relativistic! If we instead consider satellites in progressively lower altitude orbits, their speeds will increase according to Eq. (4), while the gravitational potential difference in Eq. (5) will decrease. Eventually we will reach an altitude at which the two corrections exactly cancel, so that the satellite's clock will run synchronously with an earthbound clock [10, 11].

This occurs when

$$\frac{u^2}{2c^2} = \frac{\Delta V}{c^2} \Rightarrow \frac{gr_E^2}{2r} = gr_E(1 - \frac{r_E}{r}) \Rightarrow r = 1.5r_E \quad \text{(A6)}$$

i.e., at an altitude of half an Earth radius.

SUMMARY

An outline has been presented of an electromagnetic field theory for matter. The advantages of the theory are given in section 2. Their seemingly distinct areas of physics see unified with Maxwell's equation for EM waves. They are relativistic invariance, pair creation, and wave mechanics. Light is relativistically invariant, hence, particles made out of photon are relativistically invariant. If matter is a form of electromagnetic energy, then pair creation is a transformation from energy. If particles are made out of photons they have an intrinsic wave nature and their wave motion is expected.

In section 3 we elaborated on how the wave nature of photon, which forms an electron, leads to wave mechanics of the particle. The full frequency is approached as the velocity of the particle, relative to the observer, approaches the velocity of light.

In section 4, we gave the relation between the electromagnetic and inertial energy. No energy is added in pair creation: the electromagnetic energy is transformed between photon and particle states. The inertial energy is a property of the particle in the cosmology. The cosmological gravitational potential is the negative of the inertial energy so that these mutually cancel. Therefore, no net inertial plus gravitational energy is required for pair creation.

Section 5 pointed out that the mirror image property of the positron and electron required by the failure of parity conservation in weal interactions can be attributed to the handedness of the photon which are transformed into the electron positron pair.

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