Examination of the Electromagnetic Force and Gravity through the Composite (Couplet) Photon

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Abstract

In this paper, we examine the previously published theoretical, computational and experimental evidence behind composite photon theory, that is, that the photon is composed of an electron-positron pair. The consequences of this hypothesis are discussed and we build upon the work completed by Gauthier [23] by exploring the equivalence between mass and charge. A relationship between the Coulomb force and gravitational force is identified and a gravitational constant for strong gravity is examined. Finally, we briefly discuss the expansion of Einstein's field equations to include vector gravity

Keywords: composite photon theory, couplet-photon, electron-positron pair, negative mass, antimatter, positronium

1 Introduction

Although most of the public may assume that scientists are in agreement about how to interpret the photon, there is not as much consensus as one may think. In particular, there are still debates within the academic community on the fundamental properties of photons.

For instance, a standard claim about photons is that they are massless. In assuming the rest mass of a photon is zero, the implication is that a photon cannot be at rest. Conversely, if the mass of a photon was finite, then in principle, its mass would be measurable (although not necessarily possible with the technology of our time). The consequences of the photon having finite mass include phenomena such as: the speed of light in free space being wavelength dependent, Coulomb's law and Ampère's law having deviations, the existence of longitudinal electromagnetic waves, charged black holes, the addition of a Yukawa component to the potential of magnetic dipole fields, the existence of magnetic monopoles and gravitational deflections [42].

Experiments thus far have demonstrated with a high degree of accuracy that electromagnetic radiation, in particular, fluctuating electric and magnetic fields as well as the quanta of light (i.e., the photon), propagates in a vacuum at a constant speed, c, over a wide frequency range [42]. However, according to the uncertainty principle, if the age of the universe is approximately 10^{10} years old, then there is an upper bound limit on the possible rest mass of the photon, specifically in the order of 10^{-66} g [42]. Other more recent studies in the early 2000s suggest that the upper limit of the rest mass could actually be higher, in the order of 10^{-49} g [29], [18]. A natural question that arises from these considerations is whether or not the equations of motion would remain consistent with a non-zero photon rest mass.

Prior to the nineteenth century, the descriptions of light and radiation, electricity, and magnetism were examined separately. Then, in 1861 and 1862, the behaviour of these phenomena were unified by Maxwell's mathematical formulation. His corresponding set of coupled partial differential equations (PDEs) formed the foundation of classical electromagnetism, classical optics and electric circuits and *suggest* that the speed of all electromagnetic radiation is constant. These PDEs, i.e., Maxwell's equations are defined as

$$
\begin{aligned}
\vec{\bigtriangledown} \cdot \vec{E} &= 4\pi\rho, \\
\vec{\bigtriangledown} \cdot \vec{B} &= 0, \\
\vec{\bigtriangledown} \times \vec{E} &= -\frac{1}{c}\frac{\partial \vec{B}}{\partial t}, \\
\vec{\bigtriangledown} \times \vec{B} &= \frac{1}{c}\frac{\partial \vec{E}}{\partial t} + \frac{4\pi}{c}\vec{J},
\end{aligned}
\tag{1}
$$

where $\vec{E}$ and $\vec{B}$ denotes the electric and magnetic field vectors, respectively, ρ denoted the charge density, $\vec{J}$ is the current density, and c denotes the speed of light [27]. Maxwell's equations however are not an exact description of electromagnetic phenomena and can be more precisely described using the theory of quantum electrodynamics. Although the typical interpretation of Maxwell's equations is that they result in the photon being massless, the laws

of physics themselves do not require this assumption to hold true. With respect to the equation set (1), if the photon did have finite mass, it would be incredibly small and Maxwell's equations would have two additional terms:

$$\vec{\bigtriangledown} \cdot \vec{E} = 4\pi\rho - \left(\frac{Mc}{\hbar}\right)^2 V,$$

$$\vec{\bigtriangledown} \cdot \vec{B} = 0,$$

$$\vec{\bigtriangledown} \times \vec{E} = -\frac{1}{c}\frac{\partial \vec{B}}{\partial t},$$

$$\vec{\bigtriangledown} \times \vec{B} = \frac{1}{c}\frac{\partial \vec{E}}{\partial t} + \frac{4pi}{c}\vec{J} - \left(\frac{Mc}{\hbar}\right)^2 \vec{A}, \tag{2}$$

where $\vec{A}$ denotes the magnetic potential vector, V is the electric potential, $\hbar$ denotes Planck's constant (h) divided by 2π, and M denotes the mass of the photon [26]. The equation set (2) of PDEs is referred to as Proca's equations and were first derived in the 1930s. In Proca's equations, since the mass correction terms are in squared, the mass would have a non-zero value and might be detectable.

Then in 1932, Breit and Wheeler published [5] theoretically examining previous work done by Dirac on antimatter and pair annihilation. The physical process they described is referred to as the Breit-Wheeler effect and states that an electron-positron pair can be created when two photons collide, i.e., pure light can be transformed into matter. Finally in 2021, the Relativistic Heavy Ion Collider (RHIC) in the United States successfully completed an experiment (called the Solenoidal Tracker at RHIC (STAR) detector) validating the Breit-Wheeler effect [1]. The experiment further revealed that a traveling photon in a magnetic field in a vacuum has polarization-dependent deflections.

> "*The reason that this is so interesting is because a photon has no charge, so it shouldn't, in the classical sense, be affected by a magnetic field...That's why this is a clear proof [evidence] of these very fundamental aspects of quantum mechanics. A photon can constantly fluctuate into this electron-positron pair that does interact with the magnetic field, and that's exactly what we measured*" [21].

One interpretation the STAR experimental results is that for the photon, the average charge is zero, but with a distribution that shows positive and negative charge fluctuations about the mean (i.e., there is a statistical nature). Perhaps the same could be said about the mass of the photon.

Another debate in the scientific community regarding the photon that has taken place for almost 100 years (and which this paper will be focused on) is whether the photon is an elementary particle or composite particle. In

various fields of physics, most particles are considered to have an associated antiparticle. The antiparticle can be identified as an object with the same mass as its associated particle, but with opposite physical charges (and other differences in quantum numbers) [24]. The majority of physicists however consider the photon to be an exception to this rule. Some argue that since photons do not have an electric charge, a photon would be its own antiparticle. A contradiction to this claim however is the neutrino. In particular, neutrinos are uncharged particles yet they are not their own antiparticles. Antineutrinos have opposite leptonic numbers and weakly interact (i.e., their interaction Lagrangian is non-vanishing) [40]. Thus, perhaps the justifications typically used to argue that the photon is its own antiparticle are not sufficient.

1.1   Background on Composite Photon Theory

It was Louis De Broglie in 1924 who first considered composite photon theory writing in his *A Tentative Theory of Light Quanta* that "*naturally, the light quantum must have an internal binary symmetry*" [13]. Although De Broglie's original hypothesis about the photon consisting of two neutrinos was shown experimentally to be incorrect, several other scientists have also argued that composite photon theory can be more descriptive of reality than the elementary theory. For instance, in [39], Perkins proposes that that composite theory predicts Maxwell's equations, while the elementary photon has been formulated to reflect the equations of motion:

> *In the elementary theory, it is difficult to describe the electromagnetic field with the four-component vector potential. This is because the photon has only two polarization states. This problem does not exist with the composite photon theory [39].*

Other scientists have argued that a consequence of the existence of electromagnetic attraction and repulsion means that both phenomena cannot be mediated by the same particle: attraction corresponds to the interchange of antiphotons whereas repulsion represents the interchange of photons. Further to this claim, Garcia adds that if the main form of electromagnetic radiation of matter is by the emission of photons, then perhaps the main form of electromagnetic radiation of antimatter is by the emission of antiphotons [24].

Scientists are still examining however how antimatter would behave in a gravitational field. In [43], Villata examines the possibility of gravitational repulsion between matter and antimatter within the landscape of the general theory of relativity (without any modifications). Since the physical laws are invariant under the combined CPT operations (where Villata defines C (charge conjugation) to be the particle-antiparticle interchange, P (parity) to be the inversion of the spatial coordinates, and T to be the reversal of time), Villata

transformed the physical matter system into an equivalent antimatter system in the equations from both electrodynamics and gravitation [1]. In the former case, by looking at the Lorentz force law, which describes the dynamics of a charged particle in an external electromagnetic field, Villata arrived at the well-known change of sign of the electric charge. In the latter, he finds that the gravitational interaction between matter and antimatter is a mutual repulsion, i.e., antigravity appears as a prediction of general relativity when CPT is applied. If this result is true, it supports cosmological models attempting to explain the accelerated expansion of the universe in terms of a matter-antimatter repulsive interaction.

Using Bondi's work from 1957 [4] in which he examined the negative mass hypothesis within the framework of general relativity, one could interpret Villata's findings to mean that all kinds of mass (inertial, passive gravitational and active gravitational mass) are negative. For the negative mass, the acceleration of the body would be in the opposite direction to the gravitational force. A summary of such interactions are illustrated in Figure 1.

Gauthier is another who has done extensive work on composite photon theory. In [23], Gauthier elaborates on the composite model to be a double-helix model, which consists of an electron-positron pair spinning around each other in a helical motion with two quantum-entangled spin-$\frac{1}{2}$ half-photons. He claims that the parameters of energy, frequency, wavelength and helical radius of each spin-$\frac{1}{2}$ half-photon composing the double-helix photon would remain the same in the transformation of the half-photons into the relativistic electron and positron quantum vortex models. In 1958, De Broglie considers a similar idea stating in [16] that

> *The photon being thus made up of two corpuscles, each with a spin for a total of should obey the Bose-Einstein statistics, as the exactness of Planck's law of black body radiation demands. Finally, this model of the photon permits us to define an electromagnetic field connected with the probability of annihilation of the photon, a field which obeys the Maxwell equations and possesses all the characters of the electromagnetic light wave...such a couple of complementary corpuscles can annihilate themselves on contact with matter by giving up all their energy, and this accounts completely for the characteristics of the photoelectric effect.*

Caroppo [6] and Bolland [11] also published similar work in 2005 and 2018, respectively.

Gauthier's double-helix model of the photon (as illustrated in Figure 2) provides a preferable description and imagery when considering "composite

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[1]Recall that CPT invariance means that the magnitudes of the inertial masses, mean lives, charges, and magnetic moments are identical for a particle and its antiparticle [22].
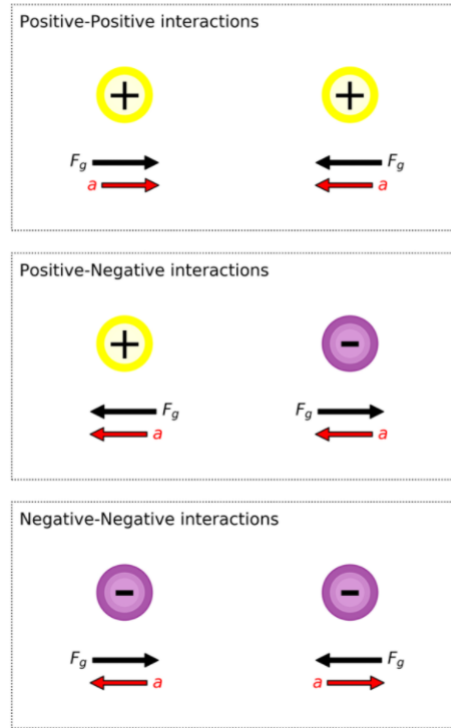
Figure 1: Comparison of positive versus negative mass for composite particle interactions from [19].

photon theory." The conventional idea of a "composite particle" may provide an unintended picture, which is why the author prefers to use the terminology *couplet photon theory*. In particular, the physics community defines a composite particle as a subatomic particle being composed of two or more elementary particles, i.e., a subatomic particle that consists of more than one quark. In quantum mechanics vocabulary, composite particles are considered as bound states with a binding energy which is larger than twice the mass of the lighter constituent allowing for spontaneous pair creation [34]. As the binding energy increases, it becomes more difficult to separate the components of a composite particle. Although from a theoretical framework, it is important to consider the binding energy of the photon relative to its mass and size, it is beyond the scope of this paper. Some limited discussions can be found in the literature (e.g., [14], [44], [2]), but the topic requires additional careful study. The author speculates however that in couplet photon theory, the positive binding electric energy would be offset by the negative gravitational binding energy (since the gravitational force is repulsive). If this is true, then the implication would be that the net binding energy would be zero.
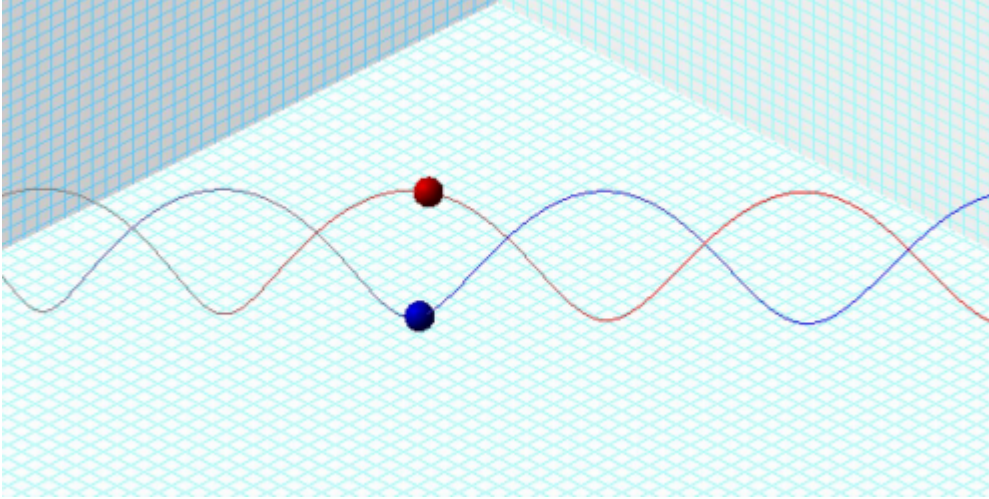
Figure 2: Illustrations of double-helix model of the photon from [23] where each quantum composes a spin-$\frac{1}{2}$ half-photon.

Although it is intriguing to consider the composite photon model, as scientists, we need to test against any claims to verify whether the photon is an electron-positron pair. If it is the case that photons and antiphotons can have opposite mechanical properties, then in theory, a sort of optical device may be used to determine whether their behaviour would differ. Garcia suggests using an experimental setup involving conducting media and proposed in [24] a type of telescope that could be one such device. In particular, Garcia explains that photons, or quanta of light, carry energy, linear momentum and spin. Hence, a beam of photons can be thought of as an electromagnetic wave carrying energy, linear momentum and angular momentum. Garcia further suggests that if we consider a photon moving in a transparent homogeneous and non-conducting medium, a beam of monochromatic photons can be interpreted as an electromagnetic polarized plane wave. In this situation, from an electromagnetic perspective, the photon and antiphoton would behave the same way in such a medium (i.e., a refracting telescope would behave in the same way). However, if the photon was moving in a conducting medium, such as a mirror, then a beam of monochromatic photons can be considered as particles and would experience the opposite force when interacting with mirrors [24]. Although this experiment has not been completed, some science research groups have conducted experiments in an attempt to verify some of the proposed ideas summarized above.

2 Experimental Evidence for Composite/Couplet Photon Theory

One set of experiments testing a proposed photon model were conducted by Bolland in 2000 [12], though he formally published his results in 2011 [12]. Bolland's experiments used microwave equipment and a Gunn diode oscillator to examine the electric field strength of microwaves transmitted along a bench. He placed a metallic plate in the center of the bench such that the plate's edge intercepted with half the beam. In the initial experimental setup, a parabolic reflector was used to focus the linear polarization radar beam toward a horn antenna and diode, which was coupled to a field strength meter. In the second experiment, the horn antenna and parabolic reflector were replaced by two helical antennas. Bolland expected that if the photon were pure energy, the resulting electric field strength to describe it would be a sine wave. However, Bolland found that for his first experiment, the plotted measured strength was a double-cycloid. He claimed that this outcome was consistent with the hypothesis that the photon consisted of two particles and further hypothesized that the two particles could be an electron-positron pair. In the second experiment, the plotted helical field strength trajectories obtained found circular polarization further suggesting that the photon consists of two particles.

In 2013, Wimmer *et al.* wanted to perform an experiment to test the hypothesis that the photon's composition consists of two symmetrical half-photons: one of positive mass and one of negative mass. In classical physics, Newton's third law of motion is considered with mass as a positive quantity. This property implies that two bodies would either accelerated away or toward each other. Theoretically speaking, if one of the bodies instead had negative mass, then the two bodies would accelerate in the same direction and one could create a diametric drive propulsion system [45]. A setup that could be used to study action–reaction symmetry breaking effects of diametric drive acceleration could be achieved using periodic structures (i.e., waves) propagating in a nonlinear time-domain optical mesh lattice. In [45], the authors present in experimental findings where they did just that. In particular, the authors produce two optical Gaussian wave packets with opposite masses and a slight frequency difference so their interaction would be incoherent and have pure cross-phase modulation. The self-trapped wave packets nonlinearly interacted with the defocused beam. The author reported that they found symmetrical halves of negative and positive mass on a dispersion diagram for light pulses interacting, which are illustrated in Figure 3. The laser pulses also appeared to display runaway self-acceleration, as outlined in Figure 1.

Similar experiments were conducted and published by Pei *et al.* in 2019 [37] and in 2020 [38]. In particular, the publications describe an optical diametric drive that is spontaneously self-accelerating. The authors speculated that the
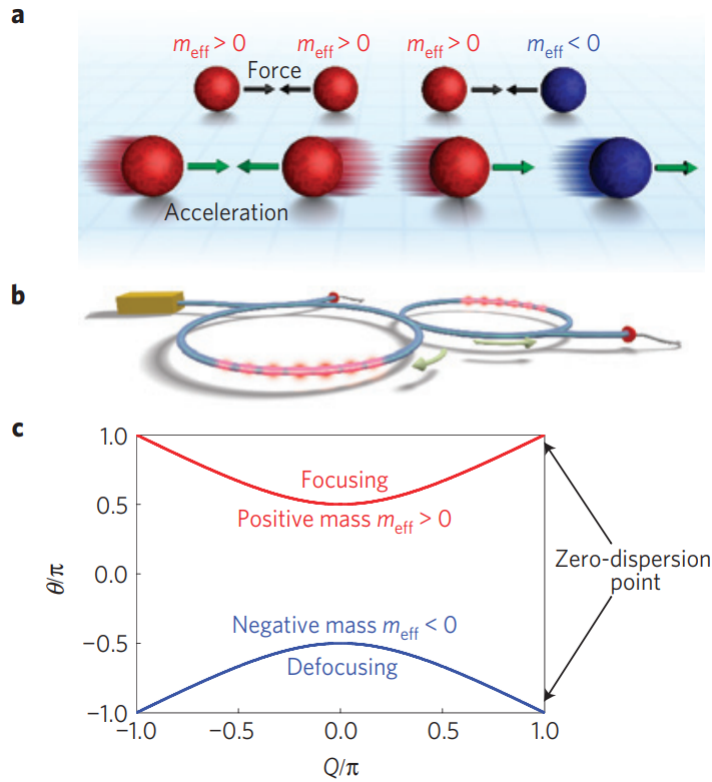
Figure 3: Diametric drive interaction between two particles, fibre-optic set-up and mesh lattice dispersion (effective mass) diagram from [45]. Top: Mass interactions Middle: Set-up of two time-multiplexed fiber loops connected through a 50/50 coupler. Sequences of light pulses circulating in both loops obey the same dynamics as in a spatial mesh lattice. Bottom: Dispersion diagram associated with two oppositely curved bands. The Kerr nonlinearity tends to focus excitations in the upper band whereas the corresponding effects in the lower band are of the defocusing type. Q, wave number; θ, propagation constant.

self-accelerating behaviour "*driven by a nonlinear coherent interaction of its two components [which] are experiencing diffractions of opposite signs in [the] photonic lattice (which is analogous to the interaction of two objects with opposite mass signs)*" [37] is the expected interaction of negative mass with positive mass particles. The authors further found that a single Gaussian-like beam can 'self bend' during nonlinear propagation in a uniform photonic lattice [38].

As discussed in [45], in the absence of an electrical field, the defocusing behaviour of positron beams is further evidence of the negative mass to negative mass interaction. This is because negative mass to negative mass repels and causes the positrons to move apart or 'defocus'. Some scientists have explored the idea of conducting an experiment to quantify the mass of a positron. How-

ever, standard experiments to determine the mass of particles (such as using a cathode ray tube as done by JJ Thompson for the discovery of the electron in 1897 [41], or using a bubble-chamber experiment which was invented in 1952 by Glaser [25] [2]) do so by measuring the angle of electromagnetic deflection, This yields the charge of the particle and the magnitude of its mass, but not its sign. The problem with such setups is there is no gravitational potential gradient in spectroscopy experiments to determine the mass/charge ratio of antimatter particles, i.e., such experimental setups were not designed to determine whether the mass would be positive versus negative.

Despite this, from the discussed experimental findings, it does not seem reasonable to dismiss the composite theory for the photon without additional investigation. From a theoretical perspective, the hypothesis that the photon is an electron-positron pair does not contradict important properties of the photon such as having zero rest mass (as the electron has positive mass and the positron has negative mass) or that it travels at the speed of light (since runaway, or self-accelerating, motion between positive and negative mass could provide an explanation). The interaction itself between positive and negative masses also does not pose a problem. This is because positive masses have an attractive effect on each other (which is why large scale structures such as stars and galaxies can form), whereas negative masses have repulsive gravitational effect with each other. Additionally, as mentioned by Choi, if negative mass (energy) exists, it is still possible to explain the dark matter and the dark energy at the same time [10].

2.1   Evidence for Antimatter having Negative Mass

Composite photons consisting of particle-antiparticle pairs having positive and negative mass provide a physical interpretation at the level of particle physics for the pair creation model of the universe developed by Choi and Rudra [10]. This idea provides a consistent and lucid explanation of how the universe developed from net zero energy and evolved into the distribution of energy density we observe today. In particular, in [10], the authors present computational results from their 'pair creation of positive energy and negative' model to investigate whether their simulations correspond to the energy ratio of the universe's components (i.e., matter, dark matter and dark energy). The authors compared their simulation results to observational data collected from NASA's Wilkinson microwave anisotropy probe (WMAP) and Planck probe. They obtained reasonable results (summarized in Table 1) demonstrating that the negative mass (energy) satisfies energy conservation. Furthermore, their models suggests that as the universe expands, the gravitational effects of

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[2]Dubois' recent paper [17] mentions further measurement methods that are not able to measure the sign of a particle's mass.

matter compared to dark matter effects differ. Comparatively, the standard lambda cold dark matter (ΛCDM) model assumes that the ratio of matter and dark matter will be constant.

Table 1: Energy distribution in the universe from NASA probe observational data and simulation results from in [10].

	WMAP	Simulation	Planck
Matter	4.6	4.5	4.9
Dark Matter	23.3	25.1	26.8
Dark Engery	72.1	70.3	68.3

Composite photons consisting of particle-antiparticle pairs having positive and negative mass further provides a physical interpretation at the level of particle physics for the gravitational dipoles proposed by [30]. In this paper, Hadjukovic suggests that a solution to the cosmological constant problem is if the particle-antiparticle pairs are gravitational dipoles, then without external fields, the gravitational charge density of the quantum vacuum is zero and hence, the cosmological constant is zero. A small non-zero cosmological constant would come about as a consequence of immersed matter.

Further support is given to negative mass cosmologies from the work developed and presented by Farnes in [19], where his results correspond well to observational evidence of the interactions and behaviour of dark matter and dark energy. In [19], Farnes proposed a model and then tested it computationally using software he developed to perform three-dimensional gravitational N-body simulations. The series of N-body simulations examined particles velocities and positions at every time-step until obtaining the final particle distribution. Farnes summarizes his findings saying:

> *The proposed cosmological model is therefore able to predict the observed distribution of dark matter in galaxies from first principles. The model makes several testable predictions and seems to have the potential to be consistent with observational evidence from distant supernovae, the cosmic microwave background, and galaxy clusters. These findings may imply that negative masses are a real and physical aspect of our Universe, or alternatively may imply the existence of a superseding theory that in some limit can be modelled by effective negative masses [19].*

Choi similarly speculated that negative mass has not been observed because even though it is gravitationally bound to massive positive masses (e.g., galaxies), it came into existence at the beginning of universe and hence, could

still exist in a vacuum state outside a galaxy structure. Choi further suggests that galaxy structures have survived as a result of pair-annihilation of positive mass and negative mass pair which also results in the vacuum energy being zero [10]. The composite photon development that will be given below thus benefits from the same observational evidence, which must be contrasted with the absolute failure of experiments to detect dark matter particles or dark energy in the laboratory.

3 Equality of Forces Acting on the Electron-Positron Pair

Considering the claim that the photon is an electron-positron pair and that a repulsive gravitational force acts between matter and antimatter, we will now calculate the strength of the gravitational force and examine an engineered state such that it is equivalent to the Coulomb force (i.e., electrostatic force).

To begin, we know that the gravitational force has the same form as Coulomb's law for the forces between electric charges, i.e., it is an inverse square force law which depends upon the product of the two interacting sources. In particular, if we consider two masses m_1 and m_2 separated by a distance r, then the gravitational force $F_{\text{Gravitational}}$ between these two masses is given by

$$F_{\text{Gravitational}} = \frac{Gm_1m_2}{r^2}$$

where G is the universal gravitation constant. If we consider two points with charges q_1 and q_2 measured in Coulombs where r is the radius of separation from the center of one charge to the center of the other charge, then Coulomb's law states that the electrostatic force F_{Coulomb} is defined as

$$F_{\text{Coulomb}} = \frac{kq_1q_2}{r^2},$$

where k is Coulomb's constant and is equal to $\frac{1}{4\pi\epsilon_0}$ where ϵ_0 is the electric constant, i.e.,

$$F_{\text{Coulomb}} = \frac{q_1q_2}{4\pi\epsilon_0}\frac{1}{r^2}.$$

Note that the attractive Coulomb force acts between a negatively charged electron and positively charged positron.

As presented by Gauthier in [23], let's now consider two half-photons with mass m_e moving on 45-degree helical trajectories separated by a distance $D = \frac{\lambda}{\pi}$, where λ denotes the wavelength of the photon. In the double-helix charged dipole model, the two half-photons carry a charge $q_1 = Q$ and $q_2 = -Q$

that allows for their double-helical trajectories. Thus, we can write the corresponding electrostatic force to be

$$
\begin{aligned}
F_{\text{Coulomb}} &= \frac{q_1 q_2}{4\pi\epsilon_0} \frac{1}{r^2} \\
&= \frac{-Q^2}{4\pi\epsilon_0} \frac{1}{D^2}.
\end{aligned}
\tag{3}
$$

We will use Gauthier's expression for the magnitude of the charge on each helically-moving half-photon on the charge dipole, which is

$$
Q = \pm e \sqrt{\frac{2}{\alpha}} \approx 16.6e
$$

where e is the electron's charge magnitude and α is the fine structure constant (which quantifies the strength of the electromagnetic interaction between the electron-positron pair). Note that we can relate the two quantities by the formula $e^2 = 4\pi\epsilon_0 \hbar c \alpha$ where $\alpha \approx \frac{1}{137}$ [23].

The weak equivalence principle tells us that the inertial mass is equivalent to the gravitational mass. Moreover, from the CPT theorem, we can say that the inertial mass of a particle is equal to that of the antiparticle. For this new description of mass, we view the electron-positron as gravitational charge, which has a magnitude and a sign. Like electrical charges, gravitational charges will move along a potential gradient. This potential gradient will, however, be gravitational (whereas current experiments to measure mass have no gravitational gradient, so they cannot tell us the sign of the mass). Hence $m_1 = m_e$ and $m_2 = -m_e$ and we can write the gravitational force as [35]

$$
\begin{aligned}
F_{\text{Gravitational}} &= \frac{G m_1 m_2}{r^2} \\
&= \frac{-G m_e{}^2}{D^2}.
\end{aligned}
\tag{4}
$$

Assuming that the photon is a stable particle and has wavelengths spanning the electromagnetic spectrum and ranging from 100,000 km to one picometre, the two forces (F_{Coulomb} and $F_{\text{Gravitational}}$) would be equal and offsetting, i.e.,

$$
F_{\text{Coulomb}} = F_{\text{Gravitational}}.
\tag{5}
$$

Using equations (3) and (4), equation (5) can be written as

$$
\begin{aligned}
F_{\text{Coulomb}} &= F_{\text{Gravitational}} \\
\frac{Q^2}{4\pi\epsilon_0 D^2} &= \frac{G_S m_e \, m_e}{D^2} \\
G_S &= \frac{Q^2}{4\pi\epsilon_0 m_e^2}
\end{aligned}
$$

where G_S denotes the strong gravitational force. Since the charge of the electron squared is $e^2 = 4\pi\epsilon_0\hbar c\alpha$, G_S can be expressed as

$$G_S = \frac{\left(\pm e\sqrt{\frac{2}{\alpha}}\right)^2}{4\pi\epsilon_0 m_e^2}$$
$$= \frac{(4\pi\epsilon_0\hbar c\alpha)\frac{2}{\alpha}}{4\pi\epsilon_0 m_e^2}$$
$$= \frac{2\hbar c}{m_e^2}. \tag{6}$$

Equation (6) gives the value of the strong gravitational constant, G_S, such that the gravitational force becomes equal to the Coulomb force. Note that the value of G_S is independent of the wavelength of the photon and acts on all photons, regardless of their energy. Since the electromagnetic spectrum covers wavelengths ranging from 100,000 km to one picometre, the force is not microscopic in range but rather operates across a wide range of distances as Newtonian gravity does.

To show the strength of the repulsive gravitational force acting between matter and antimatter is enormously strong compared to Newtonian gravity, notice the following: if M_p is the Planck mass, then for Newton's gravitational constant the gravitational force is expressed as

$$G = \frac{\hbar c}{M_p{}^2}, \tag{7}$$

which indicates the existence of a strong version of the gravitational force operating inside the composite photon consisting of an electron-positron pair. By considering the ratio of the two, we find that

$$\frac{G_S}{G} = \frac{2M_p{}^2}{m_e{}^2}, \tag{8}$$

i.e., G_S is 45 orders of magnitude stronger than G. This provides a unification between the electromagnetic force and the gravitational force, at least in the case of the electron-positron pair. Since photons can take on energies across the electromagnetic spectrum, it does not make sense to think of unification taking place at a particular energy level. Unification between the Coulomb force and the gravitational force takes place through a variation in the value of the gravitational constant, which is much higher for the strong gravitational force between the electron and the positron.

However, an important question to ask is whether this is truly a unification

or simply an equivalence. By writing equation (5), as follows

$$F_{\text{Coulomb}} = F_{\text{Gravitational}}$$

$$\frac{Q^2}{4\pi\epsilon_0 D^2} = \frac{G_S m_e^2}{D^2}$$

$$\frac{2e^2}{4\pi\epsilon_0 \alpha D^2} = \frac{G_S m_e^2}{D^2}$$

$$\frac{2e^2}{G_S D^2} = \frac{4\pi\epsilon_0 \alpha \, m_e^2}{D^2}$$

and in this representation, we obtain that an electromagnetic force with a gravitational constant is equivalent to strong gravity with an electromagnetic constant. The two forces are different aspects of the same force where one is attractive and the other repulsive. This is providing a rationale for our claim of a unification between gravity and electromagnetism; showing the origin of the two forces inside the composite photon.

This analysis provides a framework for the unification of the four fundamental forces of nature (recall that the weak force, electromagnetic force and strong force have already been shown to unify - see more below). Furthermore, our findings provide a potential resolution to the hierarchy problem (i.e., the large discrepancy between aspects of the weak force and gravity) regarding why Newtonian gravity is so much weaker than the other forces.

The composite photon model developed by Gauthier and further augmented here provide some deep insights into the process of the transformation of light into matter and antimatter as well as the annihilation process of matter and antimatter into photons.

3.1 Positronium Approximation of Strong Gravity

Another possible method to estimate the strength of the repulsive gravitational force is by considering the bound quantum state known as positronium, which is an atom that is composed on an electron and positron (i.e., it's antiparticle). If annihilation is actually the acceleration of an electron-positron pair from s-state positronium to gamma rays, then we can calculate the rate of acceleration and back out the strength of the force and the constant of strong Gravity. Recall that an s-state has zero angular momentum, i.e., overall spin quantum number is $s = 0$ [15].

The levels with spin $s = 0$ are called para-positronium levels. If we consider the lifetime of para-positronium in a vacuum to be t_0, it is approximated by [32]

$$t_0 = \frac{2\hbar}{mc^2\alpha^5}. \tag{9}$$

Using the composite photon model, we can say that the electron-positron pair accelerates from rest to the speed of light, c, in time t_0.

Since acceleration, denoted by a, can be expressed as the change in velocity over the change in time, we can obtain the following expression

$$
\begin{aligned}
a &= \frac{\Delta v}{\Delta t} \\
&= \frac{c}{t_0} \\
&= \frac{c m_e c^2 \alpha^5}{2\hbar} \\
&= \frac{m_e c^3 \alpha^5}{2\hbar}.
\end{aligned}
\tag{10}
$$

Since we know $F_{Gravitational} = -m_e a$, we find that

$$
\begin{aligned}
F_{Gravitational} &= -m_e \left(\frac{m_e c^3 \alpha^5}{2\hbar} \right) \\
&= -\frac{m_e^2 \, c^3 \alpha^5}{2\hbar}.
\end{aligned}
\tag{11}
$$

Furthermore, we can express $F_{Gravitational} = \frac{-G_S m_e^2}{D^2}$ where D would correspond to the orbital radius of the system/atom. This then yields

$$
\begin{aligned}
\frac{G_S m_e^2}{D^2} &= \frac{m_e^2 \, c^3 \alpha^5}{2\hbar} \\
G_S &= \frac{D^2 c^3 \alpha^5}{2\hbar}.
\end{aligned}
\tag{12}
$$

To approximate the value of D, the average orbital diameter between positronium and soft gamma rays (which positronium transfers into) was taken. The justification behind this is during acceleration, the distance between the electron and positron contracts from the diameter of positronium (in the rest state) to that of soft gamma rays. We know that the wavelengths of soft gamma rays are roughly 100 picometers [33], so the diameter would correspond to $\frac{100 \text{ pm}}{\pi}$ [23]. Next, the orbital radius of positronium in its rest state is twice that of the Bohr radius (i.e., the diameter would be approximately $4 * 5.29177^{-11}$ m) [27]. Therefore, taking the average of these diameters would give that $D \approx 122$ picometers.

By again considering the ratio between this approximate value of G_s and G, G_s would be 39 orders of magnitude stronger than G. Although this ratio of G_S and G is different than the previous calculation of the strong gravitational constant (i.e., (8)), the current calculation involves estimates for the radius of positronium at rest as well as for the wavelength of soft gamma rays.

Since (12) is expressed with a factor of D^2, the error in D will magnify the corresponding error of G_S. Nonetheless, from (6) and (12), it appears that the strong gravitational constant would be 10^{39} to 10^{45} orders of magnitude more powerful than Newtonian gravity. More importantly, by considering the hypothesis that annihilation is actually acceleration of the electron-positron pair, a reasonable approximation for the value of G_S was obtained.

4   Gravity in the Early Universe

In contemplating whether the composite photon theory is reasonable or not, it would be beneficial to reflect on the origins of gravity. Prior to the first 10^{-43} seconds after the big bang, which is referred to as Planck time or the Planck era, the scientific community believes there was unification of all the fundamental forces. In other words, the forces resembled each other and were of practically identical strength (as the forces of nature are symmetric at high energies and temperatures). However, after the unification point or Planck era, there was spontaneous symmetry breaking. This separated the 'original force' into four distinct fundamental forces which function in our current, low temperature universe. The four fundamental forces are the strong force, the weak force, the electromagnetic force and the gravitational force. All these forces function at different strengths and in different ranges. In particular [28]:

1. Strong force: range of 10^{-15} m with strength 1.

2. Weak force: range of 10^{-18} m with strength 10^{-6}.

3. Electromagnetic force: infinite range with strength $\frac{1}{137}$.

4. Gravitational force: infinite range with strength 6×10^{-39}.

Figure 4 is an illustration of this symmetry breaking as a function of time after the big bang. The proposed temperatures corresponding to each of the symmetry breaks are shown.

   The top of Figure 5 then presents a picture of the primordial force in the early universe, where one force is attractive and one is repulsive. The figure demonstrates a symmetrical beginning for the universe with net-zero energy. In comparing this idea to the gravitational and Coulomb force, these forces appear to be different aspects of the same primordial force as shown on the bottom of Figure 5. This may provide an understanding of how the Coulomb force and gravitational force are different aspects of the same primordial force.
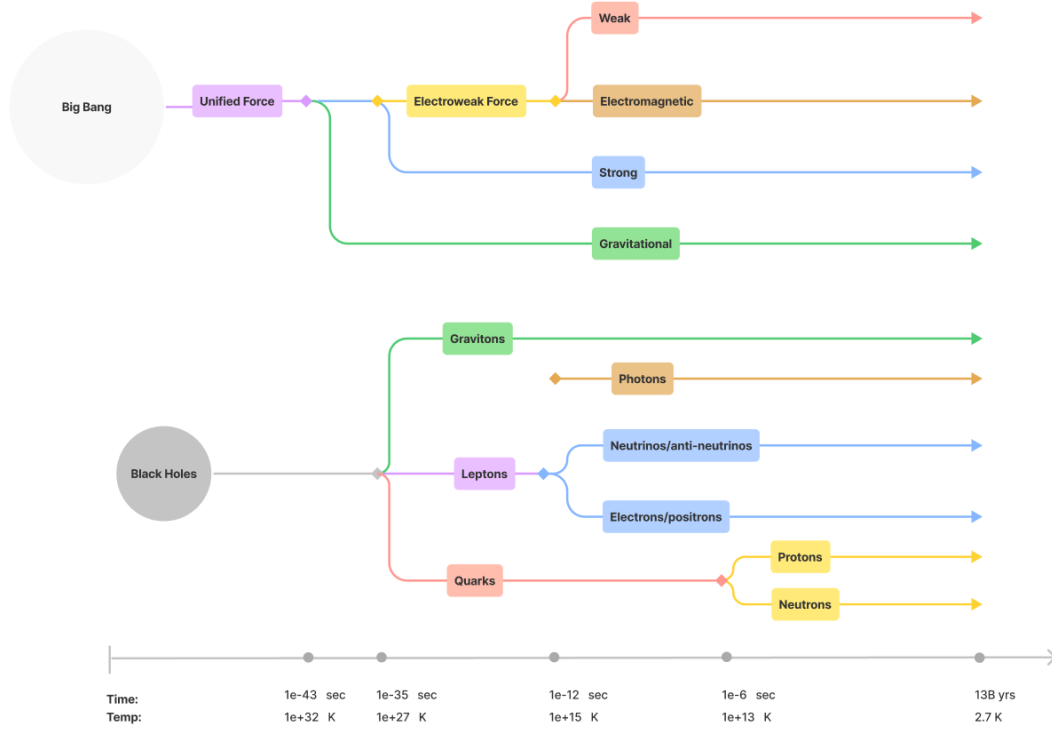
Figure 4: Evolution of the early universe.

Examining the strong gravitational force may tell us something about the origin of gravity as it can be expressed by

$$F_{\text{Gravitational}} = \frac{G_S m_e^2}{D^2}$$
$$= \frac{2hc}{2\pi D^2} \tag{13}$$

for the electron-positron pair (i.e., the elementary charged particles). This relationship follows an inverse square law that depends on distance, but is independent of the gravitational constant. If $\ell_p{}^2$ is the Planck length constant, we can substitute this minimum length into equation (13). Then $F_{\text{Gravitational}}$ tends to a maximum value of

$$F_{\text{Max}} = \frac{2hc}{2\pi \ell_p{}^2} \tag{14}$$

as the distance between the electron and positron tends to the Planck length and is repulsive. Moreover, since $\ell_p{}^2 = \frac{\hbar G}{c^3}$ we can see that
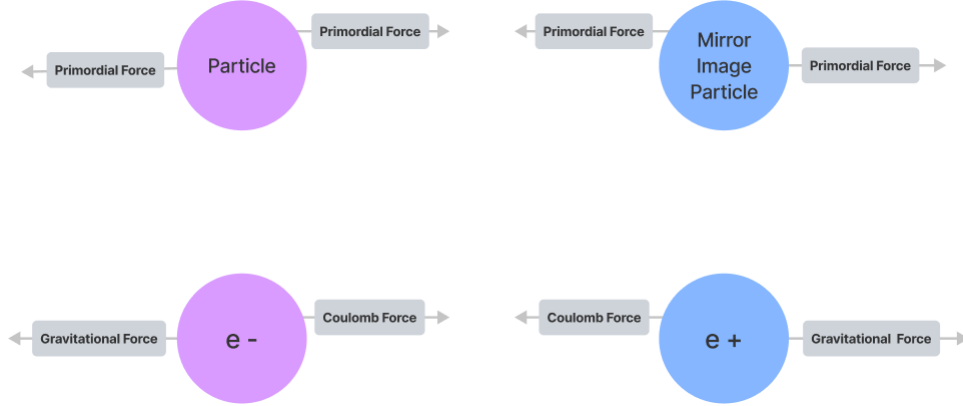
Figure 5: Top: Primordial force associated with the early universe. Bottom: Coulomb and gravitational force corresponding to an electron.

$$\begin{aligned} F_{\text{Max}} &= \frac{2hc}{2\pi \ell_p{}^2} \\ &= \frac{2\hbar c}{\hbar G}\, c^3 \\ &= \frac{2c^4}{G}. \end{aligned} \tag{15}$$

Notice equation (15) corresponds to two times the Planck force, which is associated with each cycle of a photon. Hence, at the minimum quantum distance, the strength of this force corresponds to the strongest possible force in nature, which is expected to be present at the origin of the universe. Thus, this analysis speculates that the composite photon may represent the origin of the universe.

5 Expansion of Einstein Field Equations to Include Vector Gravity

As discussed, there is some rather compelling evidence already published in the literature to suggest that a symmetrical beginning for the universe with net-zero energy and particles that are mirror images of each other could result in positive and negative electromagnetic charges as well as positive and negative gravitational charges (where there exists positive mass for matter and negative mass for antimatter). Furthermore, according to Nieto and Goldman, current experimental evidence does not exclude the possibility of vector gravity for antimatter:

> *From the particle-physics point of view, general relativity is a theory of gravity where the force is mediated by a tensor (spin-two) particle*

> *with the charge being mass—energy. Therefore, the force is always attractive. On the other hand, classical and quantum electromagnetism both have two charges, positive and negative. The forces are mediated by a vector (spin-one) field which produces an attractive force between opposite charges and a repulsive force between like charges [35].*

Although at present, we have not experimentally verified whether a repulsive force between matter and antimatter exists, it is useful to ask whether a mathematical framework is compatible with such a theory.

From the general theory of relativity, the geometric relationship of spacetime to the distribution of matter within it are described using Einstein's field equations, which are a set of nonlinear PDEs whose solutions are the components of the metric tensor. However, Einstein's theory is not perfect (e.g., there are issues in describing spin-orbit interaction) and only describes the positive-positive tensor equations. The Lorentz invariant theory of gravity (LITG) is an alternative in the weak gravitational field approximation. LITG more resembles Maxwell's electromagnetic theory in the sense that the PDEs describe the properties of two components of the gravitational field and relates them to their sources, mass density and mass current density [20]. In particular, unlike general relativity, in LITG, gravity is not considered a consequence of spacetime curvature. Instead, it is considered a force and results in the Lorentz covariance of gravitational field in the weak field limit as well as the need for torsion of gravitational field (i.e., the force field acting on the masses and bodies in translational or rotational motion). The gravitational field is therefore described via two potentials and two strengths.

The question now is: can the positive-negative interaction between the positive gravitational charge and negative gravitational charge be described by another set of gravitational equations, optimally in the form of Maxwell's equations? If so, Einstein's field equations would need to be expanded to include strong gravity, which we recall is repulsive between positive mass and negative mass. Fortunately, the relationship to Coulomb's Law discussed above provides a basis for such an expansion. Similar to LITG, we can say that an equivalence to Maxwell's equations can be developed since we may now view gravity as gravitational charge having positive and negative charges in the same manner as electromagnetism.

Recall that Maxwell's equations for electromagnetism may be derived from Coulomb's Law plus the Lorentz invariance transformations of special relativity [48]. In a parallel manner, an extended version of Einstein's field equations can be obtained from Newton's law of gravitation plus special relativity. This extension would include interactions between the positive and negative gravitational charges and reflect the strong gravitational constant calculated in this paper for the interaction between positive and negative mass. As discussed

thoroughly in Fedosin's paper [20], the equations of motion from LITG are sufficient for our desired description. The vector equations have the following form:

$$\vec{\nabla} \cdot \vec{\Gamma} = -4\pi G_S \rho$$
$$\vec{\nabla} \cdot \vec{\Omega} = 0$$
$$\vec{\nabla} \times \vec{\Gamma} = -\frac{\partial \vec{\Omega}}{\partial t}$$
$$\vec{\nabla} \times \vec{\Omega} = \frac{1}{c_g{}^2}\left(-4\pi G_S \vec{J} + \frac{\partial \vec{\Gamma}}{\partial t}\right)$$
$$= \frac{1}{c_g{}^2}\left(-4\pi G_S \rho \vec{v_p} + \frac{\partial \vec{\Gamma}}{\partial t}\right) \tag{16}$$

where $\vec{\Gamma}$ denotes the gravitational field strength vector, $\vec{\Omega}$ denotes the gravitational torsion field vector, $\vec{J}$ denotes the mass current density vector, ρ denotes the mass density, $\vec{v_p}$ denotes the mass flow velocity, and c_g is the speed of propagation of gravitational effects [20]. In LITG, c_g is not necessarily equal to the speed of light, c.

The equations set (16) is a description of gravitoelectromagnetism and are the gravitational analogs to Maxwell's equations for electromagnetism. Unlike general relativity, which is a theory of the metric field (rather than a gravitational field), in LITG, the gravitational field also determines the metrics. For a more extensive overview on the mathematical details behind this formalism, please see [20].

6 Conclusion

In this paper we examined the evidence behind composite photon theory. More specifically, we considered how a relationship between the Coulomb force and gravitational force can arise and from this relationship, derived an expression for the strong gravitational constant. From reviewing the literature, we found a substantial amount of theoretical and computational evidence to suggest that the gravitational force is repulsive between matter (having positive mass) and antimatter (having negative mass). Finally, the equivalence between mass and charge was explored and it was postulated that the Coulomb force and gravity are different aspects of the same primordial force. Implications on how to extend Einstein's field equations to include vector gravity were also provided.

The author of this paper is planning to conduct a series of experiments to test some of the proposed hypotheses, and regardless of the results, intends to publish the findings. Although one must proceed to conduct experiments to

validate the presented composite/couplet photon model, the author suspects that the simplest explanation of gravity is that it is just as the other forces. In particular, it is a quantum force given by a tensor dot product and a set of Maxwell-like vector equations. Gravity appears to be the repulsive mirror image of electromagnetism, just as antimatter is the mirror image of matter in a universe that came from nothing.

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