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Dark Matter and Dark Energy due to Photons that Attract or Repel Each Other

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***Abstract*— *The Through a simple model we study the possibility of photon with mass and charge that can produce an attractive or repulsive force at galactic distances. The main source of the dark energy can be provided by the non vanishing photon mass during the period of dark radiation of the Universe. A simple analysis shows that the non vanishing photon mass of the order of* $m_\gamma \approx 10^{-34}\,\mathrm{eV}$ *is consistent with the current observations. For distances separating nearby galaxies dominates the force of Newtonian attraction between photonic masses (Dark Matter). For distant galaxies dominates the repulsive electrical force between photon charges (Dark Energy).*

***Keywords*—Photon mass, Dark matter, Dark energy, Newton force, Universe .**

I. INTRODUCTION

The study of gravitational of interaction of Parallel-Propagating Photons has been considered in past by Tolman, Ehrenfest and Podolsky [1], as far as 1931, that first to publish studies on how light interacts with light gravitationally. After that Faraoni and Dumse [2] in 1999 and Jensen in 2013 [3] also addressed this same problem using different approaches. Heeck, [4], was able to derive the first direct bound on the photon lifetime from an analysis of the oldest light that exists in the universe, showing that the half-life of a photon is about 100 million times more than the age of universe. Heeck's calculations neglect interaction of photons with matter after the time of last scattering . These matter interactions could effects significantly, on the photon's lifetime value estimated by Kouwn et al [5], who investigated the cosmology of massive electrodynamics and explored the possibility whether the massive photon could provide an explanation of dark energy. The action is given by the scalar-vector-tensor theory of gravity, which is obtained by nonminimal coupling of the massive Stueckelberg QED with gravity; its cosmological consequences are studied by paying particular attention to the role of photon mass, where the radiation- and matter-dominated epochs are followed by a long period of virtually constant dark energy that closely mimics a Λ cold dark matter ΛCDM model. They also find that the main source of the current acceleration is provided by the nonvanishing photon mass governed by the relation $\Delta \approx m_\gamma{}^2$. A detailed numerical analysis shows that the nonvanishing photon mass on the order of $\approx 10^{-34}\,\mathrm{eV}$ is consistent with current observations. This magnitude is far less than the most stringent limit on the photon mass available so far, which is on the order of $\mu \approx 10^{-27}\,\mathrm{eV}$, [4-8].

Indeed, it has later been realized that neutrino is the lightest particle in the Standard Model (SM) with a mass smaller by at least three orders of magnitude than the electron mass. The 2015 Nobel Prize in Physics was given to the discovery of neutrino oscillations that shows neutrinos are massive. Therefore the SM should have been modified in order to give a natural explanation to the question why neutrino masses are so small but non-zero. A similar modification that makes neutrinos massive may be valid for photon. As dictated by Okun, *"such a small photon mass, albeit gauge non-invariant, does not destroy the renormalizability of Quantum Electrodynamics (QED) and its presence would not spoil the agreement between QED and experiment. This also motivates incessant searches for a non vanishing tiny photon mass"* [6].

In this short letter, we propose a simple model to explain the possibility of massive and charged photon to explain the existence of "dark matter" which takes into account the flat rotational speed of stars around spiral galaxies. In addition, to explain the existence of "dark energy" in the acceleration of the expansion of the Universe.

II. BASIC THEORY

We access here the problem of interaction between two particles, via any virtual carrier (graviton or photon), and address afresh the problem of photon inter interaction. Consider two particles with rest masses M and m, exchanging virtual hypothetical carriers of gravity (Gravitons (as yet undetected!)– A spin 2 massless particle - in the framework of quantum field theory), shown as below,

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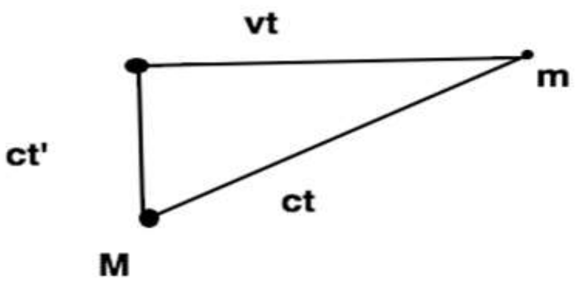

Fig.1: Geometrical position of mass M and m.

This reasoning would be also valid for electrical charges, but in this case the virtual elementary particles would be photons. The particle that emits the virtual photon loses momentum p in the recoil, and the other particle gets the momentum, but not at the time, as we will see, with the caveat of measuring all physical quantities from the reference frame placed at same position as M.

Consider that an inertial reference frame is at the particle M position and that particle m has a velocity v in relation to this frame. Therefore the information (on momentum for instance) triangle leads to the following equation, Figure 1,

$$c^2t'^2 + v^2t'^2 = c^2t^2 \qquad (1)$$

The variable t is the time in which the signal that leaves the particle M, at t = 0, reaches the original particle m position, that is, at t = t, measured at the reference frame at M. Since the particle m has a velocity v, with relation to the reference frame in M, when the information on the position of particle M reaches the original position of m, at t = t, the particle m will be at the position d' = ct', where t' is the time when the information that left the particle M reaches the position where m is "now", after a time t has passed, that is, d', $d'^2 = d^2 - v^2t^2$ Based on that, we can construct the above triangle and so, we can write a relation between t and t', where t – t' is the mismatch time between the two information arrivals or momentum exchange.

$$t' = t/\sqrt{1 - v^2/c^2} \qquad (2)$$

Therefore, the gravitational force that m would feel due to M, if v = 0, is given by,

$$F^G{}_{mM}(d) = -GmM/d^2 \qquad (3)$$

Of course the force that the particle M feels due to m is given by $F_{nM} = -GmM/d^2$, since it is at rest. Writing now the correct force (calculating the distance at the exact position where the particle m is now) that the mass m feels due to M, we have,

$$F^G{}_{mM}(d') = -GmM/d'^2 = -GmM\frac{1}{(ct/\sqrt{1-v^2/c^2})^2} = -F^G{}_{mM}(d)(1-v^2/c^2) \qquad (4)$$

where *G* is Newton's universal constant of gravitation and d' is the distance of the particle from the central massive photon.

As $m = m_\gamma = m_0(\sqrt{1-v^2/c^2})^{-1}$, then

$$F^G{}_{mM}(d') = -F^G{}_{m_0M}(d)\sqrt{(1-v^2/c^2)} \qquad (5)$$

Therefore, if v = 0, we get the usual $F^G{}_{mM} = F^G{}_{mM}$, with the caveat of considering the reference frame glued in M.

Equation (4) is our main result.

If we consider photons, of course v = c and the particle rest mass m (m = 0) will not feel any force from M (M = 0), and vice – versa. This happen irrespective to the choice of positioning of the reference frame, since in any case v = c.

For photons, the information triangle is equilateral, and that is the reason why photons see each other as static, since the distance between them is d = ct. Each side of this information exchange equilateral triangle is d.

If we look the problem from the reference frame glued in m, we conclude that we get the same mismatch calculating the force, and then looking the space – time structure of the problem we have that Proca equations describe the behavior of a massive spin-1 field, and have since been used to set an impressive upper limit on the photon mass of $\mu < 2\times10^{-54}\,\mathrm{kg}$ [4], or $10^{-18}\,\mathrm{eV}$ in the natural units used in this Letter ($\hbar = c = k_B = 1$).

However in this case we adopt a lower limit for the mass of the photon in order to have a good match with the actual background radiation of the universe. It would be impossible to perform any experiment which establishes the exact vanishing of the photon mass, but the ultimate upper limit on the photon rest mass, m, can be estimated by using the uncertainty principle to be $m_\gamma \approx \hbar/(\Delta t)c^2 = 10^{-34}\,\mathrm{eV}$ for the current age of the Universe. This simple analysis verifies the deeper study of [5], which using the long-lived low-energy photons of the cosmic microwave background. J. Heeck [5], was able to derive the first direct bound on the photon lifetime from an analysis of the oldest light that exists in the universe.

Using the largest allowed value for the photon mass from other experiments, he finds a lower limit of about 3 yr on the photon rest-frame lifetime. After including the relativistic effects of time dilation, this implies that the

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half-life of a photon of visible light would rise, in the reference system of a resting observer, to about 10^8 years: 100 million times more than the age of universe. This excessive gap means that, for all intents and purposes, the photon lives forever. For photons in the visible spectrum, in all cases CMB spectral distribution for mass is $\mu < 10^{-7}\,\mathrm{eV}$ has no visible effect.

The Heeck's analysis is completely independent of the possible particles in which a photon could disintegrate. It is based on the fact that, if a fraction of the photons in the microwave background had disintegrated, the spectrum of that radiation would not coincide with that of a blackbody. Since the spectrum of the microwave background has been measured with great precision, it possible deviation is strongly constrained by observations.

If $v/c < 1$, but v very close to c we have an attractive force between nearby galaxies given by equation (4'), which can represent the dark matter. If $v/c \geq 1$, we have a repulsive force produced by the dark energy. The main source of the dark energy is provided by the nonvanishing photon mass during the period of radiation of the Universe. If the size of Universe is about $R = 10^{26}\,\mathrm{m}$, then in electronvolts corresponds to $10^{-34}\,\mathrm{eV}$, so this simple analysis shows that the nonvanishing photon mass of the order of $m_\gamma \approx 10^{-34}\,\mathrm{eV}$ is consistent with the current observations. This magnitude is far less than the most stringent limit on the photon mass available so far, which is of the order of $m_\gamma \approx 10^{-27}\,\mathrm{eV}$ [11, 12]. In other words, if the photon's mass is 10 million times smaller than that limit, the way that photons interact with the different fields and forces in the Universe leads to a repulsive effect that looks to calling dark energy. In other words, massive photons could cause dark energy. Every fundamental force has a corresponding force-carrying boson through which it interacts with matter. The strong force has gluons, electromagnetism and photons, etc. If there is a dark-matter force, there should be some corresponding interaction boson. Here we propose a dark electromagnetism where the vector Poynting is zero [13, 14]. Just as regular matter interacts with electromagnetism through photons, dark matter would interact through "dark photons." Since dark photons wouldn't interact with regular matter, the "light" from dark matter wouldn't be seen, thus explaining its invisible nature.

On the other hand, if photons have mass, also can have electric charge, for short range interaction we have the Yukawa force law between two electric charges q_γ and Q_γ separated by a distance d' is

$$F^E{}_{mM} = kq_\gamma Q_\gamma / (d'^2)e^{-\mu d'}(1+\mu d') \qquad (6)$$

where $\mu = m_\gamma c/\hbar$ includes the photon mass m_γ, the speed of light *c*, and Planck's constant *ħ*. This equation corresponds exactly to the ordinary Coulomb force law $F^E = kq_\gamma Q\gamma / d'^2$ when the photon mass is zero. However, even for small photon mass, these equations will nearly be the same, since a small factor of μ in the Yukawa force law will hardly make any difference experimentally. On the other hand, a large mass will impose a sharp cutoff in the strength of the force, since the exponentially decaying term in the equation will throttle it. That is how the Yukawa force (with the appropriate changes to represent nuclear forces instead of electromagnetic) predicts the short range of the nuclear force and the value of the pion mass. However for cosmological distances the photon charge may be important as a positive gravitational force separating the galaxies, (see equation (4)) but considering a possible photon charge. To make this we consider that $e_\gamma \varphi = m_\gamma c^2$ so equation (4) can be transformed as an electrical force

$$F^E{}_\gamma = G\frac{e_\gamma \varphi}{c^2} M \frac{(\sqrt{1 - v^2/c^2})^2}{(ct)^2} = k' e_\gamma \nabla\varphi \qquad (7)$$

where $\nabla = 1/d$ and k' is the dielectric constant of the intergalactic space.

$$k' = G\frac{1}{c^2} M_\gamma \frac{(\sqrt{1 - v^2/c^2})^2}{(ct)}$$

Here we need to obtain an upper limit on the photon electric charge from the cosmic microwave background. Following [15, 16], we consider the cosmic microwave background radiation like a black body temperature $T_B = 2.74\,\mathrm{K}$ and the photon number density given by $n_\gamma \approx \beta(K_B T_B / \hbar c)^3$ where K_B is the Boltzmann constant, β is a numerical coefficient of order unity. If each photon has a charge q_γ, then the electric force density is proportional to $(n_\gamma q_\gamma)^2$ with the condition of

$$(n_\gamma q_\gamma)^2 = G\rho^2 \qquad (8)$$

where $\rho = \Omega\rho_c$ is the average mass density of the Universe and $\rho_c = 3H^2/8\pi G$, where H is the Hubble constant. From the numerical values of Ω, H, T_B, K_B, G and n_γ, we can obtain that $q_\gamma < 10^{-27} e$ in esu units, where e is the electron charge. Then the repulsive force

$$F^E{}_\gamma = k' q_\gamma Q_\gamma / (d'^2) \qquad (9)$$

would be responsible for the dark energy that separates increasingly distant galaxies. In short, for distances separating nearby galaxies dominates the force of Newtonian attraction between photonic masses (Dark Matter) $(n_\gamma q_\gamma)^2 < G\rho^2$. For distant galaxies dominates the repulsive electrical force between photon charges (Dark Energy).

$(n_\gamma q_\gamma)^2 > G\rho^2$.

III. CONCLUSION

Through a simple model we study the possibility of photon with mass that can produce an attractive or repulsive force at galactic distances. The main source of the dark energy can be provided by the non vanishing photon mass during the period of radiation without Poynting vector of the Universe [13, 14]. A simple analysis shows that the non vanishing photon mass of the order of $m_\gamma \approx 10^{-34} eV$ is consistent with the current observations. It would be certainly impossible to perform any experiment which establishes the exact vanishing of the photon mass, but the ultimate upper limit on the photon rest mass, m, can be estimated by using the uncertainty principle to be $m_\gamma \approx \hbar / (\Delta t)c^2 = 10^{-34} eV$ for the current age of the Universe. This magnitude is far less than the most stringent limit on the photon mass available so far, which is of the order of $m_\gamma \approx 10^{-27} eV$. From the electric point of view, the repulsive force $F_{nM} = k q_\gamma Q_\gamma / (d'^2)$ would be responsible for the dark energy that separates increasingly distant galaxies, that is, for distances separating nearby galaxies dominates the force of Newtonian attraction between photonic masses (Dark Matter). For distant galaxies dominates the repulsive electrical force between photon charges (Dark Energy).

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