Quantum Vacuum Gravitation and Cosmology
The Electromagnetic Nature of Gravitation and Matter-Antimatter Antigravity

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Abstract

Without stating any assumptions or making postulates we show that, the electromagnetic quantum vacuum derives directly from Maxwell's theory and plays a primary role in gravitation and cosmology. Photons are local oscillations of the vacuum field guided by a non-local vector potential wave function. They propagate at the speed imposed by the vacuum electric permittivity ε_0 and magnetic permeability μ_0, which we demonstrate that they are intrinsic properties of the electromagnetic quantum vacuum.

The electron-positron elementary charge derive naturally from the electromagnetic quantum vacuum. We establish the masse-charge equivalence relation showing that the masses of all particles (leptons, mesons, baryons) and antiparticles are manifestations of the elementary charges and their corresponding magnetic moments. The equivalence between Newton's gravitational and Coulomb's electrostatic law results naturally.

In addition, we show that the gravitational constant *G* is a property of the electromagnetic quantum vacuum putting in evidence the electromagnetic nature of gravity. Furthermore, we draw that *G* is the same for matter and antimatter but gravitational forces should be repulsive between particles and antiparticles because their masses bear naturally opposite signs.

The electromagnetic quantum vacuum appears to be the natural link between quantum electrodynamics (QED), particle physics, gravitation and cosmology and may constitute the basic step towards a unified field theory.

Dark Energy and Dark Matter might originate from the electromagnetic quantum vacuum fluctuations. The calculated electromagnetic vacuum energy density, related to the cosmological constant considered responsible for the cosmic acceleration, is in good agreement with the astrophysical observations. However, the cosmic acceleration may be due to both the quantum vacuum fluctuations as well as to the matter-antimatter gravitational repulsion.

Finally, we advance the hypothesis that energy, matter and antimatter in the universe emerge spontaneously from the quantum vacuum fluctuations as residues that remain stable in space and we present the principles upon which a new cosmological model may be developed overcoming the well-known Big Bang issues.

Key words: photons, electromagnetic quantum vacuum, dark light, gravitation, push gravity, antimatter, antigravity, dark energy, cosmological constant, dark matter, elementary charges, mass-charge relation, cosmology, unified field theory.

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Introduction

The ΛCDM (Lambda – Cold Dark Matter) cosmological model is considered today as the most plausible theory that has the merit to provide satisfactory answers to a large number of astrophysical observations. It is based on the enhanced Big Bang concept according to which the universe is homogeneous and whose main components are Dark Matter and Dark Energy. The last one is associated to the cosmological constant Λ, which is considered responsible for the observed cosmic acceleration [1-4].

However, besides the difficulty to conceive that the whole universe emerged from a singular point, some upsetting issues still remain such as, why did the Big Bang occurred and what happened before? Furthermore, in order to explain the horizon problem as well as the fact that the geometry of the universe is Euclidean (flat), a cosmic inflation model has been introduced [5]. But, what are the physical reasons that inflation occurred in the very first 10^{-30} seconds of the Big Bang expanding the universe at a tremendous rate, many orders of magnitude faster than the speed of light in vacuum? What happened to antimatter?

Finally, quantum field theory fails by a factor of 10^{120} to give a precise estimation to the cosmological constant [6, 7], the worst discrepancy between theory and observation in the history of science.
The above drawbacks call the human intelligence to be humble in front of the immensity and complexity of the still unknown universe. All the cosmological theories, including the one presented here, are temporary attempts to explain the observations realized up to now using the present theoretical tools and they are finally condemned to be replaced in the future according to the new observations to come.

In what follows, we make an introduction to the fundamentals of Quantum Vacuum Gravitation and Cosmology. The electromagnetic quantum vacuum, namely Dark Light, corresponds to the electromagnetic field ground state and results naturally from Maxwell's theory by considering the vector potential quantization at a single photon level. It is a real field permeating all of space and has electric potential dimension. We show that photons are oscillations of the electromagnetic vacuum field while the lepton-antilepton elementary charges derive equally from this field.

The gravitational constant *G* is a vacuum property having electromagnetic nature and is the same for matter and antimatter. The masses of particles and antiparticles derive from elementary charges and their magnetic moments and have opposite sign entailing repulsive gravitational forces between matter and antimatter.

Fluctuations of the electromagnetic quantum vacuum generate transient states of photons that are plausible to compose the Dark Energy and transient pairs of charges (particles) that might compose the Dark Matter. A small fraction of the vacuum transient states might definitely remain stable in space composing the observed energy and mass in the universe.

1. The electromagnetic quantum vacuum, the Dark Light

The electromagnetic field vector potential $\vec{\alpha}_{k\lambda}(\vec{r},t)$ with quantized amplitude for a cavity free *k*-mode photon with angular frequency ω_k and polarization λ (circular left or right) writes [8-14]

$$\vec{\alpha}_{k\lambda}(\vec{r},t) = \xi\omega_k \left[\hat{\varepsilon}_{k\lambda}\, e^{i\left(\vec{k}\cdot\vec{r}-\omega_k t+\theta\right)} + cc \right] = \omega_k\, \vec{\Xi}_{k\lambda}(\vec{r},t) \qquad (1)$$

where $\hat{\varepsilon}_{k\lambda}$ is the polarization unit vector, $\vec{k}$ the wave-vector with amplitude $\left|\vec{k}\right| = 2\pi/\lambda_k$, λ_k being here the wavelength of the mode *k*, θ a phase parameter and *cc* the complex conjugate.
The vector potential amplitude quantization constant ξ may be positive or negative and is given by

$$\xi = \frac{\hbar}{4\pi ec} = \frac{1}{(4\pi)^2}\frac{e\mu_0}{\alpha} = \pm 1.747\,10^{-25}\ V\,m^{-1}s^2 \qquad (2)$$

where *e* is the electron or positron charge, $\hbar$ is Planck's reduced constant $(\hbar = h/2\pi)$, *c* the speed of light in vacuum, $\alpha \simeq 1/137$ is the fine structure constant and μ_0 the vacuum magnetic permeability.
It is straightforward to show that the vector potential function $\vec{\alpha}_{k\lambda}(\vec{r},t)$ is a natural wave function for a free *k*-mode photon satisfying the *vector potential – energy* (wave – particle) equation for the photon

$$i\begin{pmatrix} \xi \\ \hbar \end{pmatrix}\frac{\partial}{\partial t}\vec{\alpha}_{k\lambda}(\vec{r},t) = \begin{pmatrix} \tilde{\alpha}_0 \\ \tilde{H} \end{pmatrix}\vec{\alpha}_{k\lambda}(\vec{r},t) \qquad (3)$$

where

$$\begin{pmatrix} \tilde{\alpha}_0 \\ \tilde{H} \end{pmatrix} = -i\begin{pmatrix} \xi \\ \hbar \end{pmatrix} c\vec{\nabla} \qquad (4)$$

The constants $\hbar$ and ξ characterize respectively the energy and the vector potential field quantization for a single photon state. The perfect symmetry between the photon energy $E_k = \hbar\omega_k$ and the vector potential amplitude $\alpha_{0_k} = \xi\omega_k$ expresses the simultaneous wave-particle nature of the single photon through the *vector potential – energy* equation (3).

It is worthy noticing that the amplitude of the electric field of a cavity free *k*-mode photon is proportional to the square of the angular frequency [10, 12]

$$\left|\vec{\varepsilon}_{k\lambda}(\vec{r},t)\right| = \left|-\partial\vec{\alpha}_{k\lambda}(\vec{r},t)/\partial t\right| \propto \left|\xi\right|\omega_k^2 \tag{5}$$

Obviously, for $\omega_k = 2\pi c/\lambda_k \to 0$ (that is for $\lambda_k \to \infty$) the photon energy, vector potential and electric field tend to zero. However, for $\omega_k = 0$ the resulting electromagnetic field ground state does not correspond to a perfectly empty space because the fundamental function $\vec{\Xi}_{k\lambda}(\vec{r},t)$ in the vector potential expression (1) still subsists and writes in both classical electromagnetic theory and QED [14-17]

$$\vec{\Xi}_{0\lambda} = \xi\left[\hat{\varepsilon}_\lambda\, e^{i\theta} + \hat{\varepsilon}_\lambda^*\, e^{-i\theta}\right] \tag{6a}$$

$$\tilde{\Xi}_{0\lambda} = \xi\left[\hat{\varepsilon}_\lambda\, a_{k\lambda} e^{i\theta} + \hat{\varepsilon}_\lambda^*\, a_{k\lambda}^+ e^{-i\theta}\right] \tag{6b}$$

where in the QED expression (6b) we have used the creation $a_{k\lambda}^+$ and annihilation $a_{k\lambda}$ non-Hermitian operators respectively for a *k*-mode and λ-polarization photon.

Hence, in total absence of energy, of vector potential as well as of electric and magnetic fields, $\Xi_{0\lambda}$ is the electromagnetic field ground state, the electromagnetic quantum vacuum corresponding to light at zero frequency, "Dark Light".

It is a real cosmic field permeating all of space $\left(\lambda_k \to \infty\right)$ and has electric potential nature according to the physical dimensions of ξ.

The phase parameter θ may take any value and consequently the electromagnetic quantum vacuum is composed of all possible states $\vec{\Xi}_{k\lambda}(\vec{r},t)$ corresponding to all modes and polarizations

$$\vec{\Xi}_{k\lambda}(\vec{r},t) = \xi\left[\hat{\varepsilon}_{k\lambda}\, e^{i\left(\vec{k}\cdot\vec{r}-\omega t+\theta\right)} + cc\right] \tag{7a}$$

$$\tilde{\Xi}_{k\lambda}(\vec{r},t) = \xi\left[\hat{\varepsilon}_{k\lambda}\, a_{k\lambda} e^{i\left(\vec{k}\cdot\vec{r}-\omega t+\theta\right)} + cc\right] \tag{7b}$$

From equation (4), an angular frequency operator $\tilde{\Omega}$ can be readily defined [17]

$$\tilde{\Omega} = -ic\vec{\nabla} \tag{8}$$

Using (3) and (8), we get the equation governing the fundamental function $\vec{\Xi}_{k\lambda}(\vec{r},t)$ of the vector potential in vacuum

$$i\frac{\partial}{\partial t}\begin{bmatrix}\vec{\Xi}_{k\lambda}(\vec{r},t)\\ \tilde{\Xi}_{k\lambda}(\vec{r},t)\end{bmatrix} = \tilde{\Omega}\begin{bmatrix}\vec{\Xi}_{k\lambda}(\vec{r},t)\\ \tilde{\Xi}_{k\lambda}(\vec{r},t)\end{bmatrix} = \begin{bmatrix}\vec{\alpha}_{k\lambda}(\vec{r},t)\\ \tilde{\alpha}_{k\lambda}(\vec{r},t)\end{bmatrix} \tag{9}$$

Obviously, according to the last equation, photons (electromagnetic waves) are generated by the action of the angular frequency operator $\tilde{\Omega}$ upon the vacuum function $\vec{\Xi}_{k\lambda}(\vec{r},t)$ creating a real vector potential $\vec{\alpha}_{k\lambda}(\vec{r},t)$ of a *k*-mode photon. Consequently, photons are local oscillations of the electromagnetic quantum vacuum over a wavelength, with circular polarization (left or right), guided by a non-local vector potential wave function [10, 13, 14].

The vacuum electric permittivity ε_0 and magnetic permeability μ_0 are intrinsic physical characteristics of the electromagnetic vacuum and are expressed through the fundamental physical constants $\alpha, \xi, \hbar$ and the elementary charge e

$$\mu_0 = \left(4\pi\right)^2 \alpha\frac{\xi}{e} \quad ; \quad \varepsilon_0 = \frac{\mu_0}{\left(4\pi\alpha\right)^2}\frac{e^4}{\hbar^2} = \frac{\xi e^3}{\alpha\hbar^2} \tag{10}$$

It is straightforward to verify that the product of the last expressions gives directly the velocity of light in vacuum *c*.

$$\varepsilon_0 \mu_0 = \left(\frac{4\pi e \xi}{\hbar} \right)^2 = \frac{1}{c^2} \tag{11}$$

Finally, it can be easily demonstrated [17] that any particle moving in the electromagnetic quantum vacuum with an acceleration $\vec{\gamma}$ will experience the Fulling-Davies-Unruh temperature

$$T_H = \frac{\hbar}{2\pi c k_B} |\vec{\gamma}| \tag{12}$$

where k_B is Boltzmann's constant.

2. The electromagnetic quantum vacuum fluctuations, from QED to Cosmology

2.1 Transient photons from the electromagnetic quantum vacuum. Dark Energy and the cosmic acceleration.

Quantum field theory fails to evaluate the vacuum energy density by a factor of 120 orders of magnitude. In fact, the zero-point energy levels of all fields, corresponding to the fundamental eigenstate of the harmonic oscillator Hamiltonian, yield an infinite vacuum energy density which when upper limited to Planck's energy $(\sim 10^{19} GeV)$ gives the "astronomic" value ~ $10^{110} J\,m^{-3}$, while the observed one is roughly $\sim 10^{-10} J\,m^{-3}$ [1].

This unphysical theoretical result, the worst ever in the history of science, is mainly due to the mathematical ambiguity during the field quantization procedure according to the harmonic oscillator model consisting of replacing commuting classical variables of momentum and position by non-commuting quantum mechanics Hermitian operators [10, 14, 18]. Electromagnetic waves are not composed of harmonic oscillators and no experiment has ever demonstrated that a single photon state is a harmonic oscillator. It has to be emphasized that, in contrast with material oscillators, the zero-point energy in quantum field theory, $\sum_{k,\lambda} \hbar \omega_k / 2$, resulting from the harmonic oscillator Hamiltonian, does not correspond to a physical state and this is what indeed the astrophysical observations confirm.

As frequently pointed out [10, 18], we recall that the interpretations of the spontaneous emission and the Lamb shift in QED are not due to the zero-point energy term $\sum_{k,\lambda} \hbar \omega_k / 2$ but to the properties of the photon creation $a^+_{k\lambda}$ and annihilation $a_{k\lambda}$ operators respectively. As about the well-known Casimir effect, it has been demonstrated by different methods [14 and references therein] that it can be directly explained by using the source fields or Lorentz's forces without invoking at all the zero-point energy. It has to be underlined again that the zero-point energy term $\sum_{k,\lambda} \hbar \omega_k / 2$, being a constant, commutes with all quantum mechanics Hermitian operators corresponding to physical observables and consequently has absolutely no influence to any physical process.

Conversely, it has been demonstrated [10, 14] that the electromagnetic quantum vacuum, expressed by equations (6a) and (6b), complements naturally the normal ordering Hamiltonian in QED and describes a real physical vacuum state in both classical and quantum electromagnetic theories. In addition, it explains directly the vacuum effects such as the spontaneous emission and the Lamb shift [10, 11, 14] as well as the Fulling-Davies-Unruh temperature [17].

We have seen that photons are local oscillations of the electromagnetic quantum vacuum field propagating at the speed imposed by its intrinsic properties, the vacuum electric permittivity ε_0 and magnetic permeability μ_0. On the other hand, from Heisenberg's energy-time uncertainty relation we deduce that the vector potential amplitude is also subject to a fluctuation uncertainty [10, 16, 17]

$$\delta E_k \cdot \delta t \sim \hbar \quad \rightarrow \quad \delta \alpha_{0k} \cdot \delta t \sim \xi \quad \rightarrow \quad \delta \omega_k \cdot \delta t \sim 1 \tag{13}$$

Consequently, due to the electromagnetic vacuum fluctuations, space is permanently full of transient photons at all frequencies underlying the cosmic radiation background.
Obviously, according to the uncertainty relation (13), the lower the frequency the longer the transient photons lifetime, which could explain the *1/f* ^{n} noise origin observed in astrophysical measurements.
We may assume that the probability for a transient *k*-mode photon spontaneous creation is proportional to $e^{-|\vec{\varepsilon}_k/\varepsilon_m|}$, where $|\vec{\varepsilon}_k|$ is the transient photon electric field amplitude generated in space and ε_m is a mean photon electric field amplitude over the electromagnetic spectrum. Using the result (5), that the photon electric field amplitude is proportional to the square of the angular frequency, we get the electromagnetic vacuum fluctuations energy density [19] weighing the integration by the transient photon spontaneous creation probability $e^{-|\vec{\varepsilon}_k/\varepsilon_m|} = e^{-\omega_k^2/\omega_m^2}$,

$$\rho_{vacuum} = \frac{\hbar}{\pi^2 c^3}\int_0^\infty e^{-\omega^2/\omega_m^2}\,\omega^3 d\omega = \frac{\hbar\,\omega_m^4}{2\pi^2 c^3} = \frac{2}{\pi}\varepsilon_0\mu_0 e\,\xi\,\omega_m^4 \qquad (14)$$

Note that the above calculation cannot be applied in the case of the zero-point energy term because it's an eigenvalue corresponding to a stable eigenstate composed of all *k*-mode photons and consequently the weighing factor is 1 at all frequencies.
Now, considering that ω_m is a logarithmic mean value for the angular frequency over the electromagnetic spectrum, that could be roughly in the THz region $\omega_m \sim 2\pi\,10^{12}\,Hz$, we obtain $\rho_{vacuum} \sim 3\;10^{-10}\;J\;m^{-3}$ which is in good agreement with the astrophysical observations.
Thus, the energy density of the electromagnetic quantum vacuum fluctuations (Dark Light fluctuations) is quite plausible to represent the Dark Energy considered responsible for the cosmic acceleration.

2.2 Transient charges (particles and antiparticles) from the electromagnetic quantum vacuum. Mass-charge equivalence. At the origin of Dark Matter?

It has been established that the electron/positron elementary charge *e*, a fundamental physical constant, is obtained exactly from the electromagnetic vacuum quantized amplitude constant ξ [10, 17, 20]

$$e = (4\pi)^2\,\alpha\,\frac{\xi}{\mu_0} \qquad (15)$$

Note that the last relation is neither a postulate nor a definition but derives naturally when considering the vector potential amplitude quantization at a single photon state. It becomes evident that the photon vector potential amplitude $\alpha_{0_k} = \xi\omega_k$ and the elementary charge e are directly related to the electromagnetic quantum vacuum through the amplitude constant ξ demonstrating that photons and leptons/antileptons are physically strongly related entities and derive from the electromagnetic vacuum field, putting the basis for a physical comprehension of their mutual transformation mechanism.

We recall that, from the historical experimental evidence, Planck's constant $\hbar$ is intrinsically related to the energy quantization of the electromagnetic field at a single photon state. Despite of this characteristic physical origin Planck's constant is used in quantum physics for the description of all particles. Consequently, we may guess that the electromagnetic nature should be an inherent property for any particle.
In addition, it is worthy to mention that the notion of mass introduced in the expression of Bohr's magneton is a classical concept associated to a quantum process for the description of the magnetic dipole moment $\vec{M}$ of a wave-particle with wave-vector $\vec{k}$ in a circular standing state of radius *r*. In fact, in a pure quantum description Bohr's magneton is simply the proportionality constant of the magnetic dipole moment $\vec{M} = \mu_B(\vec{k}\times\vec{r})$.

Now, the rest mass of the electron/positron m_{e^-,e^+} can be expressed exactly through the elementary charge e and its magnetic moment

$$m_{e^-,e^+} = 2\pi c\, e^2 \frac{\xi}{\mu_B} \tag{16}$$

with $\mu_B = 9.27410^{-24}\ J\,T^{-1}$ being the Bohr magneton.

The same, the proton/antiproton mass writes

$$m_{P^+,P^-} = 2\pi c\, e^2 \frac{\xi}{\mu_P} \tag{17}$$

where $\mu_P = 5.05081 0^{-27}\ J\,T^{-1}$ is the proton magneton.

Using the relation (2) for ξ, the mass m_i of any elementary particle/antiparticle writes in a general way

$$m_i = 2\pi c\, e^2 \frac{\xi}{\mu_i} = \left(\frac{c\mu_0}{8\pi\alpha}\right)\frac{e^3}{\mu_i} \tag{18}$$

where e is the electron charge for particles or the positron charge for antiparticles and μ_i is the magneton of the particle *i*.

Obviously, the rest masses of all particles/antiparticles are purely of electromagnetic nature and the relation (18) expresses simply the mass-charge equivalence.

On the other hand, the magneton μ_i of any particle/antiparticle can be expressed approximately through the Bohr magneton μ_B and the fine structure constant α

$$\mu_i \simeq \left(\frac{2\alpha}{n_i}\right)\mu_B \tag{19}$$

where n_i is simply a positive integer.

Thus, the mass of any particle i, lepton, meson or baryon, as well as of any antiparticle, is expressed with a precision of roughly 1% through the vacuum constant ξ and the electron/positron charge e [17]

$$m_{e^-,e^+} = \mu_e e^3 \quad ; \quad m_i \simeq \left(\frac{n_i}{2\alpha}\right)\mu_e e^3 \tag{20}$$

The numerical value of the proportionality constant is $\mu_e = c\mu_0 / 8\alpha\pi\mu_B = 2.21510^{26}\, kg\cdot C^{-3}$.

As an example, muon mass is obtained for n_i = 3, pion for n_i = 4, kaon for n_i =14, rho for n_i = 22, nucleon for n_i = 27, lambda for n_i = 32, sigma for n_i = 34, tau for n_i = 51…etc, while Higgs boson is obtained for n_i = 3,574.

According to the last equations, we draw that the electron/positron charge is related to photons and derive from the electromagnetic vacuum while the particles/antiparticles masses are quantum states of the vacuum field originating from charges and their magnetic moment. In fact, the presence in equation (20) of an integer n_i characterizing the particles/antiparticles masses implies that the electromagnetic vacuum must have a complex structure of quantum levels yet to discover, which might be related to string theory. Apparently, strong and weak forces seem to be particular manifestations of the electromagnetic vacuum field while quarks and antiquarks should be also states of the same vacuum field. Through this lens, all neutral elementary particles/antiparticles must be composed of positive and negative charges and consequently, gravity should have an electromagnetic nature.

Finally, we deduce that fluctuations of the electromagnetic vacuum may also give birth to transient states of positive and negative charges of matter and antimatter, corresponding to known and unknown particles. Halos of transient particles concentrations could be strongly favored near important real charges (mass) distributions and consequently might contribute to the Dark Matter.

2.3 Electromagnetic nature of the gravitational constant G.
Newton's and Coulomb's laws equivalence. Matter-antimatter antigravity.

Considering Planck's length l_P = 1.616 10^{-35} *m*, which is the shorter possible wavelength for a single photon beyond which the electromagnetic energy density transforms to a black hole, the gravitational constant *G* is expressed exactly through the elementary charge *e* and the electromagnetic vacuum constants ξ, ε_0 and μ_0 [17]

$$G = \frac{l_p^2}{4\pi\,\varepsilon_0\mu_0 e\xi} = \frac{l_p^2}{(4\pi)^3\alpha\varepsilon_0\xi^2} \tag{21}$$

The masse-charge equivalence and the electromagnetic nature of the gravitation constant *G* imply the equivalence of Newton's gravitation law to Coulomb's electrostatic law. In fact, the well-known Newton's gravitational potential between two particles *i* and *j* with respective masses m_i and m_j separated by a distance r_{ij} writes [21]

$$U_{Newton} = G\frac{m_i m_j}{r_{ij}} = \frac{1}{4\pi\varepsilon_0}\frac{e_i e_j}{r_{ij}}\eta_{ij} = U_{Coulomb} \tag{22}$$

where we have used the relations (2), (18) and (21).

Note that e_i and e_j denote the electron charge for the particles or the positron one for antiparticles while η_{ij} is a dimensionless parameter characterizing the nature of the interacting particles and depending on their magnetic moments.

$$\eta_{ij} = \frac{\pi\hbar c l_P^2}{\mu_0\mu_i\mu_j} \tag{23}$$

Note also that, when considering the algebraic sign of charges, and not their absolute values as usually, a minus sign has to be considered in Coulomb's law in the electrostatic theory for the resulting positive potential to characterize attraction (as in gravitation) and the negative one repulsion (as in anti-gravitation).

According to the equation (22) the gravitational potential writes now in electromagnetic terms

$$U = \frac{\hbar^2}{4}G\frac{e_i e_j}{r_{ij}\mu_i\mu_j} \tag{24}$$

and for a large number of particles

$$U = \frac{\hbar^2}{4}G\sum_{i,j(i<j)}\frac{e_i e_j}{r_{ij}\mu_i\mu_j} \tag{25}$$

We have used μ_B and l_p as intermediate constants in order to obtain physically meaningful relations expressing the mass-charge equivalence by equation (18) and the approximate expression (20), the electromagnetic nature of the gravitational constant *G* by equation (21) and the Newton-Coulomb potential equivalence by (22).

We recall here that Bohr's magneton μ_B is generally considered as a positive quantity so as the Larmor angular frequencies $\omega_L = \mu_B\left|\vec{B}\right|/\hbar$ for the elementary charge in a magnetic field $\vec{B}$ to be also positive and the corresponding absorbed and emitted photons to have positive energies $\hbar\omega_L$. Under this condition, considering that the magnetons μ_i of the particles are positive quantities we can draw a quite

interesting feature concerning matter, antimatter and gravity. In fact, for ε_0 and μ_0 to be positive quantities in equations (10), e and ξ should have the same sign. In this way, the gravitational constant expressed by (21) is positive for both matter and antimatter. Gravitation forces are attractive between bodies of ordinary matter, as well as between bodies of antimatter, but they should be repulsive between matter and antimatter according to Newton's gravitational potential (22) since they have "positive" and "negative" masses following the mass-charge equivalence relation.

In fact, particles and antiparticles having opposite charges are attracted by Coulomb forces overcoming naturally the weak gravitational repulsion and annihilate mutually giving generally birth to photons. Conversely, matter and antimatter neutral structures must be repelled due to repulsive gravitational forces. This result is in agreement with previous studies that have shown that CPT symmetry (Charge conjugation, Parity and Time reversal) and General Relativity cannot be compatible unless matter and antimatter are mutually repelled [22]. We expect the ALPHA-g, AEgIS and GBAR experiments at CERN to give a definite answer to that issue.

Furthermore, it is worthy investigating whether gravitation originates from the radiation pressure of the electromagnetic quantum vacuum field (Push Gravity) felt by the bodies in their own frame depending on their charge densities [16]. Under this condition, light rays should follow the paths in the electromagnetic vacuum imposed by the charge densities in space modifying locally the vacuum fluctuations and the refractive index. Therein, it is important to mention that a well-elaborated model of Push Gravity has been developed recently [23] and the similarity of "gravions" to the electromagnetic vacuum fluctuations would be of great interest to be investigated in detail.

Note that, from equation (15) for the electron, ξ is negative and consequently the ordinary masses in equations (18) and (20) are negative and those of antimatter obtained from the positron charge are positive. This is because historically, a negative charge was conventionally attributed to the electron and a positive one to the positron. Inverting, eventually, the traditional convention and attributing a positive charge to the electron and a negative to the positron, which becomes a "negatron", results to positive mass for matter (positive ξ) and negative for antimatter (negative ξ).

Also, $\varepsilon_0, \mu_0, \mu_B, G$ as well as the photon frequencies and energies are positive and identical for matter and antimatter. However, due to ξ signs, the vector potential as well as the electric and magnetic fields of photons emitted by matter have opposite signs with respect to those emitted by antimatter, which might constitute an experimental criterion for exploring antimatter structures in the universe.

Planck's length l_P is a physical parameter corresponding to the shorter possible photon wavelength and consequently characterizes the granularity of the electromagnetic quantum vacuum. According to the established equations (2), (11), (15) and (21), the fundamental constants $c = (\varepsilon_0 \mu_0)^{-1/2}$, $e = (4\pi)^2 \alpha \xi / \mu_0$, $\hbar = \alpha \xi^2 (4\pi)^3 \varepsilon_0^{-1/2} \mu_0^{-3/2}$ and $G = l_p^2 / (4\pi)^3 \alpha \varepsilon_0 \xi^2$ are expressed uniquely through the vacuum physical parameters ε_0, μ_0, ξ and l_P entailing that electromagnetism and gravitation are natural manifestations of the electromagnetic quantum vacuum field that may constitute the basic step towards a unified field theory.

3. The electromagnetic quantum vacuum cosmic source of photons (energy) and charges (mass). Quantum Vacuum Cosmology.

We have seen that transient states of the Dark Light fluctuations might be at the origin of Dark Energy and Dark Matter. Now, we may assume that a small part of the electromagnetic quantum vacuum fluctuations can indeed remain in space as residual real states. Certainly, this conflicts with the mass-energy and charge conservation laws but, as we will see later, these laws are satisfied between the initial and final states of the overall cosmic process. This statement constitutes the basis for a Quantum Vacuum Cosmological model whose main principles are described qualitatively below.

Real photons and charges (particles and antiparticles), can be created continuously in space as residues of the electromagnetic quantum vacuum fluctuations. Thus, the vacuum turns out to be a cosmic source of photons (energy) and charges (matter and antimatter). The particles generated by the vacuum fluctuations residues might be in thermal equilibrium at ~3 K, which could explain the homogeneous and isotropic Cosmic Microwave Background (CMB).

In the birth stage of the universe, the spontaneous energy-mass creation process dominates. Photons and charges (particles and antiparticles) are created continuously everywhere in an infinite and eternal space entailing that universe is homogeneous and flat. Some particle-antiparticles pairs annihilate producing photons, others combine progressively to electrons-protons and positrons-antiprotons forming respectively hydrogen and antihydrogen atoms, then molecules and gas which are progressively separated by gravitational repulsion to form distant accumulations, the first with ordinary matter and the second with antimatter. The presence of matter favors particles generation in space and that of antimatter antiparticles generation. Under the effect of gravity, following the well-known mechanisms, the increasing concentrations of hydrogen (antihydrogen) give birth to stars (antimatter stars, 'anti-stars'). Next, heavier elements (anti-elements) are produced in stars (anti-stars) by the also well-known baryon (anti-baryon) genesis process. Galaxies (antimatter galaxies, 'anti-galaxies') and clusters of galaxies (anti-galaxies) are formed progressively. Vacuum fluctuation residues are enhanced mostly near already generated massive structures entailing the formation of a local finite universe. If matter and antimatter structures are not separated completely since the beginning due to gravitational repulsion to form a local universe and a distant anti-universe, then remnants of antimatter (matter) might persist in the universe (antimatter universe, 'anti-universe'). Recent works have shown that antihydrogen atoms have the same properties with those of ordinary hydrogen atoms and particularly the same energy levels [24, 25]. We may reasonably assume that antimatter stars and galaxies should have the same birth, life and death as the ordinary matter ones, as well as similar radiation properties yielding a particular difficulty for their detection. Therein, as we mentioned above, an experimental device capable of distinguishing the opposite signs of the polarized photons vector potentials, and the resulting electric and magnetic fields, could eventually be useful for exploring the antimatter distributions in the universe. Vacuum transient photons fluctuations are mostly enhanced near charge (mass) concentrations and consequently are higher within a local universe system than in the space outside contributing by this way to a smooth accelerated expansion [19]. The presence of antimatter structures in an ordinary mass universe would also contribute to the cosmic acceleration and it might probably play a dominant role through matter-antimatter gravitational repulsion that is worthy to be further investigated.

In a second stage, energy-mass annihilation mechanisms in the universe (anti-universe), like black holes (antimatter black holes, 'anti black holes') and probably other yet unknown cosmic structures, start appearing following the death of massive stars (anti-stars), mostly in the center of galaxies (anti-galaxies). Obviously, such annihilation mechanisms appear to older galaxies, which could explain why quasars are found in big distances. The cosmic energy-mass annihilation mechanisms transform the initially spontaneously generated energy-mass back to the quantum vacuum state, which also explains simply what the huge amounts of energy and mass absorbed by black holes become in the singularity.
A period of equilibrium might be eventually established in the local universe (anti-universe) during which the energy-mass annihilation and creation rates balance. In a later stage, the annihilation mechanisms might prevail the creation ones and the generated mass-energy returns progressively to the vacuum state. In the overall energy-mass creation and annihilation processes the energy-mass and charge conservation laws are respected between the initial and final state.

Conclusions

We have visited the basic physical features that derive naturally from the electromagnetic quantum vacuum, the cosmic Dark Light. Photons (electromagnetic waves) are oscillations of the vacuum field. The vacuum electric permittivity and magnetic permeability, ε_0 and μ_0 respectively, are intrinsic properties of the electromagnetic quantum vacuum and fix the speed of light c.

Positive and negative elementary charges are states of the same vacuum field. The masses of particles and antiparticles originate from charges and their magnetic moment witnessing a complex structure for the electromagnetic vacuum with quantum levels that may be related to the string theory. The mass-charge equivalence relation results directly expressing that the masses of particles-antiparticles are proportional to the cubic power of the electron-positron elementary charge respectively. Newton's gravitational potential is equivalent to Coulomb's electrostatic potential.
Gravitation is an intrinsic property of the quantum vacuum and has electromagnetic nature. The gravitational constant *G* derives from the vacuum electromagnetic properties $\varepsilon_0, \mu_0, \xi$ and is the same for matter and antimatter. Conversely, the masses of particles and antiparticles bear naturally opposite signs entailing a mutual gravitational repulsion. Matter-antimatter antigravity may play a dominant role in the cosmic acceleration and has to be investigated experimentally.

The electromagnetic quantum vacuum is a cosmic field permeating everything in the universe and whose fluctuations last longer the lower the frequency. This could also explain the origin of the $1/f^{n}$ noise observed not only in astrophysics but also in many other technological fields.

It is of high importance to mention that we have made no hypothesis and advanced no axioms or postulates in order to obtain the above results. Everything derives naturally from Maxwell's theory once the vector potential amplitude is normalized at a single photon level. Consequently, the electromagnetic quantum vacuum field may constitute the physical basis for the development of a coherent unified field theory. Furthermore, the extreme simplicity of the established formalism relating the electromagnetic vacuum to electromagnetism, particle physics and gravitation signifies that there is a real physical background behind the equations opening new perspectives for innovative studies on gravity-antigravity.

Dark Energy and Dark Matter might both originate from transient states of Dark Light fluctuations. The first due to transient photons and the second to transient pairs of known and unknown particles. Weighing the electromagnetic vacuum fluctuations energy density in (14) we deduced that the quantum vacuum fluctuations electromagnetic energy density should have a pic in the THz region. Under these conditions, free space is not Lorentz invariant and an observer with uniform velocity, in absence of any other reference frame, would be able to detect his motion from the Doppler shift of the electromagnetic vacuum fluctuations spectrum.
We have drawn that transient photons due to vacuum fluctuations, that we identified to Dark Energy, and matter-antimatter antigravity represent the physical mechanisms that might be at the origin of the observed cosmic acceleration. A detailed experimental investigation could conclude which of the previous mechanisms plays the dominant role in this process.

Next, we advanced the hypothesis that photons as well as matter and antimatter in universe emerge spontaneously from the quantum vacuum as residues of its associated fluctuations. Thus, Dark Energy, Dark Matter, photons, matter and antimatter, all derive from the electromagnetic quantum vacuum, the Dark Light.
Energy-mass annihilation mechanisms, such as black holes, appear naturally in the later stage of the evolution of a local finite universe transforming the initially generated energy-mass back to the vacuum state. This also provides a satisfactory explanation to what the tremendous quantities of energy-mass swallowed by black holes become in the singularity.

Energy-mass and charges are conserved between the initial and final states of the overall cosmic creation-annihilation processes. A large number of finite universes, like ours, and anti-universes might be born, extend, live and die in an infinite and eternal space.
A new cosmological model could be developed on this basis overcoming the well-known Big Bang inconveniences such as, initial state, faster than the speed of light inflation, as well as the horizon, flatness and antimatter issues.

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