Scientific Research Publishing

Journal of Modern Physics, 2022, 13, 949-968
https://www.scirp.org/journal/jmp
ISSN Online: 2153-120X
ISSN Print: 2153-1196

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

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How to cite this paper: Meis, C. (2022) The Electromagnetic Nature of Gravitation and Matter-Antimatter Antigravity. Surmise on Quantum Vacuum Gravitation and Cosmology. *Journal of Modern Physics*, **13**, 949-968.
https://doi.org/10.4236/jmp.2022.136054

Received: April 20, 2022
Accepted: June 27, 2022
Published: June 30, 2022

Abstract

We show that the electromagnetic quantum vacuum derives directly from Maxwell's theory and plays a primary role in quantum electrodynamics, particle physics, gravitation and cosmology. It corresponds to the electromagnetic field ground state at zero frequency, a zero-energy cosmic field permeating all of space and it is composed of real states, called *kenons* (*κενο* = vacuum). Photons are local oscillations of *kenons* guided by a non-local vector potential wave function with quantized amplitude. They propagate at the speed imposed by the vacuum electric permittivity ε_0 and magnetic permeability μ_0, which are intrinsic properties of the electromagnetic quantum vacuum. The electron-positron elementary charge derives naturally from the electromagnetic quantum vacuum and is related to the photon vector potential. We establish the masse-charge equivalence relation showing that the masses of all particles (leptons, mesons, baryons) and antiparticles are states of the elementary charges and their magnetic moments. The equivalence between Newton's gravitational law and Coulomb's electrostatic law results naturally. In addition, we show that the gravitational constant G is expressed explicitly through the electromagnetic quantum vacuum constants putting in evidence the electromagnetic nature of gravity. 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, particle physics, gravitation and cosmology and constitutes a 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. The cosmic

acceleration may be due to both "quantum vacuum fluctuations" and "matter-antimatter gravitational repelling". All the above results are established without stating any assumptions or postulates. Next, we advance two hypotheses with cosmological impact. The first is based on the possibility that gravitation is due to the electromagnetic quantum vacuum density of states fluctuations giving rise to a photon pressure at the characteristic collective oscillation frequencies of the charge densities composing the bodies (Electromagnetic Push Gravity). The second advances 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 main principles upon which a new cosmological model may be developed overcoming the well-known Big Bang issues.

Keywords

Photons, Electromagnetic Waves, Electromagnetic Quantum Vacuum, Dark Light, Kenons, Gravitation, Matter-Antimatter Antigravity, Electromagnetic Push Gravity, Dark Energy, Cosmological Constant, Dark Matter, Elementary Charges, Mass-Charge Relation, Cosmology, Unified Field Theory

1. 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] [2] [3] [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?

Recent studies on gravitational anomalies detected on many hundreds of galactic systems revealed big discrepancies with both Newton's laws and General Relativity revealing the necessity of advancing new theoretical concepts. 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 completed or replaced in the future according to the new observations to come.

In what follows, we make an introduction to the fundamentals of the electromagnetic quantum vacuum, namely Dark Light, corresponding to the electromagnetic field ground state which 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 analyze its role in QED, particle physics and gravitation. We show that photons are oscillations of the electromagnetic vacuum field while the lepton-antilepton elementary charges derive equally from this field and are related to photons. 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. We show that the gravitational constant G is a vacuum property having electromagnetic nature and is the same for 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. Finally we advance the speculations of the Electromagnetic Push Gravity and the Spontaneous Generation of energy and matter as residues of the electromagnetic quantum vacuum fluctuations.

2. The Electromagnetic Quantum Vacuum, the Dark Light

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

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

where $\boldsymbol{\varepsilon}_{k\lambda}$ is the complex polarization unit vector, $\boldsymbol{k}$ the wave-vector with amplitude $k=2\pi/\lambda_k$. The wavelength of the mode k is λ_k, θ a phase parameter and cc the complex conjugate.

The vector potential amplitude quantization constant ξ may be positive or negative

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

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 $\boldsymbol{\alpha}_{k\lambda}(\boldsymbol{r},t)$ is a natural wave function for a free k-mode photon satisfying the *vector potential—energy* (wave-particle) equation for the photon

$$i\begin{pmatrix}\xi\\ \hbar\end{pmatrix}\frac{\partial}{\partial t}\boldsymbol{\alpha}_{k\lambda}(\boldsymbol{r},t)=\begin{pmatrix}\tilde{\alpha}_{0k}\\ \tilde{H}_k\end{pmatrix}\boldsymbol{\alpha}_{k\lambda}(\boldsymbol{r},t) \tag{3}$$

where

$$\begin{pmatrix}\tilde{\alpha}_{0k}\\ \tilde{H}_k\end{pmatrix}=-i\begin{pmatrix}\xi\\ \hbar\end{pmatrix}c\nabla_k \tag{4}$$

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 vector potential amplitude $\alpha_{0k}=\xi\omega_k$ and energy $E_k=\hbar\omega_k$ expresses the simultaneous wave-particle nature of a single photon through the *vector potential—energy* Equation (3).

It is worth 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]

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

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 $\boldsymbol{\Xi}_{k\lambda}(\boldsymbol{r},t)$ in the vector potential expression (1) still subsists and writes in both classical electromagnetic theory and QED [14] [15] [16] [17]

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

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

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 single k-mode and λ-polarization photon.

Hence, in total absence of energy, of vector potential as well as of electric and magnetic fields, $\boldsymbol{\Xi}_{0\lambda}$ 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 $(\lambda_k\to\infty)$ and has electric potential nature according to the physical dimensions of ξ. The phase θ may take any value and consequently the electromagnetic quantum vacuum is composed of all possible states $\boldsymbol{\Xi}_{k\lambda}(\boldsymbol{r},t)$ corresponding to all modes and polarizations that can be called "*kenons*" (from *κενο* = vacuum)

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

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

From Equation (4), an angular frequency operator $\tilde{\Omega}_k$ can be readily defined [17] for each mode k

$$\tilde{\Omega}_k=-ic\nabla_k \tag{8}$$

Using (3) and (8), we get the equation governing the *kenons* in vacuum

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

Obviously, according to the last equation, photons (electromagnetic waves) are generated by the action of the angular frequency operator $\tilde{\Omega}_k$ upon the *kenons* states $\boldsymbol{\Xi}_{k\lambda}(\boldsymbol{r},t)$ creating a real vector potential $\boldsymbol{\alpha}_{k\lambda}(\boldsymbol{r},t)$. Consequently, photons are local oscillations of *kenons* over a wavelength, with circular polarization (λ = left or right), guided by a non-local vector potential wave function with the real amplitude $\alpha_{0k}=\xi\omega_k$ [10] [13] [14].

Thus, the electromagnetic quantum vacuum, that is Dark Light, is composed of *kenons* and Light (Electromagnetic Waves) is composed of photons which are *kenons* transformed by the action of the angular frequency operator.

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 e

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

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

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

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

$$T=\gamma\hbar/2\pi ck_B \tag{12}$$

where k_B is Boltzmann's constant.

3. Electromagnetic Quantum Vacuum Fluctuations, QED and Cosmology

3.1. Transient Photons from the Electromagnetic Quantum Vacuum and the Cosmic Acceleration

The 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 (~10^{19} GeV) gives the "astronomic" value ~10^{110} Jm^{-3}, while the observed one is roughly ~10^{-10} Jm^{-3} [1].

This unphysical 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 canonical 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 ex-

periment 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 of a *k* mode in quantum field theory, $\hbar\omega_k/2$, resulting from the harmonic oscillator Hamiltonian, does not correspond to a physical state and this is what 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 $\hbar\omega_k/2$ but to the properties of the photon creation and annihilation operators, $a_{k\lambda}^{+}$ and $a_{k\lambda}$ respectively. As about the well-known Casimir effect, it has been demonstrated by different methods ([14] and references therein) that it can be explained directly 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 $\hbar\omega_k/2$, 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, the electromagnetic quantum vacuum, composed of *kenons* states, (7a) and (7b), 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, produced by the action of the angular frequency operator upon *kenons*, and propagate at the speed imposed by its intrinsic properties, the vacuum electric permittivity ε_0 and magnetic permeability μ_0. Consequently, due to the electromagnetic vacuum fluctuations (Dark Light fluctuations) with time, expressed by (9), space is permanently full of transient photons at all frequencies underlying the cosmic radiation background.

We may assume the probability for a transient *k*-mode photon spontaneous creation in space to be proportional to $\exp\left(-\left|\boldsymbol{\varepsilon}_k/\varepsilon_m\right|\right)$, where $\left|\boldsymbol{\varepsilon}_k\right|$ is the transient photon electric field amplitude generated in free 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] by weighing the integration with the transient photon spontaneous creation probability $\exp\left(-\left|\boldsymbol{\varepsilon}_k/\varepsilon_m\right|\right)=\exp\left(-\omega^2/\omega_m^2\right)$

$$\rho_{vacuum}=\frac{\hbar}{\pi^2c^3}\int_0^{\infty}\mathrm{e}^{-\omega^2/\omega_m^2}\omega^3\mathrm{d}\omega=\frac{\hbar\omega_m^4}{2\pi^2c^3}=\frac{2}{\pi}\varepsilon_0\mu_0e\xi\omega_m^4 \tag{13}$$

Note that the above calculation cannot be applied in the case of the zero-point energy term because it is an eigenvalue of the harmonic oscillator Hamiltonian corresponding to a stable fundamental eigenstate composed of all *k*-mode photons and consequently the weighing factor for all modes is 1.

Considering that ω_m is a logarithmic mean value for the angular frequency

over the electromagnetic spectrum, roughly in the THz region $\omega_m \sim 2\pi\times 10^{12}$ Hz, we obtain $\rho_{vacuum} \sim 3\times 10^{-10}\ \mathrm{J\cdot m^{-3}}$ in quite good agreement with the astrophysical observations.

Consequently, the energy density of the electromagnetic quantum vacuum fluctuations (Dark Light fluctuations), whose principal energy density lays in the THz spectral region, is quite plausible to represent the Dark Energy considered responsible for the cosmic acceleration. We expect the James Webb space telescope to give an answer to that issue.

3.2. Transient Charges (Particles and Antiparticles) from the Electromagnetic Quantum Vacuum. Mass-Charge Equivalence

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].

$$e = (4\pi)^2 \alpha \frac{\xi}{\mu_0} \tag{14}$$

Note that the last relation is neither a postulate nor a definition but derives naturally when considering the vector potential amplitude quantization for a single photon.

It becomes evident that the photon vector potential amplitude $\alpha_{0k} = \xi\omega_k$ and the elementary charge e are directly related to the electromagnetic quantum vacuum through the vacuum 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 mechanisms.

We recall here 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 level. Despite of this characteristic physical origin Planck's constant is used in quantum physics for the description of all the elementary particles. Hence, we may draw that the electromagnetic nature should be an inherent property of particles.

In addition, it is important to mention that the notion of mass introduced in the expression of Bohr's magneton μ_B is a classical concept associated to a quantum process for the description of the magnetic dipole moment $\boldsymbol{M}$ of a wave-particle with wave-vector $\boldsymbol{k}$ in a circular standing state of radius $\boldsymbol{r}$. In fact, in a pure quantum description Bohr's magneton is simply the proportionality constant of the magnetic dipole moment $\boldsymbol{M} = \mu_B(\boldsymbol{k}\times\boldsymbol{r})$.

Now, the mass m_{e^-,e^+} of the electron/positron is expressed exactly through the vacuum constant ξ, the elementary charge e and its magnetic moment

$$m_{e^-,e^+} = 2\pi c e^2 \frac{\xi}{\mu_B} \tag{15}$$

with $\mu_B = 9.274\times 10^{-24}\ \mathrm{J\cdot T^{-1}}$ being the Bohr magneton.

Also, the proton/antiproton mass writes

$$m_{P^+,P^-} = 2\pi ce^2 \frac{\xi}{\mu_P} \tag{16}$$

where $\mu_P = 5.0508\times10^{-27}\ \mathrm{J\cdot T^{-1}}$ is the proton magneton.

Similarly, the mass m_i of any elementary particle/antiparticle writes in a general way

$$m_i = 2\pi ce^2 \frac{\xi}{\mu_i} \tag{17}$$

where e is the electron charge for particles (with $\xi < 0$) or the positron charge for antiparticles (with $\xi > 0$) and μ_i is the magneton of the particle i.

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

$$\mu_i \simeq \left(\frac{16\alpha}{n_i}\right)\mu_B \tag{18}$$

where n_i is simply a positive integer.

Thus, the mass of any particle i (other than the electron), that is lepton, meson or baryon, as well as of any antiparticle (other than the positron), is expressed uniquely with a precision better than 0.5% through the electron/positron charge e [17]

$$m_i \simeq n_i\left(\frac{\pi ce^2}{8\alpha\mu_B}\right)\xi = n_i\sigma_m e \tag{19}$$

where we have used (2).

The value of the proportionality constant is
$\sigma_m = \hbar/32\alpha\mu_B = 4.8696\times10^{-11}\ \mathrm{kg\cdot C^{-1}}$.

The Equation (19) writes simply:

$$m_i \simeq n_i 4.3767\ \mathrm{MeV}/c^2 \tag{20}$$

In **Table 1** are shown the masses obtained for different n_i values and the corresponding identified particles (considered conventionally as positive).

Obviously, the rest masses of all particles/antiparticles are purely of electromagnetic nature and the relations (17) and (19) express simply the mass-charge equivalence. Although in **Table 1** we have considered the particles masses as positives, according to the usual convention, it is important noting that the presence of either ξ or e in (19) confers an opposite sign between particles and antiparticles masses. According to the last equations, we draw that the electron/positron charge is directly 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 (19) of the integer n_i characterizing the particles/antiparticles masses implies that the electromagnetic vacuum must have a

Table 1. Identification of particle masses obtained using equation (20) with different values of integers n_i and comparison to the experimental values. The discrepancy is lower than 0.2% for roughly 90% of the identified particles.

n_I	m_I calc. (MeV·c^{-2})	m_I exp. (MeV·c^{-2})	δ (%)	particle
24	105.0	105.65	−0.57	Muon (lepton), μ^-
31	135.6	134.97	0.46	Pion (meson), π^0
32	140.0	139.57	0.30	Pion (meson), π^+, π^-
113	494.5	493.68	0.17	Kaon (meson), K^+, K^-
114	498.9	497.70	0.24	Kaon (meson), K_S^0, K_L^0
125	547.1	547.75	−0.11	Eta (meson), η^0
177	774.7	775.8	−0.14	Rho (meson), ρ^0, ρ^+, ρ^-
179	783.4	782.59	0.10	Omega (meson), ω
214	936.6	938.27	−0.17	Proton (baryon), p^+
215	940.9	939.56	0.15	Neutron (baryon), n^0
255	1116.0	1115.68	0.03	Lambda (baryon), Λ^0
271	1186.0	1189.37	−0.28	Sigma (baryon), Σ^+
272	1190.4	1192.6	−0.18	Sigma (baryon), Σ^0
273	1198.9	1197.45	0.12	Sigma (baryon), Σ^-
300	1313.0	1314.8	−0.13	Xi (baryon), Σ^0
302	1321.7	1321.7	0.00	Xi (baryon), Σ^-
350	1531.8	1531.8	0.00	Xi (baryon), Σ^0 res.
351	1536.2	1535.0	0.07	Xi (baryon), Σ^- res.
382	1671.9	1672.45	−0.03	Omega (baryon), Ω^-
406	1776.9	1777.0	−0.00	Tau (lepton), τ^-
426	1864.5	1864.8	−0.01	D Meson, D^0
450	1969.5	1968.4	0.05	Ds Meson, D_s^+
458	2004.5	2006.97	−0.12	D Meson, D^{+0}
459	2008.9	2010.27	−0.06	D Meson, D^{++}
522	2284.6	2286.46	−0.08	Lambda c (baryon), Λ_c^+
560	2451.0	2452.9, 2453.7	−0.08	Sigma c (baryon), Σ_c^+, Σ_c^0
561	2455.3	2453.9	0.05	Sigma c (baryon), Σc^{++}
564	2468.4	2467.9	0.02	Xi c (baryon), Ξ_c^+, Ξ_c^0
565	2472.8	2471.0	0.07	Xi c (baryon), Ξ_c^+, Ξ_c^0
588	2573.5	2575.7	0.08	Xi c (baryon), Ξ_c^+ res.
589	2577.9	2578.0	−0.00	Xi c (baryon), Ξ_c^0 res.
616	2696.0	2697.5	−0.06	Omega c (baryon), Ω_c^0
804	3518.9	3518.9	0.00	Xi cc (baryon), Ξ_{cc}^+

Continued

827	3619.5	3621.4	−0.05	Xi cc (baryon), Ξ_{cc}^{++}
1206	5278.3	5279.34, 5279.65	−0.02	B Meson, B^+, B^0
1226	5365.8	5366.8	−0.02	Bs Meson, Bs0
1284	5619.7	5620.2	−0.00	Lambda 0s (baryon), Λ_b^0
1327	5807.9	5810.5	−0.04	Sigma b (baryon), Σ_b^+
1329	5816.6	5815.2	0.02	Sigma b (baryon), Σ_b^-
1356	5934.8	5935.0	−0.00	Xi' b (baryon), Ξ_b'
1361	5956.6	5955.3	0.02	Xi* b (baryon), Ξ_b^*
1381	6044.2	6046.0	−0.02	Omega b (baryon), Ω_b^-
1423	6228.0	6226.9	0.01	Xi b (baryon), Σ_b
1434	6276.1	6274.9	0.02	Bs Meson, B_c^+
18,367	80386.8	80,385	+0.00	W^- Boson
20,835	91188.5	91187.5	+0.00	Z Boson
28,640	125348.7	125,350	−0.00	Higgs Boson

complex structure of quantum levels yet to discover, which might be related to string theory. Quarks and antiquarks should be also states of the same vacuum field since they bear a fractional elementary charge ($e/3$ and $2e/3$) and consequently, strong and weak forces should be particular manifestations of the electromagnetic vacuum field. Through this lens, all neutral elementary particles/antiparticles must be composed of positive and negative charges and consequently, gravity should have electromagnetic nature.

Finally, we draw that fluctuations of the electromagnetic vacuum might 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.

3.3. Electromagnetic Nature of the Gravitational Constant, Newton's and Coulomb's Laws Equivalence, Matter-Antimatter Antigravity

Considering Planck's length $l_P = 1.616 \times 10^{-35}$ 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]

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

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 Equation (22) the gravitational potential writes now in pure 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 (19) 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 $\omega_L = \mu_B|\boldsymbol{B}|/\hbar$ for the elementary charge in a magnetic field $\boldsymbol{B}$ to be also positive and the corresponding absorbed and emitted photons to have positive energies $\hbar\omega_L$. Under this condition, if the magnetons μ_i of the particles are positive quantities then 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 Equation (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 fol-

lowing the mass-charge equivalence.

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 question.

Note that, from Equation (15) for the electron mass, 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", would result 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 $c = \left(\varepsilon_0 \mu_0\right)^{-1/2}$, $e = \left(4\pi\right)^2 \alpha\xi / \mu_0$, $\hbar = \alpha\xi^2 \left(4\pi\right)^3 \varepsilon_0^{-1/2} \mu_0^{-3/2}$ and $G = l_p^2 / 4\pi\varepsilon_0 \alpha \left(4\pi\xi\right)^2$ are expressed uniquely through the vacuum physical parameters $\varepsilon_0, \mu_0, \xi$ 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.

4. Surmise on Quantum Vacuum Push Gravity

Now, it is important remarking that Equation (22) simply transposes the problem of gravitation without giving a clear idea about its real physical origin. In other words, we have switched from the unknown reason why masses attract (or repel) each other to the equally unknown reason why the ratios of charge to the magnetic moments should attract (or repel) each other. In fact, using (19) the gravitational potential (22) writes

$$U \simeq \sigma_m^2 e^2 G \sum_{i,j(i<j)} \frac{s_{ij} n_i n_j}{r_{ij}} \tag{26}$$

where s_{ij} is the sign of the product $e_i e_j$ and n_i, n_j are the corresponding in-

tegers.

Obviously, unless pure integers attract (or repel) each other, Newton's and Coulomb's law are phenomenological mathematical expressions describing "how" gravitation and electrostatic forces act but without explaining physically "why". In addition, it is worth to note that G in Equation (21) is inversely proportional to $\left(4\pi\xi/l_p\right)^2$ which may be understood as the square of the density (in 4π solid angle) of the vacuum states. Generalizing the expression, we may write

$$G=\frac{1}{4\pi\varepsilon_0\alpha\rho\left(\xi\right)^2} \tag{27}$$

where $\rho(\xi)$ is the local *kenon* mean density.

Through this lens, G depends directly on the local density of the vacuum states and consequently may not be a universal constant. This could explain the gravitational anomalies observed on hundreds of galactic systems in contradiction with Newtonian dynamics and General Relativity. On the other hand, recent studies over 193 high-quality disk galaxies have finally ruled out with a high degree of statistical accuracy all modified Newtonian dynamics models [23].

Under these conditions, we may advance the hypothesis here that gravitation might originate from the radiation pressure of the electromagnetic quantum vacuum field (*Electromagnetic Push Gravity*), induced by the local variation of the vacuum density of states, which is felt by the bodies in their own frame and depending on the collective frequencies of their own charge densities [16].

In fact, a plasma is characterized by the plasma frequency ω_p corresponding to a collective oscillation frequency of the electron density n_e, whose well-known expression is

$$\omega_p=\left(n_e e^2/\varepsilon_0 m_e\right)^{1/2} \tag{28}$$

Similarly, whatever the temperature, all the bodies are composed of charge densities whose collective oscillations yield characteristic global frequencies, analogue to the plasma frequency. For instance, the electron density in iron is roughly 2×10^{29} m^{-3}. Assuming that the plasma frequency expression (28) is valid, the frequency obtained for the iron is roughly $\omega_{iron}\approx3\times10^{16}$ Hz·rad, which lays in the UV region.

Thus, every mass is characterized by one or more charge density collective frequencies and the *kenons* of the electromagnetic quantum vacuum field are "seen" in the mass frame as photons at the same collective frequencies inducing a radiation pressure.

Considering that a mass is characterized by a collective frequency ω_c, taking into account the two circular polarizations of *kenons* and the fact that the photon electric field seen in the frame of the mass is proportional to $\xi\omega_c^2$, according to (5), the pressure dP exerted by the *kenons* upon the mass in a solid angle $d\Omega$ writes

$$dP_{vacuum}=\left(4\varepsilon_0\xi^2\omega_c^4\right)d\Omega \tag{29}$$

The origin of gravitation appears to lay on the modification of the electromagnetic quantum vacuum field fluctuations due to the presence of localized charges (mass) which reduce locally the presence of the vacuum states, that is *kenons*. Thus, a flow of *kenons* from the surrounding space is induced towards the charge density (mass) which consequently experiences in its frame a radiation pressure at the characteristic frequency ω_c. Variations to quantum vacuum fluctuations may be also due to the presence of electromagnetic waves (photons), which also reduce the presence of *kenons* since they are composed of *kenons* themselves, enhancing by this way the gravitational effect at short distance. For instance, the photospheres of stars increase the gravitational effect felt by the bodies moving closely (perihelion). By the same token, 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.

As an example, we may attempt to evaluate in a first approximation what could be the characteristic frequency of the Earth's charge density by considering the system Sun-Earth. The characteristic distances of the system are: Radius of the Earth $R_E = 6.37\times10^6$ m, Radius of the Sun $R_S = 6.96\times10^8$ m and the mean distance Sun-Earth $R_{S\text{-}E} = 1.5\times10^{11}$ m.

Let us denote the collective frequency of the charge densities of the Earth by ω_E.

Consequently, the screening of the Sun, being considerably more important than that of the Earth, induce a force on the Earth towards the Sun due to the radiation pressure of the *kenons* flux coming from the opposite side which writes in a first approximation

$$\delta F \approx 4\varepsilon_0\xi^2\omega_E^4\left(\pi R_S^2/R_{S\text{-}E}^2\right)2\pi R_E^2 = 8\pi^2\varepsilon_0\xi^2\omega_E^4R_S^2R_E^2/R_{S\text{-}E}^2 \tag{30}$$

Obviously, except the characteristic collective frequency, the geometry of the bodies plays also an important role.

For $\omega_E \sim 2\pi\times10^{17}$ Hz·rad, which lays in the far UV region, we obtain a total attraction force exerted on the Earth due to the vacuum pressure induced by the presence of Sun equivalent to the Newtonian one, 3.5×10^{22} N.

Using the same formalism a similar result is obtained for the system Earth-Moon considering the lunar characteristic frequency ω_L. The distances are: Radius of the Earth $R_E = 6.37\times10^6$ m, Radius of the Moon $R_L = 1.74\times10^6$ m and the mean distance Earth-Moon $R_{E\text{-}L} = 3.8\times10^8$ m. We get

$$\delta F \approx 8\pi^2\varepsilon_0\xi^2\omega_L^4R_L^2R_E^2/R_{E-L}^2 \tag{31}$$

We obtain an attraction force equivalent to the Newtonian one, that is 2×10^{20} N, for $\omega_L \sim 2\pi\times5\times10^{16}$ Hz·rad which lays in the UV region.

Despite the extreme simplicity of the above calculations, the obtained results seem to be rather physical since the plasma frequency corresponding to the electron density in metals is also in the UV region. The consideration of the mutual screening effects of all the interacting bodies and the precise knowledge of their characteristic frequencies and geometries could yield results that are more accu-

rate.

Thus, a well-elaborated model of *Electromagnetic Push Gravity*, analogue to that proposed recently [24] for the Push Gravity, could be interesting to be developed and tested.

5. The Electromagnetic Quantum Vacuum as a Cosmic Source of Photons (Energy) and Charges (Mass): Surmise on the Qualitative Principles of 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 advance the hypothesis 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 could constitute 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 explains the homogeneous and isotropic Cosmic Microwave Background.

In the birth stage of the universe, the spontaneous energy-mass creation process dominates. Photons and charges (particles and antiparticles) are created continuously by *kenon* fluctuations 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 *kenon* density variations, 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 [25] [26]. 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.

Finally, the surprising homothetic structural similarities between Deoxyribonucleic Acid (DNA) and photons and the continuous coupling to *kenons* raises the question whether the triggering of life, at least in the form met on our planet, is also related to the quantum vacuum [27].

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 in 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.

6. Conclusions

We have visited the basic physical features that derive naturally from the electromagnetic quantum vacuum, the cosmic Dark Light, composed of real states called *kenons*. Local oscillations of *kenons* over a wavelength at an angular frequency ω_k give birth to a real vector potential, thus to real photons (electromagnetic waves) guided by the non-local vector potential wave function with the quantized amplitude $\alpha_{0k} = \xi\omega_k$. The vacuum electric permittivity and magnetic

permeability are intrinsic properties of the electromagnetic quantum vacuum and fix the speed of photons in vacuum c.

Positive and negative elementary charges are states of the same vacuum field and are strongly related to photons vector potential through the vacuum constant ξ. The masses of all particles and antiparticles originate from charges and their magnetic moment. The mass-charge equivalence relation results directly expressing that the masses of all particles-antiparticles are proportional to the electron-positron elementary charge respectively. Hence, the electromagnetic vacuum should have a complex structure with quantum levels that may be related to the string theory.

The gravitational constant G is also related to the vacuum electromagnetic properties implying that Newton's gravitational potential is equivalent to Coulomb's electrostatic potential. We deduce that gravitation has electromagnetic nature and that the gravitational constant G is the same for matter and antimatter. However, 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.

Finally, the generalization of the gravitational constant formula indicates that G is inversely proportional to the square of the *kenons* density and consequently may not be a universal constant.

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. The simplicity of the established formalism relating the electromagnetic vacuum to electromagnetism, particle physics and gravitation signifies that there should be a real physical background behind the equations. Consequently, the electromagnetic quantum vacuum field may constitute the physical basis for the development of a coherent unified field theory.

We have shown that Dark Energy and Dark Matter might both originate from transient states of Dark Light fluctuations. The first is due to transient photons and the second to transient pairs of known and unknown particles. Weighing the electromagnetic vacuum fluctuations energy density, we deduced that the electromagnetic energy density of the quantum vacuum fluctuations 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 these mechanisms plays the dominant role in this process.

Next, we advanced two hypotheses:

1) *Gravitation is due to the electromagnetic quantum vacuum* (*kenons*) *radiation pressure* (*Electromagnetic Push Gravity*) *seen by the charge densities* (*mass*) *in their frame at their own collective oscillation frequencies*.

Using a simple screening model, we have analyzed in a first approximation the possibility of the "*Electromagnetic Push Gravity*" due to the electromagnetic quantum vacuum (*kenons*). The modification of the vacuum field fluctuations due to the presence of a localized charge density (mass), which reduces the vacuum states (*kenons*), induces a flux of *kenons* towards the mass which in its frame experiences a radiation pressure at the characteristic frequency of the charge density collective frequency.

Photons (electromagnetic waves) may also induce a modification to the quantum vacuum fluctuations, since they are composed of *kenons*, reducing locally the vacuum states. An intense source of photons depleting continuously the vacuum states exhibits a direct gravitational effect, such as photospheres in stars corona.

Light rays follow the paths in the electromagnetic vacuum imposed by the charge densities in space reducing locally the vacuum states (*kenons*) and modifying consequently the vacuum fluctuations and the refractive index.

The approximated characteristic frequencies calculated for Earth and Moon lay in the UV spectrum and are slightly higher than the plasma frequencies attributed to metals.

2) *Photons as well as matter and antimatter in universe emerge spontaneously from the electromagnetic 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 composed of *kenons*.

Energy and mass annihilation mechanisms, such as black holes, appear naturally in the later stage of the evolution of the 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.

A large number of finite universes, as ours, and anti-universes might be born, extend, live and die in an infinite and eternal space. Energy-mass and charges are conserved between the initial and final states of the overall cosmic creation-annihilation processes.

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.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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