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Derivation of Electromagnetism from Quantum Theory of Photons: Tesla Scalar Waves

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Abstract We provide a *complete explanation of the Maxwell's equations* based on the *statistical behaviour of the photons* emitted/absorbed by charged particles, based on short-range massive photons and long-range photons. Then we explain the physical phenomena of attraction/repulsion between charged particles based on the statistical effects of short-range photons. Finally, we provide the physical explanation of the famous Tesla's scalar (longitudinal) waves based on the theory of massive long-range photons (which have the similar behaviour like the neutrinos).

Keywords: Quantum Mechanics, Massive bosons, Electromagnetism.

1 Introduction

In the IQM theory there is a deeper specification of the state of the particle, and in this approach to completion provided in [4], these states are specified by the energy-density distributions of a given particle in the Minkowski time-space. Such an ontic state, also not fully accessible (non fully observable by the measurements, and/or with non accessible small compactified higher-dimensions for the electric charge (5th timelike dimension with the coordinate $q_4 = ct_4$) and spin (6th spacelike dimension with the coordinate q_5), for example), has to represent the complete description of an individual elementary particle, in

order to be able to compute from it all properties of a particle as its rest-mass, position, speed, momentum, total energy, etc...
The standard quantum theory with the probabilistic wavefunctions and their statistical ensemble interpretation is based on the classical concept of a *point-like particle* and do not have the theory able to describe an individual particle with its trajectory and given momentum and energy in any fixed instance of time. Because of that as noted by Einstein it was an incomplete theory, differently from the classic mechanics which has both statistical theory (for example the thermodynamic of a gas) and theory for each individual object (Newton, Euler-Lagrange equations for the motion of an individual object). In the proposed completion of quantum theory [4] instead, an *individual* massive particle's wave-packet always occupies a nonzero 3-D volume.
It was shown [1, 9, 10, 4] that, generally, any massive particle can be defined in the Minkowski time-space (we will not use the real higherdimensional expressions but only its reduced forms to the 4-D representation) with the signature $(+,-,-,-)$, by the complex wave-packet

$$\Psi = \Phi(t, \overrightarrow{\mathbf{r}})\mathrm{e}^{-i\varphi_T} \tag{1}$$

where $\overrightarrow{\mathbf{r}} = q_1\mathbf{e}_1 + q_2\mathbf{e}_2 + q_3\mathbf{e}_3$ (for the 3-D Minkowski space orthonormal basis vectors $\mathbf{e}_j$, with $\mathbf{e}_j \cdot \mathbf{e}_j = -1$ for $1 \leq j \leq 3$ and $\mathbf{e}_0 \cdot \mathbf{e}_0 = 1$ for the time-coordinate $q_0 = ct$) composed by two sub components: by the shape $\Phi(t, \overrightarrow{\mathbf{r}})$ of particle's body that is a real function which defines the real *rest-mass energy-density* $\Phi_m \equiv \Psi\overline{\Psi} = \Phi^2(t, \overrightarrow{\mathbf{r}}) \geq 0$, and by the de Broglie 'phase (pilot) wave' with phase $\varphi_T(t, \overrightarrow{\mathbf{r}_T}) = -\frac{1}{\hbar}S_{t_0=0}$, where $S_{t_0=0} = \int_{0,\overrightarrow{\mathbf{r}_0}}^{t,\overrightarrow{\mathbf{r}_T}} L(t', \overrightarrow{\mathbf{r}}, \overrightarrow{\mathbf{v}})dt'$ is the Hamiltonian principal function for the initial particle's position $(t_0, \overrightarrow{\mathbf{r}_0})$ and the current position at $t \geq 0$ (its barycenter) at $\overrightarrow{\mathbf{r}_T}(t) \equiv \frac{1}{\mathbf{1}_\Phi}\int \overrightarrow{\mathbf{r}}\Phi_m(t, \overrightarrow{\mathbf{r}})dV$, and particle's Lagrangian at time t', $L(t', \overrightarrow{\mathbf{r}}, \overrightarrow{\mathbf{v}}) = E + \overrightarrow{\mathbf{v}}\,\overrightarrow{\mathbf{p}}$ where E is particle's total energy and $\overrightarrow{\mathbf{p}}$ its canonical (conjugate) momentum, and $\mathbf{1}_\Phi \equiv \int \Phi_m(t, \overrightarrow{\mathbf{r}})dV$ is the particle's invariant energy (equal to rest-mass energy m_0c^2 for massive particles and energy E_0 of a boson, measured in the frame in which massive source of this boson is in rest).
This new IQM theory for individual particles is able to compute the spectra of the rest-masses of the particles which is not possible to obtain with the statistical SQM theory. Moreover, it was demonstrated that this quantum theory completion is conservative w.r.t. the theoretical and experimental results of the statistical SQM theory. When a particle propagates in the vacuum with constant speed $\overrightarrow{\mathbf{v}}$ it has the time-invariant spherically-symmetric distribution [8], $\Phi_m = \frac{K}{\sqrt{r}}$, where $r = \|\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}}_T\|$ is the distance from its barycenter

$\overrightarrow{\mathbf{r}_T}$, corresponding to particle's hydrostatic equilibrium where each infinitesimal amount of particle's material body $\Phi_m(t, \overrightarrow{\mathbf{r}})$ is in rest w.r.t. particle's barycenter. However, generally, during an acceleration each infinitesimal amount of energy-density $\Phi_m(t, \overrightarrow{\mathbf{r}})$ moves with a different speed $\overrightarrow{\mathbf{w}}(t, \overrightarrow{\mathbf{r}})$ w.r.t. the group velocity $\overrightarrow{\mathbf{v}}(t) = \frac{d}{dt}\overrightarrow{\mathbf{r}_T}(t) = v_1\mathbf{e}_1 + v_2\mathbf{e}_2 + v_3\mathbf{e}_3$, with $v = \|\overrightarrow{\mathbf{v}}\| = \sqrt{v_1^2 + v_2^2 + v_3^2}$, of particle's energy-density wave-packet and it is shown [4] that is,satisfied the following relationship $\overrightarrow{\mathbf{v}}(t) = \frac{1}{\mathbf{1}_\Phi}\int \overrightarrow{\mathbf{w}}(t, \overrightarrow{\mathbf{r}})\Phi_m(t, \overrightarrow{\mathbf{r}})dV$, so we can introduce the variation-velocity of the particle's matter flux $\overrightarrow{\mathbf{u}}(t, \overrightarrow{\mathbf{r}}) = \overrightarrow{\mathbf{w}}(t, \overrightarrow{\mathbf{r}}) - \overrightarrow{\mathbf{v}}(t)$ at each space-time point $(t, \overrightarrow{\mathbf{r}})$ inside particle's matter (where $\Phi_m(t, \overrightarrow{\mathbf{r}}) > 0$). As shown in [4], during an inertial propagation when the particle is in a hydrostatic equilibrium, we have that Φ_m is spherically symmetric around particle's barycenter with $\overrightarrow{\mathbf{u}}(t, \overrightarrow{\mathbf{r}}) = 0$ in every point inside particle's matter, so that every infinitesimal amount of Φ_m propagates with the constant wave-packet group velocity $\overrightarrow{\mathbf{v}}$. Only during the particle's accelerations we have that $\overrightarrow{\mathbf{u}}(t, \overrightarrow{\mathbf{r}}) \neq 0$, so that particle's body changes dynamically its shape in time.

In the assumption [4] of the topology of the matter of an elementary massive particle, the wave-packet do not undergo a spreading, also when it changes its matter density distribution (i.e., its energy-density Φ_m), and tends to its stable stationary spherically symmetric distribution during inertial propagation in the vacuum. That is, the matter has some internal self-gravitational autocohesive force analogously to the peace of *perfect fluid*[1] in the vacuum, so that at any instance of time, the 3-D space topology of particle's matter distribution, and consequently its compressible energy-density Φ_m is simply connected, closed, continuous and differentiable. Each massive elementary particle satisfies the following conservation laws:

Analogously to the Euler first equation of fluid dynamics (continuity equation), which represents the conservation of mass, here we have the analog equation for the conservation of matter (that is of the particle's rest-mass energy),

$$\frac{\partial \Phi_m(t, \overrightarrow{\mathbf{r}})}{\partial t} + \nabla \cdot (\Phi_m(t, \overrightarrow{\mathbf{r}})\overrightarrow{\mathbf{w}}(t, \overrightarrow{\mathbf{r}})) = 0 \qquad (2)$$

In what follows, for the Cartesian coordinate system, $\nabla = \mathbf{e}_1\frac{\partial}{\partial x} + \mathbf{e}_2\frac{\partial}{\partial y} + \mathbf{e}_3\frac{\partial}{\partial z}$ is the gradient (for $x \equiv q_1, y \equiv q_2$ and $z \equiv q_3$) so that the Laplacian is defined

[1] We consider that the matter of an particle is a perfect fluid, that is, have no shear stresses, viscosity, or heat conduction. Perfect fluids are often used in general relativity to model idealized distributions of matter, such as the interior of a star or an isotropic universe. In general relativity, a fluid solution is an exact solution of the Einstein field equation in which the gravitational field is produced entirely by the mass, momentum, and stress density of a fluid. In astrophysics, fluid solutions are often employed as stellar models. Consequently, by the assumption that particle's material body is a perfect fluid, we obtain the full physical unification of the QM with universe.

by $\triangle = -\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ (we are using positive-time metric signature (+,-,-,-))
It holds also for bosons when they become unstable after an initial 'space explosion' and, consequently, assume the massive particle behavior and a finite but non-zero energy-density volume in open 3-D space. We need that the body of the particle Φ_m provides also the physical internal pressure $P(t, \overrightarrow{\mathbf{r}})$ (which is a non-geometrical property) in order to guarantee the hydrostatic equilibrium of the massive particles. The hydrostatic equilibrium of an massive elementary particle demonstrated that the body of this particle Φ_m is a material substance [8], which is fluid and elastic, and which can not be reduced to the time-space geometry.
Hence, in this IQM theory [4] for individual elementary particles based on energy-density wave-packets, the point-like particles are only the stable-state bosons when they propagate with speed of light in the vacuum, and with their energy-density distributed in higher compactified dimensions [5]. In Section 2.7 in [4], dedicated to the 3-D radial expansion of the bosons w.r.t. the direction of particle's propagation, to the tunneling and reflections, has been considered the cylindrical expansion of the massive boson with energy density Φ_m (that is, during the unstable boson's states where the variation-velocity $\overrightarrow{\mathbf{u}}(t, \overrightarrow{\mathbf{r}})) \neq 0$.
The real physical hyperdimensional representation of the massless bosons energy-density, for a given instance of time t, for the Euclidean space point $\overrightarrow{\mathbf{r}} = \overrightarrow{\mathbf{r}_0} + \overrightarrow{\mathbf{c}}t$, is given by $\Phi_m = \Phi^2(\mathbf{r}_4, t_4, q_5) = \sigma(q_5)\ \delta(\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}_0} - \overrightarrow{\mathbf{c}}t)$ where, $\sigma(q_5) = \frac{\mathbf{1}_\Phi}{L}$, with the length of the 6th dimension is $L = 4\pi R_5$, denotes the constant energy-density distributed in 6th dimension with radius R_5.
Thus, by integration of this hyperdimensional density over 6th dimension with coordinate q_5, from [5] we obtain the common point-like 4-D representation of the massless boson's energy-density in the 4-dimensional Minkowski time-space by the Dirac function (note that its pilot-wave phase is $\varphi_T = 0$),

$$\Phi_m(t, \overrightarrow{\mathbf{r}}) = \mathbf{1}_\Phi \delta(\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}_0} - \overrightarrow{\mathbf{c}}t) \tag{3}$$

where $\mathbf{1}_\Phi$ is a constant (equal to a total energy $E = pc$ of a boson in the frame where the source of this boson is in the rest), which is consequently *only mathematically* correct point-like representation of the massless boson. In fact, now the total energy, for a given time-instance t, can be obtained by integration in the ordinary 3-D space, by $E = \int \Phi_m dV = \mathbf{1}_\Phi \int \delta(\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}_0} - \overrightarrow{\mathbf{c}}t) dxdydz = \mathbf{1}_\Phi \cdot 1 = \mathbf{1}_\Phi$. However, it is not physically correct, because we would have an infinity density of energy Φ_m in the single point of the boson's barycenter $\overrightarrow{\mathbf{r}} = \overrightarrow{\mathbf{r}_0} + \overrightarrow{\mathbf{c}}t$. In such case, the Schwarzschild radius r_s would be greater (or equal) than the radius of the point (boson's barycenter) which is zero, so that the boson would become a black hole, which does not correspond to physical facts. Note that this fact can't happen in the case when we are using the complete 6-D expression for the wave-packet, where $\Phi^2(t, \overrightarrow{\mathbf{r}}, q_5) = \sigma(q_5)\delta(\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}_0} - \overrightarrow{\mathbf{c}}t)$ is also physically composed expression where the energy density is only $\sigma(q_5)$ and there exists only in the 6th dimension and not in M^4, and hence the Dirac 'function' δ in the Minkowski time-space M^4 defines only the *position* of the boson and not its energy-density. In effect, by the integration in 6-D time-space of boson's energy density, its total energy is $E = \int \Phi^2(t, \overrightarrow{\mathbf{r}}, q_5) dq_1 dq_2 dq_3 dq_5 = \int \sigma(q_5)(\delta(\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}_0} - \overrightarrow{\mathbf{c}}t) dV) dq_5 = \int \sigma(q_5) dq_5 = \mathbf{1}_\Phi$.

So, from (3) the volume of the massless boson in the ordinary 3-dimensional space is equal to zero. Only in such conditions a particle can travel with the maximal possible speed of light. But the matter/energy of the boson exists also in such conditions: it is uniformly distributed only in the spacelike sixth dimension (used for the spin) where it propagates with a constant speed v_5. Consequently, the hidden matter of a boson in the compactified higher dimensions results in zero rest-mass in the ordinary flat Minkowski time-space and explains why the boson can propagate with maximal possible speed. During this massless stable-state, the gravitational anti-black-hole barrier acting in the boson's barycenter (in 3-D space) does not permit the leaking of the matter from 6th into ordinary 3-dimensional space.

We consider the vacuum as the perfect 3-dimensional space symmetry where each possible direction of the propagation has the same physical conditions. Thus, the propagation of the particles in the vacuum is inertial and the particle propagates along GR geodesics with constant speed as a stable particle[2]. The asymmetry due to the presence of an infinitesimal inertial particle in flat Minkowski spacetime is purely circumstantial, because the spacetime is considered to be unaffected by the presence of this particle. However, according to general relativity, the presence of any inertial entity disturbs the symmetry of the manifold even more profoundly, because it implies an intrinsic curvature of the spacetime manifold, i.e., the manifold takes on an intrinsic shape that distinguishes the location and rest frame of the particle. Note that, from the fact that the stable bosons have no matter/energy in the ordinary 3-dimensional (open) space, the stable bosons do not generate any local time-space curvature, differently from the fermions. Thus, the local time-space neighborhood of a massless boson is always a locally flat Minkowski time-space, differently

[2] Such a 3-D space symmetry during an inertial propagation of a massive particle causes a spherical symmetry of its stable energy-density distribution $\Phi_m = \frac{K}{\sqrt{r}}$, for $r \leq r_0$ in a sphere with a radius r_0

from the fermions (and also unstable massive bosons). The fact that the stable bosons have no any curved island-metrics in the ordinary 4-dimensional time-space, results in missing of any physical resistance of the neighborhood time-space to their propagation (differently from the massive particles with energy-density present in the 4-dimensional time-space and, generated from it, curved micro-island metrics). Consequently, they propagate with maximal possible speed in the ordinary 4-dimensional time-space. Thus, the bosons have the point-like 4-dimensional structure corresponding to their position (barycenter), but physically their total energy-density is $\Phi_m(q_5) = \sigma(q_5) = \frac{1_\Phi}{4\pi R_5} = const.$
But there are the situations when a stable, stationary, photon becomes excited for a short interval of time, as in the situations when the *space symmetry* during its propagation is sharply broken. Thus, the time-space boundary conditions for the particle's propagation are drastically changed, by considering that particle's wave-packet is a time-space perturbation and, if such a perturbation meets another perturbation, it changes its form. These events we analyzed in details later for the phenomena of refraction and 'wave-behaviors' of an individual photon [4]. In all these situations a photon may change its momentum, direction of propagation and its velocity, without changing its total energy, because these 'interactions' are not based on collisions with another particles (as Compton effects, or annihilations), but on instantaneous 3-D space expansions of their geometric wave-packet scalar field Φ in the presence of a local sharply broken space symmetry. These are strong General Relativity effects correlated with the particle's 'micro-island' curvature metrics, caused by a dynamical changing of the boundary conditions in the local space around this particle. This 'materialized' rest-mass m_0 of bosons can explain the following cases in the current quantum theory:

Example 1 ***Current theory of a massive photon**:*
The photon, the particle of light which mediates the electromagnetic force is believed to be massless. The so-called Proca action describes a theory of a massive photon [11]. These photons would propagate at less than the speed of light defined by special relativity and have three directions of polarization. However, in quantum field theory, the photon mass is not consistent with gauge invariance or renormalizability and so is usually ignored. However, a quantum theory of the massive photon can be considered in the Wilsonian effective field theory approach to quantum field theory, where, depending on whether the photon mass is generated by a Higgs mechanism or is inserted in an ad hoc way in the Proca Lagrangian, the limits implied by various observations/experiments may be dif-

ferent [12].
In his 1977 paper Quark Confinement and Topology of Gauge Groups, A.Polyakov demonstrated that instanton effects in 3-dimensional QED coupled to a scalar field lead to a mass for the photon. *In such a theory, its speed would depend on its frequency, and the invariant speed c of special relativity would then be the upper limit of the speed of light in vacuum [13]. The limit obtained depends on the used model: if the massive photon is described by A.Proca theory [12], the experimental upper bound for its mass is about* 10^{-57} *grams [14]; if photon mass is generated by a Higgs mechanism, the experimental upper limit is less sharp,* $m = 10^{-14} eV/c^2$ *[12] (roughly* $2 \cdot 10^{-47} g$*).*
The massive photons are particular cases of 'virtual' particles. Some field interactions which may be seen in terms of virtual photons are:
- The Coulomb force (static electric force) between electric charges and the magnetic field between magnetic dipoles. They are caused by the exchange of virtual photons;
- The so-called near field of radio antennas, where the magnetic and electric effects of the changing current in the antenna wire and the charge effects of the wire's capacitive charge are detectable, but both of which effects decay with increasing distance from the antenna much more quickly than do the influence of conventional electromagnetic waves, and which are composed of real photons.

2 Breaking of 3-D Space-symmetry and Boson's Space Explosion

Here, instead of "spontaneous symmetry breaking", we will consider only physically and deterministically generated 3-D space breaking symmetry for a free boson when it interacts with another massive particle at a short distance from this boson. In such a mechanism we do not have to introduce any new kind of bosons like Higgs bosons, and this *physical process* may explain the phenomena of the abstract "spontaneous symmetry breaking" of the (gauge) field equations. More precisely, this initial 'inflationary' process (which *apparently* generates the energy in the ordinary 3-D space from the previously zero-energy at the bosons barycenter in 3-D space) of a spherical inflationary expansion of the bosons is done by the leaking of the energy density contained in a compactified extremely small higher space dimension into the ordinary 3-D open space around the particle's barycenter. So, the 3-D volume of a boson becomes an infinitesimally small sphere of energy-density with a radius bigger than the

Schwarzschild radius (thus, without a creation of a black hole). After this initial explosion this boson continues its radial space expansion (now against its matter-autocohesive self-gravitational forces, that generate an internal potential energy taken from the kinetic energy of this massive boson, and hence with a process of deceleration from the speed of light) and behaves as the ordinary fermions with a rest-mass greater than zero.
Notice that when a boson is stable also in its barycenter, defined by the Dirac function (3) of Φ, the energy-density is zero, so that stable boson is not a microscopic black hole.
In effect, this extremely small compactified spacelike dimension is strongly curved because of the presence of the boson's energy in it. If such a 'rest-mass' boson's energy would enter in the open 3-D space, from the bosons barycenter (which is just a point in 3-D space) it would generate extremely strong gravitational force in the open 3-D space and consequently a microscopic black-hole. It is just this extreme force that guarantee the stability of the massless bosons with a delimitation of the boson's total energy-density only in this higher compactified spacelike dimension. This equilibrium is rendered unstable only when another massive particle with its micro-island curved 4-D time-space interferes in the multidimensional time-space manifold with the higher dimension of the boson where is contained its total energy; this interferences of the curved multidimensional time-space metrics of the boson and another particle generates a new common time-space curvature for both particles in which it is possible this process of passing the bosons energy-density from a compactified into the open 3-D space without generation of a black-hole.
The microscopical 'big-bang inflationary' process of 3-D space expansion of the energy-density in fact avoids the transformation of the previously stable boson into a black-hole, as it is considered in the cosmological gravitational theory of 'big-bang', with a difference that here the amount of energy involved in this expansion is infinitesimal w.r.t. the cosmological big-bang. The radius of this 3-D small sphere (which contains the *rest-mass energy* of this massive boson) after this microcosmic big-bang is significatively bigger than the Schwarzschild radius, so that it is avoided the generation of a microscopic black-hole.
This extremely small sphere of the massive boson can have other radial expansions as other massive particles, and the cylindrical extreme expansions (as in the case of the electrons in the double-slit experiments) described in [7].
When the boson in this unstable massive state bypasses the material obstacle (the strongly curved 'island' metric of this obstacle) and now continues its propagation again in a locally flat Minkowski time-space, the autocohesive self-

gravitational forces (and internal potential energy developed during the space expansion against these autocohesive forces) determine the inverse process of space implosion of the boson's energy-density in the open 3-D space. Successively, by an inverse non-linear process, instead to become a point-like particle with whole energy concentrated in the single point of the boson's barycenter which would generate a black-hole in 3-D space, this energy density is again expelled from the 3-D space and conserved into the 6th compactified dimension. At the end of this implosion, the gravitational barrier in the point of the boson's barycenter is recreated again, making stable this boson with the rest-mass equal to zero and with zero 3-D volume of its matter/energy-density. During this implosion process, the previously generated (by expansion) internal potential energy is restituted to the kinetic energy of this still massive particle, so that we have a progressive acceleration of this boson, whose rest-mass progressively reduces in proportion of how much the energy-density is expelled from the 3-D space and hence, in the moment when the whole energy is expelled into the 6th dimension of the particle's barycenter, this boson becomes again a massless particle propagating with the speed of light.
Consequently, if a massless particle with total energy E does not propagate in the free space but very near to another massive particles, then we can obtain a spatial explosion into a microscopic (quasi-infinitesimal) sphere with highly compressed energy/density Φ_m, and consequently very high positive potential energy V, so that it becomes massive boson with rest mass $m_0 = \frac{1_\Phi}{c^2}$. So, based on this positive internal (selfgravitational) energy V, a radial expansion begins by progressive deceleration of particle's velocity. If another massive particles are relatively far from its trajectory this expansion will be up to the reaching of the equilibrium state of this massive particle with rest-mass m_0. Otherwise can be very significant (with cylindrical expansion described in [7], by transforming its matter-distribution in a radial disc w.r.t. the direction of the propagation, and with generation of the negative potential energy V (subtracted from the kinetic energy) as it was considered above for the ordinary fermions.
Let us describe *how* a stable boson with Dirac function (3) of energy-density in the Euclidean space, which propagates with the speed of light and momentum p_0, that is, with the energy $E = p_0 c$, transforms into an unstable massive boson with the rest mass $m_0 > 0$ and energy-density distribution $\Phi(t, \overrightarrow{\mathbf{r}})$, in the small but *finite* 3-dimensional volume V_t: if we want to consider just the process of transformation, from an initial massless boson at time-instance $t = 0$, up to $t = \triangle t$ (the moment when we obtained a definite massive form of this boson), then during this interval of time, $0 < t \leq \triangle t$, the speed of this boson

degrees continuously from the initial speed of light $v(0) = c$ to the final velocity $v(\triangle t) < c$. That is, during a deceleration with time-dependent particle's velocity $v(t)$, so that this velocity decrease corresponds to the time-dependent changing of massive-boson's internal potential energy $V(t)$ [7].

Definition 1 3-D SPACE EXPLOSION OF A MASSLESS BOSON ASSUMPTION*: Given a stable boson with Dirac function energy-distribution, which propagates with the speed of light and momentum p_0, with energy $E = p_0 c = \mathbf{1}_\Phi \sqrt{\frac{1-\beta_s}{1+\beta_s}}$, where $-1 < \beta_s = \frac{v_s}{c} < 1$ and v_s the velocity between the observer and source of this boson. Then, when it interacts with other particles on its trajectory, it transforms into an unstable massive boson with the rest-mass m_0, and the quantity $\mathbf{1}_\Phi$ In this initial 3-D space explosion, its matter density expands from higher dimensions into a micro-sphere (with a radius greater than Schwarzschild radius) with an energy density Φ_m and a non-observable internal potential energy $V(t)$. So, we consider the transformation of a massless into a massive boson, during time interval $0 < t \leq \triangle t$, which propagates with a decreasing speed $v(t) < c$, from its initial speed of light $t = 0$, $v(0) = c$, into the final velocity $v(\triangle t) < c$, by preserving the following dynamic relativistic dispersion relation*

$$(E + V(t))^2 \equiv m_0^2(t)c^4 + c^2 p^2(t) \tag{4}$$

where $m_0(t)$ is the increasing in time rest-mass, from $m_0(0) = 0$ to $m_0(\triangle t) = \frac{\mathbf{1}_\Phi}{c^2}$ when whole energy of boson is transferred into 3-D space, and the relativistic kinetic momentum for the massive boson's velocity $v(t) < c$ for $t > 0$,

$$p(t) = m(t)v(t) = \frac{m_0(t)}{\sqrt{1-\beta^2}} v(t) \tag{5}$$

with $\beta = \frac{v(t)}{c} < 1$ and $p(0) = p_0 = \frac{E}{c}$.

Hence, if we consider the final state at $t = \triangle t$, after *complete* expansion in 3-D space so that $m_0(\triangle t) = \frac{\mathbf{1}_\Phi}{c^2}$ obtains its maximal possible value, from initial internal potential energy $V(0) = 0$ to the final internal energy $V(\triangle t)$ in (6), and the final speed $v = v(\triangle t) < c$ with $\beta = \frac{v}{c}$.
Notice that a massive boson is generally a virtual particle. In effect, for the cases when the source of emitted boson moves toward the observer and hence $0 < \beta_s < 1$, if we apply the *standard* energy conservation law of QM for this massive boson then we obtain that $p^2 c^2 = E^2 - m_0^2 c^4 = 1_\Phi^2 \frac{1-\beta_s}{1+\beta_s} - 1_\Phi^2 = -1_\Phi^2 \frac{2\beta_s}{1+\beta_s} < 0$ is negative, as it verifies in the current QM theory of 'virtual' particles.

So, from (4) and (5)), we obtain $E + V(\triangle t) = \frac{m_0(\triangle t)c^2}{\sqrt{1-\beta^2}} = \frac{\mathbf{1}_\Phi}{\sqrt{1-\beta^2}}$ and hence, we obtain the final potential non-observable internal energy at $t = \triangle t$,

$$V(\triangle t) = \mathbf{1}_\Phi\left(\frac{1}{\sqrt{1-\beta^2}} - \sqrt{\frac{1-\beta_s}{1+\beta_s}}\right) \tag{6}$$

which does not participate in the conservation law during collisions but only as an internal potential energy (during the self-gravitational internal stability process). In fact, in the case when we have a direct collision with another particle (Compton effect), this massive boson has the observable (used in collision and energy/momentum conservation of Compton effects) energy $E = p_0 c$ as for the massless boson, and hence during the collisions we have preserved ordinary laws of conservation of the energy and momentum.

The meaning of V is the following: for a stable boson when $v = \vartheta = c$, we have that $V = 0$ and $m_0 = 0$, so that (4) reduces to $E = p_0 c$, as expected.

In the case of an unstable massive boson which propagates with the speed $0 < v < c$, the small mater-density expansion of this unstable boson 'generates' a temporary internal potential energy $V > 0$ of the 3-D space explosion and determines the appearance of the non-zero finite matter-distribution volume and, hence, the manifestation of the rest-mass m_0. This internal potential energy is a consequence of the radial expansion of this massive boson: it generates the pressure force against the self-gravitational forces generated by the presence of boson's energy density in 3-D space. This process ends when this massive boson bypasses material obstacle (which caused its 3-D space explosion) and continues again the propagation inside the symmetric 3-D vacuum space. In that moment we have the inverse process of implosion during which this massive boson becomes again a stable massless boson with Dirac function distribution in 3-D space, zero 3-D volume of its energy-density and zero rest-mass. However, if this process of expansion is enough time long (as in the case of the large massive barriers in front of the boson's propagation, producing the reflection or tunneling of this boson, or in double-slit experiments) then this massive particle (now with constant $m_0(\triangle t)$ rest-mass) continues to expand over its autoequilibrium state, so that V begins to decrease (now, instead of (4), for $t > \triangle t$, $(E + V(t))^2 = m_0^2(\triangle t)c^4 + c^2 p^2(t)$ must be satisfied) and hence decreases the momentum $p(t)$, the speed and kinetic energy. In fact, the decrease of V during expansion of particle's body means that this amount is subtracted from the kinetic energy when the volume of matter is expanded w.r.t. to its hydrostatic equilibrium volume. This energy (subtracted from the kinetic energy so that particle decreases its speed) is used to overcome the resistance of the autocohesive self-gravitational force during radial expansion.

For example, we know that in the medium different from vacuum (air, glass, water, etc...) the group velocity of light (photons) v is less than c. Thus, we have the statistical effects of a numerous expansions of the Dirac energy-distribution which happens when the photon's trajectory passes very near to the massive particles in this medium as anticipated in [4]. The velocity of light in this medium is an average value of the effects of such numerous expansions of each single photon during the propagation in this medium. It is well known that the refractive index of such medium is $n = \frac{c}{\vartheta} > 1$, thus with the phase velocity ϑ less than the speed of light. However, also for the cases when refractive index is less than 1 (interactions of photons with plasma medium, for example), when $\vartheta > c$ the relationship above is satisfied with smaller values of the photon (group) velocity v, so that in such a medium, the group velocity of light is always less than the speed of light c in the vacuum. Notice that a transformation from stable into massive bosons happens also when a photon passes from the vacuum into an medium with the refractive index $n = \frac{c}{\vartheta}$, where ϑ is the phase velocity of the light in this medium and $\frac{\partial n}{\partial \lambda}$ is an experimentally determined dependence of the refractive index on the wave-length $\lambda = \hbar \frac{2\pi}{p}$ of the photons.

Measurement of massive boson's rest-mass: Thus, we are able to measure the rest-mass of the massive bosons if we know the energy E of the photons in the vacuum and if we measure the group velocity v of the photons (light) in this refractive medium. In fact, based on the Rayleigh law, we have that,
$v = \frac{\partial E}{\partial p} = \frac{\partial (p\vartheta)}{\partial p} = \vartheta - \lambda \frac{\partial \vartheta}{\partial \lambda} = \vartheta (1 + \frac{\lambda}{n} \frac{\partial n}{\partial \lambda}) = \frac{E}{p} (1 + \frac{h}{np} \frac{\partial n}{\partial \lambda})$
where h is Plank constant and p is the momentum of this massive photon during the propagation in this refractive medium. Hence, we can compute, for the known energy E of the photon and measured speed v in this refractive medium, the momentum p of the photon during the propagation in the medium, from above, by $\frac{v}{E} p^2 - p = \frac{h}{n} \frac{\partial n}{\partial \lambda}$ and then, the massive boson rest-mass is $m_0 = \frac{p}{v} \sqrt{1 - \frac{v^2}{c^2}}$ and its phase velocity $\vartheta = \frac{E}{p}$. The previous analysis has shown how we can have the *massive bosons* (massive photons, for example) as well.

3 Theory of Long-range and Short-range Photons

This phenomena of a temporal transformation of the massless bosons into massive bosons is used to explain a number of examples, in the case of the photons, like the refraction, reflection and double-slit experiments. However, we need also the complementary part of this phenomena, especially for the theory of emission of photons from the charged massive particles, fundamental also for the short range interactions (in contrast to massless bosons and their long range interactions strictly connected with the transmission of the gauge field energies as, for example, the Poynting vector $\overrightarrow{S}$, representing the density of the electromagnetic power-flow for the transverse electromagnetic waves). Maxwell's equations in vacuum involve six components, three for the electric field $\overrightarrow{E}(t, \overrightarrow{\mathbf{r}})$ and three for the magnetic field $\overrightarrow{B}(t, \overrightarrow{\mathbf{r}})$, with the following system-independent (inhomogeneous in the first two and homogeneous in the second two) equations in the SI unit system, at a point $(t, \overrightarrow{\mathbf{r}})$:

$$\nabla \cdot \overrightarrow{E} = \frac{\rho}{\varepsilon_0}, \quad \nabla \times \overrightarrow{B} = \mu_0 \overrightarrow{j} + \frac{1}{c^2}\frac{\partial \overrightarrow{E}}{\partial t}, \quad \nabla \cdot \overrightarrow{B} = 0, \quad \nabla \times \overrightarrow{E} = -\frac{\partial \overrightarrow{B}}{\partial t} \tag{7}$$

where ρ is the charge density and 3-dimensional $\overrightarrow{j}$ the current density. So, we define the 4-vector current density by $\mathbf{J}_4(t, \overrightarrow{\mathbf{r}}) \equiv (c\rho, \overrightarrow{j}) = c\rho \mathbf{e}_0 + \overrightarrow{j} = \sum_{j=0}^{3} \mathcal{J}_j \mathbf{e}_j$ with $\mathcal{J}_0 = c\rho$ and the speed of light $c = \sqrt{\frac{1}{\varepsilon_0 \mu_0}}$, with the charge continuity equation $\frac{\partial \rho}{\partial t} + \nabla \overrightarrow{j} = 0$ (obtained from $\nabla \cdot (\nabla \times \overrightarrow{B}) = 0$). In the time-space points $(t, \overrightarrow{\mathbf{r}})$ without the presence of charges (and currents), that is, where $\rho(t, \overrightarrow{\mathbf{r}}) = 0$ and $\overrightarrow{j}(t, \overrightarrow{\mathbf{r}}) = 0$, we have only the propagation of the massless point-like photons which statistically generate the transverse electromagnetic plain-waves, which satisfy the following equations (easily derived from the vector equation $\nabla^2 \overrightarrow{Y} + \nabla \times (\nabla \times \overrightarrow{Y}) = \nabla(\nabla \cdot \overrightarrow{Y})$, by considered that, in this case, the right-side of this equation is equal to zero both for $\overrightarrow{E}$ and $\overrightarrow{B}$):

$$\nabla^2 \overrightarrow{E} - \frac{1}{c^2}\frac{\partial^2 \overrightarrow{E}}{\partial t^2} = 0, \qquad \nabla^2 \overrightarrow{B} - \frac{1}{c^2}\frac{\partial^2 \overrightarrow{B}}{\partial t^2} = 0 \tag{8}$$

with the solutions $\overrightarrow{E}$ and $\overrightarrow{B}$ which are perpendicular to each other and to the direction of wave propagation, and are in phase with each other. A sinusoidal plane wave (as that considered in (15) for the long-range photons) is a special solution of these equations and hence also the wave-packets obtained as a linear composition of the plain waves. Maxwell's equations explain how these waves can physically propagate through the 3-D space. The changing magnetic field creates a changing electric field through Faraday's law. In turn, that electric field creates a changing magnetic field through Maxwell's addition to Ampere's law. This perpetual cycle, which satisfy, for the frequency ν and wavelength λ, with the period of oscillation T and velocity of propagation $v \leq c$, the equation

$$\frac{1}{T} = \nu = \frac{v}{\lambda} \tag{9}$$

allows these waves, known as electromagnetic radiation, to move through space at velocity c. These fields can be derived from the contravariant 4-potential vector is $\mathbf{A}_4 = (\frac{\phi(t,\overrightarrow{\mathbf{r}})}{c}, \overrightarrow{A}(t, \overrightarrow{\mathbf{r}}))$ (or the covariant 4-potential vector $(\frac{\phi(t,\overrightarrow{\mathbf{r}})}{c}, -\overrightarrow{A}(t, \overrightarrow{\mathbf{r}}))$, where ϕ is a scalar potential and $\overrightarrow{A}$ is a 3-dimensional vector potential, such that

$$\overrightarrow{E} = -\nabla\phi - \frac{\partial \overrightarrow{A}}{\partial t}, \qquad \overrightarrow{B} = \nabla \times \overrightarrow{A} \tag{10}$$

so that, by substitution these two equations in the first row of (7), we obtain

$$-\nabla^2\phi - \frac{\partial}{\partial t}(\nabla \cdot \overrightarrow{A}) = \frac{\rho}{\varepsilon_0}, \qquad (-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\overrightarrow{A} + \nabla(\nabla \cdot \overrightarrow{A} + \frac{1}{c^2}\frac{\partial \phi}{\partial t}) = \mu_0 \overrightarrow{j} \tag{11}$$

In particular, in next, we will consider the emission of "virtual" (i.e., massive) photons, which usually happens in the following situations:

- The Coulomb force (static electric force) between electric charges and the magnetic field between magnetic dipoles. They are caused by the exchange of virtual photons.

- The so-called near field of radio antennas, where the magnetic and electric effects of the changing current in the antenna wire and the charge effects of the wire's capacitive charge are detectable, but both of which effects decay with increasing distance from the antenna much more quickly than do the influence of EM waves.

The common property for all these phenomena is that we have no any transmission of the electromagnetic energy, that is, we have no the phenomena of radiation waves.
So, the massive photons, that explain these three phenomena above, are physically different from the photons which would have the long-range interaction by generating the electromagnetic waves with consecutive transfer of the emitted

energy from the source charged particles (the accelerated electrons, for example) into the space:

1. **Emission of the long-range photons**: It is natural to suppose that in the moment of any generation of a new photon, it passes from its excited unstable state with a 'materialized' rest-mass and with its velocity v less than the velocity $\overrightarrow{\mathbf{c}}$ of light in the vacuum, and after very short interval of time in the free 3-D space (vacuum) of propagation, it reaches its stable (stationary) state with velocity of light and the energy-density $\Phi_m = \Phi^2$ equal to the Dirac function (3), so that $\Psi = \sqrt{\mathbf{1}_\Phi \delta(\overrightarrow{\mathbf{r}} - \overrightarrow{\mathbf{r}_0} - \overrightarrow{\mathbf{c}}t)}\, \mathrm{e}^{-i\varphi_0} = \sqrt{\Phi_m}$, where $\overrightarrow{\mathbf{r}_0}$ is its position at $t = 0$ and $\varphi_0 = (\overrightarrow{\mathbf{p}}(\overrightarrow{\mathbf{c}}t) + Et)/\hbar = 0$ is a constant phase shift. It was demonstrated [4] that the continuity equation (2) for such a stable boson is

$$\frac{\partial \Phi_m}{\partial t} = \overrightarrow{\mathbf{c}} \nabla \Phi_m = -\nabla \cdot (\overrightarrow{\mathbf{c}} \Phi_m) \tag{12}$$

The distance that such a massive photon passes in this unstable (unstationary) initial state, in order to become the massless photon, must be very short. Thus, such emitted log-range photons must have an infinitesimal 3-D volume with very high energy-density inside it, so that the self gravitational force inside this volume is very high and tends to decrease the volume of this massive photon. The decreasing of its volume must be obtained by a continuous expelling of the initial amount of the energy inside photon's 3-D body into higher dimensions, in order to avoid the process of a generation of a black hole. So, by maintaining the initial momentum (when this photon is generated and emitted by a charged particle) and by decreasing its rest-mass energy, that is, the rest-mass of this massive photon, the speed of this massive photon necessarily increments. Consequently, at the end of this continuous process, when the whole energy of the photon is expelled from its 3-D space into the higher dimensions, we obtain the zero 3-D volume massless photon, which propagates with the speed of light in the vacuum. Thus, in such a creation of a long-range photon, the source charged massive particle loses an amount of energy, used to generate this photon. For example, it happens when such a photon is irradiated from the electron in an atom and, consequently, this electron passes to the lower energy-level.

Let us show that indeed such long-range massless photons, that satisfy the equation (12) above, generate statistically the well-known Hertzian transverse electromagnetic wave, with the propagation of their wave energy by the speed of light in the vacuum.

Let us consider the case of the simple plain wave, a *linearly polarized* solution of Maxwell's equations (8), generated by the antenna dipole (for example the

Hertzian dipole) oriented along the axes $z = q_3$ with the unit vector $\mathbf{e}_3$ which emits the long-range photons in orthogonal direction $x = q_1$ (w.r.t. the dipole's direction) with the unit vector $\mathbf{e}_1$. Then inside this dipole (for $x = 0$) we have the electric current $\overrightarrow{j} = J\sin(\omega_k t)\mathbf{e}_3$, with constant amplitude J, so that the velocity of each free electron which constitute this current is $\overrightarrow{\mathbf{v}}_c = v\sin(\omega_k t)\mathbf{e}_3$ for some constant speed v. So, in this case when we have the zero scalar potential $\phi = 0$ (from $\rho = 0$, so that from the first equation in (11) we obtain the particular case of the Lorenz gauge condition $\nabla \cdot \overrightarrow{A} = -\frac{1}{c^2}\frac{\partial \phi}{\partial t} = 0$), the second equation in (11) becomes equal to $(-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\overrightarrow{A} = \mu_0 \overrightarrow{j} = \mu_0 J\sin(\omega_k t)\mathbf{e}_3$ where $\omega_k = kc$ with $k = \frac{2\pi}{\lambda}$ and $\omega_k = 2\pi\nu$ in (9). Thus, the *direction of the vector potential* $\overrightarrow{A}$ corresponds to the direction of the velocity of the electrons of the dipole's current which emit these long-range photons. So, for any $x \neq 0$ (outside of this dipole), we have the electromagnetic radiation wave propagating in direction x, composed by these long-range photons, satisfying

$$(-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\overrightarrow{A} = 0 \tag{13}$$

and hence the vector potential wave with an amplitude A_k, which propagates along the axis $x > x_0$ (where x_0 is a near-antenna distance) is:

$$\overrightarrow{A} = A_k \sin(k(x - ct))\mathbf{e}_3 \tag{14}$$

Thus, from equation (10), we obtain the solution for the electric field

$$\overrightarrow{E} = E_k \cos(kx - \omega_k t)\mathbf{e}_3 = E_k \cos(k(x - ct))\mathbf{e}_3 \tag{15}$$

for a real constant $E_k \in \mathbb{R}$, so that (we will use here the CGS Lorentz-Heaviside metric system, instead of SI used in rest) from $\frac{\partial \overrightarrow{B}}{\partial t} = c\nabla \times \overrightarrow{E} = -ckE_k \sin(kx - \omega_k t)\mathbf{e}_3$, by integration, we obtain the magnetic field

$$\overrightarrow{B} = E_k \cos(k(x - ct))\mathbf{e}_2 \tag{16}$$

which is in phase with the electric field. The vector potential $\overrightarrow{A}$ is oriented in the direction of the electric field, but with $\frac{\pi}{2}$ phase difference.
It is easy to verify that generally (always), for any transversal electromagnetic wave, the potential vector $\overrightarrow{A}$ is orthogonal to the direction of the propagation: also for the long-range photons emitted not orthogonally to the dipole's antenna, that is in any direction, so that at a some distance from this small dipole antenna the electromagnetic wave is a spherical wave, and only on the large distances can be locally considered as a plain-wave. In fact, we know that the

Poynting vector $\overrightarrow{S}$ is in direction of propagation, so that $\overrightarrow{A}\overrightarrow{S} = \overrightarrow{A}c(\overrightarrow{E}\times\overrightarrow{B}) = c\overrightarrow{A}(-\frac{\partial\overrightarrow{A}}{\partial t}\times(\nabla\times\overrightarrow{A})) = -c(\nabla\times\overrightarrow{A})(\overrightarrow{A}\times\frac{\partial\overrightarrow{A}}{\partial t})$
$= -c(\nabla\times\overrightarrow{A})\frac{1}{2}\frac{\partial}{\partial t}(\overrightarrow{A}\times\overrightarrow{A}) = 0.$
However, from the fact that the Maxwell's equations are satisfied also for the superposition of the simple harmonic linearly-polarized solutions in (15), that is, for $\overrightarrow{E} = \mathbf{e}_3\sum_k E_k\cos(k(x-ct))$ and, from (16), $\overrightarrow{B} = \mathbf{e}_2\sum_k E_k\cos(k(x-ct))$, it is valid for any continuous spectra which generates an electromagnetic wave-packet $\overrightarrow{E} = \mathbf{e}_3\int_{k\in\mathbb{R}} E_k\cos(k(x-ct))dk$ and $\overrightarrow{B} = \mathbf{e}_2\int_{k\in\mathbb{R}} E_k\cos(k(x-ct))dk$ with

$$\overrightarrow{E}\times\overrightarrow{B} = \mathbf{e}_1[\int_{k\in\mathbb{R}} E_k\cos(k(x-ct))dk]^2 \tag{17}$$

In electrodynamics, Poynting's theorem is a statement of conservation of energy for the electromagnetic field in the form of a partial differential equation (in CGS system)

$$\frac{\partial u}{\partial t} = -\nabla\cdot\overrightarrow{S} - \overrightarrow{\jmath}\overrightarrow{E} \tag{18}$$

where $u = -\frac{1}{2}(\overrightarrow{E}^2 + \overrightarrow{B}^2)$ is the energy density of this electromagnetic wave and $\overrightarrow{S} = c(\overrightarrow{E}\times\overrightarrow{B})$ is the Poyinting vector. So, in our case of the propagation in the vacuum, and hence with the current $\jmath = 0$, from the fact that for this electromagnetic wave it holds that $\|\overrightarrow{E}\times\overrightarrow{B}\| = u$, and hence, $\overrightarrow{S} = \overrightarrow{\mathbf{c}}u$, we obtain that (18) reduces to:

$$\frac{\partial u}{\partial t} = -\nabla\cdot(\overrightarrow{\mathbf{c}}u) \tag{19}$$

Let us now consider that this electromagnetic wave-packet be composed by coherent massless photons with a density N w.r.t. the unit surface orthogonal to the direction of propagation, each one with the same energy $\mathbf{1}_\Phi$ and propagating along the axis x with the speed of light c, such that the coefficients E_k, $k\in\mathbb{R}$, are taken in the way to satisfy the equation (Fourier representation),

$$\sqrt{\delta(x-ct)} = \frac{1}{\sqrt{N\mathbf{1}_\Phi}}\int_{k\in\mathbb{R}} E_k\cos(k(x-ct))dk \tag{20}$$

then we obtain the direct correspondence between the classical electrodynamics and new IQM for individual photons, by considering that $u = \|\overrightarrow{E}\times\overrightarrow{B}\|$ is now, from (20) and (17) $u = [\int_{k\in\mathbb{R}} E_k\cos(k(x-ct))dk]^2 = N\mathbf{1}_\Phi\delta(x-ct) = N\Phi_m$, proportional to the density N of photons (N is a constant number of photons in a unit surface orthogonal to the propagation of such electromagnetic wave), so that we obtain

$\frac{\partial u}{\partial t} = \frac{\partial (N\Phi_m)}{\partial t} = N\frac{\partial \Phi_m}{\partial t} = -\nabla \cdot (\overrightarrow{\mathbf{c}}u) = -\nabla \cdot (\overrightarrow{\mathbf{c}}N\Phi_m) = N(-\nabla \cdot (\overrightarrow{\mathbf{c}}\Phi_m))$
and hence (19) reduces to the continuity equation of a single massless photon in (12).
Note that the same result we obtain also for a continuous dense laser stream of coherent photons, which generate classical linearly-polarized plain wave, satisfying the simple mono-frequency solution (15) with $k = \frac{p}{\hbar}$, where p is the momentum of such plain wave, with the surface equal to the cross-section surface of such laser's beam. Similarly, it can be demonstrated for any kind of polarization of the propagating electromagnetic wave.
Notice that in the direction of the propagation of a polarized plane wave (for example, in x direction, orthogonal to the dipole antenna emitter) we have no the electric effects, but only the propagation of the energy of photons in this optical beam. The only electric effects are transversal to the direction of the propagation of such beam of photons, cause by the vector potential $\overrightarrow{A}$ which direction is initially fixed by the direction of the electrons (the emitters of these long-range photons) in the antenna's current ! That is, the transversal movements of the photons in a linearly polarized plain wave (the direction of this movement is just the direction of the polarization vector of this plane wave) generate the electric field of such a polarized plain wave. When this plain wave reachs a receiver, theses transversal momentum components of these long-range photons generate the movement of the free electrons in this receiver and hence the electric current (the statistical electromagnetic effect in the receiver). So, in this way, the transversal movement (momentum) of the photons, w.r.t. the direction of plain-wave propagation, is the generator of the vector potential $\overrightarrow{A}$ and transmission of the signals from the dipole antenna emitter and a receiver.
Let us consider a tube in the vacuum from which comes out a water with a strong pressure as a concentrated beam of water molecules. It is similar to a beam of photons emitted from a laser. If we now move the end of this tube up-down harmonically with displacement less than the radius of the water beam, the person which will be at some distance in front of this water-beam would fill this up-down water wave and the constant longitudinal pressure of the water beam (which is constant and hence non-wave). This transversal up-down water wave is similar to the up-down polarized transversal electromagnetic wave composed on photons. Thus, in both cases we generated *the waves in the vacuum*; one composed on the fast moving molecules of water and another composed on photons. Thus, it confirms the Einstein, we do not need the aether different from the gravitational potential. Hence, the deterministic part of quantum theory (IQM) is in accordance with classical (statistical) Maxwell's theory for

transversal electromagnetic waves in all cases: from a simple monochromatic plain wave to an extremely short wave impulse with practically Dirac's function wave-packet distribution.

2. **Emission of the short-range photons**: In this case, the interactions of electrons and photons are based on these unstable photons with 'materialized' rest-mass (short distance interaction). Thus, we have that in the case of the unstable states, so-called massive bosons, when the energy-density Φ^2 is different from the Dirac function, we have from (1), $\Psi = \Phi(t, \overrightarrow{\mathbf{r}})\mathrm{e}^{-i\varphi_T}$, where φ_T is the de Broglie pilot-wave phase (which expresses the minimal action of particle's Lagrangian). In order to generate a static electric field around a single charged fermion (as electron, for example), these short-range massive photons must be constantly emitted in *all* radial directions from this charged fermion, so that the number $N >> 1$ of emitted photons must be very high at each fixed instance of time. Consequently, the energy E of each photon is much smaller than the energy of the long-range photons. However, in order to maintain the constant energy-level of the charged fermion, it means that practically all of irradiated short-range photons will come back to be absorbed by the same fermion. So, the total emitted energy from a charged fermion corresponds to the total absorbed energy of the same fermion. The same happens also for the total momentum: from the fact that the emission of these short-range photons is in all radial directions and with the equal density, the total momentum of all irradiated photons, in each instance of time, is ideally zero (the same holds for the absorbed short-range photons). So, the movement of this charged fermion is ideally invariant w.r.t. the emissions and absorptions of the short-range photons, if we have no another charged fermions near to this observed charged fermion. Only if there are another significatively near charged fermions, this balance will be changed, and we will discuss these phenomena in next Section.

4 How Do Photons Generate the Attraction/Repulsion between Charged Particles?

We assume that the positively charged elementary particle emits the ordinary matter photons, while the negative charged particle emits the antimatter photons. For the massless photons they are equal. However, the electron-emitted massive photon will be an antiparticle which has negative value of density $\Phi(t, \overrightarrow{\mathbf{r}}) < 0$ inside massive-photon's body. The rest mass m_0 of each short-

range massive photon has an exactly prefixed value. Any single short-range photon emitted by a given charged fermion (based on the general framework for the emission of the short-range photons presented in the end of Section 3), if it will not have the interaction with other charged particles then it will come back to this charged fermion. Thus, it will start the propagation with a high initial speed $v(0)$ (at initial time $t = 0$) from the emitter and then will decelerate up to the moment $t_s > 0$ when will be arrested at some distance r_s from the emitter. After that, the inverse process of accelerated propagation toward this charged fermion (emitter) will initiate, so that, ideally, its speed at any fixed distance $r \leq r_s$ will be the same, but in the inverse radial direction w.r.t to the speed that it has at this distance during $0 < t \leq t_s$.
If we denote the moment of the absorption, of this massive photon with small rest-mass m_0, by t_f then, ideally, we have that $v(t_f) = -v(0)$, so that it returns with the opposite (to the initial) momentum. From the fact that the total energy E of this photon is not changed, after its absorption, the perfect energy equilibrium of the emitter is established. From the fact that emission of this photon is balanced by contemporary emission of another photon with the same momentum but in the opposite direction (from the surface of the opposite part of emitter's body), the momentum of the charged emitter remains invariant. From the fact that this short-range boson is arrested at a characteristic distance r_s from the emitter, and the fact that this photon is uncharged (and also the gravitational force between its extremely small rest mass m_0 and the massive charged emitter can be neglected, we need to define a model for an internal short-range massive photon dynamics which produces such a propagation process during $0 \leq t \leq t_f$:

Definition 2 SELF-ARREST OF A SHORT-RANGE PHOTON ASSUMPTION*:*
In the moment of the generation, the energy-density of a massive photon $\Phi_m(t, \overrightarrow{\boldsymbol{r}}) = \Phi^2(t, \overrightarrow{\boldsymbol{r}})$ *in a small initial 3-D volume is significatively greater at the back side of photons body w.r.t. the front side (in radial direction of propagation w.r.t. the emitter).*
We consider that, at the initial time $t = 0$ *of generation of a massive photon, in the reference frame with the center at charged emitter particle, it obtains an initial internal (non observable) energy*[3] $V(0) > 0$*, an infinitesimal rest-mass* m_0 *and total energy* $E = \mathbf{1}_\Phi = m_0c^2$ *because in this frame at* $t = 0$ *this massive*

[3]This positive internal energy corresponds to the super-pressure inside massive photons body, because this photon is generated inside the charged particle where the pressure is high. So, when it is expelled from the emmiter's body into the vacuum, this internal pressure is higher than the hydrostatic pressure of this massive photon and hence begins the process of body expansion of this photon when it is expelled from the charged emitter.

photon is in rest (all these three properties have the prefixed values, *equal for each emitted short-range massive photon). Consequently, the 'virtual particle' energy relationship, analog to (4) but now in different dynamics from that of massless boson explosion (because our short-range photon is created as massive from the very beginning) holds, for* $t \geq 0$, *from (4)*

$$(E + V(t))^2 = m_0^2 c^4 + c^2 p^2(t) \tag{21}$$

so that immediately after generation of this massive photon it has the initial momentum $p(0) = \frac{1}{c}\sqrt{(m_0 c^2 + V(0))^2 - m_0^2 c^4}$ *and hence it begins to propagate from the emitter with high speed* $v(0)$. *Its evolution in time, for* $\beta = \frac{v(t)}{c} < 1$, *is standard* $p(t) = mv(t) = \frac{m_0}{\sqrt{1-\beta^2}} v(t)$ *such that it is maximal at* $t = 0$ *and* $t = t_f$, *and zero at* $t = t_s$ *(when (21) reduces to* $(E + V(t_s))^2 = m_0^2 c^4$ *so that* $v(t_s) = 0$ *and* $V(t_s) = 0$, *that is, the internal energy is completely consumed for the extension of this photon up to its rest). So, the photon's deceleration from initial speed* $v(0)$ *to the zero speed at* $t = t_s$, *is explained by the progressive decreasing of the internal energy (from maximal* $V(0)$ *to minimal* $V(t_s) = 0$*), because this energy is used for the (dominant) longitudinal expansion (against internal self-gravitational forces) of photon's body in direction of propagation, during* $0 < t \leq t_s$.
Physically, it looks like that this longitudinal expansion of photon's body (analog to the case of the radial expansion of particle's body during its perfect reflection from a massive large barrier orthogonal to the propagation of this particle, when the kinetic energy is again used against self-gravitational forces [7] during such radial expansion) consumes the kinetic energy of this massive photon, with $E + V(0) > E + V(t) > 0$ *where the observable energy* E *remains invariant.*

However, differently from the case of the elastic reflection from a massive large barrier, during an extreme radial expansion of a massive particle, which consumes all its kinetic energy for such a radial expansion and we obtain the complete arrest of the particle in front of the barrier surface, here in the case of the short-range photons (or other bosons as well), we have no any barrier which prohibits to this massive photon to continue to move in another direction instead to come back to its emitter. We have here the following phenomena: when the longitudinal expansion is interrupted and this massive photon is arrested, now the self-gravitational forces (after spending previously all kinetic energy and hence the internal energy) are dominant. Thus, the inverse process of (dominant) longitudinal restriction starts, and from the fact that the main density is in the back particle's side, we have the dominant restriction

of the front part of this massive particle. Consecutively, main internal movement of the energy-density inside photon's body is just in the opposite direction w.r.t. previous direction of photon's propagation. This internal movement of the rest-mass energy generates now a momentum in this opposite direction, that is, toward the charged fermion (the emitter of this photon). Thus, now we have the acceleration toward the emitter of this photon, i.e., an inverse internal dynamics, where the work done by the self-gravitational forces during the longitudinal restriction of photon's body is used to increment its internal energy $V(t)$ during $t > t_s$, and hence the photon's kinetic energy and velocity.
In an ideal situation, when we have no any charged particle except the photon's emitter, in the time-instance t_f when this returned photon will be absorbed by the emitter, the velocity and momentum of this photon will be equal of that during its emission but in the opposite direction. Consequently, $\overrightarrow{\mathbf{p}}(0) + \overrightarrow{\mathbf{p}}(t_f) = 0$. Moreover, the time t_s, and the maximal distance r_s from the emitter are equal for all short-range massive photons.
So, in such an ideal case with the vacuum around the emitter, its cloud of emitted and then absorbed short-range massive photons would generate a perfect sphere around this emitter, with the density of this claude of photons which depends only on the distance $r \le r_s$ from the emitter. That is, this density ρ of short-range massive photons of this isolated charged emitter is, from the fact that $\int_S \rho dS$ is ideally constant for any sphere surface $S = 4\pi r^2$ with radius $r < r_s$, equal to

$$\rho \sim \frac{|\mathbf{q}|}{r^2} \tag{22}$$

where $\mathbf{q} \lesseqgtr 0$ is the charge of the emitter (greater charge produces proportionally a bigger number of short-range massive photons). Such a non extremely high density ρ, both with the infinitesimal volume of each massive photon, guarantees that the self-interaction of the photons generated by an emitter is very limited, similarly to the ordinary point-like long-range photons. This density of emitted massive photons, each one with its momentum, generates the radial electric force field $\overrightarrow{E}$, acting on another charged particle as will be explain in next, with the intensity $\|\overrightarrow{E}\| = K\rho$ where K is a real constant. So, we define

$$\overrightarrow{E} \equiv k_e \frac{\mathbf{q}}{r^2} \mathbf{e}_r \tag{23}$$

where k_e is Coulomb's constant, experimentally measured as $k_e = \frac{1}{4\pi\varepsilon_0} \approx 8.9875518 \times 10^9 N \cdot m^2 \cdot C^2$, and $\mathbf{e}_r$ is the unit radial vector of this emitter's rest-frame with the coordinate center fixed in the barycenter of this charged particle. So the 4-potential vector of this electrostatic field is $(\frac{\phi}{c}, 0)$, with magnetic 3-D vector potential $\overrightarrow{A} = 0$, so that from the first equation in (10), we obtain the scalar Coulomb potential generated by a charged particle

$$\phi = k_e \frac{\mathbf{q}}{r} \tag{24}$$

as expected. So, we explained how the scalar potential is a resulting statistical effect of the short-range massive photons emmited/absorbed by a given charged particle. We need to show that also the magnetic 3-D vector potential $\overrightarrow{A}$ is generally a statistical result of the same short-range photons of the charged particles. In effect, for any other frame for which the charged particle is not in rest (as considered above), but moves with a constant speed $\overrightarrow{\mathbf{v}}$, the cloud of short-range photons generated by this charged particle does not move more in a spherically-symmetric way (for this new frame) and hence, because of this effect, appears also the 3-D vector potential $\overrightarrow{A} \neq 0$. That is, like the fact that the magnetic field $\overrightarrow{B}$ appears as an effect of movement of charged particles, we can show that the vector-potential $\overrightarrow{A}$ is an effect of the moving of the electrostatic (scalar) potential ϕ. This relationship is evident in the case of the L.V.Lorenz gauge potentials,

$$\nabla \cdot \overrightarrow{A} = -\frac{1}{c^2}\frac{\partial \phi}{\partial t} \tag{25}$$

when for the moving electrostatic potential ϕ we have that $\frac{\partial \phi}{\partial t} \neq 0$.
To have Hendrik Antoon Lorentz invariance, the time derivatives and spatial derivatives must be treated equally, i.e. of the same order (note that the Coulomb gauge $\nabla \cdot \overrightarrow{A} = 0$ is not Lorentz covariant, and hence is not used in covariant perturbation theory, which has become standard for the treatment of relativistic quantum field theories such as quantum electrodynamics). So, with (25), the plasma equations with two variables ϕ and $\overrightarrow{A}$ in (11) become *decoupled*

$$(-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\phi = \frac{\rho}{\varepsilon_0}, \qquad (-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\overrightarrow{A} = \mu_0 \overrightarrow{j} \tag{26}$$

where the first equation corresponds to the *scalar* longitudinal waves in plasma with charge density ρ. Let ϕ be the electrostatic scalar potential of a given set of charged particles with the constant density ρ in a given rest-frame, so that $\overrightarrow{A} = 0$ in this frame, while the electrostatic scalar potential ϕ satisfies the first equation in (26).
Let us consider another frame for which ρ propagates with a constant speed

$\overrightarrow{\mathbf{v}}$, so that for this new frame we have the current density $\overrightarrow{j} = \rho\overrightarrow{\mathbf{v}}$, so from (26), the vector-potential $\overrightarrow{A}_1$ satisfies $(-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\overrightarrow{A}_1 = \mu_0\overrightarrow{j} = \mu_0\rho\overrightarrow{\mathbf{v}}$ and hence, from this equation and the first equation in (26), we obtain that in this second frame, the vector-potential is obtained as the effect of the movement of the electrostatic scalar field ϕ defined in the rest-frame,

$$\overrightarrow{A}_1 = \frac{\phi}{c^2}\overrightarrow{\mathbf{v}} \tag{27}$$

that is, as the flux of the electrostatic scalar field (defined in a rest-frame). So, the direction of $\overrightarrow{A}$ is equal to the direction of the velocity $\overrightarrow{\mathbf{v}}$.
If we consider a general case, that the current $\overrightarrow{j}$ is composed by $n > 1$ charged particles, each one with its electrostatic potential ϕ_j moving with the speed $\overrightarrow{\mathbf{v}}_j$, by superposition we obtain that the resulting 3-D vector potential generated by this current is equal to

$$\overrightarrow{A} = \sum_{j=1}^{n}\frac{\phi_j}{c^2}\overrightarrow{\mathbf{v}}_j \tag{28}$$

that is, $\overrightarrow{A}$ is a result of moving of the electrostatic potentials of the charged particles. Thus, the fundamental electromagnetic phenomena is based on the emission/absorption of the short-range photons by charged particles, that in the rest-frame of each j-th charged particle generate the electrostatic Coulomb potential ϕ_j. Let us show now that the L.V.Lorenz gauge condition (25) is the unique physically significant gauge pick-up, between all mathematically possible fixings of the electromagnetic 4-potential $\mathbf{A}_4 = (\frac{\phi}{c}, \overrightarrow{A})$. In fact, not only that by this gauge fixing we obtain the *decoupled* set of equations in (26), from the set of equations (11) in which both statistical variables ϕ and $\overrightarrow{A}$ are present in each differential equation, but we can also provide a clear physical explanation of this decoupling-fixing of the gauge. In effect, by this decoupling, resulting in (26), we obtain that the scalar potential ϕ is equal to the superposition of the electrostatic potentials of the charged particles which are in rest w.r.t. a given reference frame (the charged particles composing the charge density ρ on the right-hand side of the first decoupled equation).
The second decoupled equation demonstrates that the magnetic vector potential $\overrightarrow{A}$ is generated by the movement of charged particles (w.r.t. the same given reference frame) composing the current density vector $\overrightarrow{j}$. We have shown from (28) that this magnetic phenomena is only the relativistic effect of the movements of the electrostatic potentials of each charged particle in this current $\overrightarrow{j}$. So this Lorenz gauge decoupling has a clear physical meaning, and whole

electromagnetic phenomena is obtained by the electrostatic potentials (moving or not w.r.t. a given reference frame) of the individual charged particles. That is, all electromagnetic fields can be explained by the electrostatic scalar fields of the charged particles, which are the statistical results of the dense clouds of the short-range massive photons (emmited/absorbed by each charged particle) which move together with their charged emitters. We obtained finally the logical connection between the statistical theory (Maxwell) of light and theory of photons as required by Einstein. This relativistic (w.r.t. a given reference frame) effect can be clearly expressed by the two analog continuity equations, of the 4-current vector $\mathbf{J}_4 = (c\rho, \overrightarrow{j})$ and of the 4-potential $\mathbf{A}_4 = (\frac{\phi}{c}, \overrightarrow{A})$, valid for this physically determined gauge fixing (by Lorenz gauge condition),

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \overrightarrow{j} = 0, \qquad \frac{1}{c^2}\frac{\partial \phi}{\partial t} + \nabla \cdot \overrightarrow{A} = 0 \tag{29}$$

where the first terms in both equations consider the charged particles which are in rest w.r.t. a given reference frame, while the second terms consider the charged particles which are in movement w.r.t. the same reference frame.

These two continuity equations can be compactly represented as the zero 4-divergences, $\nabla_4 \mathbf{J}_4 = \nabla_4(c\rho, \overrightarrow{j}) = 0$ and $\nabla_4 \mathbf{A}_4 = \nabla_4(\frac{\phi}{c}, \overrightarrow{A}) = 0$ with $\partial_0 = \frac{\partial}{\partial q_0} = \frac{\partial}{\partial ct}$. Note that the second continuity equation (which is physically the conservation law) in (29) above is just mathematically the Lorenz gauge condition.

Differently from the long-range photons emitted by charged particle non continuously but only in the specific acceleration conditions (so that they can have very different energies), the short-range massive photons have practically the same energy E, infinitesimal rest-mass m_0 and initial speed v and are continuously emitted (with the same frequency) in each radial direction from a given charged particle.

If we assume that the massive photons generated by a positively charged particle are made of matter, that is with $\Phi > 0$ inside their body-volume, the massive photons generated by a negatively charged particle are made of antimatter, that is with $\Phi < 0$. Thus, the short-range massive photons of an electron and a proton are two perfect antiparticles, with the same rest mass m_0. So, we have the annihilation between two massive photons, one generated by electron and another generated by a proton, during their collisions. From the fact that they are very low energy antiparticles, after such an annihilation, the two new matter-antimatter photons are regenerated again, with the same rest-masses m_0 and energy E, but not with the same momentum p that they

have before the annihilation. That is, the internal energies V of these regenerated pair particle/antiparticle massive photons can be different than they had before the impact in order to satisfy the energy relationship (21).
Let us consider now what kind of dynamics of massive photons happen between two charged massive particles. We considered that in an 'isolated' situation, when a single charged particle is in the vacuum (at distance $r > r_s$ from any other charged particle), so that there is no any interaction between the short-range photons of this emitter with another charged particle, we have perfect spherically symmetric emission/absorption of massive photons of this 'isolated' charged particle. We consider that the absorbed massive photons with their momentum generate a pressure (force density) on the emitter's surface. Thus, in this ideal equilibrium (corresponding to the minimal activity of the emission of the short-range photons and hence the *minimal energy* $\triangle\mathcal{E}$ of the charged particle is used to generate a claud of massive photons around it in a given instance of time t), we have the equal pressure-force (caused by absorption of this cloud of short-range photons) on the emitter's surface from all radial directions. This equilibrium is broken when we have another charged particle at a distance $r < r_s$, because now from this radial direction the observed emitter receives a higher density of the massive photons, caused by the irradiation of the short-range photons also from this new charged particle. From the fact that, for any received massive photon, the charged particle responds by the emission of a new massive photon, and the fact that this charged particle tries to remain in the equilibrium (its natural "minimal energy dispersion" $\triangle\mathcal{E}$ state with the minimal electrodynamic activity), now the distribution of the new generated short-range photons over whole emitter's surface changes: the maximal number (in a given instance of time) of emitted photons is achieved from the small part of the emitter's surface oriented toward the other charged particle, and *minimal* from the opposite side of the surface of this emitter.
That is, the maximal *intensity* of the emission/absorption of the short-range massive photons is concentrated in the part of the emitter's surface oriented toward other charged particle (which suffers the same electrodynamic emission/absorption effect) and minimal intensity on the emitter's surface on the opposite side. The integral (over particle's surface in a given instance of time), of the whole irradiated energy used for the generation and emission of the new photons, tends naturally to be minimized and to converge to minimal activity-state energy $\triangle\mathcal{E}$. So, we consider the two possible cases:

- Between two charged particles with *the same* charge sign:

In this case these two charged particles are repelled because a number of massive photons emitted by the first charged particle will be absorbed by the another charged particle. So, the momentum of these massive photons will produce an additional pressure to another charged particle which absorbed them, and this generates the repulsive Coulomb force. It is intuitively easy to understand: as described above the intesity/density of the emitted/absorbed massive photons is bigger between these two charged particles w.r.t. the their opposite sides. So, the pressure force of the absorbed photons to any charged particle coming from another charged particle is bigger than the opposite pressure force acting on its opposite surface-side, and hence these two charged particles are repelled. That is, the pressure of the cloud of massive photons between two charged particles is greater than that on their opposite surface-sides.

- Between two charged particles with *the opposite* charge sign:
  In this case, we have an attractive Coulomb force between these two charged particles, which is not so intuitively easy to understand. We have seen that the emission of a massive photon with a given small momentum does not change the momentum of the emitter, because in the opposite side of this emitter is also emitted (statistically) another massive boson with the same but opposite momentum direction. The same fact happens for the returned and absorbed massive photons of the same emitter: if a charged particle is in vacuum, far from other charged particle, the returned massive photons will have the same value but in opposite directions. So, we have the attraction between these two opposite charged particles only when the previously emitted photon in the direction of another charged particle returns back (to be absorbed by its emitter) with smaller momentum. Indeed, during the collisions between the massive photons moving toward the oppositely charged particle, we have the annihilations of the photons and corresponding anti-photons (emitted from the positive and negative charged particles respectively). After such an annihilation, these two massive photon/anti-photon are regenerated, with the same rest mass m_0 and energy E, but with opposite and *very small* momentum w.r.t the momentum that they had before the annihilation. Consequently, when these regenerated photons are reabsorbed by their own emitters, we obtain that the absorbed photons from the opposite side of each of these two charged emitters have greater momentums w.r.t to these regenerated between these two opposite-charged particles. The final result is that we

obtain the attraction between these two oppositely charged particles.
In fact, with these massive-photon/antiphoton annihilations, we obtain that the pressure of the absorbed photons *between* two oppositely charged particles is diminished w.r.t to the standard pressure that charged particles receive from the other radial directions from their own clouds of short-range massive photons.

This electrostatic attracive/repelling force between two charged particles, with charges $\mathbf{q}_1$ and $\mathbf{q}_2$ respectively, corresponds to the Lorentz force of the radial electrostatic field (23) of the first charged particle (proportional to the density of its emitted short-range photons at the distance r, between these two charged particles) to the electric charge $\mathbf{q}_2$ of the second charged particle: $\|\overrightarrow{F}\| = \|\mathbf{q}_2\overrightarrow{E}\| = k_e\frac{|\mathbf{q}_1\mathbf{q}_2|}{r^2}$
Conventionally, it is assumed that the electric field $\overrightarrow{E}$ to a point charge is everywhere directed away from the charge if it is positive, and toward the charge if it is negative. Consequently, from (23), we obtain that the charged particle at position $\overrightarrow{\mathbf{r}}_0$ generates the following electric field at point $\overrightarrow{\mathbf{r}}$: $\overrightarrow{E} = k_e\frac{(\overrightarrow{\mathbf{r}}-\overrightarrow{\mathbf{r}}_0)}{\|\overrightarrow{\mathbf{r}}-\overrightarrow{\mathbf{r}}_0\|^3}\mathbf{q}$.
So, the Lorentz force that acts on the second charged particle with charge $\mathbf{q}_2$, at the position $\overrightarrow{\mathbf{r}}$, is given by:

$$\overrightarrow{F} = \mathbf{q}_2\overrightarrow{E} = k_e\frac{(\overrightarrow{\mathbf{r}}-\overrightarrow{\mathbf{r}}_0)}{\|\overrightarrow{\mathbf{r}}-\overrightarrow{\mathbf{r}}_0\|^3}\mathbf{q}\mathbf{q}_2 \tag{30}$$

In this case, the 4-vector potential $(\frac{\phi}{c}, \overrightarrow{A})$ of the electromagnetic field has only the scalar potential ϕ (with vector potential $\overrightarrow{A} = 0$), and from the fact that $\overrightarrow{E} = -\nabla\phi$, we can define also the electrostatic potential.

5 Tesla's Scalar Waves

"*Towards the close of 1898 a systematic research, carried on for a number of years with the object of perfecting a method of transmission of electrical energy through the natural medium, led me to recognize three important necessities: First, to develop a transmitter of great power; second, to perfect means for individualizing and isolating the energy transmitted; and, third, to* ascertain the laws of propagation of currents through the earth and the atmosphere. *Various reasons, not the least of which was the help proffered by my friend Leonard E. Curtis and the Colorado Springs Electric Company, determined me to select for my experimental investigations the large plateau, two thousand meters above* *sea-level, in the vicinity of that delightful resort, which I reached late in May, 1899. I had not been there but a few days when I congratulated myself on the happy choice and I began the task, for which I had long trained myself, with a grateful sense and full of inspiring hope.*" -Nikola Tesla, Serbian-American inventor (Communicated to the Thirtieth Anniversary Number of the Electrical World and Engineer, March 5, 1904.)

Wardenclyffe Tower (1901-1917), also known as the Tesla Tower, was an early experimental wireless transmission station designed and built by Nikola Tesla in Shoreham, New York in 1901-1902. Contrary to popular belief his tower was not built to radiate Hertzian (transverse) waves into the air. Tesla's system was used to send out thousands of horsepower *through the earth*- he has shown experimentally how power can be sent without wires over distances from a central point. Tesla intended to transmit messages, telephony and even facsimile images across the Atlantic to England and to ships at sea based on his theories of *using the Earth to conduct the signals.*

Nikola Tesla invented the modern age, patenting every form of modern technology or it's conception as it's basis for today[4]. Many inventions attributed to others were first developed by Tesla. Marconi's admitted to using Tesla's earlier patented work for research and his 1894 "Shadow Graphs" that predated Wilhelm Roentgen X-Rays in 1895. He publicly stated his conception of the internet and Television as he was the first to invent wireless remote control before 1900. He invented fluorescent bulbs in his lab some 40 years before industry "invented" them; robotics, electric motors, wireless electricity, toaster coils, lasers, practically everything the world uses today he had a hand in it at some time, as he is the inventor of alternating electrical current.

Tesla reported that[5], driven by his observation of mysterious damage to photographic plates in his laboratory, he began his investigation of x-rays (at that time still unknown and unnamed) in 1894. Apart from experiments using the Crookes tube, he invented his own vacuum tube, which was a special unipolar x-ray bulb. It consisted of a single electrode that emitted electrons. There was

[4]Nikola Tesla was born in a Serbian family 1856 in the small village of Smiljan. After finishing high school in Croatia, he continued his education in engineering in Graz, Austria, until 1878. Four years later he moved to Paris, France, and started working for the Continental Edison Company. In 1884 he emigrated to the United States, where he first began to work with Thomas Edison but soon afterward formed his own Tesla Corporation as competition to Edison's company. He patented about 300 inventions worldwide, many of which are still famous today. Courtesy of the Tesla Museum, Belgrade, Serbia. Fortunately for me, I have studied the Electrical engineering at ETF, Nikola Tesla, at Belgrade, where I obtained the Assistant professor position for electromagnetic, microwave and laser techniques, immediately after my Msc at Telecommunications (when I was 27 years old).

[5]This information is provided from https://teslauniverse.com/nikola-tesla/articles/nikola-tesla-and-discovery-x-rays

no target electrode; therefore, electrons were accelerated by peaks of the electrical field produced by the high-voltage Tesla coil. Even then, Tesla realized that the source of x-rays was the site of the first impact of the "cathodic stream" within the bulb, which was either the anode in a bipolar tube or the glass wall in the unipolar tube he invented. Nowadays, this form of radiation is known as Bremsstrahlung or *braking radiation*. In the same article, he stated that the cathodic stream was composed of very small particles (ie, electrons). His idea that the produced rays were minute particles was not wrong at all; many years later, physicists described particle properties of electromagnetic radiation quanta called photons. It is really difficult to find a well defined concept for the "scalar waves", so I can take this one, find in popular web sources[6]:

"*Scalar waves also referred to as Tesla waves or longitudinal waves are capable of penetrating any solid object including Faraday cages. A transmitter can be placed in a box of thick metal and a receiver outside of the box will still receive the scalar wave. Scalar waves are capable of passing through the earth from one side to another with no loss of field strength as Tesla showed in one of his experiments... Scalar Waves are not electromagnetic but composed of pure zero point energy. They also have the potential to be used as a power source. Some point to the 1908 Tunguska event as Tesla's own proof of concept test. So scalar waves can be used for communication, energy, and other applications. Scalar waves (longitudinal waves) do what transverse waves cannot. They are fast, penetrating, connected, and can broadcast magnified power. Their potential is almost limitless...*"

or the following[7]:

"*Scalar waves were originally detected by a Scottish mathematical genius called James Clerk Maxwell (1831-1879) He linked electricity and magnetism laying the foundation for modern physics, but unfortunately the very fine scalar waves (which he included in his research) were deliberately left out of his work by the 3 men, including Heinrich Hertz, who laid down the laws taught for physics as a discipline at colleges. They dismissed Maxwell's scalar waves or potentials as 'mystical' because they were physically unmanifest and only existed in the 'ethers' and so were determined to be too ineffectual for further study. These enigmatic (but more powerful than even microwaves when harnessed and concentrated into a beam) scalar waves may have been forgotten except that Nikola Tesla accidentally rediscovered them... By 1904, Tesla had developed trans-*

[6]Provided from https://www.lifeenergysolutions.com/scalar-waves/, the first line in response to the research in Google for "Scalar Tesla waves", February 2018.

[7]Provided from https://www.tokenrock.com/explain-scalar-wave-technology-77.html, February 2018

mitters to harness scalar energy from one transmitter to another, undetectably bypassing time and space. He could just materialize it from one place to another through hyperspace, without the use of wires, it was just sucked right out of the space-time/vacuum and into a transmitter and into a beam which could be targeted to another transmitter. Unfortunately he got no financial support for replacing electricity, which used wires and therefore earned money, and to this day, this is the reason why scalar energy is still not acknowledged in mainstream physics."

Consequently, in the absence of the scientifically accepted opinions, I will consider as trusted basis only the Tesla's experimental proofs, that is, that the scalar waves *are not* the transverse plain (spherical) waves for which we know that are composed by the stable point-like zero rest-mass photons that propagate with maximal possible velocity of light (in the vacuum or quasi-vacuum) after *some distance* from the antenna.

So, the transmission of the energy by these waves (composed by the bosons in their particular conditions) can not be obtained by the Poynting vector which represents the *directional energy flux* (the energy transfer per unit area per unit time) of a transverse electromagnetic field (where the electric and magnetic fields are mutually orthogonal lying in the plain which is orthogonal to the direction of the wave propagation). We know that, from the Maxwell's theory, that the Poynting vector is zero only if the vector product of electric and magnetic fields is zero. This fact is confirmed also by Tesla's observation that "*Scalar waves are capable of passing through the earth from one side to another with no loss of field strength*", and if such a wave would have electric component different from zero, from the fact that earth is semi-conductor, we would have enormous loosing of the energy of such a wave.

Nikola Tesla advanced the electromagnetism theory into new dimensions, further than Hertz and other scientists of his time could conceive. He described his "wireless" waves being far superior to Hertzian (transverse) waves, which *diminish with distance.* Tesla foretold of a brilliant new future for humankind, using his non-Hertian "wireless system," including the ability to generate power and transmit it to various parts of the globe. Tesla wanted to harness the ground to utilize his technology; however, *with the Hertzian system the atmosphere is used* as the medium and ground is not a major part of the design.

Tesla considered *the entire terrestrial globe to be an electrical conductor that could be made to resonate* at different frequencies. Moreover, the earth had various terrestrial resonances, which could be "tuned" or tapped into, provid-

ing planet Earth's citizens with a clean and inexhaustible source of energy. After the many years of research into his concept of electromagnetic wave propagation through the earth or ground, Tesla was able to refine and perfect his inventions. More and more, Tesla's inner mind conceived this new kind of energy and the effects it would have on our science. Nikola Tesla showed he could send electrical energy without wires. It turned out not to be good for business and it was also classified. He used *longitudinal waves.* The field pointer travels in the direction of propagation, much *like sound waves and plasma waves* do. Their potential is "scalar" but longitudinal wave vectors can be produced from them. However, they are simply called "scalar waves." He described this energy as having the ability to be transmitted to any distance without any loss:
"*That electrical energy can be economically transmitted without wires to any terrestrial distance, I have unmistakably established in numerous observations, experiments and measurements, qualitative and quantitative. These have demonstrated that it is practicable to distribute power from a central plant in unlimited amounts, with a loss not exceeding a small fraction of one per cent, in the transmission, even to the greatest distance, twelve thousand miles — to the opposite end of the globe.*"
Nikola Tesla
Consequently, from the above experimentally provided results from Tesla (confirmed, as it seems, also by a number experiments after Tesla), the only possibility that the photons irradiated by the electric antenna are in a particular state, very different from the standard zero-mass point-like long-range photons that we have in the situation of the transverse electromagnetic wave when propagates in the vacuum, so that the scalar wave, also composed by the photons, does not have more *observable* electromagnetic properties: this can explain also why such waves can pass through "*any solid object including Faraday Cages*".
Moreover, by Tesla's ideas, these longitudinal (scalar) waves propagate like sound or plasma waves: both of these waves are composed by a high number of corpuscular particles (or molecules for sound waves) that have the rest-mass different from zero, differently from the stable massless point-like photons. This means that such waves, generated by photons (from the electrical sources, i.e., antennas) must have the particular states of these photons, different from the "normal" states during their propagation in vacuum with the velocity of light, when their statistical effect generates the transverse electro-magnetic plain wave (with the electric and magnetic fields orthogonal to the direction of the wave propagation, that is, the propagation of a beam of such massless photons).
The second important point is that, from the fact that the photons are inter-

mediary bosons for the electrically charged massive particles, the propagation of a beam of such photons is governed by the Maxwell's equations: it means that also the beam, composed by a high number of such "not normal state" photons, must satisfy Maxwell's equations, also if the resulting electric and magnetic fields of such beam *are equal to zero*.

That is, the scalar longitudinal waves generated by a beam, composed by a high number of these "not normal photons", must satisfy the Maxwell's equations and to transfer their energy also when the electric and magnetic fields of such a wave are zero and the Poynting vector (different from zero for the ordinary transverse electromagnetic waves) is equal to zero! Such a particular condition is in fact provided by the recent publication of the C.I.A document CIA-RDP96-00792R000500240001-6, approved for release 2001/03/07 (about a century after Tesla's discovery) with the subject: Scalar Waves (Ref: Verbal Request for Summary Statement on Scalar Waves). In this document, point 2, is written:

"*There is a community in the U.S.A. that believes that the scalar waves are realizable. In recent conference sponsored by the IEEE these where openly discussed and a proceedings on the conference exists. The conference was dedicated to Nicola Tesla and his work, and the paper presented claimed some of Tesla's work used scalar wave concepts*".

In what follows I will use all this information in order to find a possible solution for the nature of these scalar Tesla's waves, without changing the Maxwell's theory and in accordance with quantum theory and special relativity in which the maximal possible velocity is that of light. I will also show where was the error of Tesla to suppose that the speed of such scalar waves (and the photons that compose such waves) is superluminal. The origin of this error is that they apply, for the frequency ν and wavelength λ, with the period of oscillation T and velocity of propagation $v \leq c$, the equation (9) $\frac{1}{T} = \nu = \frac{v}{\lambda}$, valid *only* for the standard transverse electromagnetic waves and not for the longitudinal (scalar) waves, as it will be shown.

Moreover, we explained the statistical meaning of the electromagnetic equations. That is, the electric and magnetic fields, $\overrightarrow{E}$ and $\overrightarrow{B}$ respectively, are the statistical effects of the interactions of the charged (negative and positive) elementary particles with the intermediary bosons (photons) between them, which are not electrically charged elementary particles. So, a single photon has no associated with it an own electric field.

We know also that if an electron in a given reference system is in rest then the photons emitted and absorbed by this electron, which generate an electric field

$\overrightarrow{E}$ around it, *do not generate* any magnetic field. The magnetic field is the statistical effect of the photons generated by this electron *only* for other reference systems for which this electron moves with some speed $\overrightarrow{\mathbf{v}}$. Thus, the magnetic field is only a relativistic phenomena in quantum physics (Special Relativity) as, for example is the *total* energy and relativistic effect w.r.t. the invariant rest-mass energy of the same massive particle. The electric field, differently from the magnetic field, there exists in every reference system (is an 'objective' field property), also for the proper frame of charged particle (where the speed of this electrically charged particle is zero).
Just because of that, $\nabla \cdot \overrightarrow{E}$ is different from zero in the regions where there exist the charged elementary particles (the electrons, for example), and is proportional to the density of these charged elementary particles in a given region of space. No one elementary particle if found whit the *magnetic charge*. So there is no any density of such hypothetic magnetically-charged elementary particles in a given space region, in order to obtain that $\nabla \cdot \overrightarrow{B} \neq 0$. The only way to avoid such a dissipation of the photons energy can be obtained when the electric field of such a scalar wave is equal to zero. In this way, this scalar wave does not interact with the electrons in the earth, similarly for the propagation of neutrinos. However, here we have the propagation of the photons emitted by the electromagnetic Tesla's antenna and composing these scalar waves, not the propagation of neutrinos! Tesla did not try to modify the Maxwell's theory, in order to explain some of his experimental results, and hence I will try to obtain a possible interpretation of his "scalar waves" strictly *inside* the valid Maxwell's theory. Hence, in the case of the Lorenz gauge potentials (25), when $\nabla \cdot \overrightarrow{A} = -\frac{1}{c^2}\frac{\partial \phi}{\partial t}$, the equations in (11) become equal to plasma's equations

$$(-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\phi = \frac{\rho}{\varepsilon_0}, \qquad (-\nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2})\overrightarrow{A} = \mu_0 \overrightarrow{j} \tag{31}$$

where the first equation corresponds to the *scalar* longitudinal waves in plasma with charge density ρ (like that obtained in the microwave traveling-wave-tubes (TWT)).
However, we can not use these equations for the Tesla's scalar waves, because such waves will be absorbed in the earth (in fact, for example, we have the vacuum inside the TWT where propagates beam of electrons with longitudinal electromagnetic waves).
In order to obtain the scalar longitudinal waves with zero electric and magnetic field, which can propagate trough earth without loses, we must have a beam of the photons which does not generate the electric and magnetic fields, like

neutrinos which are massive particles with infinitesimal but finite rest-mass and able to propagate with the speed close to the speed of light. It is well known that such massive particles propagate with very small losses through any material and are able to pass through Faraday cages, as verified by Tesla. Consequently, as in the case of the antenna's near-field, we can consider the massive photons as constituent parts of the Tesla's longitudinal scalar waves. Such massive photons, with the low-frequency (low energy), would have the small rest-mass as that of neutrinos, and hence the same propagation properties. The only difference is that neutrino is a neutral fermion with spin $\frac{1}{2}$ and fixed invariant rest-mass, while the massive photon has no a fixed invariant rest-mass and has the boson's spin 1.

Let us consider the longitudinal scalar wave composed by the massive long-range photons with energy density $\Phi_m(t, \overrightarrow{\mathbf{r}})$, which propagates with the constant extremely high speed $\overrightarrow{\mathbf{c}} = c\mathbf{e}_1$ (with c less than the speed of light in the vacuum) as a dense beam along the axes x. From the fact that the (group) speed of these photons c corresponds to the speed of light, c is just the "speed of light in the earth", and hence less than the speed of light in the vacuum. Consequently, this speed of massive photons $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ in the earth can be used in Maxwell's equations as the speed of light from the fact that ε_0 and μ_0 are different from that in the vacuum, so that the speed of light c is less than the speed of light in the vacuum. Thus, the motion equation (2) of the massive photon, $\frac{\partial \Phi_m}{\partial t} = \overrightarrow{\mathbf{v}} \nabla \Phi_m$, where $\overrightarrow{\mathbf{v}} = \overrightarrow{\mathbf{c}}$ is the light speed in the earth, becomes equal to:

$$\frac{\partial \Phi_m}{\partial t} = \overrightarrow{\mathbf{c}} \nabla \Phi_m \tag{32}$$

Let us consider a beam of such massive photons whose density $\rho_p(t, q_1)$ depends only on the time and distance $q_1 = x$ along the direction x of the propagation (so that $\overrightarrow{\mathbf{c}} = c\mathbf{e}_1$ and the gradient of ρ_p is collinear with $\overrightarrow{\mathbf{c}}$, so that $(\overrightarrow{\mathbf{c}} \nabla \rho_p) \overrightarrow{\mathbf{c}} = (\overrightarrow{\mathbf{c}}\, \overrightarrow{\mathbf{c}}) \nabla \rho_p = -c^2 \nabla \rho_p$, such that its motion equation is analog to that of the single photons (32) that compose it. So, if we can neglect the absorption of these massive photons trough the Earth (as confirmed by Tesla) then we have the conservation $0 = \frac{d\rho_p(t,q_1)}{dt} = \frac{\partial \rho_p}{\partial t} + \frac{\partial \rho_p}{\partial q_1}\frac{dq_1}{dt} = \frac{\partial \rho_p}{\partial t} + c\frac{\partial \rho_p}{\partial q_1}$, i.e.,

$$\frac{\partial \rho_p(t, q_1)}{\partial t} = \overrightarrow{\mathbf{c}} \nabla \rho_p(t, q_1) = -c\frac{\partial \rho_p}{\partial q_1} \tag{33}$$

and hence by derivation on time, $\frac{\partial^2 \rho_p}{\partial t^2} = c^2 \frac{\partial^2 \rho_p}{\partial q_1^2} = c^2 \nabla^2 \rho_p$, we obtain the longitudinal scalar wave for the beam of massive photons that propagates with a constant very high speed c less than the speed of light in the vacuum:

$$\nabla^2 \rho_p - \frac{1}{c^2}\frac{\partial^2 \rho_p}{\partial t^2} = 0 \tag{34}$$

Let us now define the 4-vector electromagnetic potential for this longitudinal wave (where the scalar potential ϕ is proportional to the *pressure* of the photon's beam (like in the hydrodynamics, where electromagnetic vector $\overrightarrow{A}$ is in correspondence with the hydrodynamic fluid velocity [3, 2]) in direction of coordinate q_1 and hence, from the fact that the speed of photons is constant, it is proportional to the density of the photons in this wave) by:

$$\phi \equiv a_\rho \rho_p(t, q_1), \qquad \overrightarrow{A} \equiv \frac{\phi}{c^2}\overrightarrow{\mathbf{c}} \tag{35}$$

where a_ρ is a real constant such that for a given positive density ρ_p of the massive photons in the beam, it gives to ϕ the right sign and physical dimension of scalar potential.

Notice that the equations above specify the 4-potential vector, for a fixed instance of time t, in the 3-D regions where is presented this beam of massive photons. The vector potential $\overrightarrow{A}$ is defined in analog way as in (27) and is just in the direction of the propagation of the photons (of the light), differently from the Hertzian *transversal* linearly polarized waves when it is orthogonal to the direction of the wave propagation in (14). This physical phenomena justifies the name of '*longitudinal* waves' given to these Tesla scalar waves.

In fact, for the harmonic antenna (Tesla resonance of its antenna of scalar waves, at position $x = 0$ on the Earth's surface, with period T) that produces the scalar waves with wave-length $\lambda = cT$, with $k = \frac{2\pi}{\lambda}$, we obtain the beam density oscillation $\rho_p(t, x) = \rho_m + \rho_0 \sin(k(x - ct)) > 0$, for some constants $\rho_m > \rho_0 > 0$. Note that for a fixed position x_0 the intensity of pressure of this beam of photons to the plane orthogonal to the direction x of propagation at this fixed position changes harmonically in time with period T, from $\rho_m - \rho_0$ to $\rho_m + \rho_0$. So, if $x_0 = n\lambda$, $n >> 1$, and x_0 is the opposite point of Earth's surface from which these massive photons reflect, then we obtain the standing wave of this scalar wave of photons inside the Earth which behaves as Tesla's EM resonator. Note that the equation (34) corresponds to the *Lorenz gauge potentials* satisfying (25), so that 4-potential satisfy the equation (31) but with the electric charge density $\rho = 0$ and current density $\overrightarrow{j} = 0$. So, from (10):

- Magnetic field, $\overrightarrow{B} = \nabla \times \overrightarrow{A} = \nabla \times (\frac{a_\rho}{c}\rho_p(t, q_1)\mathbf{e}_1) = 0$.

- Electric field,
  $\overrightarrow{E} = -\nabla\phi - \frac{\partial \overrightarrow{A}}{\partial t} = a_\rho(-\nabla\rho_p) - \frac{\vec{\mathbf{c}}}{c^2}\frac{\partial}{\partial t}\rho_p) = -a_\rho(\frac{\partial\rho_p}{\partial q_1}\mathbf{e}_1 + \frac{1}{c}\frac{\partial\rho_p}{\partial t}\mathbf{e}_1) = 0,$
  from (33).

That is, we obtained that for this longitudinal scalar wave, composed by the massive photons, the produced electric and magnetic fields are equal to zero. Thus, this beam does not interact with charged particles (as it does transverse electromagnetic wave of photons) and hence it will not have the significant losses during the propagation through the earth (like to the beam of neutrinos). Thus, such scalar waves are able to explain the experimental results of Tesla's waves, that propagate through the earth with less than some percent of losses. This phenomena confirms the fact that 4-potential electromagnetic vector is more fundamental natural phenomena than the derived electric and magnetic forces $\overrightarrow{E}$ and $\overrightarrow{B}$ respectively. Moreover, in this case of the Tesla's longitudinal scalar waves, composed by the massive photons, the 4-potential electromagnetic vector is uniquely determined from the density ρ_p of the massive photons, in this way:

- From (35) we have that the vector potential $\overrightarrow{A} = \frac{a_\rho}{c}\rho_p(t, q_1)\mathbf{e}_1$, of a dense beam of massive photons, represents the force of the energy density of massive photons, that is, the pressure vector of this scalar wave.

- From (35) we have that the scalar potential $\frac{\phi}{c} = \frac{a_\rho}{c}\rho_p(t, q_1)$ represents the scalar value of the pressure of this wave.

- Consequently, the 4-potential vector for Tesla scalar (longitudinal) waves, is given in the following simple 4-gradient of the density of the massive photons ρ_p propagating with the speed of light in the given medium:
  $\mathbf{A}_4 = (\frac{\phi}{c}, \overrightarrow{A}) = \frac{a_\rho}{c}\rho_p(t, q_1)(\mathbf{e}_0 + \frac{\vec{\mathbf{c}}}{c}).$

Thus, differently from the transverse electromagnetic linearly polarized wave, for which scalar potential $\phi = 0$, and we have the single vector potential wave (13) that propagates in the vacuum with the speed c of light, here we have also the scalar potential wave, because $\phi \neq 0$, which propagates with the vector potential wave by the speed v. Consequently, from the fact that μ and ϵ in the earth are different from that in the vacuum, this speed v can be considered the "speed c of light in the earth", so that are satisfied the Maxwell's equations (31) in the earth for Tesla's scalar waves. The standard transverse electromagnetic waves, with massless long-range photons, cannot propagate through the earth, because they have both electric and magnetic field different from zero and hence such waves are absorbed by the earth. Only the Tesla scalar waves, with massive long-range photons, can propagate through the earth because their electric and magnetic fields are zero. The massive photons of the Tesla scalar wave propagate like neutrinos through the earth (without significative losses), but from the fact that are not fermions but massive bosons, they reflect from the surface of discontinuity between earth and air (on the opposite Earth-side w.r.t. Tesla's antenna, so that can produce the resonance system with *standing waves* inside the Earth (differently from the neutrinos) as shown by Tesla's experiments.

Consequently, based on the standard electromagnetic Maxwell's theory and the IQM theory of massive photons, the Tesla's scalar (longitudinal) waves and the resonant system with possibility to transfer the enormous quantities of electromagnetic energy through the Earth (transported with the speed of light trough the Earth by the massive photons) have a physical explanation. However, the practical applications need some verifications because not all massive photons would reflect from the opposite side of the Earth (it is not a perfect resonator), and this can produce some danger collateral consequences around the region of the reflection of these massive photons.

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