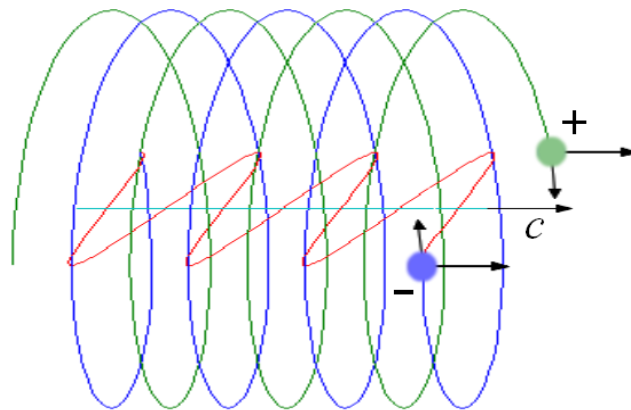


# The Photon Double-Helicoidal Model

by studies and researches of

Oreste Caroppo



An Heuristic Model for the Photon to Explain all its Properties  
and its Equation  $E=hc/\lambda$  :

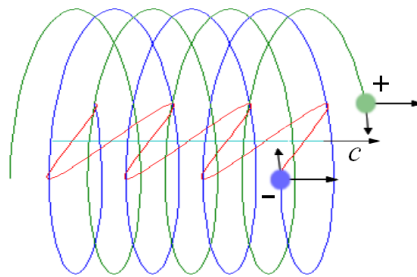
The Electric Dipolar Double-Helicoidal Dynamic Model of the  
Photon.

The Interpretation of the Physics Origin of the Planck Constant

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## The Electric Dipolar Double-Helicoidal Dynamic Model of the Photon

## The Interpretation of the Physics Origin of the Planck Constant

### Abstract

I want to propose to your attention a mechanic model for the photon. In modern physics scenery directed towards a great unification and an omni-inclusive mathematical description of the whole Universe, I think, perhaps, it needs again deepening discrete aspects of the reality. Fascinated by the photon, I thought necessary to find a photon model of its fine structure, to explain all its properties. I saw with great amazement, the energy equation of the photon  $E_{ph} = h\nu$ , and imaging my emotion caused by a mysterious structure hidden in the photon, I began working to try to discover this elusive structure, to explain deeply the photon linear relationship between energy and frequency,

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Note: the figures in the pages 1 and 3, which are the same, represent, schematically, a photon in our model; inside the double helix, the sinusoidal curve plotted corresponds to the classical, often symbolic, representation of the photon.

confident that this new model could have opened to me a new road to explain  $h$ , Planck constant, and with it some aspects of quantum physics again dogmatic or obscure. After several years of solitary and independent studies and researches, I have the pleasure to present you my ideas and their mathematics supports. I thank my colleagues, physicists, mathematicians, professors and the other friends, who, after having read this my paper, enthusiastic, suggested me to publish it, to publish, what they call “*Caroppo’s Photon Model*”, in this scientific article.

The descriptions of our model will be made in an inertial frame of reference. In our photon model, photon energy, and then its relativistic mass, we think, is divided to half between two sub-particles, separated in space, having opposite elementary charges. It is respected the electrical neutrality of the real photon, but the hypothesis of a discrete distribution of charges in it, gives us a way to understand how it is possible for the photon to carry the electromagnetic field and then, to generate the elementary electromagnetic quantum wave impulse. The two semi-photon particles of our photon model are in a dynamic equilibrium, which gives stability to the system during its propagation, creating between them a dynamic bond. In this new point of view, the generation of a matter-antimatter pair, generally electron-positron, from a photon, appears as a phenomenon implicating a breaking of the dynamic bond of the two sub-particles constituting the photon, revealing the presence in it of two particles with the same energy-mass, and with opposite elementary charges. In this heuristic photon structure, the two sub-particles, imagined punctiform, material points (at least in a first approximation), move themselves in a precise roto-translation motion along two helicoidal trajectories, two coaxial cylindrical helixes with the same step and screwing direction, and opposite between them, that is out of phase of  $\pi$  rad. In each moment the two semi-photon particles are on the same plane orthogonal to the common axis of the helixes, with the same distance between them, a distance equal to the common diameter of both helixes; the two photon sub-particles form, therefore, a dichotomic rigid system, an electric dipole in which the same photon would consist. The screwing angle of these helixes is  $45^\circ$ ; the two semi-particles move themselves with a total velocity of magnitude  $\sqrt{2}c$ ; hence, they rotate with a speed  $c$ , and they translate with an identical speed  $c$ , the speed of light, in the direction of the helix axis, therefore the photon system translates globally, along helix axis with an uniform straight line movement, of  $c$  speed, perfectly like in a real photon. The two sub-particles are tachyons; they have a superluminal speed, but their total velocity magnitude,  $\sqrt{2}c$ , reveals some interesting mathematic properties in special relativity equations.

Radius of the helixes is such that in the time of a complete rotation, of  $2\pi$  rad, the photon system translates of  $\lambda$ , the wavelength of the real photon of the same energy;  $\lambda$  is the common step of both helixes. The inverse of the time of a complete rotation, the frequency,  $\nu$ , of the rotation movement, is then, the frequency of the photon. Now, in the time of a complete rotation, which is the time of a translation of the system of a wavelength,  $\lambda$ , effectively we have a complete rotation-fluctuation of the electric and magnetic fields of our photon model, and therefore of its associated and by it generated, electromagnetic wave! Therefore, by our model, we give a more defined description of  $\lambda$  and  $\nu$ , wave properties of the photonic particle, that, here, we bring back to the intrinsic kinematics of the photon fine structure; a result which can recompose the traditional “wave-corpucle dualism” in the phenomenological behaviour of the electromagnetic radiation, without the necessity of a dogmatic principle of dualism for it.

This photon system, as described, has a momentum which is the same of a real photon with the same energy; identical magnitude and identical momentum direction, that of the translation motion of our system, hence of the real photon we want to describe structurally here. Our system has a spin which is exactly, that of the real photon, also with one xor the other of the two possible right-handed and left-handed screwing directions, corresponding respectively, to a vector spin parallel

xor anti-parallel with the translation direction. Magnetic momentum of spin is null as in the real photon, too. Also, the total rest mass of our photonic system, which is zero, is the same of the real photon. More, we find in our model a three-dimensional photon, non punctiform, with a transversal radius linearly proportional to  $\lambda$ , and of the same magnitude, exactly as diffraction experiments suggest us for the real photons; however,  $\lambda$ , which is traditionally a longitudinal property, does not lose here, this longitudinal aspect!

The magnetic Lorentz forces between the opposite charges in motion of the two semi-photon particles are null in our described system.

The dynamic stability of Caroppo's Photon Model, with the relativistic formula of Newton's second law of motion, considering the electric Coulomb force between the two photon sub-particles, gives us a surprising result, proper the equation of a linear relationship between photon energy and its frequency, as obtained in the studies of Planck and Einstein, and as verified after, in many other experiments!

The discussion about the proportional constant of this equation, which must be equalled to the experimental Planck constant,  $h$ , gives us the opportunity to present a new interpretation of  $h$ . We

find  $h = K_{sv} \frac{e^2}{c} \pi$ , where  $K_{sv}$  is the magnitude of Coulomb's constant, in Coulomb's electrostatic interaction between the charges of the two superluminal photon sub-particles. If  $K$  is traditional Coulomb's constant in the vacuum, we have  $K_{sv} > K$ . We attribute the greater magnitude of  $K_{sv}$ , to the inertia of the vacuum, a dielectric inertia, that is the intrinsic inertia of the charged particles of the vacuum, "virtual" particles called according to modern physics; particles connected to the intrinsic energy of the empty space. For their inertia, we think they can not respond to the too much variation in space and time of the electric field connected with the superluminal passage of the internal charges of the photon, so the charges of the photon sub-particles are not screened, and they travel in a vacuum not polarized, while ever it is polarized for the electric interaction between charges in subluminal speed. This could also explain the nature of the origin of the "Fine Structure Constant"! The analyses of the electric and magnetic dynamic fields of our photon system, (that is of the elementary electromagnetic quantum wave impulse), generated by its constituting two opposite charges in motion, show exactly, in particular important straight lines, the same characteristics as orthogonalities, circular polarizations, time and space variations of their Cartesian components, which we find in the plane monochromatic electromagnetic wave in Maxwell's theory!

A theoretical model so potent that can not be ignored, although it takes us towards new revolutionary perspectives of looking at nature, certainly ever joinable with our previous scientific conquests as the history of science suggests!

## Prolegomenon

In this article I propose a possible model to describe photon structure. The necessity of this model is born to understand the phenomenological photon characteristics and to solve some aspects of the quantum physics which have until now a dogmatic nature and which are covered by an intellectual fog. A photon model so astonishing that gives us the possibility to obtain the important equation  $E_{ph} = h\nu$ , by electric and dynamic intrinsic aspects of the fine structure of the photon!

## Synopsis

Initially, an abstract of the work, then a little prolegomenon to it. It follows a resume about the main properties of the photon. Then, we became to expound a possible microstructure for the photon, “Caroppo’s Photon Model”, the double-helix in the fine photon structure. At the beginning, a description of the fine constituents of this model, it follows a presentation of its geometric and kinematic aspects. Hence, we show how kinematic and geometric properties can give reason of the photon frequency,  $\nu$ , which appears, here, a physical property intrinsic in our photon dynamic structure. The model gives substantiality to the phenomenological finite not null transversal dimensions of the photon. According photon spin with our model, we can find physical reason to its intrinsic angular moment. We define better the internal kinematics, to accord it with the real movement characteristics of the photon, we calculate the screwing angle of the helical trajectories, and we demonstrate the accord between theory and physics about magnetic momentum of spin too. Then, we show as our model has the same momentum and rest mass of a real photon of the same total energy. Some considerations about energy and momentum conservation. A focus about the real photon spatial dimensions explained in our model. From considerations about the stability of our dynamic photonic system, we show that our model predicts a linear relationship between the total photon energy and its frequency! Following, we will return to analyse deeply this very important result, in accord with experimental measurements. Considerations about the generation of a photon. An exposition about the idealizations in our photonic theoretical model and some calculations about the inside gravitational interaction in it. Considerations about the microscopical tachyon nature of the photon in our model and about this as a not radiative accelerated dipolar system. A deep analysis about “Planck constant” to the light of our photonic model and about “Fine Structure Constant”. Considerations about photons in the electromagnetic radiation, and about the solution of the dogmatic “wave-corpucle dualism” of light. Perspectives of investigation opened. Some considerations about electric and magnetic fields of a photon showing important similitude between electromagnetic wave impulse, here predicted and described for the photon, and Maxwell’s electromagnetic wave. Conclusion.

## The Phenomenological Photon Characteristics

We list some photon properties; following we will explain and we will understand better them in our photon model.

- Photon is a particle associated to the electro-magnetic wave (e.m.w.); photon carries the electromagnetic field of the radiation wave, and we can say, a photon is an electro-magnetic wave, in particular its quantum wave impulse and an electro-magnetic wave is the photon of a group of photons. Photon is the quantum, the basic unit, of the e.m. radiant energy. Then if  $\lambda$  is

the wavelength of the electromagnetic wave associated to a photon, and  $\nu$  its frequency, these are photon properties too.

- Photon, like its associated electromagnetic wave, moves itself along a precise straight line, and direction, (this in absence of gravitational field), with a constant speed of translation  $c$  in vacuum, where  $c$  is the *light speed* in the empty space.
- It is ever valid in the empty space this relation:

$$c = \lambda \nu \quad (1)$$

- We know by experiments, as photoelectric effect and its Einstein's interpretation, and by theoretic studies, as Planck's resolution of black-body emission problem, that photon connected with an electromagnetic wave of frequency  $\nu$ , has a total energy  $E$ , proportional to  $\nu$ , with *Planck constant*,  $h$ , as proportional coefficient:

$$E_{ph} = h \nu \quad (2)$$

In this equation the profound sense of *Planck constant* is hidden! Quantum physics is founded on  $h$ .

A structure for the photon that explains its equation,  $E_{ph} = h \nu$ , will give us the possibility to understand the physics sense and the real nature of  $h$ .

Photon carries energy, and this can explain the energy transported by the electromagnetic wave, which is made by one or more photons.

Being  $c = \lambda * \nu$ , substituting, we have

$$E_{ph} = \frac{hc}{\lambda} \quad (3)$$

Then, photon energy is a function of  $\lambda$ , too!

Note: all photons, that exist or that are generated in the Universe, have not the same energy, or a discontinuous set of values of energy, a set of limited or unlimited numbers of energy levels, but they can have any value of energy (and thus of frequency) within the "electromagnetic spectrum", which is a large continuous range of energy values. Thus the different photons can have energy values that may differ among them with continuity in the range of energy values of the electromagnetic spectrum. Obviously, more photons, with the same energy, can exist, or can be generated!

- Photon has a *quantum spin number*,  $S$ ,  $+1$  xor  $-1$ , and its magnetic momentum of spin,  $\mu$  is null. The photon spin is a longitudinal property of the photon since it can be parallel ( $S = +1$ ) xor antiparallel ( $S = -1$ ), with the photon velocity direction. Independently of its frequency the spin

magnitude is ever  $\hbar = (2\pi)^{-1}h$ . The two possible direction for the photonic spin, are correlated with the two possible rotation directions of a circular polarized electromagnetic wave. All these properties, about photon spin, have been predicted in theory and they have indeed been experimentally verified.

- According to relativity, a photon has

- a relativistic mass,  $m_{ph}$ : 
$$m_{ph} = \frac{E_{ph}}{c^2} \quad (4)$$

- a rest mass,  $m_{o\_ph}$ , null: 
$$m_{o\_ph} = 0 \quad (5)$$

- To a photon, it is associated a *momentum*,  $\overrightarrow{P}_{ph}$ , with the direction that of the  $c$  velocity of the photon, and with its magnitude,  $P_{ph} = \left\| \overrightarrow{P}_{ph} \right\|$ :

$$P_{ph} = m_{ph}c = \frac{E_{ph}}{c} = \frac{h\nu}{c} \quad (6)$$

Photon carries momentum too, and this can explain the momentum also transported by the electromagnetic wave, which is made by one or more photons.

- Photons interaction, as diffraction, happens like photon occupies a sphere in space whose diameter is proportional to  $\lambda$ , and of the same order of magnitude, then like photon has a circular section orthogonal to its translation direction, of a diameter proportional to  $\lambda$ , and of the same order of magnitude.
  - When the maximum length,  $D$ , of an object orthogonally to the photon (or e.m.wave) velocity direction, is :  $D \ll \lambda$ , no significant influence is made on the photon (or e.m.wave).
  - When the maximum length,  $D$ , of an object orthogonally to the photon (or e.m.wave) velocity direction, is :  $D \approx \lambda$ , the interaction with photon (or e.m.w.) becomes evident.
- Another photon characteristic is that it is an electrically neutral particle.
- In particular condition a photon can transform itself into a pair of particles of matter and antimatter, (particle-antiparticle pair), each one with the same rest mass equal or minor to the half of the relativistic mass of the original photon, and with opposite elementary electric charge,  $e$ , complying with the principles of conservation of mass-energy and of charge, in the photon transformation into a matter-antimatter pair, generally of an electron and a positron (anti-electron).

Note that all our considerations, here and after, about a photon model and about photon properties are done, in this first exposition, considering a photon propagation in empty space, and describing and observing it in an inertial reference frame.

# A Possible Microstructure For The Photon

## “Caroppo’s Photon Model”

### The Double-Helix In The Fine Photon Structure

*“La via corretta è spesso la più semplice!”*

(Oreste Caroppo)

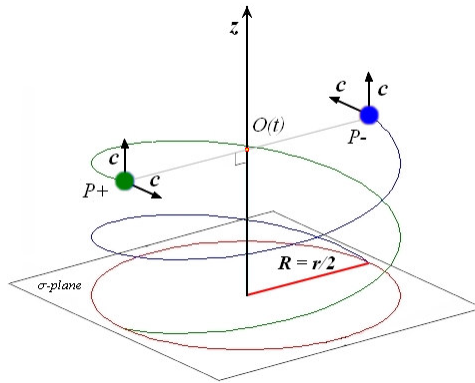


Figure 1: a schematic representation of a photon in our model.

Let us take a generic photon with a total energy  $E_{Tot\_ph}$ .

We know that a photon in particular condition can transform itself in a couple of particles of matter and antimatter with opposite elementary charges, according to the principle of conservation of charge, being photon a neutral particle, or system.

In addition, we know photon is the carrying particle of the electromagnetic field, then it is logical thinking that the fluctuations of the electric and magnetic fields of an electromagnetic wave (e.m.w.), and the same electric field (e.f.) and magnetic field (m.f.) of the wave, are generated by the same photon and by its motion, and they are connected to an its more fine microstructure, mysterious and never explored or even supposed, until now!

These and other photon characteristics, furthermore, ask a model for the photon which explains them organically.

On the base of this observation, in our photonic model, we image, the photon, classically a “particle”, not like a single elementary indivisible particle, but like a particular system dynamically stable of two constituents, two more fine particles, two sub-particles, that we call “semi-photon particles”. We indicate them,  $P+$  and  $P-$ , or respectively,  $ph+$  and  $ph-$ , too.



In this first and simple dichotomous photon model, we consider  $P+$  and  $P-$ , as punctiform particles, two perfect material points, with their mass and charge confined in each time into a null volume in their respective Euclidian space-time position point.

We think  $P+$  and  $P-$  separated in space by a finite not null distance; we indicate it with  $r$ ,

$$r = \overline{P_+ P_-}$$

We image each semi-photon particle has an elementary charge, (the charge of the electron),  $e$  in absolute value, but of opposite sign.

Conventionally, we call  $P+$  the photon sub-particle with charge  $+e$ , and we call  $P-$  the photon sub-particle with charge  $-e$ ; respectively

$$\begin{aligned} Q_{P_+} &= +e \\ Q_{P_-} &= -e \end{aligned}$$

Hence, we think the charges only revealed and not generated during the production of matter-antimatter pairs, (particle-antiparticle pairs), by and from a photon, though theoretically it is a possible process to generate opposite charges from vacuum, since this respects the conservation principle of the total charge of the Universe.

We remember here, that charge is relativistically invariant; its magnitude is constant for every velocity of the particle which carries it!

In this way the total electric charge of the photon, the photon system in this model, is zero,

$$Q_{ph} = \sum_{i=P_+, P_-} Q_i = Q_{P_+} + Q_{P_-} = (+e) + (-e) = 0$$

in perfect coherence with empirical observations, in which photon appears electrically neutral; really according to our point of view, photon is totally neutral but with a microscopic discrete charge distribution of null sum. This distribution is necessary to generate a mobile electric dipole system which explains us the electric and magnetic fluctuated fields that a photon carries in its wave impulse during its propagation.

Instead, in the general modern physics thought, usually photon is considered as a particle null in charge, since in it, there is no charge.

Not only, the null magnitude in photon of its magnetic momentum of spin, takes us in error; in addition, it makes us thinking photon without a charge distribution of null charge sum; instead, we will show our model is compatible also with a discrete charge distribution of zero charge sum and with a null magnetic momentum of spin!

We are considering a photon of a generic total energy  $E_{Tot\_ph}$ .

The relativistic mass of a body, or of a system, is the total quantity of energy in it (divided by the constant quantity  $c^2$ ), therefore except for the physical unit, relativistic mass is a synonym of total energy.

For the photon relativistic mass, we have:  $m_{ph} = \frac{E_{ph}}{c^2}$

The total energy of a composite system can be determined by adding together the values of the energy of its components.

Hence, in our photon system total energy is equal to the sum of the total energy of  $P+$  and  $P-$ .

$$E_{Tot\_ph} = E_{Tot\_P+} + E_{Tot\_P-}$$

Obviously, it needs total energy of our photonic system,  $E_{Tot\_ph}$ , is equal to the total energy of the real photon,  $E_{ph} = m_{ph}c^2$ , that we want to describe through our model:

$$E_{Tot\_ph} = E_{ph} = m_{ph}c^2$$

In our photon model, we think that, for symmetric reason, each semi-photon particle has a same total energy equal, being  $E_{Tot\_ph} = E_{Tot\_P+} + E_{Tot\_P-}$ , to the semi-total energy of the photon,

$$E_{Tot\_P+} = E_{Tot\_P-} = \frac{E_{ph}}{2}$$

Hence, the relativistic masses,  $m_{P+}$  and  $m_{P-}$ , of the photon sub-particles, are equal to half of the relativistic mass of photon,  $m_{ph}$ ,

$$E_{Tot\_P+} = m_{P+}c^2 \quad E_{Tot\_P-} = m_{P-}c^2$$

$$m_{P+} = m_{P-} = \frac{m_{ph}}{2}$$

Therefore, the relativistic mass of our photon system, which is obviously, being  $E_{Tot\_ph} = E_{ph}$ , the relativistic mass of the real photon here described in a theoretical model, is equal to the sum of the masses of its components:

$$m_{ph} = \sum_{i=P+,P-} m_i = m_{P+} + m_{P-}$$

The relativistic mass, is linearly proportional to energy, so conservation of energy means relativistic mass is conserved.

We show that in the ideal conditions a photon is an isolated system that does not exchange energy with the environment, conserving therefore, its energy and its relativistic mass, as normally it happens during the propagation of a photon in vacuum without any external perturbations!

Now, we observe that in diffraction and in other phenomenons, an electromagnetic wave, like a single photon, shows us an interaction with objects, which depends of a sort of a spatial transversal dimension not null; photon appears like a sphere whose diameter is linearly proportional to the wavelength associated to it, and of the same order of magnitude, apart the intuitively think of any microscopical particle as a sphere, really in phenomenons, a photon shows us it occupies in space a surface orthogonal to its velocity direction, whose dimension, diameter, is linearly proportional to the wavelength, and of the same order of magnitude; nonetheless, in the general modern physics thought photon is considered often, as a punctiform particle, that is with a null intrinsic volume!

Not only, we observe that :

- when the maximum length,  $D$ , of an object orthogonally to the photon (or e.m.wave) velocity direction, is :  $D \ll \lambda$ , no significant influence is made on the photon (or e.m.w.);
- when the maximum length,  $D$ , of an object orthogonally to the photon (or e.m.wave) velocity direction, is :  $D \approx \lambda$ , the interaction with photon (or e.m.w.) becomes evident.

This sort of photonic disk structure, orthogonal to photon velocity direction, appears therefore, practically total empty, like the positions of photon matter constituents, were distributed only on the borderline circumference of this disk, whose diameter is linearly proportional to  $\lambda$  and of the same order of magnitude.

It is a possible qualitatively model to explain this photon interaction properties.

These aspects oriented me toward my mathematical quantitative photonic model.

My basic question was “how it is possible, that in a photon its interactions with objects, are connected with a sort of its transversal property linearly connected with e.m. wavelength, which is classically only a longitudinal property of photon and e.m. wave?”. Longitudinal and transversal according to photon velocity direction, which is the direction of propagation of the associated e.m. wave.

In addition, the existence of a photon spin not null, suggests us the idea of a three-dimensional, not punctiform, structure for the photon; not only, the spin vector has a direction parallel xor antiparallel with the direction of photon propagation; these aspects give more strength to the reality of a distribution of parties of the mass of the photon in the space in a surface, a sort of disk, orthogonal to its translation direction.

We image a structure for the photon which can resume all its exposed properties.

Called  $z$ -axis the classical translation straight line of the real photon, here in analysis, with its positive direction coincident with the direction of the photon movement, we image that the two semi-photon particles  $P+$  and  $P-$ , constituting it in our model, move themselves around this axis, describing in time two coaxial helicoidal trajectories with the same step and screwing direction, and opposite, that is between them out of phase of  $\pi$ .

They are cylindrical helices with the same helix radius,  $R = r/2$ , kinematically described by the two material points,  $P+$  and  $P-$ , with the same velocities of translation along  $z$ ,  $\vec{V}_{tr}$ , and with the same in magnitude but opposite in direction velocities of rotation around it,  $V_{tg}$ . Kinematic aspects we will expound accurately.

The cylindrical helix can be kinematically described as the path of a material point which rotates describing a circumference in a  $\sigma$ -plane with an uniform circular movement, in our case of radius  $R = r/2$ , and whose plane moves itself translating with an uniform straight line movement along an axis,  $z$  in our case, orthogonal to it. Then the same material-point, of this kinematic description sums in it two movements, a rotation movement and a translation movement with the same constant translation velocity of the  $\sigma$ -plane. In this case, the material point goes along helix with a total velocity constant in magnitude.

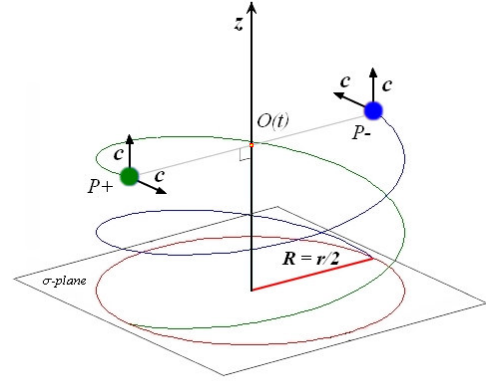


Figure 2: a schematic representation of a photon in our model.

Generally, a point, which goes along a helix, not necessarily, must be a total velocity constant in magnitude; its movement is ever a roto-translation motion, that is a composition of a translation motion and a rotation motion.

Therefore, the velocity of a point which describes in space a cylindrical helix, as in our model, can be decomposed in two components,

- one along  $z$ -axis, it is the translational velocity component; we indicate its magnitude with  $V_{tr}$ ;
- the other in the  $\sigma$ -plane, it is the rotation velocity component, which is tangent to the helix circumference in  $\sigma$ -plane; we indicate its magnitude with  $V_{tg}$ .

If  $\vec{V}_{tr}$  is constant, for the kinematic properties of the helix,  $V_{tg}$  must be constant in size and in its direction of rotation.

Our  $P+$  and  $P-$  are exactly considered in our ideal model, as material points.

For the symmetric movement supposed for  $P+$  and  $P-$ , we have

$$\vec{V}_{tr} = \vec{V}_{P+_tr} = \vec{V}_{P-_tr} \quad \text{and for their magnitudes} \quad V_{tr} = V_{P+_tr} = V_{P-_tr}$$

$$\vec{V}_{P+_tg} = -\vec{V}_{P-_tg} \quad \text{and for their magnitudes} \quad V_{tg} = V_{P+_tg} = V_{P-_tg}$$

In geometry, a cylindrical helix (from Greek  $\acute{\epsilon}\lambda\iota\xi$ , *spire*) is a curve in a three-dimensional space, giving by a line wrapped with a constant angle around a cylinder. This constant cylindrical helix screwing angle, the “helix angle” called,  $\theta$ , is given by this equation, based on geometrical considerations,

$$\theta = \arctan \frac{HelixStep}{2\pi R}$$

Kinematically, the helix angle is also the angle of the vector of the total velocity,  $\vec{V}_{Tot} = \vec{V}_{tr} + \vec{V}_{tg}$ , with  $\sigma$ -plane; therefore  $\theta$  is given also by this other equation, based on kinematic considerations,

$$\theta = \arccos \frac{\vec{V}_{Tot} \bullet \vec{V}_{tg}}{\|\vec{V}_{Tot}\| * \|\vec{V}_{tg}\|}$$

Our photon structure is a rigid structure since the distance between  $P+$  and  $P-$ ,  $r$ , is constant in time during the photon propagation in empty space without any external perturbation.

In this way, it is guaranteed the existence of a sort of transversal photonic disk totally empty, except for the dynamic localization of photon material components, on its borderline circumference. This disk diameter appears to remain constant during the normal propagation of a photon in an empty space without any external perturbation; all this corresponds to a photon dynamic double helicoidal structure which remains without any alteration in time, and we see that proper in empty space without any external perturbation, it happens.

We know in photon there is a relation between  $\lambda$ , which is a longitudinal property of the e.m. wave (and of the photon) respecting its translation direction, and its transversal dimensions, perpendicular to its axis  $z$ .

$\lambda$  is connected with longitudinal periodically fluctuation of electric and magnetic field in the e.m. wave.

In our model we explain all this, imaging the existence in the photon of two particles,  $P+$  and  $P-$ , of opposite charge with a fixed finite and not null distance,  $r$ , between them, an electric dipole in other words, rotating and translating, which generates an electric and magnetic field which fluctuate giving oscillations that can explain e.m. wave and e.m. field.

Then, it is necessary, as later we will show analysing electric and magnetic wave in our photon model, that  $P+$  and  $P-$  stay in every time on a plane orthogonal to the  $z$  axis, in particular on an axis perpendicular to  $z$ , and that intersected  $z$ , the axis of the helices, in a point that we call  $O(t)$ , a function of time,  $t$ , obviously being  $P+$  and  $P-$  position time functions,  $P_+(t)$  and  $P_-(t)$ .

In each time,  $t$ , in our kinematic model,  $P_+(t)$  and  $P_-(t)$  have an equal and constant distance from  $O(t)$ ; we call it  $R=r/2$ , being  $r$  the constant distance between  $P+$  and  $P-$ ,

$$\overline{P_+(t)O(t)} = \overline{O(t)P_-(t)} = R = \frac{\overline{P_+(t)P_-(t)}}{2} = \frac{r}{2}$$

$O(t)$  is the position of the *center of mass* of the photon system, as evident by symmetric aspects or by simple calculations.

Its relativistic mass, the mass of the center of mass is equal to the relativistic mass of the system, and then, of our real photon in analysis.

This point moves itself only translating along  $z$  axis, the axis of propagation of our photon.

Its total velocity must be the translation velocity of the photon,  $c$ , in vacuum, the constant light velocity:  $\overrightarrow{V_{O(t)}} = c \hat{z}$

Now, by the kinematic conditions of our model, we have that  $P+$  and  $P-$  semi-photon particles translation velocity components along  $z$  axis,  $\overrightarrow{V_{P+_{tr}}}$  and  $\overrightarrow{V_{P-_{tr}}}$ , are equal to the velocity of  $O(t)$  point,  $\overrightarrow{V_{O(t)}}$ , then

$$\overrightarrow{V_{O(t)}} = \overrightarrow{V_{P+_{tr}}} = \overrightarrow{V_{P-_{tr}}} = \overrightarrow{V_{tr}} = c \hat{z}$$

and considering only their magnitudes

$$V_{O(t)} = V_{P+_{tr}} = V_{P-_{tr}} = V_{tr} = c$$

For the generality of our argumentation, this result about  $V_{tr}$  magnitude is valid for every photon in empty space, that is  $V_{tr}$  is independent of photon energy, frequency and wavelength.

Consequently, remembering what we exposed about helix properties,

$$\text{if } \overrightarrow{V_{tr}} \text{ is constant, then } V_{tg} \text{ is constant.}$$

We have, therefore, in our kinematic fine structure of the photon,

$$V_{tg} = \left\| \overrightarrow{V_{tg}} \right\| = \left\| \overrightarrow{V_{P+_{tg}}} \right\| = \left\| \overrightarrow{V_{P-_{tg}}} \right\| = Const$$

This constancy in time and space, is valid for every photon during its existence and propagation, but nothing tells us until now, if this rotation velocity magnitude changes from a photon to another; later we will demonstrate  $V_{tg} = Const$  must be the same for every photon in empty space.

Now, the electric field of the e.m. wave changes periodically in time and in space; in a translation of the photon, of length  $\lambda$ , its intrinsic electric field makes a complete fluctuation. Having connected this fluctuation with the variation of the position in space of our photon electric dipole  $\overrightarrow{P_- P_+}$ , it needs that in the time of a complete rotation of  $P+$  and  $P-$ , the system advances in  $z$  positive direction of a length of  $\lambda$ , that is our helixes must have a step of  $\lambda$  length. In order that all this happens, it needs in the period  $T_\sigma$  of the uniform circular movement in  $\sigma$ -plane, which is the time necessary to the photon dipole, and then to  $P+$  and  $P-$ , to assume again the same positions in  $\sigma$ -plane, our system moves itself in translation along  $z$ -axis, of a step equal to  $\lambda$ .

Called  $\omega$  the angular speed of  $P+$ , or of  $P-$ , (they are the same by our architecture of the photon structure), the period,  $T_\sigma$ , of a complete rotation in  $\sigma$ -plane, is

$$T_{\sigma} = \frac{2\pi}{\omega}$$

This period must be equal to the period of the oscillation of the e.m. wave connected to the real photon here theoretically described,

$$T_{e.m.w.} = \frac{\lambda}{c}$$

Hence

$$T_{\sigma} = T_{e.m.w.} = T$$

Frequency  $\nu$  and period  $T$ , are for their definition, one the reciprocal, the inverse, of the other

$$T = \frac{1}{\nu}$$

Then, in our system the e.m.w. frequency, a translation property of the e.m. wave connected to the photon, (a photon longitudinal property), must be the frequency of rotation of the photon subparticles in the space around its axis of translation, the axis-direction of the wave propagation, (a photon transversal property),

$$\nu_{\sigma} = \nu_{e.m.w.} = \nu$$

Now we remember that, physically

$$\omega = 2\pi\nu$$

then

$$V_{tg} = \omega R = \omega \left( \frac{r}{2} \right) = 2\pi\nu \left( \frac{r}{2} \right) = \pi\nu r$$

from which:

$$r = \frac{V_{tg}}{\pi\nu} \quad (7)$$

Now,  $r$  is the diameter,  $d$ , of the photonic transversal disk in  $\sigma$ -plane we have discussed before.

$$d = 2R = r = \frac{V_{tg}}{\pi\nu}$$

Remembering that in the e.m.w.

$$\lambda\nu = c$$

we have

$$d = r = \left( \frac{V_{ig}}{\pi c} \right) \lambda$$

Experimentally, we have evidence, as we have seen, for a linear relationship between photon transversal diameter,  $d$ , and its wavelength,  $\lambda$ ,

$$d \propto \lambda$$

Then, all this imply that  $\left( \frac{V_{ig}}{\pi c} \right)$ , the proportional constant between  $d$  and  $\lambda$ , is constant and independent of  $\lambda$ , and then from photon energy and frequency.

Observe  $\pi$ , pigreek, is an adimensional constant and  $c$ , a physics constant of nature.

Consequently,  $V_{ig} = Const$  and it is independent of photon energy, frequency and wavelength, that is  $V_{ig}$  has a constant value valid for every photon in empty space!

The existence of a *Spin*,  $S$ , an intrinsic angular momentum of the photon not null, with its direction parallel xor antiparallel to the positive direction of  $z$ -axis, tells us intuitively, that there is in the photon a distribution of masses that go around  $z$ -axis, while they translate with the velocity of their center of mass,  $c$ , in  $z$  direction (that is the positive direction of  $z$ -axis),  $\hat{c} \hat{z}$ .

Now, in our model we can understand better this intrinsic mass distribution, and by it, we will obtain, utilising the experimental magnitude of photon Spin, the magnitude for our incognita,  $V_{ig} = Const$ .

A photon can have

*spin quantum number*,  $+1$  xor  $-1$ ;

these correspond respectively to an intrinsic angular momentum,

$$\vec{S}_{ph} = +\hbar \hat{z} \quad \text{xor} \quad \vec{S}_{ph} = -\hbar \hat{z}$$

Where  $\hbar$ , (pronounced "h-bar"), is the "*reduced Planck constant*", also called "*Dirac constant*" too, whose magnitude is connected to *Planck constant*,  $h$ ,

$$\hbar = \frac{h}{2\pi}$$

$\hbar$  is also called the "quantum of angular momentum" or the "quantum of action".



Let us determine the Spin of our photonic system,  $\overrightarrow{S}_{Tot\_ph}$ .

The Spin (angular momentum of spin) of a body or discrete system, is its total angular momentum associated with the rotation of its parts around its center of mass.

Analysing the way in which we have defined the structure of the photon, we see that its component parts,  $P+$  and  $P-$ , translate with the center of mass  $O(t)$ , with the same velocity  $c\hat{z}$ , and on the  $\sigma$ -plane, orthogonal to  $z$ -axis, they go around  $O(t)$ , (which is fixed in the  $\sigma$ -plane), in a circular movement with constant distance  $r/2$  from  $O(t)$ , and with a tangential velocity of idem direction of rotation and magnitude,  $V_{tg}$ ,

$$\overrightarrow{V}_{P+_tg} = -\overrightarrow{V}_{P-_tg} \quad \text{and for their magnitude} \quad V_{tg} = V_{P+_tg} = V_{P-_tg}$$

This rotation is what interests us to calculate our photon model spin.

Indicating with  $vers(\overrightarrow{Vector}) = \left\{ \frac{\overrightarrow{Vector}}{\|\overrightarrow{Vector}\|} \right\}$ , the versor of a vector,  $\overrightarrow{Vector}$ , that is its unitary vector,

we define

$$vers(\vec{r}) = vers(\overrightarrow{P}P_+) = vers(\overrightarrow{O}_{(t)}P_+) = -vers(\overrightarrow{O}_{(t)}P_-)$$

We have

$$\begin{aligned} \overrightarrow{S}_{Tot\_ph} &= \overrightarrow{O}_{(t)}P_+ \times (m_{P+} \overrightarrow{V}_{P+_tg}) + \overrightarrow{O}_{(t)}P_- \times (m_{P-} \overrightarrow{V}_{P-_tg}) = m_{P+} [\overrightarrow{O}_{(t)}P_+ \times (\overrightarrow{V}_{P+_tg}) - \overrightarrow{O}_{(t)}P_+ \times (\overrightarrow{V}_{P-_tg})] = \\ &= m_{P+} \left[ \left( \frac{r}{2} vers(\vec{r}) \right) \times (\overrightarrow{V}_{P+_tg}) - \left( \frac{r}{2} vers(\vec{r}) \right) \times (\overrightarrow{V}_{P-_tg}) \right] = \frac{m_{ph}}{2} \frac{r}{2} vers(\vec{r}) \times (\overrightarrow{V}_{P+_tg} - \overrightarrow{V}_{P-_tg}) \end{aligned}$$

$$\overrightarrow{S}_{Tot\_ph} = \frac{m_{ph}}{2} \frac{r}{2} vers(\vec{r}) \times (2\overrightarrow{V}_{P+_tg}) = \frac{m_{ph}}{2} \frac{r}{2} vers(\vec{r}) \times (2\overrightarrow{V}_{P+_tg}) = \frac{m_{ph}}{2} V_{P+_tg} vers(\vec{r}) \times vers(\overrightarrow{V}_{P+_tg})$$

According to the direction of rotation, anticlockwise xor clockwise, we have, respectively, two possibilities for Spin direction,

- if the helicoidal screwing direction is right-handed :

$$vers(\vec{r}) \times vers(\overrightarrow{V}_{P+_tg}) = \hat{z}$$

- if the helicoidal screwing direction is left-handed :

$$vers(\vec{r}) \times vers(\overrightarrow{V}_{P+_tg}) = -\hat{z}$$

Theoretically, there is not any preference for one xor other spin direction, as observed, generally, in nature for the photons.

Then, the Spin magnitude is

$$\left\| \overrightarrow{S_{Tot\_ph}} \right\| = \frac{m_{ph} r}{2} V_{P+tg} \left\| \hat{z} \right\| = \frac{h\nu}{2c^2} \frac{V_{P+tg}}{\pi\nu} V_{P+tg} = \frac{h}{2\pi} \left( \frac{V_{P+tg}}{c} \right)^2 = \hbar \left( \frac{V_{P+tg}}{c} \right)^2 = \hbar \left( \frac{V_{tg}}{c} \right)^2$$

Hence, the two possible spins of our photonic system are:

$$\overrightarrow{S_{Tot\_ph}} = \pm \hbar \left( \frac{V_{tg}}{c} \right)^2 \hat{z}$$

Our photonic model gives reason of the two possible spin directions of a real photon, parallel xor antiparallel to  $z$  direction.

Not only, on the base of the precedent result, that told us  $V_{tg} = Const$  for every photon in the empty space, with the same value independently of its energy, frequency and wavelength, we obtain here the constancy of spin magnitude, and its independence respecting photon frequency,  $\nu$ , energy,  $E_{ph}$ , and wavelength,  $\lambda$ , all this in perfect accord with what experimentally observed.

Now, equalling the obtained expression of the spin,  $\overrightarrow{S_{Tot\_ph}}$ , to the experimental photon spin,

$$\overrightarrow{S_{ph}} = \pm \hbar \hat{z},$$

$$\overrightarrow{S_{Tot\_ph}} = \pm \hbar \left( \frac{V_{tg}}{c} \right)^2 \hat{z} = \pm \hbar \hat{z} = \overrightarrow{S_{ph}}$$

we have for our kinematic structure of the photon:

$$V_{tg} = \pm c$$

Mathematically, the double sign,  $\pm$ , indicates the two possibilities about the rotational direction. Indicating only the magnitude value, with  $V_{tg}$ , we have

$$V_{tg} = c$$

This result confirm the necessity in our theoretic model of the structure of a real photon, of the constancy of  $V_{tg} = Const$ , with the same identical value for every photon, and more it gives us its precise constant magnitude  $V_{tg} = c$ , with what, perfectly, our model gives reason of the real experimental photon spin!

Hence, photon spin is connected with a sort of intrinsic circular polarization of the elementary electromagnetic wave associated to the photon. In this little-wave, a sort of single wave impulse, the

vector of the intrinsic electric field of the photon in  $O(t)$ , (orthogonal to the vector of the intrinsic magnetic field in  $O(t)$ , and to the velocity of translation like in a classic Maxwell's electromagnetic wave, as we will show later), rotates only with an angular speed  $\omega = 2\pi\nu$ , proportional to photon frequency, and with one of the two possible rotational directions, connected with a *Spin +1*, xor with a *Spin -1*.

Now, we can calculate the total velocity magnitudes of  $P+$  and  $P-$ . They have different total velocity directions, but identical total velocity magnitudes, since they have identical magnitudes of their velocity components.

In general, for  $P+$  and  $P-$ ,  $\overrightarrow{V_{P\_Tot}} = \overrightarrow{V_{P\_tr}} + \overrightarrow{V_{P\_tg}}$ , and  $\overrightarrow{V_{P\_tr}}$  and  $\overrightarrow{V_{P\_tg}}$  are perpendicular between them; therefore

$$\|\overrightarrow{V_{P\_Tot}}\| = \sqrt{\|\overrightarrow{V_{P\_tr}}\|^2 + \|\overrightarrow{V_{P\_tg}}\|^2} = \sqrt{c^2 + c^2} = \sqrt{2}c$$

Thus, the identical magnitude of the total velocities of  $P+$  and  $P-$ , is

$$\|\overrightarrow{V_{P\_Tot}}\| = \sqrt{2}c$$

We can calculate  $\theta$ , the constant cylindrical helix screwing angle,

$$\theta = \arccos \frac{\overrightarrow{V_{Tot}} \cdot \overrightarrow{V_{tg}}}{\|\overrightarrow{V_{Tot}}\| * \|\overrightarrow{V_{tg}}\|} = \arccos \frac{(\overrightarrow{V_{tr}} + \overrightarrow{V_{tg}}) \cdot \overrightarrow{V_{tg}}}{\|\overrightarrow{V_{Tot}}\| * \|\overrightarrow{V_{tg}}\|} = \arccos \frac{0 + c * c * \cos(0)}{\sqrt{2}c * c} =$$

$$\theta = \arccos \left( \frac{1}{\sqrt{2}} \right) = \arccos \frac{\sqrt{2}}{2} = \frac{\pi}{4} \text{ rad} = 45^\circ$$

A great geometric perfection appears in this heuristic photon structure!

Now, we will verify, as in our model, the *magnetic momentum of spin*,  $\overrightarrow{\mu_{Tot\_ph}}$ , is null, according to what we observe in nature in the photons,  $\overrightarrow{\mu_{ph}} = 0$ .

$$\begin{aligned} \overrightarrow{\mu}_{Tot\_ph} &= \frac{Q_{P+}}{2m_{P+}} \overrightarrow{O}_{(t)} P_+ \times (m_{P+} \overrightarrow{V}_{P+_tg}) + \frac{Q_{P-}}{2m_{P-}} \overrightarrow{O}_{(t)} P_- \times (m_{P-} \overrightarrow{V}_{P-_tg}) = \\ &= \frac{(+e)}{2} \overrightarrow{O}_{(t)} P_+ \times (\overrightarrow{V}_{tg\_P+}) + \frac{(-e)}{2} \overrightarrow{O}_{(t)} P_+ \times (\overrightarrow{V}_{tg\_P-}) = \left(\frac{e}{2}\right) \overrightarrow{O}_{(t)} P_+ \times (\overrightarrow{V}_{P+_tg} + \overrightarrow{V}_{P-_tg}) = \\ &= \overrightarrow{\mu}_{Tot\_ph} = \left(\frac{e}{2}\right) \overrightarrow{O}_{(t)} P_+ \times (\overrightarrow{V}_{P+_tg} - \overrightarrow{V}_{P+_tg}) = 0 = \overrightarrow{\mu}_{ph} \end{aligned}$$

Another important result which spurs us to continue on this cogitative road !

## About the Momentum of the Photon in our Model

We know that a photon has a momentum,  $\overrightarrow{P}_{ph}$ , that we can write vectorially, in our inertial reference frame, and concerning the real photon we are describing theoretically:

$$\overrightarrow{P}_{ph} = m_{ph} c \hat{z} = \frac{E_{ph}}{c} \hat{z} = \frac{h\nu}{c} \hat{z}$$

Note that in the equation for momentum

$$\overrightarrow{P} = M\overrightarrow{V}$$

the mass, that it needs, is the relativistic mass; in other words, the relativistic mass is the proportionality constant between the velocity and the momentum. For this reason in the calculations about spin we have employed the relativistic masses.

In our model, photon system momentum,  $\overrightarrow{P}_{Tot\_ph}$ , must be equal to  $\overrightarrow{P}_{ph}$ .

The total momentum of a system,  $\overrightarrow{P}_{Tot\_ph}$  in this case, is a vector quantity, and it can be computed by adding together vectorially the momenta of every component of the system.

$$\overrightarrow{P}_{Tot\_ph} = \overrightarrow{P}_{P+} + \overrightarrow{P}_{P-} = m_{P+} (\overrightarrow{V}_{P+_tr} + \overrightarrow{V}_{P+_tg}) + m_{P-} (\overrightarrow{V}_{P-_tr} + \overrightarrow{V}_{P-_tg})$$

Now, let us observe that

$$m_{P+} = m_{P-} = \frac{m_{ph}}{2}$$

$$\overrightarrow{V_{P_+tr}} = \overrightarrow{V_{P_-tr}} = c \hat{z}$$

$$\overrightarrow{V_{P_+tg}} = -\overrightarrow{V_{P_-tg}}$$

Substituting

$$\overrightarrow{P_{Tot\_ph}} = \overrightarrow{P_{P_+}} + \overrightarrow{P_{P_-}} = \frac{m_{ph}}{2} \left( \overrightarrow{V_{P_+tr}} + \overrightarrow{V_{P_+tg}} + \overrightarrow{V_{P_-tr}} + \overrightarrow{V_{P_-tg}} \right) = \frac{m_{ph}}{2} 2c \hat{z} = m_{ph} c \hat{z} = \frac{E_{ph}}{c} \hat{z} = \overrightarrow{P_{ph}}$$

which is the same  $\overrightarrow{P_{ph}}$  associated to the real photon of the same energy, here in analysis!

$\overrightarrow{P_{Tot\_ph}}$  is a resulting vector whose action line, according to composition rules of applied vectors, and according to the symmetry of our system, is the  $z$ -axis line, which includes in it the  $O(t)$  point, the center of mass of our photonic model, where the  $\overrightarrow{P_{ph}}$  can be considered applied! The momentum direction of our photon system is that of the positive direction of  $z$ , that is the direction of the global system translation, coinciding with the direction movement of the real photon, here in analysis.

The particular geometry of our dynamic model, though in a relativistic condition, defines and gives a physical importance to the center of mass which, resuming in it some same aspects of the real photon, appears like that photon in those reductive punctiform conceptions about it; a punctiform conception practically, valid in some theoretical interpretation of some physics phenomenon!

$O(t)$ , middle point of  $\overline{P_+P_-}$  segment in every time, can be considered a virtual theoretical particle, which corresponds to what it is classically, reductively, sometimes thought as the photon. We will see some its aspects, in which we will recognize the classical photon:

- the motion of  $O(t)$  consists in a pure translation with an uniform rectilinear movement along  $z$ -axis, with  $c$  speed in vacuum, as for the classical photon of which we are studying a possible fine structure;
- in  $O(t)$  it is applied  $\overrightarrow{P_{ph}}$ , which is directed along  $z$ -axis, with the same magnitude and direction of the classic real photon, here in analysis;
- geometrically,  $O(t)$  is the center of mass of our system; to the center of mass of a system, like what constitutes our photon, we must attribute a relativistic mass equal to the total relativistic mass of the system. The total relativistic mass is the sum of the relativistic masses of the system components, since the relativistic mass is synonymous with the total energy, and energy is an additive quantity; hence, in our case

$$m_{ph} = \sum_{i=P_+,P_-} m_i = m_{P_+} + m_{P_-} = M_{CM}$$

Hence, we can attribute theoretically to the mass center the total energy of the system too.

Its mass, as mass of the center of mass of our system, is the relativistic mass of the total system, which is obviously for our theoretical architecture, the relativistic mass of the classical real photon here in analysis; idem for its total energy which is linearly proportional to the total relativistic mass;

- as the real photon carries a finite momentum and a quantum of energy, so our system associated to it, and in theory its  $O$  point, carries the same momentum in all its vectorial properties, and the same quantum of energy;
- to the center of mass of a system, like what constitutes our photon in our theory, we must attribute a rest mass equal to the total rest mass of our system. But, in difference respecting the relativistic mass, the rest mass of a composite system is not equal to the sum of the rest masses of the parts, unless all the parts are at rest. The *invariant mass* is another name for the *rest mass*, usually reserved for systems which consist of separated particles. The rest mass of an object or a discrete system, is the Newtonian mass as measured by an observer moving along with the object; unlike the relativistic mass, the rest mass does not depend on observer's frame of reference. The invariant mass of a closed system is also independent of observer or inertial frame, and it is a constant, a conservative quantity for closed systems and single observers, even during chemical and nuclear reactions.

We know that the invariant mass of a single body, like a particle, or of a system, is given, considering its total energy and the magnitude of its total momentum vector, by:

$$m_o = \frac{\sqrt{(E_{Tot})^2 - \|\vec{P}_{Tot}\|^2} c^2}{c^2}$$

And in the case of our photon model, substituting the previously found quantities, we have:

$$m_{o\_Tot\_ph} = \frac{\sqrt{(E_{Tot\_ph})^2 - \|\vec{P}_{Tot\_ph}\|^2} c^2}{c^2} = \frac{\sqrt{(m_{ph}c^2)^2 - (m_{ph}c)^2 c^2}}{c^2} = 0$$

Then the invariant mass of our photonic system and that of its center of mass, is null:

$$m_{o\_Tot\_ph} = m_{o\_CM} = 0 = m_{o\_ph}$$

exactly as relativistically predicted for a photon,  $m_{o\_ph} = 0$ , which is a particle of finite energy, moving with  $c$  speed, and for this reason with a real and null rest mass.

Historically, in this my physics and mathematical study about photon, it was when I verified, at the end, the property of a null rest mass for my photon model, null like for the real photon, that I exclaimed “*èureka!*” (*ἠὺρηκα*), or better “*ìvvrìka!*” in the local Greek-Latin ancient Mediterranean language of my Italian region, Salento in Puglia, in the South-East of Italy! “*èureka*”, which means in Greek “I found”, is the famous exclamation of Archimedes, (the great Greek scientist lived in Sicilia, isle of the South-Italy, in the third century B.C.), after an his scientific discover.

Hence, a photon is a *luxon*, and in our model it conserves this property, but moreover appearing as a composite system of two opposite *tachyons*, that give reason of the other important experimental properties of the photon! Photon can be imagined again like a particle, a perfect *luxon* particle, but composed of two subparticles, *tachyon* particles! More details later.

Note. It is important to remark, that  $O$  is a pure Euclidian point, a virtual theoretical particle, a geometrical punctiform particle, which reassumes in it important properties of the whole system.

## Some considerations about energy and momentum conservation

In an entire closed isolated system:

- the invariant mass is independent of observer or inertial frame, and it is a constant, a conserved quantity;
- energy is a conserved quantity;
- the total momentum is also conserved, as the rest mass.

So it happens in a real photon, which moves itself in a space empty without any external fields or objects, (these are our “standard photon motion conditions”); so it must happen in our photon system in the same standard conditions of the environment during its existence and propagation!

So that it happens, it needs, as a real photon does not radiate (mass-energy) outside it, so our photonic system does not radiate other e.m.w. different from itself. Since, we will demonstrate the dynamic stability of our system in standard conditions, the important point about a possible photon self-radiation, it will be discussed later, with more details and considerations.

Note: the considerations about  $h$ , will bring us to consider the electrical friction produced by vacuum totally null, this explains perhaps, the “eternal stability” of a normal photon in vacuum, and the perfect respect of the law of inertia.

Note: existence and propagation in a photon are two faces of the same money, since photon can not exist if it does not propagate!

## About Photon Spatial Dimensions Explained in our Model

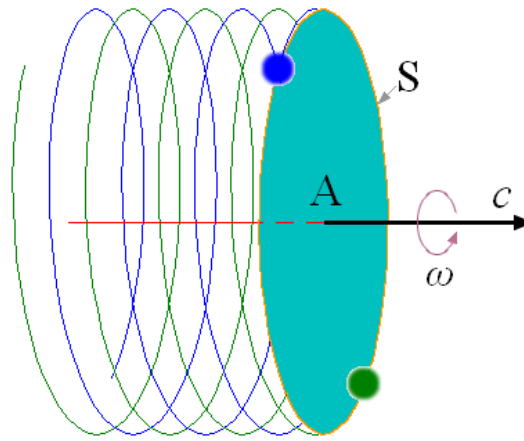


Figure 3: a schematic representation of a photon in our model, focusing on its transversal section.

Now, in our model we have for a photon a circular surface,  $A$ , a circle, described by the projection of the trajectories of its two structural particles,  $P+$  and  $P-$ , on a surface orthogonal, to the photon translation direction.

This circle, with ray,  $R=r/2$ , and area,  $A$  :

$$r = \frac{V_{tg}}{\pi\nu} = \frac{c}{\pi\nu} \quad (8)$$

$$A = \pi \left( \frac{r}{2} \right)^2 = \pi \left( \frac{c}{2\pi\nu} \right)^2 = \pi \left( \frac{\lambda\nu}{2\pi\nu} \right)^2 = \pi \left( \frac{\lambda}{2\pi} \right)^2 = \frac{1}{4\pi} \lambda^2$$

The diameter,  $d$ , is

$$d = 2R = r = \frac{c}{\pi\nu} = \frac{\lambda}{\pi} = \left( \frac{1}{\pi} \right) \lambda$$

$$d \propto \lambda$$

Diameter is linearly proportional to the wavelength, with an adimensional constant

$$\frac{1}{\pi} = \pi^{-1} \cong 0,3$$



$$d \cong 0,3\lambda$$

Then we have with our model, like empiric observations suggest us, both  $d \propto \lambda$  and  $d$  approximately of the same order of magnitude of  $\lambda$ .

Observe that the circumference  $C$ , of the circle  $A$ , is

$$C = 2\pi R = \pi d = \pi \frac{1}{\pi} \lambda = \lambda$$

$$C = \lambda$$

It is on the base of this photonic physical aspect that we can understand the interactions at the basis of diffraction and other photonic behaviours, where it appears necessary having a similar magnitude between  $\lambda$  and  $D$ , the length of an object, or bore, in orthogonal disposition respecting the e.m. wave propagation direction.

Our theoretical photonic disk is practically total empty, the position of photon matter constituents,  $P+$  and  $P-$ , involve only its borderline circumference;

- when the maximum length,  $D$ , of an object orthogonally to our photon system translation velocity direction, is :  $D \ll \lambda$ , no significant influence is made on the system;
- when the maximum length,  $D$ , of an object orthogonally to our photon system translation velocity direction, is :  $D \approx \lambda$ , the interaction with the system becomes evident.

The whole is in perfect accord with physics observations for real photons and electromagnetic waves!

The photonic penetration deep into a matter, generally, increases increasing the photon energy.

On the base of this model, we can explain this aspect also observing that more a photon is energetic, more its interaction section is little, ( $A$ , adding corrections in order to include electric interaction effects of border), more it can go into a body formed microscopically by a discrete structure of atoms, since it can better penetrate into the vacuum space in the matter, without meeting obstacles.

Now we can apply the first equation previously shown, for the helix angle, to calculate it

$$\theta = \arctan \frac{HelixStep}{2\pi R} = \arctan \frac{\lambda}{C} = \arctan \frac{\lambda}{\lambda} = \arctan(1) = 45^\circ$$

which is exactly, and obviously, the same helix angle already calculated with the second equation for  $\theta$ .

The curvilinear length of the sub-particles motions along their helix trajectories in a period, the time of an entire rotation,  $T = \frac{1}{\nu}$ , is the same, and it is

$$L = V_{Tot} T = \sqrt{2}c \frac{1}{\nu} = \sqrt{2}\lambda$$

It is equal to the hypotenuse of a right-angled triangle of which the catheti are one of length that of the circumference  $C$ , and the other of length that of the helix step,

$$L = \sqrt{C^2 + \lambda^2} = \sqrt{\lambda^2 + \lambda^2} = \sqrt{2}\lambda$$

## About the Stability of our Dynamic Photonic System

At this point an important analysis is connected with the stability of our dynamic photonic system.

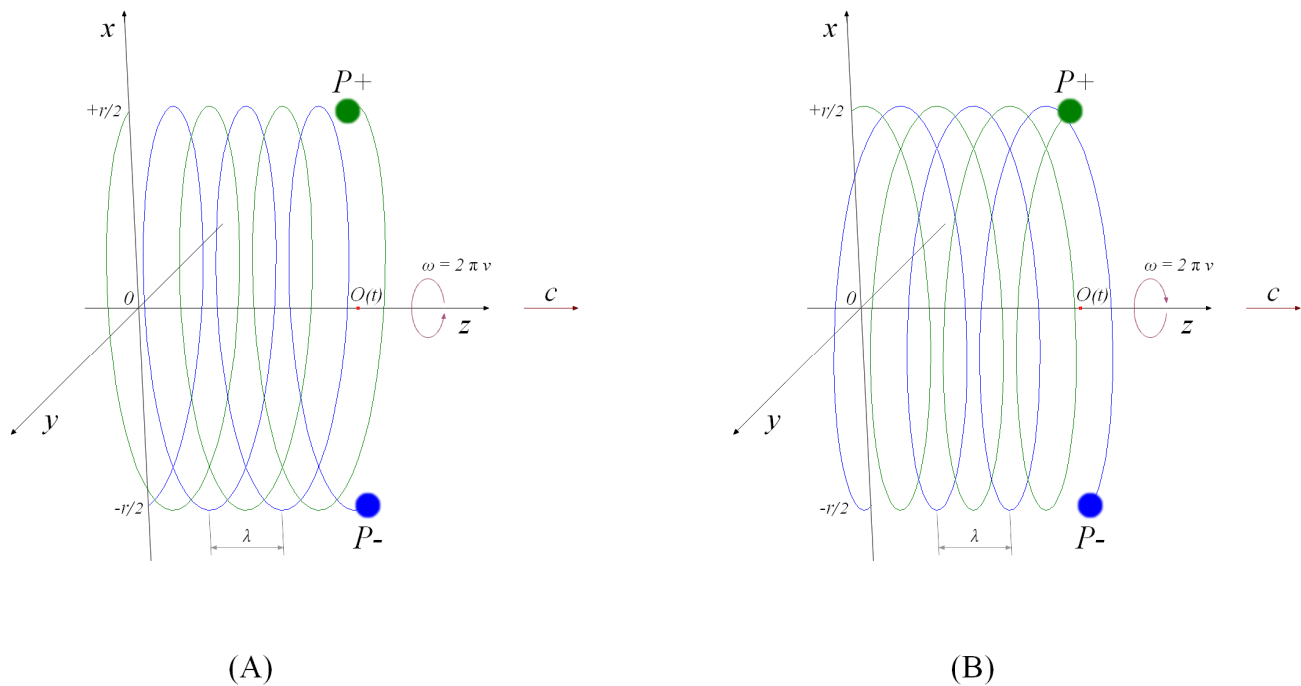


Figure 4: schematic representations of two photon with same features, but opposite spins.

In an inertial Cartesian frame of reference,  $Oxyz$ , with  $z$  axis coinciding with our previous  $z$  axis, and with initial conditions:  $P+(r/2, 0, 0)$ ,  $P-(-r/2, 0, 0)$ , the movement equations of  $P+$  and  $P-$ , can be so expressed :

- for a photonic system in which helicoidal trajectories are right-handed, (case A in the previous figure), the motion equations of the two sub-particles,  $P+$  and  $P-$ , as parametric equations, are

P+

$$\begin{cases} x = \frac{r}{2} \cos(\omega t) \\ y = \frac{r}{2} \sin(\omega t) \\ z = ct \end{cases}$$

P-

$$\begin{cases} x = \frac{r}{2} \cos(\omega t + \pi) = -\frac{r}{2} \cos(\omega t) \\ y = \frac{r}{2} \sin(\omega t + \pi) = -\frac{r}{2} \sin(\omega t) \\ z = ct \end{cases}$$

- for a photonic system in which helicoidal trajectories are left-handed, (case B in the previous figure), the motion equations of the two sub-particles,  $P+$  and  $P-$ , as parametric equations, are

P+

$$\begin{cases} x = \frac{r}{2} \cos(-\omega t) \\ y = \frac{r}{2} \sin(-\omega t) \\ z = ct \end{cases}$$

P-

$$\begin{cases} x = \frac{r}{2} \cos(-\omega t + \pi) \\ y = \frac{r}{2} \sin(-\omega t + \pi) \\ z = ct \end{cases}$$

These two cases are connected to the two possible intrinsic rotational directions for a photon, which are immediately connected to the two possible circular polarization for the elementary e.m. wave of the single photon, as we will show in detail later.

For symmetric motives and simplicity, we consider in this exposition only the right handed case, and we focalize the attention on  $P+$ .

About first derivation of its time equation, and then about the velocity of  $P+$ :

P+

$$\begin{cases} \dot{x} = -\frac{r}{2} \omega \sin(\omega t) \\ \dot{y} = \frac{r}{2} \omega \cos(\omega t) \\ \dot{z} = c \end{cases}$$

$$\begin{cases} V_{P+_{tg}}^2 = \dot{x}^2 + \dot{y}^2 = \left(\frac{r}{2} \omega\right)^2 = c \frac{\omega}{2\pi\nu} = c \\ V_{P+_{tr}} = \dot{z} = c \end{cases}$$

About second derivation of its time equation, and then about  $\vec{a}$ , the acceleration of P+:

$$\begin{cases} \ddot{x} = -\frac{r}{2} \omega^2 \cos(\omega t) \\ \ddot{y} = -\frac{r}{2} \omega^2 \sin(\omega t) \\ \ddot{z} = 0 \end{cases}$$

$$\vec{a}_{P+} = \ddot{x} \hat{x} + \ddot{y} \hat{y} + \ddot{z} \hat{z} = -\frac{r}{2} \omega^2 \left( \cos(\omega t) \hat{x} + \sin(\omega t) \hat{y} \right) = -\frac{r}{2} \omega^2 \text{vers}(\vec{r})$$

Where:

$$\text{vers}(\vec{r}) = \cos(\omega t) \hat{x} + \sin(\omega t) \hat{y}$$

is the versor of a vector incident and perpendicular to  $z$  axis, and directed from  $z$  axis to P+ position.

After kinematic observations, let us go to dynamic considerations about our system.

In our photon model, it needs having, in order to have the described movement for  $P+$ , a total force  $\overrightarrow{F_{Tot\_onP+}}$ , acting on  $P+$ , whose expression is given by the relativistic formula of Newton's second law of motion, "the law of resultant force" called too:

$$\overrightarrow{F_{Tot\_onP+}} = \frac{d}{dt}(\overrightarrow{P}_{P+}) = \frac{d}{dt}(m_{P+} \overrightarrow{V}_{P+}) = \frac{d}{dt}(m_{P+} (\overrightarrow{V}_{P+-tg} + \overrightarrow{V}_{P--tg})) = m_{P+} \frac{d}{dt}(\overrightarrow{V}_{P+}) + (\overrightarrow{V}_{P+}) \frac{d(m_{P+})}{dt} =$$

Observe that in the movement described for our photonic system, we have that in time  $\|\overrightarrow{V}_{P+}\|$  is constant, therefore

$$m_{P+} = \frac{(restMass)_{P+}}{\sqrt{1 - \frac{\|\overrightarrow{V}_{P+}\|^2}{c^2}}} = f(\|\overrightarrow{V}_{P+}\|) = g(t) = const(\forall t)$$

in consequence

$$\frac{d(m_{P+})}{dt} = 0$$

Hence, similarly to the case of the application of Newton's second law of motion in its classic formula, we have

$$\overrightarrow{F_{Tot\_onP+}} = m_{P+} \frac{d}{dt}(\overrightarrow{V}_{P+}) = m_{P+} \overrightarrow{a}_{P+} = -m_{P+} \frac{r}{2} \omega^2 \text{vers}(\vec{r}) = -\frac{m_{ph}}{2} \frac{2}{r} \left(\frac{r}{2} \omega\right)^2 \text{vers}(\vec{r}) = -m_{ph} \frac{V_{P+-tg}^2}{r} \text{vers}(\vec{r})$$

that is a centripetal force.

A relativistic equation tells us that

$$E_{ph} = m_{ph} c^2$$

and substituting in the previous equation, we obtain

$$\overrightarrow{F_{Tot\_onP+}} = -m_{ph} \frac{V_{P+-tg}^2}{r} \text{vers}(\vec{r}) = -\frac{E_{ph}}{c^2} \frac{(V_{P+-tg})^2}{r} \text{vers}(\vec{r})$$

Now, we will consider the forces applied on  $P+$ , which are only, in our idealization, internal forces to the photonic system.

There are two contributes,

1.)

one connected with Coulomb's electrostatic force of attraction applied by  $P-$  electric field on  $P+$ ,

$$\overrightarrow{F_{C\_P-onP+}} = -K_{SV} \frac{e^2}{r^2} \text{vers}(\vec{r})$$

Note we indicate here, Coulomb's constant with the symbol:  $K_{SV}$ ; later we will discuss the significance of the acronym  $SV$ .

Obviously for "Newton's third law of motion", the law of reciprocal actions, also called the "action-reaction principle":

$$\overrightarrow{F_{C\_-(P+)on(P-)}} = -\overrightarrow{F_{C\_-(P-)on(P+)}}$$

2.)

and another contribute connected with the Lorentz force applied by  $P-$  magnetic field on  $P+$ :

$$\overrightarrow{F_{L\_P-onP+}} = \frac{1}{c^2} \overrightarrow{V_{P+}} \times (\overrightarrow{V_{P-}} \times \overrightarrow{F_{C\_P-onP+}})$$

Obviously for "Newton's third law of motion":

$$\overrightarrow{F_{L\_P-onP+}} = -\overrightarrow{F_{L\_P+onP-}}$$

Let us calculate the Lorentz force

$$\overrightarrow{F_{L\_P-onP+}} = \frac{1}{c^2} \overrightarrow{V_{P+}} \times (\overrightarrow{V_{P-}} \times \overrightarrow{F_{C\_P-onP+}}) = \frac{1}{c^2} \overrightarrow{V_{P+}} \times \left( \overrightarrow{V_{P-}} \times \left( -K_{SV} \frac{e^2}{r^2} \text{vers}(\vec{r}) \right) \right)$$

$$\overrightarrow{F_{L\_P-onP+}} = -K_{SV} \frac{e^2}{r^2} \frac{1}{c^2} \overrightarrow{V_{P+}} \times (\overrightarrow{V_{P-}} \times \text{vers}(\vec{r}))$$

$$\overrightarrow{V_{P-}} \times \text{vers}(\vec{r}) = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{r}{2} \omega \sin(\omega t) & -\frac{r}{2} \omega \cos(\omega t) & c \\ \cos(\omega t) & \sin(\omega t) & 0 \end{vmatrix} =$$

$$= \hat{x}(-c \sin(\omega t)) - \hat{y}(-c \cos(\omega t)) + \hat{z} \left( \frac{r}{2} \omega (\sin^2(\omega t)) + \frac{r}{2} \omega (\cos^2(\omega t)) \right)$$

$$\overrightarrow{V_{P-}} \times \text{vers}(\vec{r}) = \hat{x}(-c \sin(\omega t)) + \hat{y}(c \cos(\omega t)) + \hat{z} \left( \frac{r}{2} \omega \right)$$

$$\begin{aligned} \overrightarrow{V_{P+}} \times (\overrightarrow{V_{P-}} \times \text{vers}(\vec{r})) &= \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ -\frac{r}{2}\omega \sin(\omega t) & +\frac{r}{2}\omega \cos(\omega t) & c \\ -c \sin(\omega t) & c \cos(\omega t) & \frac{r}{2}\omega \end{vmatrix} = \\ &= \hat{x} \left( \frac{r^2}{4} \omega^2 \cos(\omega t) - c^2 \cos(\omega t) \right) - \hat{y} \left( -\frac{r^2}{4} \omega^2 \sin(\omega t) + c^2 \sin(\omega t) \right) + \\ &\quad + \hat{z} \left( -\frac{r}{2} \omega c (\sin(\omega t) \cos(\omega t)) + \frac{r}{2} \omega c (\cos(\omega t) \sin(\omega t)) \right) = \\ &= \hat{x} \left( \frac{r^2}{4} \omega^2 - c^2 \right) \cos(\omega t) + \hat{y} \left( \frac{r^2}{4} \omega^2 - c^2 \right) \sin(\omega t) = \left( \frac{r^2}{4} \omega^2 - c^2 \right) \left( \hat{x} \cos(\omega t) + \hat{y} \sin(\omega t) \right) = \left( \frac{r^2}{4} \omega^2 - c^2 \right) \text{vers}(\vec{r}) \end{aligned}$$

Then

$$\overrightarrow{F_{L-P-onP+}} = -K_{SV} \frac{e^2}{r^2} \frac{1}{c^2} \left( \frac{r^2}{4} \omega^2 - c^2 \right) \text{vers}(\vec{r}) = -K_{SV} \frac{e^2}{r^2} \frac{1}{c^2} (V_{P+_{tg}}^2 - c^2) \text{vers}(\vec{r})$$

The total resultant of the forces applied on P+ is

$$\begin{aligned} \overrightarrow{F_{Tot\_P-onP+}} &= \overrightarrow{F_{C\_P-onP+}} + \overrightarrow{F_{L\_P-onP+}} = -K_{SV} \frac{e^2}{r^2} \text{vers}(\vec{r}) - K_{SV} \frac{e^2}{r^2} \frac{1}{c^2} (V_{P+_{tg}}^2 - c^2) \text{vers}(\vec{r}) = \\ &= -K_{SV} \frac{e^2}{r^2} \frac{V_{P+_{tg}}^2}{c^2} \text{vers}(\vec{r}) \end{aligned}$$

Now equalling the centripetal force with this resultant expression

$$-\frac{E_{ph}}{c^2} \frac{V_{P+_{tg}}^2}{r} \text{vers}(\vec{r}) = -K_{SV} \frac{e^2}{r^2} \frac{V_{P+_{tg}}^2}{c^2} \text{vers}(\vec{r})$$

We found that in our photonic model,  $V_{P+_{tg}} = V_{ig} = \text{Const}$  for every photon, independently of its energy,  $E_{ph}$ , and frequency,  $\nu$ . To arrive to that result we had not utilized the experimental equation,  $E_{ph} = h\nu$ , that we have used later to accord our model with the experimental value of photon spin, obtaining  $V_{P+_{tg}} = c$ .

Substituting  $r = \frac{V_{tg}}{\pi\nu}$ ,

$$\frac{E_{ph}}{c^2} \frac{V_{P+tg}^2}{V_{P+tg}} \pi\nu = K_{SV} \frac{e^2}{V_{P+tg}^2} \frac{V_{P+tg}^2}{c^2} \pi^2 \nu^2$$

$$E_{ph} = \left( \frac{K_{SV} e^2 \pi}{V_{P+tg}} \right) \nu = H\nu$$

Remembering that  $V_{P+tg} = Const$ , for every photon energy,  $E_{ph}$ , and frequency,  $\nu$ ,

$H = \left( \frac{K_{SV} e^2 \pi}{V_{P+tg}} \right)$  is a constant, since it is made of physics constants, fixed numbers and constant magnitudes, independent of photon energy,  $E_{ph}$ , and frequency,  $\nu$ .

Thus, we obtain by our theoretical photon structure, a formula proper of linear relationship between the energy,  $E_{ph}$ , and the frequency,  $\nu$ , of the photon; in other words,  $E_{ph} \propto \nu$ , since H is constant,

$$E_{ph} = H\nu$$

This surprising result is in perfect coherence with what is observed in nature and condensed in the important photon equation

$$E_{ph} = h\nu$$

which tells that, experimentally,  $E_{ph} \propto \nu$ , with the famous Planck constant  $h$ .

Therefore, equalling the second members of the two equations, it must be,

$$H = h.$$

Note we have arrived to  $E_{ph} = H\nu$ , with H constant, without utilising the experimental datum  $E_{ph} = h\nu$ !

Now, remembering the more particular result  $V_{P+tg} = c$ , obtained utilising the experimental equation,  $E_{ph} = h\nu$ , in order to accord our model, as perfectly it allowed, with the experimental value of photon spin, we obtain

$$h = H = \left( \frac{K_{SV} e^2 \pi}{V_{P+tg}} \right) = K_{SV} \frac{e^2}{c} \pi$$



$$h = K_{SV} \frac{e^2}{c} \pi \quad E_{ph} = h\nu = \left( K_{SV} \frac{e^2}{c} \pi \right) \nu \quad (9)$$

Later we will discuss the implication of this model, to explain the physics intrinsic nature of  $h$ .

This result confirms an important condition of our photonic model, the constancy of  $V_{tg}$ , necessary to obtain in our photon structure a linear relationship between its total energy and its frequency, being  $H = f(V_{tg})$  !

Note: we can observe that the mutual Lorentz forces between  $P+$  and  $P-$ , are null.

$V_{P+_{tg}} = c$  implies infect,

$$\overrightarrow{F_{L_{-}P_{-}onP_{+}}} = -\overrightarrow{F_{L_{+}P_{+}onP_{-}}} = -K_{SV} \frac{e^2}{r^2} \frac{1}{c^2} (V_{P+_{tg}}^2 - c^2) \text{vers}(\vec{r}) = \vec{0}$$

Probably, it is another important feature that reveals as our model, which is theorized in this scientific work, describes the special inevitable kinematical configuration of the photon, derived by fundamental principles of conservation!

## Considerations about the generation of a photon

We can image that when, in every way, it is created a photon of a precise quantum of energy,  $E_{ph}$ , utilizing a pre-existent identical energy, (according to the ‘‘Conservation Energy Principle’’), a couple of elementary charges with opposite signs is generated from null, not created since it exists in potency, or it is utilized a pre-existent couple with their two charges, (we imagine them punctiform), which are not in the same point of the space in the same time, then in this second case without problem of singularity connected with the divergence of the electric potential energy when spatial distance between two charges goes to zero in the limit. In every case it must be respected the ‘‘Conservation of Charge Principle’’. Now, in this generation act, it happens an immediate transitory phase, in which each charge assumes an half of the energy (mass) of the system, no preference between them and their identical charge absolute value explains this symmetry in the photon structure.  $P+$  and  $P-$  take themselves to a precise  $r$  distance between them, and they begin moving itself with the described kinematics for them.

$P-$  and  $P+$  take themselves in a geometric and kinematic system that correspond to a stable dynamic state, which gives to photon its special properties, among this the possibility to transport energy, momentum, the electromagnetic wave and so on, in vacuum; a stability which derived it from the properties of the Universe.

In this stable state, distance  $r$  is an equilibrium distance according to the mass-energy of the system and the electrostatic internal interaction.  $R$  connected to the stability of the system, determines the particular  $\lambda$  (or identically  $\nu$ ), of the photon and of the connected e.m. wave, and this explains the famous equation for the photon:  $E_{ph} = h\nu$ .

Studying in deep the ways of photon generation, the photon and e.m. wave emissions, we can understand better the e.m. wave characteristics at the light of this photon structure.

We observe, that with this model of the photon, in the phenomena of transition between photons and matter-antimatter, the maintenance of the opposite charges in the photon at finite distances, not null, has the great physical and theoretical advantage that, in those phenomena, (which are called of annihilation or creation of pairs of matter-antimatter), phenomena of annihilation or generation from nothing of couples of charges are not involved, (as instead it is superficially believed until now), thus avoiding problems of singularity in the electrical potential energy that these phenomena would have involved.

## Idealization in our Photonic Model and the Inside Gravitational Interaction in it

*“La Natura rivela i suoi segreti a chi la ama.”*

(Oreste Caroppo)

Note we consider, in this studies, an idealized condition, an empty space in which photon propagates without any external influence, no magnetic, electric or gravitational fields, no obstacles, only internal electromagnetic interaction between  $P+$  and  $P-$ . This conditions we called “standard photon motion conditions”, or simply “standard conditions”. Then, the uniform and rectilinear translational propagation along  $z$  axis, with a speed  $c$ , happens accordingly with Newton’s first law of motion, “the law of inertia” called too. The rotational movement, which, combined with the first, generates the helicoidal trajectories in the time-space, is produced by the electromagnetic interaction between  $P+$  and  $P-$ , (in particular by their electrostatic interaction).

Really, between  $P+$  and  $P-$ , another force of interaction exists, the gravitational interaction between the masses of  $P+$  and  $P-$ , which is an attractive force, obviously respecting the “action-reaction principle”:

$$\overrightarrow{F_{G_{-(P-)}on(P+)}} = -\overrightarrow{F_{G_{-(P+)}on(P-)}} = -\gamma \frac{m_{P+} m_{P-}}{r^2} \text{vers}(\vec{r})$$

whose size is:

$$\left\| \overrightarrow{F_{G_{-(P-)}on(P+)}} \right\| = \left\| \overrightarrow{F_{G_{-(P+)}on(P-)}} \right\| = \gamma \frac{m_{P+} m_{P-}}{r^2} = \gamma \frac{1}{4} \frac{1}{r^2} m_{ph}^2 = \gamma \frac{1}{4} \frac{\pi^2 v^2}{c^2} \frac{h^2 v^2}{c^4} = \frac{\pi^2}{4} \frac{\hbar^2}{c^6} v^4$$

Instead, the size of the electric force is

$$\left\| \overrightarrow{F_{C_{-(P-)}on(P+)}} \right\| = \left\| \overrightarrow{F_{C_{-(P+)}on(P-)}} \right\| = K_{SV} \frac{e^2}{r^2} = \frac{1}{r} h v = \frac{\pi v}{c} h v = \pi \frac{h}{c} v^2$$

We confront their intensity:

$$\frac{\left\| \overrightarrow{F_{C_{-(P-)on(P+)}} \right\| - \left\| \overrightarrow{F_{G_{-(P-)on(P+)}} \right\|}{\left\| \overrightarrow{F_{C_{-(P-)on(P+)}} \right\|}} = 1 - \frac{\left\| \overrightarrow{F_{G_{-(P-)on(P+)}} \right\|}{\left\| \overrightarrow{F_{C_{-(P-)on(P+)}} \right\|}} = 1 - \frac{\frac{\pi^2 \hbar^2}{4 c^6} v^4}{\frac{\pi h}{c} v^2} = 1 - \frac{\pi \hbar}{4 c^5} v^2 \approx 1 - 1.4 * 10^{-86} * v^2$$

We can say, approximately, that only for  $v \gg 10^{40} Hz$ , the gravitational force begins to become near in magnitude to the electrical force in a photon, and we can tell that never until now, in experiments or in astronomical observations, it is observed a photon of a so great energy!

To date the highest gamma ray energy detected is around  $10^{13} eV$ , that is the maximum magnitude for frequency detected in a photon is, until now, around  $v \approx 10^{27} \div 10^{28} Hz$ !

Consequently, we can be sure about the goodness of our approximation concerning to ignore the gravitation interaction in forces and in energy balancings in our photonic system.

Note that an electrically neutral or charged accelerated massive particle, tachyon or bradyon, could lose its energy, according to some theories, by gravitational radiation of gravitons, that is gravitational waves, since it has a gravitational mass, which is its relativistic mass. For tachyon this is a gravitational Cherenkov radiation. Hence, this phenomenon can produce a reduction of the energy of a photon during its existence, but perhaps the gravitational energy dispersed by  $P+$  could be absorbed by  $P-$  and vice versa, maintaining the total energy of the photon system constant in time ... questions of investigation for future studies!

## Considerations about the Microscopical Tachyon Nature of the Photon in our Model

*“La luce si muove ad una velocità superiore alla velocità della luce!”*

(Oreste Caroppo)

Semi-photon particles  $P+$  and  $P-$ , have a velocity decomposable in two components, one of translation,  $V_{tr} = c$ , and another of rotation,  $V_{ig} = c$ , orthogonal to the first and also orthogonal to the cylindrical surface of the cylindrical helixes. Then, semi-photon particles have a total speed super-luminal ( $V_{Tot} > c$ ); semi-photon particles are for this reason, tachyons;

- “tachyon”, (from Greek language, ταχύνιον, {*takhyónion*}, from ταχύς, {*tachýs*}, i.e. “swift”, “fast”, “speedy”), is an hypothetical particle that travels at super-luminal speed, with  $V_{Tot} > c$ ; tachyons have a rest mass not null and totally imaginary accordingly to the special relativity in order to have a real total energy;
- “bradyon”, (from Greek language, βραδύνιον, {*bradyónion*}, from βραδύς “*bradys*”, “slow”), is called every ordinary particle that travels at sub-luminal speed, with  $V_{Tot} < c$ .

Bradyons are also called “tardyon”. These particles have a real and non-zero rest mass, accordingly to the special relativity;

- “luxon”, (from Latin language “lux”, “light”) is every particle that travels at luminal speed, with  $V_{Tot} = c$ ; luxons are massless particle, particle whose rest mass is zero, accordingly to the special relativity. The photon and the graviton, respectively, the quantum of e.m. field and of the gravitational field, are luxons.

For us, to date, tachyons are exotic theoretical particles, never detected, but their existence, it is an important point, is not against relativity!

Note that already the existence of a not null spin in a photon, with direction parallel to  $z$ -axis, tells us intuitively, thinking to quantum spin as in Newtonian physics, that some photon constituent parts have a component of their velocity, orthogonal to the  $c$ -velocity of translation, therefore this implicates a their total speed super-luminal!

$P+$  and  $P-$  have, like tachyons, relativistic mass,  $m_p$ , and total energy,  $E_p$ , real, but a rest mass totally imaginary,  $im_{o_p}$  :

$$m_p = \frac{im_{o_p}}{\sqrt{1 - \left(\frac{V_{P-Tot}}{c}\right)^2}} = im_{o_p} \gamma$$

$$E_p = m_p c^2 = \frac{im_{o_p} c^2}{\sqrt{1 - \left(\frac{V_{P-Tot}}{c}\right)^2}} = im_{o_p} \gamma c^2$$

indicating with  $P$ ,  $P+$  and  $P-$ , being their relativistic and rest mass and their energy the same.

Here,  $\gamma$  is the Lorentz factor, the Lorentz term called too:

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{V_{P-Tot}}{c}\right)^2}}$$

Substituted  $V_{P-Tot}$  in  $\gamma$ :

$$\left(V_{P-Tot}\right)^2 = \left(V_{P-tr}\right)^2 + \left(V_{P-tg}\right)^2 = c^2 + \left(V_{P-tg}\right)^2$$

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{V_{P\_Tot}}{c}\right)^2}} = \frac{1}{\sqrt{1 - \left(\frac{\sqrt{c^2 + (V_{P\_tg})^2}}{c}\right)^2}} = \frac{1}{\sqrt{-\left(\frac{(V_{P\_tg})^2}{c^2}\right)}} = \frac{1}{\sqrt{-1} \sqrt{\left(\frac{(V_{P\_tg})^2}{c^2}\right)}} = \frac{1}{i \sqrt{\left(\frac{(V_{P\_tg})^2}{c^2}\right)}}$$

In particular being in our model  $V_{P\_tg} = c$ , as we found, we have:

$$\gamma = \frac{1}{i} = -i \quad (10)$$

where  $i$  is the “imaginary unit” in the “complex numbers”.

Hence,

$$m_P = \frac{im_{o\_P}}{i} = m_{o\_P}$$

$$E_P = m_P c^2 = \frac{im_{o\_P} c^2}{i} = m_{o\_P} c^2$$

The total velocity of  $P+$  and  $P-$ , have a constant magnitude in time:

$$(V_{P\_Tot})^2 = (V_{P\_tr})^2 + (V_{P\_tg})^2 = c^2 + c^2 = 2c^2$$

$$\left\| \overrightarrow{V_{P\_Tot}} \right\| = \sqrt{2}c \quad (11)$$

It is the only velocity magnitude that gives

$$\gamma = \frac{1}{i} = -i$$

and then, the particular result  $relativisticMass = |restMass|$ , that is the relativistic mass is equal to the modulus or magnitude of the rest mass, as complex number. Correctly, also for  $V = 0 \Leftrightarrow \gamma = 1$  the mass equality is valid, being in that case, the rest mass real,

$$relativisticMass = restMass (= |restMass|)!$$

This interesting property, connected to  $V_{P\_tg} = c$  of the photon in our model, can not be casual, but it must derive from more profound reasons that our studies involve to investigate!

Quantum theory applied to tachyons shows that they must be spinless particles. There is no reason to suppose *a priori* that tachyons must be either neutral or charged. They also must be created and annihilated in pairs, if charged with charges of identical magnitude and opposite sign.

All these properties mathematically predicted in the physics theory about tachyons, are perfectly in accord with the theoretic features of our  $P+$  and  $P-$  tachyons, properties implied by photon real physical properties in our model.

Now, connected with the special value of the Lorentz factor  $\gamma = -i$ , we will show in our model an interesting aspect of conservation, in the phenomenon of the photon pair generation, the transformation of a photon in a matter-antimatter pair of particles.

Consider the theoretical limit case in the photon pair generation, in which the energy of the photon is exactly equal to the energy relativistically connected with the total rest mass of the generated pair. We take here, for instance, the electron-positron pair.

- Electron has an elementary negative charge,  $-e$ , and a rest mass  $m_{o\_e}$ .
- Positron, the antielectron, so called too, has an elementary positive charge,  $+e$ , and a rest mass  $m_{o\_e}$ , exactly equal to the electron rest mass.

We image the speeds of the two particles null or near zero, after their generation, this implies their rest mass and their relativistic mass are equal,  $m_{o\_e} = m_e$ .

Then, in these limit conditions,

$$E_{ph} = 2m_e c^2$$

(for the photon generation pair, it must be  $E_{ph} \geq 2m_e c^2$ )

Now we image that in the photon pair generation:

- the photon sub-particles  $P-$ , which has a charge  $-e$ , and a relativistic mass  $\frac{E_{ph}}{2c^2} = m_e$ , becomes the electron, or it gives origin to it, since it has the same charge and relativistic mass (and then energy);
- the photon sub-particle  $P+$ , which has a charge  $+e$ , and a relativistic mass  $\frac{E_{ph}}{2c^2} = m_e$ , becomes the positron, or it gives origin to it, since it has the same charge and relativistic mass (and then energy).

In this new setting, we consider the variation of the rest masses:

- $P-$  has a rest mass  $im_{o\_P-} = im_{P-} = i\frac{E_{ph}}{2c^2} = im_{o\_e}$  and the electron has a rest mass  $m_{o\_e}$
- $P+$  has a rest mass  $im_{o\_P+} = im_{P+} = i\frac{E_{ph}}{2c^2} = im_{o\_e}$  and the positron has a rest mass  $m_{o\_e}$

Then, we can observe that in the photon pair generation the rest masses changes; before in the photon sub-particles, they are totally imaginary complex numbers, complex quantities, after they

are totally real numbers (that is complex numbers with the imaginary part of zero), real quantities in the matter-antimatter pair. Nevertheless, in this conversion, there is a quantity which is conserved, it is the absolute value (or modulus or magnitude so called too), of the rest masses, which can be ever considered complex quantities, being a real number as a complex number with the imaginary part null. In fact,

$$|im_{o\_P-}| = |m_{o\_electron}| = m_{o\_e}$$

$$|im_{o\_P+}| = |m_{o\_positron}| = m_{o\_e}$$

These interesting observations signal, perhaps, an important principle underlying.

In conclusion, we remark interesting constant aspects in the photons, according to our model, independent of their energy, and then, frequency and wavelength; they are their helix angle of  $45^\circ$ , their translation speed  $c$  and the total speed  $\left\| \vec{V}_{P\_Tot} \right\| = \sqrt{2}c$  of  $P+$  and  $P-$ .

A great geometric perfection appears at the basis of the photon structure and dynamics!

Note: other very important properties, of our photon model, can be derived by an energetic analysis of it, using the principle of conservation of the total energy, which must be a sum of the potential and kinetic energies of the two sub-particles of the photon in our theory!

## Considerations about Photon as a Not Radiative Accelerated Dipolar System

In our system we have charges accelerated, it happens since semi-photon particles,  $P+$  and  $P-$ , which are charged, although they have a constant magnitude of their velocity, have a curvilinear trajectories, hence a centripetal acceleration.

According to the electromagnetic radiation theory, a charge accelerated radiates an electromagnetic wave, which is energy diffused in space, that reduces the energy of the same charged particle.

It would happen in accelerating tachyons with an electric charge, just like in ordinary accelerating charged particles, (accelerating charged bradyons); in particular in tachyon case, being the particle superluminal, the emitted radiation would be a Cherenkov radiation, just as ordinary charged particles do when they exceed the local speed of light of the propagation medium. As a consequence of this emission, the total energy of an accelerated charged tachyon, so as of an accelerated charged bradyon, decreases.

Conservation of proper energy of our photon system is very important for the adherence of our model to the reality, but also for the dynamic stability of our photon model. Conservation of proper energy is exactly what happens in a photon, which is the fruit of an irradiation process, and not itself a radiative system.

Now, the total emission or not of its energy in an e.m. radiation, by our photon model, is an important theoretical study to prove the reliability or to understand the physical validity, of our photon model.

In our system for its particular geometric, kinematic and dynamic properties, and since  $P+$  and  $P-$  have two charges of opposite sign and idem magnitude, it is probably that the electromagnetic wave issued by  $P+$  and that issued by  $P-$ , interfere destructively, then none electromagnetic wave is issued by our photonic system, and nothing of its energy is dispersed in radiation! Continuously  $P+$  issues radiation energy and absorbs in the same time a same quantity of energy radiated in space by  $P-$ , idem for  $P-$  respecting  $P+$ ; a non-stopped and continuous push and pull of radiation energy between  $P-$  and  $P+$ , which assures the conservation of the energy of our photon model during its stationary existence (= propagation), which maintains continuously constant and identical to the half of the total relativistic mass, the masses of  $P+$  and  $P-$ .

In other way, we can image that as in the atom, where an electron can go around nucleus without emitting radiation although it is a charged accelerated particle, in the same way and by the same principles and reasons, no emission happens in the photon structure for its charged accelerated sub-particles! To the limit we can image photon emits continuously and totally itself giving origin to its propagation in space-time...and so on with various hypothesis!

Mathematically, in this valuation, it will be very interesting to value if the electromagnetic dynamic field generated by the two charges, in this photon model, (and constituted by the electric and magnetic fields generated by those two charges in motion, considering the simple Coulomb's electric force, and the magnetic force generated by them, in a dynamic situation with the movement of the two charged origins of the two fields, and in the hypothesis of an instantaneous effect at distance of the electric and magnetic interaction, as later discussed), satisfies the Maxwell's equations for an electromagnetic wave! In the positive case, our photon model, which is a relativistic model, should be implicated by the same classical Maxwell's theory, which is a theory of the electromagnetic field in coherence with Einstein's theory of special relativity!

## Considerations about Planck constant “to the light” of our Photonic Model

*“Tutti vogliono descrivere il cosmo, ma nessuno vuole prima descrivere h !”*

(Oreste Caroppo)

In particular condition, a photon can transform itself into a couple of particles of matter and antimatter, each one with a same rest mass, equal or minor to the half of the relativistic mass of the original photon, and with opposite elementary electric charge,  $e$ , respecting in this way the “charge conservation principle”; the constancy of the total charge before, during and after photon transformation into a particle-antiparticle pair, generally of an electron and a positron (anti-electron). Before, the total photon charge is null, and after the total charge of the matter-antimatter pair is null again,

$$Q_{ph} = 0 = Q_{material} + Q_{antimaterial} = (+e) + (-e)$$



In theory, the two elementary and complementary charges can stay in the same point annihilating between them; a point can have infinite couples of complementary charges, (that is with null total charge); this is theoretically possible or in any case, ever in accord with the charge conservation principle; classically, it is the conception about photon and then, about the state before the generation pair, the two complementary charges of the pair were thought as not existent or it is the same, existent in the same point, the punctiform photon point of a classic theoretical photon conception. Now instead, we have already in our photon model the two elementary and complementary charges existing separately in space, in the two material constituent photon points,  $P+$  and  $P-$ , (their middle point,  $O(t)$ , coincided with the photon mass center identifiable with the classic theoretical punctiform photon); in their separated existence and in their electro-magnetic dynamic stability it consists the same photon, its energy, its particular propagation at the speed of light in vacuum space, its properties and those of the electron-magnetic wave; dynamic stability of our photon model is connected to the electro-magnetic interaction between charges! All this on the base of the universal conservation principles, special relativity, dynamic laws, classical electrostatic and magnetostatic interaction laws.

At this point of our written, we can analyse the significance of Planck constant at the light of this new photonic theory.

We obtained

$$h = \left( K_{sv} \frac{e^2}{c} \pi \right)$$

from which

$$K_{sv} = \frac{hc}{\pi e^2} \quad (12)$$

where  $K_{sv}$ , is Coulomb's constant of the electrostatic interaction between  $P-$  and  $P+$  charges in the photon dynamic system.

We imaged

$$Q_{P+} = +e \quad \text{and} \quad Q_{P-} = -e$$

We have not motives to think for  $Q_p = |Q_{P+}| = |Q_{P-}|$ ,

$$Q_p = |Q_{P+}| = |Q_{P-}| \neq e$$

The elementary charge, is the most plausible choice for  $Q_p$ , accordingly with what we can see in the generation of matter-antimatter pair, from a single energetic photon.

Then, an apparent problem is given by this difference in value:

$$K_{sv} \neq K$$

where  $K$  is the constant in Coulomb's electrostatic interaction law between two charges in vacuum space.

$$\frac{K_{sv}}{K} = \frac{hc}{\pi Ke^2} = 2 \frac{h}{2\pi} \frac{c}{Ke^2} = 2 \frac{\hbar c}{Ke^2} = \frac{2}{\alpha}$$

Where  $\alpha = \frac{Ke^2}{\hbar c}$  is a famous adimensional constant, called in physics "Fine-Structure Constant", also called "Sommerfeld fine-structure constant"

$$\left( \alpha = \frac{Ke^2}{\hbar c} \cong \frac{1}{137} \right) \Rightarrow (K_{sv} > K)$$

Although,  $P+$  and  $P-$  are in vacuum space, the electrostatic interaction between their charges happens with a different Coulomb's constant value! In particular with a new value which remains constant for every photon, but which is much grander than  $K$ !

It is as  $P+$  and  $P-$  charges see a different vacuum, a vacuum with different properties in relation with them. The electrical attraction strength is much grander for their charges between them, respecting the electrical strength between two same charges in the same distance and empty space, but quite or in subluminal speed conditions, (the conditions in which until now experimentally Coulomb's law is been analyzed and measured, and in which for Coulomb's constant, a constant  $K$  value is been ever calculated for charges in vacuum)!

The only way we have to explain this discrepancy is this:

the dielectric characteristics of empty space, of vacuum, change if a charge is in sub-luminal conditions (or quite to the limit), or in super-luminal conditions!

This can happen because vacuum is not really empty! As Casimir effect reveals and quantum mechanics theory suggests on the base of the "indetermination principle" of Werner Heisenberg, called "Heisenberg's principle" or "uncertainty principle" too, vacuum is not really empty. In vacuum there are a lots of matter-antimatter pairs of particles, of particle-antiparticle pairs. According to the orthodox interpretation of Heisenberg's principle of indetermination, they are short-lived couples of particles, ephemeral quantum fluctuations of vacuum, and consequently, they are called "virtual particles", "virtual pairs"; in another way, we can consider them as fundamental constituents of a finite vacuum energy density. Some of these "virtual" particle-antiparticle pairs are charged, (e.g., virtual electron-positron pairs); such charged couples are therefore, pairs of charges,  $(e+)- (e-)$ ; the totally charge of an empty space associated with this particles, is then null, but their existence creates in vacuum a spatial charge distribution which can be electrified, polarized, by an external charge particle put in that space or near it! Infect, these charged "virtual" pairs act as electric dipoles, which can be polarized. In the presence of an external electric field, (e.g., the electromagnetic field around an electron as its source, which is a charged bradyon), these particle-antiparticle pairs react, and they reposition themselves, breaking their symmetry of null their total

field, creating in this way a their opposite electric field, thus partially counteracting the external field; it is a sort of dielectric effect. Therefore the resulting field will be weaker of what would be expected if the vacuum were completely empty. This reorientation of the short-lived particle-antiparticle pairs is referred to as “vacuum polarization”; vacuum is like a sort of dielectric material! This dielectric effect acts as a partial screening effect too; in fact, vacuum electrification induced by an external charge screens the same charge reducing its effective electric field in vacuum, that is its total final electrostatic effect over another charge in space! All this happens normally with charges in vacuum, and this effect is quantified in  $K$ , Coulomb’s constant for vacuum! Coulomb’s electrostatic interaction law, with  $K$  as constant, is been observed and confirmed for charges in subluminal state, as to the limit, with charges in quite or in subluminal speed near the speed of light in vacuum, too! To date, never directed observations about charged tachyons, since never a tachyon has been detected in our experimental ways in physics to observe nature.

We can think that in vacuum there is in every moment and in every point of the universe a constant density of matter-antimatter pairs with the same statistic characteristics and energy distribution in them. It is a constant property of vacuum, or perhaps a property of the universe changing in the universe evolution!

We think, that for the electrification of vacuum, in particular for the polarization of its matter-antimatter pairs, a particular intrinsic inertial exists!

Then, until a charge moves itself in subluminal conditions, virtual couples have the time to polarize themselves rapidly, the time to screen the external charge, and we have the traditional magnitude  $K$ , for the traditional Coulomb’s constant for the empty space, in the electrical interaction between two charges in the same subluminal kinematic conditions.

When the speed of a charge is over a special speed as  $c$ , or superior, certainly when its speed is  $V = \sqrt{2}c$ , we think that a charge goes through the vacuum, which is full of virtual particles, so rapidly that, by their inertial, matter-antimatter virtual pairs have not the sufficient time to polarized themselves; it is like the couples do not see the passage of the superluminal charge, though they continue to perceive the electric (and magnetic) field of that charge!

Note: we image, here, an instantaneous modification in the whole universe of the electrostatic field, with the motion of its charge source!

Then, in electric interaction, and consequently in the magnetic interaction, this superluminal charge appears without an electrical screen, without an electrified space around it, and it can explain a bigger electrical influence over other charges. Vacuum seen by these superluminal charges, appears really empty, therefore, we call this vacuum condition, which concerns a particular charge speed state, *Super-Vacuum*, (*SV* in acronym).

In our photonic model  $P+$  and  $P-$  are two charged particles in this special speed condition. In their Coulomb’s electric interaction, Coulomb’s constant  $K_{SV}$ , quantifies these aspects, the two charges of the photon are not screened, they interact in a super-vacuum condition, for this reason we put *SV*, in the symbol  $K_{SV}$ , and for the same reason we have  $K_{SV} > K$  !

Now we have for the first time the possibility to watch to the  $h$ , Planck constant, in a different way, giving them a physics interpretation connected to the intrinsic properties of vacuum!

We found for Planck constant:

$$h = K_{sv} \frac{e^2}{c} \pi$$

$h$  is connected to the intrinsic properties of vacuum, which influence  $K_{sv}$ .

On  $h$  is founded the whole quantum theory! The consequences in physics studies and cosmology of this potential new way of looking to the nature are unimaginable!

Hence, considering  $\alpha$ , the “Constant of Fine Structure”,

$$\alpha = \frac{Ke^2}{\hbar c} = \frac{2\pi Ke^2}{hc} \cong \frac{1}{137}$$

it is connected proper to the “fine structure” of vacuum, which is not really empty, but characterized by a distribution of matter-antimatter pairs.

Planck constant value is an experimental result, that is directly influenced by the density of the vacuum energy and by the distribution of its virtual particles, then,  $h$  is the main key to explore and understand the vacuum in our Universe.

Perhaps, these considerations suggest also a road to understand why it is possible for a photon to translate in a uniform straight line movement, accordingly to Newton’s first law of motion, the law of inertia, with light speed,  $c$ . It happens since in vacuum in absence of any gravitational, magnetic and electric resulting force, not any friction effect acts on semi-photon particles!

By the characteristics of our photon model, vacuum space appears to it almost completely empty, the super-vacuum which is a not-polarized vacuum; then, in the absence of every external field, in vacuum there is nothing which can brake our photon; without polarization, virtual particles exercise no distance interaction on the superluminal semi-photon particles; if we add that according to us, all the fine particles of nature are punctiform, as the virtual particles and the semi-photon particles, the possibilities of a collision between them, becomes very much low, and in these idealized conditions, what we will see it is a perfect respect in the photon behaviour of the “law of inertia”, exactly what happens really for a real photon in vacuum!

Continuing to consider for the equation of the electrical interaction between the two complementary charges of the photon, the normal magnitude for Coulomb’s constant in vacuum,  $K$ , we necessary must attribute a different magnitude,  $|Q|$ , to the charges of  $P+$  and  $P-$ , ever two charges opposite and of the same value, for the same symmetric reasons.

Equalling the two expressions of Coulomb’s electrostatic force

$$\frac{K_{sv}e^2}{r^2} = \frac{KQ^2}{r^2}$$

we obtain

$$Q^2 = \frac{K_{sv}}{K} e^2 = 2 \frac{\hbar c}{K e^2} e^2 = 2 \frac{\hbar c}{K}$$

$$Q = \pm \sqrt{2} \sqrt{\frac{\hbar c}{K}} = \pm \sqrt{2} Q_p \quad (13)$$

Where  $Q_p = \sqrt{\frac{\hbar c}{K}}$ , is a physics constant, traditionally called “Planck charge”. It is  $Q_p > e$ .

$$|Q| = \sqrt{2} \sqrt{\frac{\hbar c}{K}} = \sqrt{\frac{\hbar c}{\pi K}} > e$$

Really, the two charges of photon are in absolute value the elementary charge,  $e$ , but since space around them is not electrified, as instead, in example, for an electron, (a charged bradyon of the same magnitude charge), they have a bigger electrical effect in the same empty space in which we consider the electron; therefore without considering the modification of the dielectric properties of vacuum, and then the modification of Coulomb’s constant for superluminal charges, it appears as the two photon charges, conserving their opposite original signs, have a magnitude  $|Q|$ , bigger than the elementary charge  $e$ !

## Photons in the Electromagnetic Radiation

We do not investigate here the groups of photons and the interaction among photons, which are important points of analysis to explain on the base of our electric model of the photon, the properties of the electromagnetic waves.

### In Photon Structure the “Wave-Corpuscle Dualism” of Light

Our electric-double helicoidal model of photon is a sort of undulatory-corpuscular theory of photon, which integrates the two experimental natures of photon (that is of light, in its more general meaning, intending with it every wave of the e.m. radiation spectrum), that undulatory of wave and that corpuscular of particle (corpuscle); in this way with one theory we resolve and explain the dogmatic phenomenon of the “wave-corpuscle dualism” of photon, which is until now at the basis of the optical studies, of photon and of the electromagnetic radiation.

## Perspectives of Investigation

Our microscopic structure for photon, the consequent interpretation of Planck constant and the discovery of possible tachyon semi-photon particles, opens a vast range of analysis in the studies of nature, and like a little physics revolution, they take us towards a more profound comprehension of many physics aspects and phenomenons! Not only, it seems showing us a nature in which it is possible an instantaneous non-local action at a distance for some interactions, that resurrects an old conception in our age essentially refused, but which appears again necessary to explain non-local quantum entanglement phenomenons! Photon carries momentum and energy and it explains the momentum and the energy transported in a finite time at a distance by the electromagnetic wave made by one or more photons. But now, inside the photon its structure appears based on an instantaneous Coulomb's electrostatic interaction. Now, the electrostatic interaction must be, or it seems to be, an instantaneous non local action at a distance, that is it happens with an infinite speed and a zero time although the existence of a finite distance, (the same for the Lorentz's magnetostatic interaction), all this in accord with our mathematic description of our photon model and with the logical consideration that no photon can generate, "mediate", the electrostatic interaction inside the same photon; it would be a recursive reasoning!

That which is implicated, by this new model of the photon for the electromagnetic interaction, is in harmony with Isaac Newton's conception for the gravitational field, in its theory for gravity, since Newton thought that gravitation was an instantaneous interaction at distance.

All this is in conflict with those theories, in modern physics, that think the gravitational field and the electromagnetic field are mediated by particular particles; fields in which the interaction would be mediated by particles; particles that would be exchanged, emitted and absorbed, continuously, and that would be characterized by a finite speed, not exceeding the speed of light,  $c$ . These "force-mediating particles", with an energy, and then a mass, would be the photon for the electromagnetic field, and the graviton for the gravitational field. The graviton would have a speed identical to  $c$ , the same speed of light, and then of the photon!

But the features of the "black holes", theorized and astronomically discovered, which tell us that, in a black hole, mass and charge do not disappear, but they continue to interact normally, with, respectively, masses and charges in the whole Universe, out of the black hole, reveal that gravitational and electromagnetic interactions are not mediated by particles, respectively the graviton and the photon, since, no mass, then no light, no particles, no energy can normally be emitted by a black hole, in coherence with its nature in physics, and its same eloquent name!

## Some Considerations about Electric and Magnetic Fields of a Photon in our Model

A photon, in our model, is made by a distribution of charges, a rigid distribution of two charges which constitute an electrical dipole. It generates around it an electric field typical of a dipole, a field which changes its position instantly everywhere, with the movement of the photon in space, then with the movement of its sources, (the inside photon charges), the movement of its source dipole. Since the two charges move themselves, they create around them a magnetic field too, connected obviously, with their electric field. Hence, we have in a single photon an electric and a magnetic field, of which vectors and field lines are rigid with the photon dipole, and then, they change in space and time during photon propagation!

Note: we image, as already told, an instantaneous modification in the whole universe of the electrostatic field, (and hence, of the magnetostatic field), with the motion of its charge source!

Photon, which is classically the carrier of the electromagnetic field, has in its intrinsic structure the origin, the sources of the electric and magnetic fields changing in time and space; the fields which are those of its electromagnetic wave. All this which is obvious and which is predicted now in this theory, could not be explained with the traditional conception of the photon like a one particle without any internal charge distribution.

I am trustful that deepening the generation, emission and absorption of photon, and the interaction between groups of photons, it will be possible to explain the traditional theoretical properties of Maxwell's electromagnetic fields and waves, and the optical phenomenons, with the properties of photon according to our model, and to explain deeply the interactions between photons and particles, atoms and molecules!

Here, we will analyse only the characteristics of the electric and magnetic field of the photon in its center of mass point,  $O(t)$ ; an important geometrical photon point, in our model, we told which can represent perfectly for some same aspects, the common and diffuse classic conception of the photon as a punctiform particle.

Now, to explore the electric field,  $\vec{E}_{ph}$ , generated by our photon, it needs a probe charge  $q$ .

Note: do not confuse  $\vec{E}_{ph}$ , the electric field, with  $E_{ph}$ , the total energy of the photon!

The electric field will be different if  $q$  is associated to a subluminal particle or to a particle with a velocity of magnitude  $\sqrt{2}c$ .

In the second case, to calculate electric field, we must take  $K_{sv}$  for Coulomb's constant, and for  $P+$  and  $P-$ , their normal charges, respectively,  $+e$  and  $-e$ .

In the first case, we imagine that, in our frame of reference,  $q$  is motionless (its velocity  $V = 0$ ), or with a speed in magnitude very more small than the velocity  $c$  ( $V \ll c$ ); with good approximation, beyond a certain distance between  $q$  (we consider punctiform) and the point  $P+$ , (and between  $q$  and the point  $P-$ ), here we can take for Coulomb's constant, the classic  $K$  magnitude for empty space, and for the charges of  $P+$  and  $P-$ , their corrected magnitude, respectively,  $+|Q|$  and  $-|Q|$ , which we have previously calculated; all this, in consequence of the vacuum polarization for  $q$ , and of the absence of a vacuum polarization for the charges of  $P+$  and  $P-$ .

To date, experimentally, we are, ever, in this first case, we will consider.

In a generic point  $P$ , the electric field generated by a photon in a precise time,  $t$ , is

$$\vec{E}_{ph}(P) = \frac{1}{q} \vec{F}_{Coulomb\_ph}(P)$$

Indicating  $|Q|$  with  $Q$ ,

$$\vec{F}_{Coulomb\_ph}(P) = \vec{F}_{Coulomb\_P+}(P) + \vec{F}_{Coulomb\_P-}(P)$$

where

$$\vec{F}_{Coulomb\_P+}(P) = -\frac{K(+Q)q}{|(P)-(P+)|^3} ((P)-(P+))$$

$$\vec{F}_{Coulomb\_P-}(P) = -\frac{K(-Q)q}{|(P)-(P-)|^3} ((P)-(P-))$$

then,

$$\vec{F}_{Coulomb}(P) = -\frac{K(+Q)q}{|(P)-(P+)|^3} ((P)-(P+)) - \frac{K(-Q)q}{|(P)-(P-)|^3} ((P)-(P-))$$

and

$$\vec{E}_{ph}(P) = -\frac{K(+Q)}{|(P)-(P+)|^3} ((P)-(P+)) - \frac{K(-Q)}{|(P)-(P-)|^3} ((P)-(P-))$$

where,

$$\vec{E}_{P+}(P) = -\frac{K(+Q)}{|(P)-(P+)|^3} ((P)-(P+))$$



$$\vec{E}_{P-}(P) = -\frac{K(-Q)}{|(P)-(P-)|^3}((P)-(P-))$$

and in accord with the superimposition principle of the electric field

$$\vec{E}_{ph}(P) = \vec{E}_{P+}(P) + \vec{E}_{P-}(P)$$

For  $P = O = O(t)$  :

$$\vec{E}_{P+}(P) = -\frac{K(+Q)}{\left(\frac{r}{2}\right)^3} \left(\frac{r}{2}\right) \left(\text{vers}(\overrightarrow{OP+})\right) = -4 \frac{KQ}{r^2} \left(\text{vers}(\overrightarrow{OP+})\right)$$

$$\vec{E}_{P-}(P) = -\frac{K(-Q)}{\left(\frac{r}{2}\right)^3} \left(\frac{r}{2}\right) \left(\text{vers}(\overrightarrow{OP-})\right) = +4 \frac{KQ}{r^2} \left(\text{vers}(\overrightarrow{OP-})\right)$$

Now,

$$\text{vers}(\overrightarrow{OP-}) = -\text{vers}(\overrightarrow{OP+})$$

then,

$$\vec{E}_{P+}(O(t)) = \vec{E}_{P-}(O(t)) = \frac{\vec{E}_{ph}(O(t))}{2}$$

and

$$\vec{E}_{ph}(O) = -8 \frac{KQ}{r^2} \text{vers}(\overrightarrow{OP+})$$

it is the “vectorial equation” of  $\vec{E}_{ph}(O)$ .

Since  $O = O(t)$  the center of mass of the photon and  $P_+ = P_+(t)$  the point position of the semi-photon particle  $P_+$ , are time functions,  $\vec{E}_{ph}(O(t))$ , is a vectorial function of time:

$$\vec{E}_{ph}(O(t)) = -8 \frac{KQ}{r^2} \text{vers}(\overrightarrow{OP_+(t)}) \quad (14)$$

Its magnitude is

$$\|\vec{E}_{ph}(O(t))\| = \left\| -8 \frac{KQ}{r^2} \text{vers}(\overrightarrow{OP_+(t)}) \right\| = 8 \frac{KQ}{r^2} \quad \text{in every time.}$$

Then, the size of the electric field in  $O(t)$ , is constant in time!

$\vec{E}_{ph}(O(t))$  is ever orthogonal to  $z$  axis; its point of application,  $O(t)$ , is ever on this axis and it translates with the constant speed  $c$ , ever with the same velocity direction, the positive  $z$ -direction;  $\vec{E}_{ph}(O(t))$  direction rotates with an angular speed  $\omega = 2\pi\nu$ , and with a direction of rotation in accord with the spin of the photon, which defines the screwing direction of the circular polarization of the e.m. wave impulse associated to the photon; screwing direction coinciding with that of the two photon sub-particles of the same photon.

All this remembers exactly, the property of the electric vector in a plane monochromatic Maxwell's electromagnetic wave, with the wavelength the same of our photon, when the wave is polarized circularly; in this case the wave electric field vector, (which is orthogonal to the induction vector and to the direction of the propagation velocity of the wave), rotates around the direction of propagation with an angular speed exactly, equal proper to  $\omega = 2\pi\nu$ , and with one xor the other of the two possible rotation directions. Circular polarization may be referred to as right-handed or left-handed, depending on the direction in which the electric field vector rotates; right-handed or left-handed, as seen from the receiver, or as seen from the source, according with the convention. We take in this work, the first convention, which coincides with the general convention normally adopted about spin direction! If you could stop time and look at the electric field along the beam, its vector apex would trace a helix around the propagation direction, with one xor the other of the two possible circular polarizations; proper a similar property we can observe in our photon, for  $\vec{E}_{ph}(O(t))$ !

Now we consider an inertial Cartesian frame of reference,  $Oxyz$ , with  $z$  axis coincided with our previous  $z$  axis with the same positive direction, and with initial conditions  $P_+(r/2, 0, 0)$ ,  $P_-(-r/2, 0, 0)$ ; in this set up the equations of motion of  $P_+$  and  $P_-$ , can be so expressed:

for a photonic system in which helicoidal trajectories are right-handed

$P_+$

$P_-$

$$\begin{cases} x_{P_+} = \frac{r}{2} \cos(\omega t) \\ y_{P_+} = \frac{r}{2} \sin(\omega t) \\ z_{P_+} = ct \end{cases}$$

$$\begin{cases} x_{P_-} = \frac{r}{2} \cos(\omega t + \pi) = -\frac{r}{2} \cos(\omega t) \\ y_{P_-} = \frac{r}{2} \sin(\omega t + \pi) = -\frac{r}{2} \sin(\omega t) \\ z_{P_-} = ct \end{cases}$$

$O(t)$

$$O(t) = \frac{(P_+) + (P_-)}{2} \Leftrightarrow \begin{cases} x_o = 0 \\ y_o = 0 \\ z_o = ct \end{cases}$$

In this frame of reference, the decomposition of the vector  $\vec{E}_{ph}(O(t))$ , gives :

$$\begin{cases} E_{ph}(O(t))_x = -8 \frac{KQ}{r^2} \cos(\omega t) \\ E_{ph}(O(t))_y = -8 \frac{KQ}{r^2} \sin(\omega t) \\ E_{ph}(O(t))_z = 0 \end{cases}$$

We show, in the following graph, the projections of  $P+$  and  $P-$  positions in time, and of the electric vector  $\vec{E}_{ph}(O(t))$ , on the  $[x,z]$  plain, that is, for  $\vec{E}_{ph}(O(t))$  its component  $E_x$ , in  $x$ -direction (that is the positive direction of  $x$ ), since  $E_z$  is null:

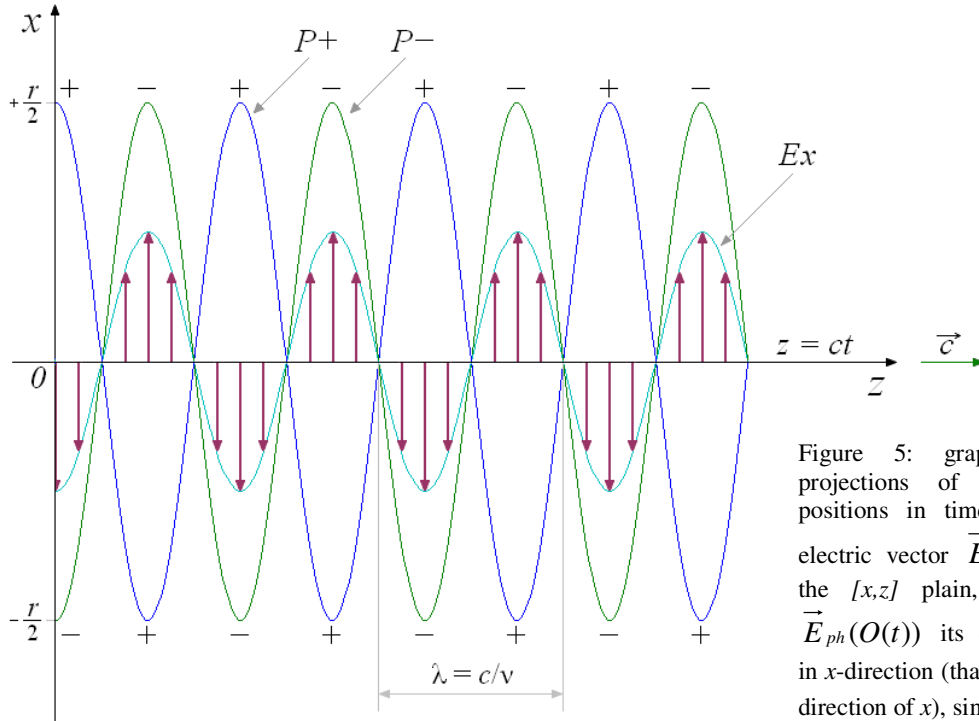


Figure 5: graph with the projections of  $P+$  and  $P-$  positions in time, and of the electric vector  $\vec{E}_{ph}(O(t))$ , on the  $[x,z]$  plain, that is, for  $\vec{E}_{ph}(O(t))$  its component  $E_x$ , in  $x$ -direction (that is the positive direction of  $x$ ), since  $E_z$  is null.

The visualized properties of  $\vec{E}_{ph}$ , in the graph, remember same properties of the electric field in the monochromatic plane harmonic electromagnetic wave!

Electrically, photon in our model is a simple electric dipole, then with a total null charge, consequently around it, going away, rapidly, the size of the electric field nears to zero.

Let us explicate electric field magnitude

$$\left\| \vec{E}_{ph}(O(t)) \right\| = 8 \frac{KQ}{r^2} = 8K \sqrt{\frac{hc}{\pi K}} \frac{1}{\left(\frac{c}{\pi v}\right)^2} = \left( 8 \sqrt{\frac{\pi^3 h K}{c^3}} \right) v^2 = Kost * v^2$$

Remembering that  $K = \frac{1}{4\pi\epsilon_0}$ , where  $\epsilon_0$ , is the famous “dielectric constant of vacuum”,

$$Kost = \left( 8 \sqrt{\frac{\pi^3 h K}{c^3}} \right) = \left( 4\pi \sqrt{\frac{h}{\epsilon_0 c^3}} \right)$$

$Kost$  is a constant, since made by physics constants and fixed adimensional numbers.

$$\left\| \vec{E}_{ph}(O(t)) \right\| = \left( 8 \sqrt{\frac{\pi^3 h}{c^3} \frac{1}{4\pi\epsilon_0}} \right) v^2 = \left( 4\pi \sqrt{\frac{h}{\epsilon_0 c^3}} \right) v^2$$

The electric interaction between two charges is mutual, since it is valid Newton’s third law of motion, the law of reciprocal actions; consequently, we understand the possibility that a charge has to perturb a photon; a perturbative interaction which, probably, explains partly in the electromagnetic radiation, like the light, the diffractive effects of deviation of the trajectories of the photon near the borders of an object, normally clad by clouds of negative charges, of electrons.

About the magnetic field generated by our photon in a generic point  $P$ , in an instant, we use the expression of the magnetic field generated by a single charge in movement, for the two charges of  $P+$  and  $P-$ , and then, we take their vectorial sum, as we have made for the electric field, in accord now, with the superimposition principle of the magnetic field.

$$\vec{B}_{P+}(P) = \frac{1}{c^2} (\vec{v}_{P+} \times \vec{E}_{P+}(P)) \quad \vec{B}_{P-}(P) = \frac{1}{c^2} (\vec{v}_{P-} \times \vec{E}_{P-}(P))$$

where

$$\vec{E}_{P+}(P) = -\frac{K(+Q)}{|(P)-(P+)|^3} ((P)-(P+)) \quad \vec{E}_{P-}(P) = -\frac{K(-Q)}{|(P)-(P-)|^3} ((P)-(P-))$$

$\vec{B}$  are the magnetic induction vectors,  $\vec{V}$  the total velocity vectors, for everyone of the two semi-photon particles  $P+$  e  $P-$ .

In accord with the superimposition principle of the magnetic field, the magnetic induction vector of the photon is

$$\vec{B}_{ph}(P) = \vec{B}_{P+}(P) + \vec{B}_{P-}(P)$$

We consider in particular, the magnetic induction vector of the photon in  $P = O(t)$ .

$$\vec{B}_{ph}(O(t)) = \vec{B}_{P+}(O(t)) + \vec{B}_{P-}(O(t)) = \frac{1}{c^2}(\vec{V}_{P+} \times \vec{E}_{P+}(O(t))) + \frac{1}{c^2}(\vec{V}_{P-} \times \vec{E}_{P-}(O(t)))$$

but,

$$\vec{E}_{P+}(O(t)) = \vec{E}_{P-}(O(t)) = \frac{\vec{E}_{ph}(O(t))}{2}$$

then,

$$\vec{B}_{ph}(O(t)) = \frac{1}{c^2} \left( (\vec{V}_{P+} + \vec{V}_{P-}) \times \frac{\vec{E}_{ph}(O(t))}{2} \right) = \frac{1}{c^2} \left( (2c \hat{z}) \times \frac{\vec{E}_{ph}(O(t))}{2} \right) = \frac{1}{c} \left( -8 \frac{KQ}{r^2} \right) \left( \hat{z} \times \overrightarrow{vers}((P_+(t)) - O(t)) \right)$$

$$\vec{B}_{ph}(O(t)) = \frac{1}{c} \left( 8 \frac{KQ}{r^2} \right) \left( \hat{z} \times \overrightarrow{vers}((P_-(t)) - O(t)) \right) = \frac{1}{c} \hat{z} \times \vec{E}_{ph}(O(t)) \quad (15)$$

In magnitude

$$\|\vec{B}_{ph}(O(t))\| = \frac{1}{c} \|\vec{E}_{ph}(O(t))\| = \frac{1}{c} \left( 4\pi \sqrt{\frac{h}{\epsilon_0 c^3}} \right) v^2 = \frac{Kost}{c} * v^2$$

$$\|\vec{E}_{ph}(O(t))\| = c \|\vec{B}_{ph}(O(t))\|$$

This relation remembers a typical result of the electromagnetic wave in Maxwell's theory, where  $\|\vec{E}(P)\| = c \|\vec{B}(P)\|$ . Moreover, in Maxwell's electromagnetic wave, electric field and magnetic field are together orthogonal between them and orthogonal to the wave direction of propagation (which

we identified, in example here, with our  $z$ -direction), and the magnetic field is in the anticlockwise position respecting electric field direction for an observer along  $z$ -axis who sees arriving the e.m.wave; these are all features of  $\vec{E}_{ph}(O(t))$  and  $\vec{B}_{ph}(O(t))$  in our model !

Note: ever in this work where we speak about ‘magnetic field’ or ‘magnetic vector’, we are intending the ‘magnetic induction field’ or the ‘induction vector  $\vec{B}$ ’, respectively!

$\vec{B}_{ph}(O(t))$  is constant in magnitude, in every time it is orthogonal to  $z$  axis and to  $\vec{E}_{ph}(O(t))$ , and an observer along  $z$  axis who sees arriving the photon, sees  $\vec{B}_{ph}(O(t))$  in the anticlockwise position respecting  $\vec{E}_{ph}(O(t))$  direction. Its point of application,  $O(t)$ , is ever on  $z$  axis and it translates with a constant speed  $c$ , ever with the same velocity direction, the positive  $z$ -direction.  $\vec{B}_{ph}(O(t))$  direction rotates with an angular speed  $\omega = 2\pi\nu$ , and with a direction of rotation in accord with the spin of the photon, which defines the screwing direction of the circular polarization of the e.m. wave impulse associated to the photon; screwing direction coinciding with that of the two photon sub-particles of the same photon. Respecting  $\vec{E}_{ph}(O(t))$ ,  $\vec{B}_{ph}(O(t))$  is out of phase with  $\Delta\varphi = \frac{\pi}{2}$ .

If the components of  $\vec{E}_{ph}(O(t))$ , are, in the precedent frame and case analysed :

$$\begin{cases} E_{ph}(O(t))_x = -8 \frac{KQ}{r^2} \cos(\omega t) \\ E_{ph}(O(t))_y = -8 \frac{KQ}{r^2} \sin(\omega t) \\ E_{ph}(O(t))_z = 0 \end{cases}$$

the components of  $\vec{B}_{ph}(O(t))$ , are

$$\begin{cases} B_{ph}(O(t))_x = -8 \frac{KQ}{cr^2} \cos\left(\omega t + \frac{\pi}{2}\right) = +8 \frac{KQ}{cr^2} \sin(\omega t) \\ B_{ph}(O(t))_y = -8 \frac{KQ}{cr^2} \sin\left(\omega t + \frac{\pi}{2}\right) = -8 \frac{KQ}{cr^2} \cos(\omega t) \\ B_{ph}(O(t))_z = 0 \end{cases}$$

In the following graph, we show a three-dimensional representation of the projections of the electric vector  $\vec{E}_{ph}(O(t))$ , on the  $[x,z]$  plain, that is, its component in  $x$ -direction,  $E_x$ , (since  $E_z$  is null), and of the magnetic vector  $\vec{B}_{ph}(O(t))$ , on the  $[y,z]$  plain, that is, its component in  $y$ -direction,  $B_y$ , (since  $B_z$  is null):

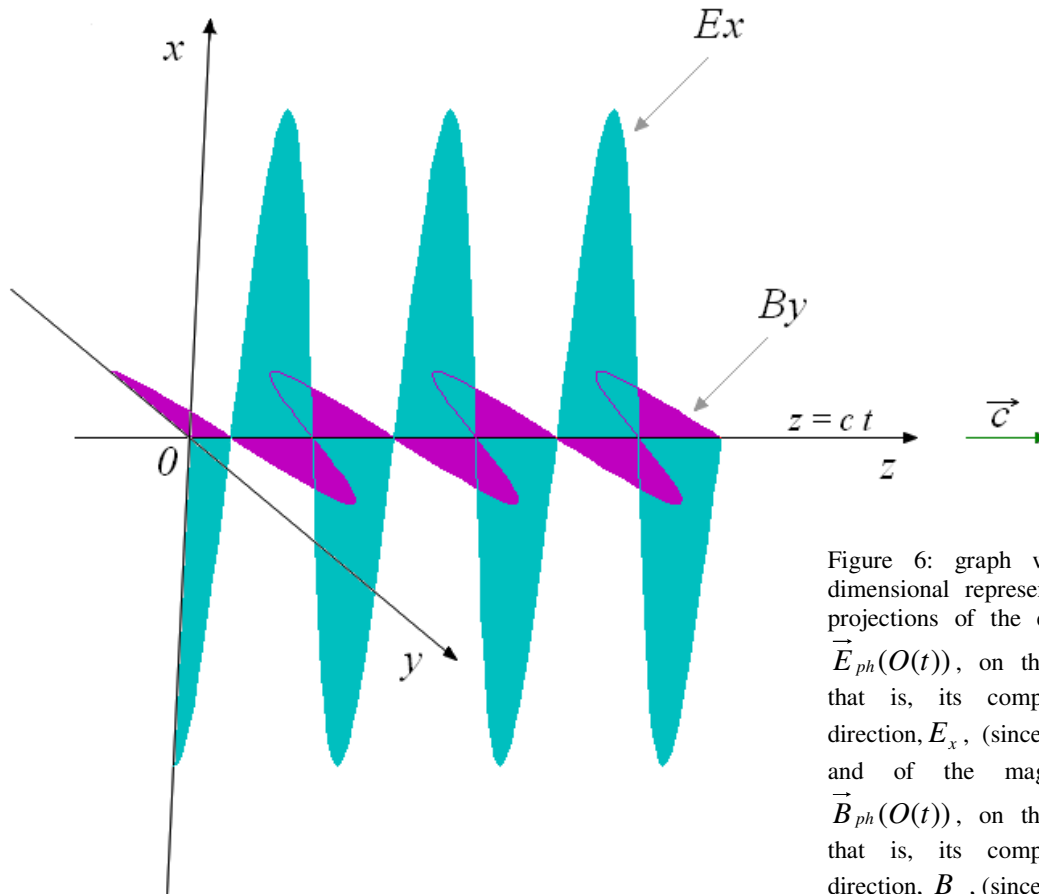


Figure 6: graph with a three-dimensional representation of the projections of the electric vector  $\vec{E}_{ph}(O(t))$ , on the  $[x,z]$  plain, that is, its component in  $x$ -direction,  $E_x$ , (since  $E_z$  is null), and of the magnetic vector  $\vec{B}_{ph}(O(t))$ , on the  $[y,z]$  plain, that is, its component in  $y$ -direction,  $B_y$ , (since  $B_z$  is null).

It is great in this representation the similitude with the electric and magnetic field of a monochromatic plane electromagnetic wave in Maxwell's theory.

## Conclusions

This didactic presentation of my photon model will be obviously perfected by other works about it with a more complex mathematics and a more profound discussion about relativity and so on, but it is its disarming simplicity that gives us a great trust about its true relevancy with the real nature of the photon!

Many other characteristics and properties of the electromagnetic waves and of their photons can find explanations to the light of this “*Caroppo’s Photon Model*”. Not only, it opens us a road to explain the microscopic structure of the elementary particles and to progress in physical and technical development. It lights us about profound aspects of the quantum physics and the superluminal speed in nature, and perhaps it will allow solving some epistemology problems opened again.

In the previous exposition in no point I polemized about quantum physics ideas and developments, but it is evident that this new my model can implicate some revision about them!

This is only a little theory, though gigantic in the prospectives which it could open, if it will be verified. In the scientific method, we are here, only to the step of the hypotheses of a possible theoretical model of our investigated object, the photon, after the observations about a group of features of it; properties which can have a complete explanation proper in our photon dynamic structure. A little prediction from our architectural conjecture, is the linear relationship between photon energy and its frequency, which is verified in the real photon, by  $E_{ph} = h\nu$ ; this equation gives us, in a second step, the opportunity to find the correct values of our constant parameters (the internal speeds and the dielectric constant of the internal electric interactions), arriving to an exact explanation of the analyzed photon features.

I am sure that with your interest and attention, we will can deduce soon other predictions of this heuristic model of explanation, in order to set up experiments to test if it is a good theoretical base for an our further broadening in the knowledge of the loved and beautiful Nature which surrounds us and of which we are, with our body and thought, indivisible parts!

## Bibliography

For the particular nature of this work, I am sure you excuse me if I indicate here no books or articles. This work did not born in a precise restricted current of physics studies, it is debtor to every men who has preceded me in the speculations about nature, its reality and its ideas, and its wonderful mysterious mathematic order!

21.3.2005 (proofreading and added until 2008)

Oreste Caroppo





## The Photon Double-Helicoidal Model

*by studies and researches of Oreste Caroppo*

An Heuristic Model for the Photon to Explain all its Properties and its Equation  $E=h\nu$  :

The Electric Dipolar Double-Helicoidal Dynamic Model of the Photon.

The Interpretation of the Physics Origin of the Planck Constant

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