New York Science Journal

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MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Planck'S Constant: Its Fundamental Role In The Universe

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Abstract: Using the Principles of Quantum Mechanics and Relativity our calculations show that Planck's constant (h) has an *equivalent-mass* corresponding to 10^{-48} grams. This non-zero h value, although infinitesimal, can acquire a determining role in many physical phenomena: in the atomic and subatomic physics, in Quantum Mechanics, as well as in Astrophysics. Thus, the h *equivalent-mass* can help explain the intimate physical mechanism of known phenomena such as the photoelectric effect or the Compton effect, or less known and less investigated phenomena such as the decrease in the temperature of the Black Holes, or the negative value of their specific heat. In addition, the non-zero h value added to the radiation pressure exerted by electromagnetic radiation, could give a concrete, physical consistency to the *Wave Function Collapse* of a quantum object and contribute to the description of this phenomenon, as well as solving one of the most intricate and intriguing puzzles of the subatomic Physics and Quantum Mechanics: the *Measurement Paradox*. Furthermore, a non-zero h value may represent a possible solution to the problem of *divergences,* which constantly emerge from the *Perturbation Calculus.* Lastly, the infinitesimal value of h could help us understand, and try to solve, one of the major scientific problems still unsolved: the nature of Dark Energy.
[Antonio PUCCINI. **Planck'S Constant: Its Fundamental Role In The Universe.** *N Y Sci J* 2020;13(8):9-39]. ISSN 1554-0200 (print); ISSN 2375-723X (online). http://www.sciencepub.net/newyork. 2. doi:10.7537/marsnys130820.02.

Keywords: Planck's Constant; Fundamental Role; Universe

1. Introduction

As it is known, the dispute on the nature of light, particle or wave, dates back to Pythagorean, that is 2500 years ago. Along with Pythagoras School the common light is made of corpuscles. So, this idea has been valid for more than 2000 years, since Descartes, Hooke, Boyle and Newton (1672) times, who imagined luminous rays made of globules, that is particles of different sizes propagating with successive impulses stimulating the optical nerve. Afterwards, at the beginning of the 19th century Young famous experiment showed a like-wave nature of light. Then, around 1860 Kirchhoff studying the radiation coming

from the sun, understood that the ratio between the energy emitted by a heated body as electromagnetic waves and the absorbed energy, was a *function*, *P*:

$P(\lambda, T)$ (1),

where λ indicate the wavelength of the emitted electromagnetic radiation (EMR) and T is the absolute temperature.

It is important to keep in mind that this *function* is not dependent on the material nature but only on λ and T. Moreover, if a body able to absorb radiation of each wavelength is named *black body*, then its electromagnetic (EM) emission (when heated) coincides with an universal *function*, *P*, as shown by Eq. (1).

As we all know, one of the first attempts to specify the *P function* was made by Paschen (1889), who obtained experimentally the law (today known as Paschen law) illustrated by Eq. (2):

$P = \beta\lambda^{-\gamma} e^{-A/\Lambda T}$ (2),

where γ is a constant, while β and α are factors to be determined.

Hence Wien considered the density of the energy, instead of the total energy, and studied a cavity of the internal reflecting walls, as *black body* model, according to which the spectra emissions of the solids can be explained only with molecular vibrations:

$P = \beta \lambda^{-5} e^{-\alpha/\lambda T}$ (3).

The Eq. (3), known as Wien's law (Wien 1897), fitted with the experimental data and with Paschen law, as shown by Eq. (2), on the condition that was considered γ = 5. Finally, "at the beginning of 1900, lord Rayleigh analyzed the *black body radiation*, considering it as a group of stationary waves, and determining the number of its vibration ways"(La Teana).

In this way, Rayleigh obtained the following *function*:

$P(\nu, T) \alpha \nu^2 T$ (4),

where T is the temperature and *ν* the frequency. Rayleigh noted that when the frequency (*ν*) increased, a concentration of energy was obtained, thus he added to the *function* (*P*), illustrated by Eq. (4), the *dimming factor* $e^{-\beta\nu/T}$ for the high frequencies, obtaining the following formula:

$P(\nu, T) \alpha \nu^2 T e^{\beta\nu/T}$ (5),

where β is a factor to be determined. The Eq. (5) is known today as Rayleigh' Law (Rayleigh,1887).

However, some experiments performed by Lummer and Pringsheim (Lummer,1900), or by Rubens and Kurlbaum (Rubens,1900), suggested the inadequacy and the invalidity of the Wien's law.

1.1 The Planck'S Law

Therefore, the problem remained unsolved until the end of the 1900 when, as Penrose reminds us, "to suppress the anomalous behavior of the *black body radiation* in presence of high frequencies, Planck proposed that the EM oscillations come only like *quanta* of EM radiation"(Penrose,1989). As it is known, indeed, Planck communicated his conclusions during the Meeting of the German Physical Society, in Berlin, on December 14, 1900 (Planck,1900) (Planck,1901).

So, Max Planck synthesized his ideas in the following formula (later called the Planck's Law):

$$P = \frac{8\pi h\nu^3}{c^3} \cdot \frac{1}{e^{\frac{h\nu}{kT}-1}} \quad (6),$$

where *h* is the Planck's constant, *k* is the Boltzmann constant (as Planck called it), *c* is the light speed in vacuum, *υ* is the oscillating frequency of the involved electromagnetic radiation (EMR), $e^{\frac{h\nu}{kT}-1}$ is the modified Rayleigh *dimming factor* and *P* is the *function*, which is not dependent on the material nature but only on the EM wavelength (λ) and the absolute temperature (T).

1.2 The Planck'S Constant (*H*)

As we all know, in order to obtain this formula, Planck was forced to admit that the energy of the oscillators (i.e., the EM source: an electron, for instance) can coincide only with *discrete* values, that is discrete quantities defined as *energy quanta*, EMR's *quanta*. In this respect, Planck stated: "Considering that — and this is the crucial point of the whole calculus — the *energy* (ε), oscillator energy, is made of a defined number of finished and same parts, we can use to this purpose the natural constant $h = 6.55 \cdot 10^{-27}$[erg·sec]. If this constant is multiplied for the normal oscillators' oscillating frequency, (*υ*), we get the Energieelement (the *element of energy)*, ε, expressed in erg·sec"(Planck,1900).

Planck revealed, indeed, that he had been able to infer his formula relating to the distribution mode of the EMR emitted by the *black body* only by admitting that the EM source emits or absorbs energy only in the form of *packets of energy* (ε) proportional to their oscillation frequency. To this purpose, in fact, Planck enunciated: "The essential point is to consider *Energy*, at each frequency, as made of a certain number of Energieelements, all equal to each other, indistinguishable and indivisible" (Planck,1901). Each of them represents an *elementary action quantum* corresponding to the Planck's contant: *h*. Thus, Planck "was forced to divide the *Energy* (ε) into blocks of units (*packets*) $h \cdot \upsilon$ " (Kumar), as shown in the following formula, now known as Planck's postulate:

$\varepsilon = h\upsilon$ (7),

where the *quantum h* expresses an energy value, while *υ* gives the frequency, i.e. the number of oscillations made by Planck's *grain* (*h*) in a second. In

this way, "Planck got to the conclusion that the light's energy, ε, and thus of all other forms of EMR, could be emitted or absorbed by matter only in fragments: *energy's quanta*, or *energy packets*, packaged in various formats"(Kumar).

In brief, Planck did not confute the *energetic continuum*, on which Boltzmann had worked, he only divided it in *elementary cells* with a $h\,v$ size. Thus, for the first time it was clear that the *energy* of the EMR was not emitted with an uninterrupted flux, but through the flow of many *packets of energy* extremely close one to the other, but well distinct one from the other, and "divided in *elementary cells* with a size of $h \cdot v$"(Hermann). Hence, "a photoelectric cell manages to count them, one by one" (Feynman,1989).

1.3 The Light Quantum (Or Photon)

Einstein said: "A monochromatic radiation with a reduced density (within the validity limits of Wien's formula on radiation) behaves, as far Thermodynamics is concerned, as if it was made of *quanta of energy*, independent one from the other, with a size:

$(R/N)\ \beta \cdot v$ [$= h\ v$]"(Einstein,1907). Thus, from a different way, Einstein got to Planck's same conclusions: see Eq. (7), which is also known as Planck-Einstein equation (Puccini, 2008). Furthermore, in keeping with Einstein, the energetic value (E) of an EMR *quantum*, or photon, corresponds to:

$$E = (\frac{R}{N})\beta \cdot v \qquad (8),$$

where, as Einstein specifies, R is the absolute constant of the gas equation, N is the number of molecules contained in a gram-molecule, β is the exponential coefficient of Wien and Planck (corresponding to $4.866 \cdot 10^{-11}$) and v is the frequency of light (Einstein,1907).

In other words, "Einstein was thinking of the relation between his idea of *light quanta* and Planck's previous researches. He realized that the idea of *light quanta* had already been used by Planck and that in Planck's theory also the energy of all atoms (within the cavity) was *quantized*. If each atoms vibrates a certain fixed number of times every second — that is with a fixed frequency — the energy of the vibrating atom could come only in entire multiples of Planck's constant (h), times the frequency (v)"(Farmelo), just as Eq. (7) shows. "Thus the minimum energy (E) that a vibrating atom can have is $E = h\,v$; besides the atom could have energy values $2hv$, $3hv$, $4hv$ etc. Einstein was saying that the equation $\varepsilon = h\,v$ can be applied to any kind of atom in a solid. Assuming that the *vibrating energy of every atom is quantized*, Einstein theorized that the atom mean energy in a solid, decreases slowly as the temperature decreases, till zero. His predictions were confirmed by the measures carried out 25 years earlier. In September 1909 Planck invited Einstein to talk to the physics congress in Salzburg where Einstein presented a new research on the nature of light, maintaining that, as an electron, every *quantum of radiation* propagates in a specific direction: technically the *quantum* has a *momentum*. For the first time Einstein suggested in public that the radiation is made of particles"(Farmelo), that is to say *corpuscles*, in full accordance with Newton (Newton,1664) (Newton,1670). Farmelo adds: "Einstein also affirmed that since the Theory of Relativity had made superfluous the *ether*, it was not necessary any more to imagine the radiation as existing in something, but as something existing independently, just as matter. In that occasion Planck showed his reluctance to suppose that luminous waves were composed of particles, but he accepted the idea that, when the radiation interacts with the matter, the energy of the radiation goes, as discrete quanta to the atoms making that matter"(Farmelo).

Well, taking inspiration from Einstein's intuitions, de Broglie proposed a similar process, in reverse, to be applied to particles. Therefore, without experimental data, de Broglie suggested to give particles the same property as waves (de Broglie,1923). He gave each particle a its own wave length depending only on the *momentum* of the particle itself (Puccini,2005,b). In reference to this context, any particle with a *momentum*

($\boldsymbol{P}$) "seems to be something periodic, as a wave, with an universal relation between the *wavelength* of the particle, indicated by λ, and modulus $\boldsymbol{P}$ of its *momentum*" (Penrose,2004). Thus we have the formula:

$$\lambda = h\,\boldsymbol{p}^{-1} = \frac{2\pi\,h}{\boldsymbol{p}} \qquad (9),$$

or more simply:

$$\lambda = \frac{h}{\boldsymbol{p}} \qquad (10),$$

where h is the Planck's constant. This is the value of the wavelength (λ), according to de Broglie formula (Eq.10), which indicates the nature, also wave-like, of all material particles.

The so-called *momentum* ($\boldsymbol{P}$), as known, was introduced in order to calculate how much a body in motion *weighs*. Newton, indeed, was the first one to fully deal with this context. To this purpose, in fact, in the first pages of "Philosophiae Naturalis Principia Mathematica" (1687), Newton also reported the following definition: "*Quantitas motus est mensura ejusdem orta ex Velocitate et quantitate Materiæ conjunctim*", that is, the *momentum* is a measure in itself, since it depends on both the speed and the quantity of matter"(Newton,1687).

Well, the sole mass or speed does not therefore describe what happens in real cases. Newton then referred to what we call *momentum*: something that

originates jointly from the speed and quantity of matter. Thus, Newton defined this vector magnitude in the following way:

$$\vec{p} = m \cdot \vec{v} \qquad (11).$$

Hence, Eq. (11) describes the *quantity of motion* (***P***) of a body having a mass *m* and moving at a speed **V.** In other words, the *momentum* of a particle is the product of two quantities: the particle's mass and its speed. *Momentum* is a *vector quantity*: it has both magnitude and direction, and direction and line coincide with those of **V.** In fact, the vector ***P*** has the same direction and the same line of the speed **V** and its module is the mass times the speed module. Thus, we find it of particular value, as well as rich in meaning and potential, to point out that the momentum module of an object is directly proportional to the mass of the object, and to its speed too (Puccini,2020,a). In sum, the unit of ***P*** is the product of the units of mass and velocity.

So, in Newtonian Mechanics ***P*** is represented by the formula $\vec{p} = m \cdot \vec{v}$. On the contrary, in Quantum Mechanics (Hongbao Ma), along with the *de Broglie formula* (as shown by Eq.10), ***P*** is described by the formula:

$$\boldsymbol{P} = \frac{h}{\lambda} \qquad (12),$$

where *h* is the Planck's constant and λ is the wavelength of the considered *quantum object.*

Therefore, the old question, wave or particle, can be solved with the Quantum Mechanics (*QM*) leaving to the particles – rather, to *quantum object* (QO) - a *wave function* (WF) of their own, indicated with Ψ(*x*), or simply Ψ. It describes correctly both their wave and particle character (Puccini,2011,b).

Thus, the WF is a *mathematical function* which depends on time (*t*) and on the position (*x*) of the particle it is referred to. "The function Ψ(x) is usually called *the wave function* because it often has the form of a complex wave in its variables. The WF for a single particle *is* a 'field', in the sense that it is a function of position: Ψ(x) "(Feynman,1965,b).

Feynman adds: "In Newtonian physics the ***P*** value is given by: ***P*** = *m***v** (where **V** is the speed). But since ***P*** is related to the *wave number* (***K***), there exists in nature still another way to measure the ***P*** of a particle –photon or otherwise- which has no classical analog, because it uses the formula:

$$\boldsymbol{P} = \hbar \boldsymbol{K} \qquad (13),$$

where $\hbar$ is the *rationalized* Planck's constant ($\hbar = h/2\pi$) and ***K*** indicates the quantity of waves carried with the considered *momentum* (***P***)" (Feynman, 1965a). This parameter (***K***) is similar to the frequency. Feynman goes on: "Now in Quantum Mechanics (*QM*) it turns out that ***P*** is a different thing—it is no longer *m*v. It is hard to define exactly what is meant by the velocity of a particle, but ***P*** still exists. In spite of the differences, the law of conservation of ***P*** holds also in *QM*"(Feynman,1965,a). Moreover, Feynman makes a fundamental clarification: "In *QM* the difference is that when the particles are represented as particles, ***P*** is still *m*v, but when the particles are represented as waves, ***P*** is measured by the number of waves per centimeter (equation 13): the greater this number of waves, the greater ***P***"(Feynman,1965,a).

Hence, the Eq. (13) shows the deep bond in a wave between ***P*** and the *wave number* (***K***): these values are directly proportional, as to say that the greater ***K***, the greater ***P***.

1.4 The *Momentum* Of Photon

To this purpose, Feynman states: "That light carries energy we already know. We now understand that it also carries *momentum,* and further, that the *momentum* carried is always 1/*c* times the energy (where *c* is the light speed in the *vacuum*).

The energy (*E*) of a light-particle is *h* (the Planck's constant) times the frequency (*v*):

$$E = h\,v \qquad (14).$$

We now appreciate that light also carries a *momentum* equal to the energy divided by *c*, so it is also true that these effective particles, these *photons*, carry a *momentum* (***P***):

$$\boldsymbol{P} = \frac{E}{c} = \frac{hv}{c} \qquad (15).$$

The direction of the *momentum* is, of course, the direction of propagation of the light. So, to put it in the vector form:

$$E = h\,v;\ \boldsymbol{P} = \frac{hv}{c} \qquad (16).$$

We also know, of course, that the energy and the *momentum* of a particle should form a *four-vector.*

Therefore it is a good thing that the latter equation has the same constant (*h*) in both cases; it means that the Quantum Theory and the theory of Relativity are mutually consistent"(Feynman,1965,a). The latter, in our opinion, is an important clarification made by Feynman. At this regard Fermi writes: "The photon too, as other particles, is a corpuscle, a *light's quantum* and has a its own *momentum* (***P***) through which transfers all its energy to the hit particle"(Fermi,1926).

Moreover, it seems useful to make a clarification: apparently the second of the Eq. (15), ***P***=*hv*/*c*, is in contrast with the *de Broglie formula* (***P***=*h*/λ), as it is shown by Eq. (12).

However, from the formula of electromagnetic waves $c = v\,\lambda$ (where *c* is the light speed in vacuum and *v* is the frequency) we get that the rate *v*/*c* is the same as 1/λ, thus the second of the equations (15) becomes: ***P***=*h*/λ, just as Eq. (12).

1.5 Einstein's Mass-Energy Equivalence Principle

Thus, electromagnetic radiation's *quanta* are elementary particles, which Lewis in 1926 defined as photons. On many occasions, indeed, they behave like real particles. In this respect, Weinberg says: "We have to renounce to the classical idea of radiation in terms of electromagnetic waves we have used so far, and use the more modern *quantum* vision, according to which the radiation is made of particles known as photons. A normal luminous wave has a high number of photons which travel together"(Weinberg,1977). Feynman adds: "I want to emphasize that light comes in this form: particles. It is very important to know that light behaves like particles: light is made of particles" (Feynman,1985). Thus, *light's quanta*, or photons, they are also subject to Einstein's *Mass-Energy Equivalence Principle* (MEEP) (Einstein, 1905, b):

$$E = m\,c^2 \qquad (17),$$

where c is the light speed in the *vacuum*, equal to 299792.458(±0.4) (Achenbach). Consequently, the *equivalent-mass* (m) of h must correspond to:

$$m = \frac{E}{c^2} \qquad (18).$$

That's how Einstein commented upon his MEEP: "The value of the considered mass refers to the value of an *inertial mass"*(Einstein,1913).

2. Discussion

2.1 Planck Constant's Equivalent-Mass

Thus, in full compliance with MEEP, to an "energetic" particle, carrying energy, forces etc., should correspond a *mass equivalent* to the energy carried, divided c^2 (Puccini,2005,b). In fact, since there is no zero energy for the *Zero Point Energy*, just as Chandrasekhar (1998) reminds us, there should not be any particle carrying energy, with a zero mass (Puccini, 2011,d). Hence, it may be incongruous to say that a particle with energy does not have an *equivalent mass* (Puccini,2011,a), it does not "conceal", at least, a mass. It is just the MEEP equation to show that this particle has a mass, otherwise the equation would be null, the result would be zero.

At this regard, Zeilinger writes: "What is the deep meaning of a relationship like $E = mc^2$? What is *hidden* behind these symbols? For many physicists the equation $E=mc^2$ is to say that energy and mass are the same thing, two faces of the same medal; there is therefore *equivalence between mass and energy*: energy is just another form of mass, and vice versa, mass is another form of energy" (Zeilinger). Thus, there should not be real particles, having any energy, with a zero mass. If there are, they should "subtend" a tiny mass, a *Zero Point Mass* (Puccini,2011,d).

In this respect, Feynman says: "Energy and mass differ just for a c^2 factor, which is merely a question of units, so we can say energy *is* the mass. Instead of having to write the c^2, we put $E=m$. In the Einstein Relativity Theory, anything which has energy has mass—mass in the sense that it is attracted gravitationally. Even light, which has en energy, has a *mass*" (Feynman,1965a). To this purpose, indeed, Einstein writes to Conrad Habicht: "The Principle of Relativity, in association with Maxwell fundamental equations, requires that the mass is a direct measure of the energy contained in a body; ***The Light Carries A Mass***" (Galison). Thus, according to Einstein there should be a mass associated to the photon, as to say the Planck's *grain*, the light quantum. Feynman adds: "When a light beam, which has energy in it, comes past the sun there is an attraction on it by the sun. Thus the light does not go straight, but is deflected" (Feynman,1965,a). In this respect, it is interesting what Eddington communicated in 1919: "The simplest interpretation of the deflection of the light beam is the one that considers it as an effect of the weight of light"(Eddington). At the dinner of that meeting, Eddington read out some verses he had composed; we will quote the last quatrain: "We will compare the measures taken, one thing at least is certain, **Light Has Weight**. One thing is certain and the rest debate. Light rays, when near the Sun, do not go straight"(Eddington).

2.2 *Push Effect* Exerted By Planck'S Quanta

Planck's quanta, indeed, exert a compressive action on the hit object: the so-called *Radiation Pressure*. Namely, it was Iohanne Keplero in 1619 who first proposed the concept of *Radiation Pressure* to explain the observation that a tail of a comet always points away from the Sun (Keplero).

As it is known, in fact, Lord Eddington clearly points out the *mechanical effect* exerted by Planck *grains*, in complete agreement with our conviction that light carries with it also a mass (the *dynamic-mass* of Planck's *quanta*) (Puccini,2017,b). At this regard, Peter Galison writes:: "Planck stated that also the transfer of heat adds a mass"(Galison). Well, what is heat made of? It is made of electro-magnetic radiations (EMR_s), that is Planck's *quanta*. Hence, in line with Planck, "a transfer of radiation from A to B will cause an increase in the mass of B. It seemed that a hot pot was heavier than a cold one, although exactly the same size. It was a new idea: in Newtonian physics there was nothing suggesting a variation in mass as a consequence of the energy"(Galison).

In sum, to a very small energy, as in the case of the h value, corresponds a very small mass, however ≠ 0. The h value, as known, is equal to $6.626 \cdot 10^{-27}$[erg·s].

In short, it is crucial keeping in mind that the value of the *density of mass energy* carried out by h,

i.e. by the Planck's *grain*, although infinitesimal (and without considering its number of oscillations per second) will always be ≠ 0! And this is incontrovertible. Barrow adds: "The non-null value of the Planck constant (*h*) is important for the stability of matter. In the impacts between the atoms and the electromagnetic radiations, the value of *h* is large enough to take a rather strong '*stroke*' to push the electrons to the immediately higher permissible level. *h* identifies with Planck 'grain, with the quantum of light, that is with a photon. And yet, a massless photon is capable of inferring such a *stroke*, besides giving "stability to matter!"(Barrow). This makes us think about what Hawking writes:" When an electron moves from an orbit to one closer to the nucleus, it will emit a real photon, observed as visible light, so if a (real) photon collides with an atom, it will move an electron on a more external orbit. This movement uses the energy of the photon" (Hawking,1988). Well, why cannot we suppose that at the bottom if this phenomenon there is a strictly mechanic action of the photon, as to say the *Planck's grain*, which with its energy-mass would raise the kinetic energy of the orbiting electron from which it was absorbed? This goes along with the fact that just after 10^{-8} sec the electron get free from the mass-energy of the photon and goes back to its previous orbit, the one with a minor waste of energy. Hence, the excitation and the un-excitation of the electron and therefore of the atom, should not depend on a merely energetic effect, but also on a specifically mechanic effect, as a consequence of the probable dynamic-mass carried by the Planck quantum.

Hence, it could be a *push effect*, that's a mechanical effect, exerted by Planck's *quanta*.

At this regard, we cannot exclude that the Chlorophyll Photosynthesis represents a consequence of the mechanic effect (more than just energetic) induced by photons. It is common knowledge that the first process of the photosynthesis occurs in leaves pigments, where photons react with the water molecules. The most important think to underline is that the photons take two electrons from the molecules of the water: "water photolysis"; the freed electrons will be used in chloroplasts to induce some biochemical processes, useful to the surviving of the plant (Puccini,2012,b).

As it happens in other circumstances, in the leaves too the optic photons are able to produce an effect able to remove electrons. It is thought that it is just a phenomenon induced by the energy of the solar light, to free the electrons of the water contained in the pigments of the leaves. In our opinion, however, it could be a mass effect, i.e. a *pushing effect* induced by light quanta, to move away the electrons. It could be objected that photons, as corpuscles, are very small compared to electrons, so they cannot move them just with a "push" effect, given by their own mass. But yet we need to consider that with a visible light ray carries 100.000 billions of light quanta per second. That is, we are talking about a large number of Planck grains which for each ray bombe every second water molecules in the pigments of the leaves. Considering these quantities we cannot exclude a mass effect induced by light quanta, that is a kind of mechanic effect. We should keep in mind the Superposition Principle of the photons. Well, more than an unspecified energetic effect given by the energy of photons, it may be the "push" given by a huge quantity of Planck's grains to "pull away electrons", stuffed together in an extremely small space. In sum, it is a strictly mechanic phenomenon, in our opinion, produced by the *dynamic-mass*, the *equivalent mass*, carried out by the photons, rather than a phenomenon produced only by the energy of the light quanta (Puccini,2012,b).

In reference to this context, it could be helpful the legendary "Lectures with four hands" that Penrose had with Hawking to the students of Isaac Newton Institute for Mathematical Sciences of Cambridge University in 1994. Penrose states: "The photon (P) can be a combination

$$P = z|A\rangle + w|B\rangle \qquad (19),$$

where z and w are complex numbers. The state of P is exactly the complex superimposition.

We can consider that the photon actives the movement of a thick mass that if it is in a delicate situation of unstable balance it can fall down only after a push of the photon (Penrose,1996). Hence, in these cases the intimate light mechanism happens through a "push effect" on electrons. This *push effect* can be interpreted as a real mechanic effect, rather than energetic.

To this purpose Feynman specifies: "When light is shining on a charge and it is oscillating in response to that charge, there is a driving *Force* in the direction of the light beam. This *Force* is called *Radiation Pressure* or *Light Pressure* (*F*). Let us determine how strong the *Radiation Pressure* is. It is clear that the light's force (*F*) on a particle, in a magnetic field (*B*), is given by:

$$F = q\boldsymbol{vb} \qquad (20),$$

and it is at right angles both to the field and to velocity (**V**); q is the charge. Since everything is oscillating, it is the time average of this, $\langle F \rangle$. We know that the strength of the magnetic field is the same as the strength of the electric field (***E)*** divided by c (the velocity of light in vacuum), so we need to find the average of the electric field, times the velocity, times the charge, times $1/c$:

$$F = q\frac{\boldsymbol{vE}}{c} \qquad (21).$$

But the charge q times the field E is the electric force on a charge, and the force on the charge times the velocity is the work dW/dt being done on the charge! Therefore, the force, the *Push Momentum*, that is delivered per second by the light, is equal to $1/c$ times the *energy absorbed* from the light per second! That is a general rule, since we did not say how strong the oscillator was, or whether some of the charges cancel out.

In any circumstance where light is being absorbed, there is a Pressure. The *momentum* that the light delivers is always equal to the energy that is absorbed, divided by c"(Feynman,1965a):

$$F = \frac{\frac{dW}{dt}}{c} \qquad (22).$$

The energetic value of h, just as any other electromagnetic radiation (EMR) *quantum*, is shown by Eq. (14), where the value of the frequency (ν) is expressed in cycle per second [c/s].

If we comply with the *fundamental state* of the energy (E) given in the MEEP, we begin to consider the minimum possible oscillation of h and thus of a photon. In the case of a photon at the *inertial state,* that is when it interacts with another particle, so it stops running, at least for that infinitesimal moment it will probably oscillate much less. Namely, we will never be able to know with *accuracy* how much an interacting photon can oscillate, that is what the number of oscillations [c⁄s] in that moment could be. Let's indicate this unknown value with 10^n[c⁄s],which is an *uncertainty factor* (Puccini,2020,c). The photon stops running when it hits another particle, as it happens during a *measurement*. It will not oscillate as when it was running, though it never stops running or oscillating completely: it is the Heisenberg Uncertainty Principle to deny it, since in this case we would know simultaneously two *complementary parameters*, as the *position* and the *momentum* of the particle (Heisenberg,1927) (Puccini,2005,a).

Thus, also in the inertial state the oscillating frequency (ν) of the photon can never be 0, but always ≥1⁄s, that is ≥ one oscillation per second (if not even ½ oscillation per s., or a fraction of its).

Hence, let's to consider the energy of the photon in its *inertial state*, indicated with E_o. In this respect we indicate the frequency (ν) of Eq. (14) with 10^n [c/s].If value of n was 0, we would have:

$$E_o = h\ \nu = h \cdot 10^0 [\text{c/s}] \qquad (23).$$

Since $10^0 = 1$, that is, a single oscillation per second, the E_o will correspond precisely to the value of the Planck constant:

$$E_o = h\ [1/\text{s}] \qquad (24),$$

that is:

$$E_o = 6.626 \cdot 10^{-27} [\text{erg} \cdot \text{s}] \cdot [1/\text{s}] \qquad (25),$$

$$E_o = 6.626 \cdot 10^{-27} [\text{erg}] \qquad (26).$$

This should be the Energy value of a photon at an inertial state. We may say its *minimal energy value*, or *Zero Point Energy*. One may reply that it is an excessively minimized value, but in any case it is hypothetically possible and it is allowed by the Quantum Mechanics (*QM*).

As the *erg* value is expressed in [g·cm/s²·cm], that is in [g·cm²⁄s²], we have:

$$E_o = 6.626 \cdot 10^{-27} \left[\frac{\text{g} \cdot \text{cm}^2}{s^2}\right] \qquad (27).$$

Well, let's try to calculate its mass (m), which we can clearly define as the *inertial mass*, the so-called *rest-mass* (m_o) of this Planck's quantum. Thus, we insert the value of E, resulting from Eq. (27), into equation 18 ($m=E/c^2$):

$$m_o = \frac{E_o}{c^2} = \frac{6.626 \cdot 10^{-27} [\text{g} \cdot \frac{\text{cm}^2}{s^2}]}{(2.9979 \cdot 10^{10})^2 [\frac{cm}{s}]^2} \qquad (28).$$

Now, let us calculate this value following the *cgs* system:

$$m_o = \frac{6.626 \cdot 10^{-27}}{(2.9979)^2} \cdot 10^{-20} \cdot \frac{[\text{g} \cdot \frac{\text{cm}^2}{s^2}]}{\frac{\text{cm}^2}{s^2}} \qquad (29),$$

and we have:

$$m_o = \frac{6.626}{(2.9979)^2} \cdot 10^{-27-20} \cdot \left[\text{g} \cdot \frac{\text{cm}^2}{s^2}\right] \cdot \frac{\text{s}^2}{cm^2} \qquad (30),$$

$$m_o = \frac{6.626}{(2.9979)^2} \cdot 10^{-47}\ [\text{g}] \qquad (31),$$

i.e.:

$$m_o = 7.372 \cdot 10^{-48} [\text{g}] \qquad (32).$$

What we get is that the *minimal mass value*, or Zero Point Mass, of the Planck constant corresponds to 10^{-48+n} grams. Thus, if the value of n was 10^0, that is one oscillation per second, m_o would be 10^{-48}[g]: this value corresponds to the *inertial mass-energy*, or Zero Point Mass, of the *Planck's grain*. On the other hand, if n was 10^3 oscillation per second, as a radio wave, we would have $m_o = 10^{-45}$[g].

Of course, in all cases it is an extremely small value, but it is ≠ 0. Thus, according to *de Broglie formula* ($\boldsymbol{P} = h/\lambda$), let us to analyze the $\boldsymbol{P}$ value of photons with different wavelength. As Weinberg (1977) reminds us, the mean wave length (λ) of a photon in the optical band corresponds to $\approx 5 \cdot 10^{-5}$[cm] and its $\boldsymbol{P}$ is:

$$\boldsymbol{P} = \frac{h}{\lambda} = \frac{6.626 \cdot 10^{-27} [\text{erg} \cdot \text{s}]}{5 \cdot 10^{-5} [cm]} \qquad (33),$$

$$\boldsymbol{P} = \frac{6.626 \cdot 10^{-27} [\text{g} \cdot \frac{\text{cm}^2}{s}]}{5 \cdot 10^{-5} [cm]} \qquad (34),$$

that is:

$$\boldsymbol{P} = 1.325 \cdot 10^{-22} [\text{g} \cdot \frac{cm}{s}] \qquad (35).$$

As shown by Eq. (35), the momentum ($\boldsymbol{P}$) of a luminous photon carries out a *dynamic-mass*, a

pushing momentum bigger than the *rest mass* of 100 protons. No surprise!

To this purpose Feynman writes: "The *momentum*, as a mechanical quantity, is difficult to hide. Nevertheless, momentum *can* be *hidden*, i.e., in the electromagnetic field. This case is another effect of relativity" (Feynman1965,a). As to say that the *momentum* carries, albeit *hidden*, a dynamic-mass.

In brief, the photon, as well as its *Planck's grain* (which materially represents it), cannot be considered massless. Its mass is simply, along with Feynman: "hidden".

At this regard, Sir Roger Penrose adds: "In a conference held in Japan in 1922, Einstein said: 'If a person falls freely he will not feel his own weight'. In fact, when you are in *free fall* (like when you launch from a plane, before you open the parachute) you have the impression that the earth Gravity Interaction is *suspended*: the Earth's gravitational field seems to have *disappeared*. Where's the Gravity Interaction? Actually the Gravity Interaction has not vanished, it is *hidden*"(Penrose,2004). In these circumstances, hence, we seem to be able to see a significant behavioral analogy between the electromagnetic (EM) field and the gravitational field.

Well, it is as if in both of them something disappeared, temporarily concealed, *hidden*, during the event: 1) the dynamic-mass, transported by the *momentum* of the photon (in the EM field); 2) the Gravity Interaction (in the gravitational field).

In sum, analyzing a lot of physics phenomena, happening more or less ordinarily, it seems that sometimes the photon, rather than a particle made merely by energy, behaves like a particle incorporating a certain mass, though infinitesimal, but not always insignificant or effect less. We think, indeed, that several physic phenomena, in which the Planck's grain is involved, are not completely explainable only with the energy of the light quantum, but they make us think that the photon under its energetic "shape", hides a mass too. Again, a mass which we cannot see when the photon shows us its "wave-like aspect"; indeed according to the Complementarity Principle (Bohr, 1928) only when the Planck's quantum stops travelling as a wave it can shows its "corpuscular aspect", and in that occasion we can hope to detect the probable mass of the light quantum (maybe not directly, that is observing its effects) (Puccini,2005b).

2.3 Non-Zero Mass Value Of The Planck'S Constant: Its Applications

This non-zero value of *h*'s *equivalent-mass* can have important consequences both in Atomic and Subatomic Physics, in Astrophysics and in the General Relativity.

Moreover, in our opinion one of the most striking aftermath of the non zero value of the mass of *h*, or Planck's constant, lies in its application in the field of the Perturbation Calculus.

2.4 Removal Of *Divergences* From Perturbation Calculus

As previously reported, indeed, emerges that the quantum of light, i.e. the photon, is not completely massless since, even in its *minimum energy state*, or Zero Point Energy, or *inertial mass* (m_o), it carries a mass value which is not null, but corresponding to: $m_o = 7.372 \cdot 10^{-48}$[g], as shown in Eq. (32).

This is certainly a very small value, of no value in our macroscopic world and without the slightest meaning in our daily life. Anyway, although it is infinitesimal, it is still $\neq 0$, so it can assume, in our opinion, a its value, a its role, both in the sub-atomic world and in the mathematical formalism (Puccini, 2019,d). On the other hand, if we refer to a photon in full swing, then we have to consider its *dynamic-mass*, perfectly represented by its *momentum*, (***P***), which in the case of a visible photon corresponds to $1.325 \cdot 10^{-22}$ [g$\cdot \frac{cm}{s}$], as illustrated by Eq. (31).

Of course, we are going to replace this last value of the *Planck quantum* with the massless photon inserted in all equations of the *Perturbation Theory* and of the *Quantum Fields Theory* (QFT), including the Yang-Mills equation (Yang and Mills,1954). What do we expect?

It is clear: the disappearance of *divergences* and *infinities*.

2.4.1 Removal Of Massless Photon From Perturbation Equations

According to the Mass-Energy Equivalence Principle (MEEP), $m=E/c^2$, as shown in Eq. (14), to an "energetic" particle, carrying energy, forces etc., should correspond a *mass equivalent* to the energy carried, divided c^2. Since there is no zero energy for the *Zero Point Energy*, as Chandrasekhar (1998) reminds us, there should not be any particle carrying energy, with a zero mass.

Of course, it may be incongruous to say that a particle with energy does not have an *equivalent mass*, it does not "conceal", at least, a mass. It is Einstein's equation to show that this particle has a mass, otherwise the equation would be null, the result would be zero (Puccini,2011,a). Consequently there should not be real particles, having any energy, with a zero mass. If there are, they should "subtend" a tiny mass, a *Zero Point Mass* (Puccini, 2011,d).

Hence, to a very small energy, as in the case of the light quantum, corresponds a very small mass, however $\neq 0$. Thus, we believe that the base concept of the *gauge theories*: 'the mass *breaks* the symmetry'

is not applicable to the Planck constant. No! In brief, Planck's constant is a real value, ineradicable, represented by an *intrinsic energy-mass* value, equal to $6.626 \cdot 10^{-27}[\,erg \cdot \sec\,]$: it expresses the value of the density of energy-(*equivalent mass*) of the *Planck Quantum*, the *Planck's grain.*

Therefore, reduce this value to zero, in order to correct the *divergences* and *infinities* emerging from the equations of the *Perturbation Calculus*, would totally cancel the very existence of *Planck Quantum* and, consequently, also the energy of light: we would have a world everywhere *dark* and totally devoid of power! No, it is not possible (Puccini, 2019,e).

However, in our opinion especially a way could provide a solution: correct the *infinities*, without Renormalization, but by removing the massless photons from the equations of the *Perturbation Calculus*.

Equally, even the calculation of the *electron self-energy* will not give null results any more. No! With a photon value no more massless, the zeros disappear. They appeared whenever one tried to multiply the electron mass-energy with the *quanta* of his field, i.e. with the light's quanta, the photons.

Consequently, with this value of photon other than zero, all *divergences* emerging from the equations of Perturbation Calculus, Quantum Electro-Dynamics (QED) and QFT disappear.

In short, we believe that the *removal of the infinites* emerging from the perturbation QED and the other QFT, can be obtained with 2 modes: 1) Replacing in the equations of such theories the value of 0 of a photon massless, with the real mass-energy value of the Planck quantum, the photon, as represented by equations (35) or (32). 2) Replacing in the equations of the QFT the *point size* value attributed to the radius of the electron, therefore $\rightarrow 0$, with the real value of its radius.

2.4.2 Removal Of Pointlike Electron From Perturbation Equations

As it is known, in keeping with *QM*, the *Wave Function* (Ψ), that is the *quantum state* of a particle, represents the way in which we can find the particle when it does not interacts, when it is not *disturbed*, *measured*, observed. Thus, indicating with t the time, and with $x^1,.....x^N$ the possible positions or space coordinates of the considered particle, we have the formula:

$$\Psi = \Psi\,(x^1,.....x^N,t) \qquad (36).$$

Thus, before we search the particle, that is before we *measure* it, the particle is *spread* throughout the employable space, as if for each point there was associated a precise value of *probability density* we have to find. In other words, before the *measurement* (M) the wave or particle aspects are not at all outlined: the Ψ *square of the modulus* of the Ψ, that is $|\Psi|^2$, has to be interpreted as a *distribution,* as the *density of probability* to find the particle, its quantum state, in one of the several possible positions. Before the M, indeed, the phase of Ψ gives to the particle its "wave-like character", since the Ψ is *diffused* in the space occupied by the particle the Ψ is referred to. Therefore, it is thought that before the M, an electron could be found potentially in one of the several points of its *wave volume*, each corresponding to probability amplitude, to a probability density (Puccini,2019,d).

In fact, this is really in clear and blatant conflict with continuing to consider that an electron can occupy a null volume, like saying that its radius (a) is zero, that is: $a \rightarrow 0$, causing the *divergences* in the *gauge theories* and QFT equations. In short, before the M, the electron is *not determined* and, in keeping with Lloyd (2006), it should be characterized by an *overlap of quantum states*: it certainly does not occupy a spatial dimension of one point, that is equal to zero!

Moreover, "As regards the *problem of infinites*, just think about the energy of the electric field of a charged sphere, which radius (r) tends to zero: $r \rightarrow 0$; i.e. the energy $\rightarrow \infty$, diverges, such as $1/r$. For the theory of Special Relativity, part of the mass of the sphere comes from the (divergent!) energy contained in the surrounding electromagnetic field. However, one might think that no electrical charge is actually point size and that the problem is simply due to a *mathematical abstraction*"(Passera). We read from literature: "An ordinary light microscope uses optical band photons, which are equivalent to waves with a wavelength of roughly 400–700 nanometers. But if you want to see finely detailed things that are "smaller than light" (smaller than the wavelength of visible photons), you need to use particles that have an even shorter wavelength than photons: in other words, you need to use electrons. In an electron microscope, a stream of electrons takes the place of a beam of light. An electron has an equivalent wavelength of just over 1 nanometer, which allows us to see things smaller even than light itself (smaller than the wavelength of light's photons)"(Woodford). It should also be mentioned the right value suggested by de Broglie, who calculated "the radius of the electron superimposable on the wave length (λ) of a X ray, equal to $10^{-8}-10^{-9}$ cm"(de Broglie,1931).

Let us now try to calculate *mathematically* and *physically* the actual value of the electron ray. To this purpose, we consider the value of the electron energy-mass density in its state of *minimal energy*, or *inertial mass* (m_o), which in the *cgs* metric system corresponds to $9.109383 \cdot 10^{-28}$[g].

From Planck-Einstein formula E=*hv* (shown in the equation 2), where *v* is the frequency, thus *v* =E/*h*, we get the value of the electron frequency (*v*):

$$v = \frac{E}{h} = \frac{mc^2}{h} = \frac{9.109383\cdot10^{-28}[g]\cdot\left(2.9979^2\cdot10^{20}\left[\frac{cm^2}{s^2}\right]\right)}{6.626\cdot10^{-27}[erg\cdot s]}$$

$$= \frac{81.8697\cdot10^{-8}\left[g\cdot\frac{cm^2}{s^2}\right]}{6.626\cdot10^{-27}[g\cdot\frac{cm^2}{s^2}]} = 1.23558\cdot10^{20} \quad (37).$$

Hence, the electron frequency, in its *minimal energy state*, or *Zero Point Energy*, corresponds to $\approx 10^{20}$ oscillations per second, or Hertz, or cycles per second (c/s).

Let us now consider the formula of the electromagnetic waves, i.e.: $\lambda \cdot v = c$, of which we now know 2 parameters, i.e. c and *v*. Let's calculate the 3rd parameter, i.e. λ, which refers to wavelength of the electron in its *minimal energy state:*

$$\lambda = \frac{c}{v} = \frac{\left(2.9979\cdot10^{10}\left[\frac{cm}{s}\right]\right)}{1.23558\cdot10^{20}\left[\frac{cm}{s}\right]} \quad (38),$$

i.e.:

$$\lambda = 2.426\cdot10^{-10}[\text{cm}] \quad (39).$$

Well, this is the value, according to de Broglie (1931), that in our opinion should be inserted in the equations of the Perturbation Calculus and QFT (QED included) to represent the radius of the electron (*a*), replacing the null value which has been considered so far:

$$E = \frac{3e^2mc^2}{hc}\log\left[\frac{h}{mca} + \sqrt{1+\left(\frac{\hbar}{mca}\right)^2}\right] \quad (40),$$

where *E* is the electron *self-energy*, *m* its mass and *a* its ray, considered as a point (thus 0).

As can be clearly seen, in the last equation the *null* value of *a* appears twice in the denominators: we shouldn't marvel at the *infinities*! Obviously, this occurs because in the equations a point size value for the radius of the electron (a) is introduced, thus $a \to 0$ (which is as to give the value a = 0). Hence, the calculation results in an infinite shift: for $a \to 0$ diverges as $1/a^2$.

Of course it is not possible, there is an error, which certainly does not lie in the values of *m* or *c*; thus the error must be in the value given to *a*, that is to the radius of the electron, considered equal to a point, that is equal to zero (Puccini,2019,d). Moreover, as illustrated by Eq. (40), the energy of the electron tends to ∞. Instead, we all know that the electron rest-energy is *only* 0.511MeV/c^2!

In short, electrons - being massive particles - can in no way occupy a void or point volume of space (that is equal to 0) but necessarily its *wave volume*.

Of course, no longer dividing by a zero value, *infinities* and *divergences* will disappear. Thus, as in all material particles, the more the electron is accelerated, the more its wavelength will be restricted, but never reaching zero or close to zero values! For example, if we replaced the value expressed by the Eq. (39) with the null value of the electron ray inserted in the equations of the Perturbation Theory, of the QFT and the Yang-Mills theories, all *divergences*, that is all the zeros and infinities, would suddenly disappear. Consequently, if we replace also the null value of a massless photon with its real mass-energy value, as expressed by Eq. (32) or (35), the limits imposed by the *Spontaneous Symmetry Breaking* will vanish too.

Hence, there is no longer any need to deny the mass to the Nuclear Forces bosons (Puccini,2018,a), including the Yang-Mills ***B*** *quantum* (Yang, Mills 1954), which corresponds to the boson of the Strong Nuclear Force.

2.5 Non Zero *H* Value In Atomic And Subatomic Physics

It is of particular importance to bear in mind that the energetic effect determined by Planck's quanta occurs for a mechanic effect induced by the right quantity of *Planck constant* (*h*) carried by the single electromagnetic (EM) wave. At this regard, it is important to underline the so called *threshold limit value* to elicit a certain effect. For instance the right wave length (the right frequency), in order to have the photosynthesis take place, is the visible light's.

So, in the case of the photoelectric effect (PEE), the EM wave must have a frequency higher than radio waves and microwaves. Infrared rays are able to induce the effect only if they interact with some materials. In this respect, let's suppose that Planck's quanta were really corpuscles with a their own individuality. Thus, the fact they had also a corpuscular aspect allowed Einstein (1905,a) to explain the PEE. As known, this effect is carried out by photons with a certain frequency, thrown against a metallic surface with the result that electrons from the atoms of the target metal are pulled away. It is fundamental that the photons have a frequency higher or equal to a certain value (*threshold* or *cut level*), which changes slightly as the target changes. Hence, the PEE is performed only when the energy carried by the photon, that is the frequency of the EM wave, is the same or higher than the energy (*binding energy*) relating the electron to the nucleus. Generally the *threshold level* corresponds to the frequency of the infrared rays, for some metals, (especially cesium and rubidium) or to the optic band for some others such as alkaline metals. In other words, if the light's quantum will have enough power to push away the electron from the atom, just as a billiard small ball, thrown with the right energy, pushes away the opponent ball.

It could be a suitable example, since the *kinetic energy* of the small ball is given 100% to the pushed ball. The PEE is a phenomenon of "corpuscles" (Einstein1905,a) more than of waves. That is a photon which manages to push away an electron from its orbit, seems more a *mechanic effect,* that is a *mass effect of the light quantum*, namely a "*push effect*", rather than a merely "energetic effect".

That is, the Planck's grains involved in the PEE behave like ultramicroscopic spinning small balls (carrying probably a tiny mass), rather than as ethereal waves.

As for the Compton effect (CE), the right EM band is the X rays (Compton). As Chandrasekhar reminds us "Compton demonstrated that directing a flux of X rays against motion less electrons, it was shown that these rays behaved like particles, since (rather than going around the obstacle, as the radio waves would have done) they bounced against the electrons conserving (an energy and) a *momentum*"(Chandrasekhar). Also in CE the comparison with the billiard small ball fits perfectly. The photon after striking the electron (opponent ball) will keep moving, just as a billiard small ball.

At this regard, let's calculate the *momentum* of a Planck's *grain* oscillating at a X photon frequency (Abdel Raouf), which λ can correspond to 10^{-9} [cm]. We have:

$$\boldsymbol{P} = \frac{h}{\lambda} = \frac{6.626 \cdot 10^{-27}[\text{erg}\cdot \text{s}]}{10^{-9}[cm]} \quad (41),$$

that is:

$$\boldsymbol{P} = 6.626 \cdot 10^{-18}\,[\text{g}\cdot \frac{cm}{s}] \quad (42).$$

As it is clear from Eq. (42), a X radiation carries out a *momentum* (***P***) of no less than 4 orders of magnitude greater than that of visible radiation. In other words a X photon strikes the electron with an impact force 10,000 times greater than the one exerted by ordinary visible light. It is a clear physical demonstration of why an optic photon, for example, is not able to induce the CE.

CE would have never been possible with the only wave hypothesis of the light. On the contrary, the CE confirmed clearly the existence of also a corpuscular behavior of the Planck's grains. Compton, indeed, supposed that in the collision with the graphite atoms, X rays behave like real particles, with energy and *momentum* (Compton). What Compton underlined was confirmed later by Raman (1928). As known, the Raman Effect occurs when the photons of an intense monochromatic beam of light, with a specific frequency, passing through a material (mainly liquid or gaseous) undergo an inelastic collision with the molecules of the means they pass through. In this way the Planck quantum *pushes away* the electron from its orbit: it appears to be in effect a *mechanical effect* produced by the light. The Raman Effect cannot be interpreted in the classical physics, however it can be easily explained as a quantum mechanical effect (Puccini,2008).

In sum, many of these phenomena will be elicited only starting from a certain EM frequency because a higher frequency carries, in the unity of time and space, a large amount of Planck quanta. It could be argued that a high EM frequency indicates a high energy as well. But we can state again that the so called "energetic effect" induced by photons may happen, as an intimate mechanism, through a mechanic action given by the high number of quanta carried by the EM signal. In other words, the mechanic action is not given by a low EM frequency (that is carrying few quanta), the action occurs only if the wave carries thousand of billion of *Planck' grains* (of course without changing the unity of time and space), which hit all together a particle, and push it away.

The extremely small equivalent mass of an *h* (a *Planck constant*), multiplied some hundred billion of these units of equivalent mass, for each second, may be at the bottom of all these mechanisms. These may probably be just an effect of the Superposition Principle (Glenn).

2.5.1 Wave Function Collapse (Wfc)

It is interesting to emphasize that the impact force exerted by the *momentum* (***P***) of light quanta could still provide a real physical value to a phenomenon that, for different Schools of Physics, is considered a mere mathematical abstraction. We refer to the Wave Function Collapse since, as mentioned above, each particle can be represented by its Wave Function (WF). In Quantum Mechanics (*QM*) the WF is indicated by the symbol $\Psi_{(x,t)}$, or simply Ψ, whose *argument* $_{(x,t)}$ refers to the possible position in space and time of the considered particle. And 'interesting to highlight that as long as the particle, or *quantum object* (QO), is not disturbed, observed, or measured, it *lives* in ways we will never know: very roughly we can imagine it travels like a wave. In agreement with *QM* "we are not able to say that a quantum system, before being observed, has well defined properties, since we cannot know them"(Zeilinger). When the particle is not disturbed, that is when any *Measurement* is carried out, it stays in its natural state: it *lives,* as a QO (Puccini,2017,b), it occupies a volume, it is *spread* in the space which is allowed to it (it is *delocalized*), and it is represented by *superimposed quantum states*: it tends to behave as a wave.

This is the so-called *phase of linear unitary evolution* ***U*** (***U*** *phase*) (Penrose,2004), which corresponds to the "*Process* 2" described by von Neumann (1955). This physical condition of the QO

lasts until it is disturbed, observed (Puccini2017,a). Every time a *Measurement* (M) is carried out (always using the *Planck's quanta*), the observed particle undergoes a *probabilistic reduction of the state vector,* indicated as Reduction Process, or ***R*** *Process* (Penrose,2004), which corresponds to the "*Process* 1" of von Neumann.

So, with the ***R*** *Process* the *state vector,* represented by |Ψ>, *jumps* to another stated vector, let's say |ϕ>, which represents one out of two or more *orthogonal* alternative possibilities: the other can be |q>, | X >, etc..., which depend on the kind of observation, the kind of M carried out. With the M, in fact, we move immediately from the phase ***U*** to ***R***, and the *jump of the quantum state* is induced, known as Wave Function Collapse (WFC). Consequently, with the M, thus with the WFC, it is possible to find and see the particle in a determined point. In the ***R*** *Process*, the particle shows as a corpuscle and gives us its position: now the particle is *localized* (Penrose,1989).

To sum up, during the ***U*** *Phase*, that is before the M, the particle presented an undulating behaviour, and was not detectable: we did not have any information about its position, it was *delocalised*.

The M, therefore, produces a big changes on the physical properties of the observed particle, of the measured QO, as well as on its morphological configuration. How do these changes happen? What is the secret mechanism which creates the WFC? We don't know. We only know that these modifications happen any time we try to see how a physical phenomenon takes place, or when we want to study the behaviour of a particle: to do so we have to carry out a M.

Briefly, the WFC takes place every time M is carried out. Which mean do we use to carry out a M? A light quantum, i.e. a photon with a short wave length. Hence, it is automatic to link together the three parameters: 1) *Light quanta*; 2) M; 3)WFC.

In fact the WFC happens only after a M, and the M cannot be carried out without using the electromagnetic radiation, the *light quanta*: it is a *conditio sine qua non.* Thus, we can infer that the Wave Function (WF) of the observed particle, |Ψ>, *jumps* in a different quantum state (|ϕ>) when the photon occurs. Without *light quanta* it would not be possible to have neither the M, nor, as a consequence, the WFC! There is no other explanation.

Someone may say: if it is so how does the light quantum induces the WFC? Well, we have stated that the *Planck's quantum* is not evanescent, ethereal, inconsistent, but, in agreement with Keplero, it produces a mechanical action: the so called *radiation pressure* of light, of photons (National Academy of Science, USA). In fact, "the solar light gives, on the earth surface, a *radiation pressure* having a weight of 1mg per mt^2 per second"(Frova). Furthermore, we know that if a single light quantum hits an electron changes its journey and deviates it from its trajectory. In the same way, we think that the photon is able to create a real WFC of the hit electron! In this regard, we associate ourselves with that current of thought described as *Objective Collapse Theory*, to which Penrose also adheres. This theory treats the WFC as a real physical phenomenon, which is concretely realized in the reality of the subatomic world, rather than appearing as a mere mathematical abstract.

In short, the *mechanical effect* carried out by a luminous photon against an electron, against a QO, is not at all negligible: as shown by Eq. (35), the electron is hit by a *crash force* equal to 10^{-22} [g·cm/s], that is 100.000 times bigger than the *rest-mass* of the electron itself (Puccini,2012,b). It is a considerable strike! There is no wonder if, after such a strike, the quantum structure of the electron (with its superposition of quantum states), and its morphological configuration, undergo a significant modification. It is as if under the hit with the light quantum, the electron deformed immediately (thug just for a very short time), as if it *shrivelled* (as pinched balloon), *reducing* its quantum states: in this way showing itself as a corpuscle, a *localised* and observable particle. Just with a single photon.

Well, the light really hit violently the electron and the atomic particles. Hence, before being hit by light quanta, in agreement with *QM* the particle is a mathematical quantity known as a quantum state, or Wave Function (WF): WF (|Ψ>), that should contain all the information necessary to describe the considered quantum system (Puccini,2012,a). When it exists in this phase (***U*** *phase*), not disturbed, the particle will not give any information concerning its *look* and contents.

In this regard, Prigogine asks himself: "Does a unobserved nature, different from observed nature?"(Prigogine). It seems so! In fact, as far as we try to see it, the observed particle immediately change its *look*, its quantum configuration and its trajectory.

Thus we can only try to imagine: it says that the particle occupies a volume, it goes like a wave, in a *combination of several overlapping quantum states* and widespread, spread in the whole space it can occupy, space that should be the Hilbert Space (**Hs**) (Penrose,2004). Feynman (1965,b) said: "the Wave Function for a single particle is a *field* in the sense that it is a function of position". This field could be the space occupied by the particle, when it is not disturbed, i.e. when it is in ***U*** *phase*.

We don't think to be wrong in considering the **Hs** like the field, the space occupied by each particle, that is by its quantum superimpositions both it is a

lepton (like an electron) and it is a hadron (like a proton, for instance). Therefore, according to Penrose, the **Hs** should be a real, *objective* space: the space to be occupied by a QO.

2.5.2 Measurement's Paradox

As it is known, one of the most mysterious phenomena of the *QM* is represented by the so-called Measurement's Paradox. In fact, what happens is that the observation, the measurement (M) modifies the physical system (in the microscopic world) we are examining: not only does it deviate immediately the trajectory of the observed QO but, what is even more interesting, very likely it generates also a deep change in its physical states.

With the M, indeed, we have the *collapse* of the superposition of the different quantum states characterizing the QO: they may converge in a circumscribed, *localised* space (Miller). In this way the M of the position of a QO generates the so called *reduction* of quantum superposition which characterize it, also known as *Amplitude Reduction*, or *Reduction of the state vector (R Process).* The M, in fact, induces the *transformation* of the QO, that is the transformation of its quantum state, known as *quantum jump,* represented by the quantum-mechanical formalism by:

$$<\Psi \mid \phi> \mid^2 \qquad (43),$$

which describes the *probability* that the WF (Ψ) of a QO *jumps* in one of the *possible self-states*, indicated by $\mid \phi>$, which represents one out of more *orthogonal* alternative possibilities. What happens is that the M generates the Wave Function Collapse (WFC) of the examined QO (Puccini,2011,b). In other words, when we make a M, when we try to see and study an electron, and we shoot against it even a single light quantum (the minimum quantity to be able to see it), what happens is that the electron is hit by a corpuscle with a dynamic-mass bigger than its, most likely *succumbing* under its mechanical effect, under such a shot, thus it *collapses*. In fact, "to observe electrons, we need a light because the light rebounding on electrons make them visible. Nevertheless the light affects the result because the result of light on is different from that of light off. We can say that the light affects electron behaviour. The electrons are very sensitive. When light is sent on an electron, it makes the electron vibrate so that the electron because of light, behaves in a different manner" (Feynman,1965,a).

Thus, every time a M is carried out (always using the *Planck's grains*, the light quanta), the observed particle undergoes a *probabilistic reduction of the state vector,* indicated as Reduction Process, or ***R** Process*. With the ***R** Process* the *state vector,* represented by |Ψ>, *jumps* to another stated vector, let's say |ϕ>, which represents one out of two or more *orthogonal* alternative possibilities: the other can be |q>, | X >, etc..., which depend on the kind of observation, the kind of M carried out. So, with the M we move immediately from the phase ***U*** to ***R***, and the induced *jump of the quantum state* is known as WFC. It seems right to us to underline that this peculiar phenomenon is always related to use of the *Planck's quanta*" (Puccini,2018,b).

Therefore, to observe a QO we cannot do without the *Planck grains*, the light quantum. In our opinion, more than a mere and non-specific energetic effect, to induce the Measurement's Paradox, and therefore the WFC, is a real mechanical action exerted by the *dynamic-mass,* the *momentum (**P**)* of the *light's quanta.*

2.6 Non Zero *H* Value In Astrophysics

And at this point, let's analyze why the energy value of Planck's constant, as well as that of its equivalent-mass, could play a leading role also in Astrophysics.

2.6.1 The Missing Mass

To this purpose it can be interesting to mention that at the beginning of the 30's Zwicky noticed that peripheral stars rotating around the centre of a galaxy have such a speed that the gravity force should not be able to keep them in orbit. Zwicky assumed the existence of an invisible mass on which the gravity force acted. So, he hypothesized the existence of an invisible *missing mass* (MM), whose gravitational effect adds to the visible matter's. In this way account balanced (Zwicky). Giacconi and Tucker write: "Apparently galaxies are immersed in a halo of invisible matter. These results were confirmed by radio observations, showing that galaxy invisible halo must contain about ten times more mass than what can be seen in the visible and radio waves"(Giacconi).

Well, what is the invisible mass of the universe (MM) made of? As known, the hadron matter is only about 4.9% of the total mass (Chun-Xuan J.). "Cosmological considerations seem to exclude that the MM is under the shape of a normal baryonic matter" (Giacconi). Most scientists agree that it is made of WIMPs (Weakly Interactive Mass Particles), that is very massive super symmetric particles (100 times heavier than a proton). They interact very little with the matter, even less than neutrinos. WIMPs are being searched at the Gran Sasso (Italy), and in particle accelerators, however no definite result has been obtained so far. In this respect, Giacconi and Tucker add: "One of the most spectacular examples of invisible halos was shown around the big elliptic galaxy M87 by Fabricant and Gorenstein, and by Forman and Jones (at the Harvard-Smithsonian Centre for Astrophysics). The data was collected with the

Einstein-X ray counter. Every time there is a central galaxy in a cluster of galaxies we find that it is surrounded by a wide X ray crown and, implicitly, by a big halo of invisible mass"(Giacconi).

Why can't we think these halos are made mainly of *light quanta* belonging to invisible bands?

If we look around we simply notice that the Universe is full of light, full of electromagnetic radiation (EMR) with different frequencies. Furthermore, the density of radiant energy in the actual Universe is about one thousand million times bigger than the density of the matter. In reference to this context, Weinberg points out: "Going back to the early universe there has always been a number of photons for proton or neutron between 100 millions and 20 thousand millions. In order to simplify things I will round it off and consider that in the universe there is, and there has always been, *only* one thousand millions of photons for each nuclear particle"(Weinberg,1977). Penrose adds: "The *entropy* of the *bottom fossil radiation* left by the Big Bang is equal to10^8-10^9 photons for baryon. But since the main contribution to total entropy comes from the massive Black Holes, we get an entropy for baryon equal to 10^{21}, that is 10^{21} photons for baryon"(Penrose,2004).

That's like saying the Universe is full of light! If we consider that a *quantum* of the common visible light carries a momentum (***P***), a *dynamic mass* equal to the rest-mass of 100 protons –as shown by Eq. (31)- curiously it corresponds exactly to the mass given to the hypothetic WIMP. Thus, the value of the momentum of a *light quantum*, that is the ***P*** of a photon, coming from our calculations, could contribute to represent the invisible mass, the *missing mass* (MM), which adds a gravitational mass about 10 times bigger than the mass observed in stars and in galaxy gases (Puccini,2010,a).

Hence, if the invisible halos surrounding the galaxies were made mainly of invisible electromagnetic radiation, we could explain the gravitational effect 10 times bigger than the visible mass and better understand the mystery of the MM. Thus, in full accordance with Zwicky, the invisible mass (MM) represents the mass on which the gravity force acts. After all, it is known that the light is deflected by a gravitational mass: we should just remember the verification carried out by Lord Eddington during the 1919 eclipse of the sun (Eddington).

2.6.2 The Specific Heat Of Black Holes

Another peculiar astrophysical phenomenon in which *Planck's constant* may be involved concerns the Temperature and the Specific Heat of the Black Holes (BH_s). At this regard, let's read: "Apparently in the case of a BH there is quite a simple way to violate the Second Law of Thermodynamics, such as throwing in BH some matter with a certain *entropy*, for example a container full of gas"(Hawking,1988), resulting in an increase of the BH's *entropy*. It was Beckenstein (1973) to suggest that the area of the *event horizon* (EH) was a measure of the BH's entropy. This idea is mathematically represented by Beckenstein-Hawking formula:

$$S_{BH} = \frac{Kc^3 A}{4G\hbar} \qquad (44),$$

where A is EH' superficial area of the BH, K is Boltzmann' constant, c is the speed of light, G is the gravitational constant, $\hbar$ is Planck's constant written in Dirac's way ($\hbar=h/2\pi$), S is the entropy of the BH. It was extremely convenient to adopt for all these *constants* the unitary value, i.e. 1:

$$G = c = \hbar = K = 1 \qquad (45),$$

as "measured in *Planck units*"(Dirac).

Hence, the Eq. (44) can be reformulated in following way:

$$S_{BH} = \frac{1}{4} A \qquad (46).$$

So, in line with the Beckenstein-Hawking's formula, the entropy (S) of a BH will just be one fourth of EH's area of the BH we took in consideration. Hence, every time the matter (carrying some entropy) fell in a BH, the area of the EH would increase, so that the total entropy (that is the entropy inside and outside the BH) would not decrease. So, the Second Law was not violated!

But a BH having entropy implies a thermic radiation, an inside temperature, so it should behave as a *black body* (Hawking,1983). As known, a body with a particular temperature must emit radiation with a certain rhythm. This radiation is required to prevent the violation of the Second Law. Hawking specifies: "It is shown that quantum mechanical effects cause BH_s to create and emit particles" (Hawking,1975). He goes on: "It seems that any BH will create and emit particles such as neutrinos or photons at just the rate that one would expect if the BH was a body with a temperature of:

$$\frac{\mathrm{k}}{2\pi} \cdot \frac{\hbar}{2K} \approx 10^{-6} \left(\frac{M}{M}\right) K \qquad (47),$$

where k is the surface gravity of the BH, M are the masses and K indicates the temperature in degrees Kelvin (Hawking,1974). So, the peculiar astrophysical phenomenon highlighted by Hawking consists in the negative value acquired by the Specific Heat of a BH which absorbs electromagnetic radiation, *light quanta*. Apparently, indeed, as the electromagnetic radiation absorbed by BH increases, in an inversely proportional ratio, the value of Temperature (T) and BH' Specific Heat decreases.

In other words, if we apply heat to an ordinary body, its T will increase and its Specific Heat will have a *positive* value. Whereas, if we apply heath to a BH its T will decrease and so its Specific Heat, so that the Specific Heat will acquire a value really negative, according to Hawking's relation:

$$T_{BH} = \frac{8\pi}{m} \qquad (48),$$

related to a Schwarzchild's BH, where T is its temperature and *m* its mass. How can the Specific Heat of a BH be negative? The application of heat to BH. Thus, it is the heat to give mass to the BH, to make it more massive. Which mechanism explains that? Well, as it is known the heat is thermic energy, i.e. *quanta* of *electromagnetic radiation*.

In sum, it is the *Planck's grains,* light quanta which provide mass to the BH, although it has always been stated that photons are massless. We need to keep in mind that any *quantum* of electromagnetic radiation, any photon, whatever its frequency, has a momentum (***P***). Since we are considering thermic photons, that is infrared rays, their λ can correspond to $\approx 5 \cdot 10^{-3}$[cm], we have:

$$\boldsymbol{P} = \frac{h}{\lambda} = \frac{6.626 \cdot 10^{-27}[\text{erg} \cdot s]}{5 \cdot 10^{-3}[cm]} \qquad (49),$$

$$\boldsymbol{P} = \frac{6.626 \cdot 10^{-27}[\text{g} \cdot \frac{\text{cm}^2}{s}]}{5 \cdot 10^{-3}[cm]} \qquad (50),$$

that is:

$$\boldsymbol{P} = 1.325 \cdot 10^{-24}[\text{g} \cdot \frac{cm}{s}] \qquad (51).$$

This is the *momentum*'s value of a *quantum* of the infrared band which, as Fermi (2009) and Feynman (1965,a) remind us, is entirely transferred to the particle with which it interacts.

Hence, from Eq. (51) we get that a *quantum* of infrared radiation with its *momentum* carries a *dynamic-mass* roughly equal to the rest mass of a proton!

Furthermore, considering that a single infrared ray carries $\approx 10^{13}$ Planck's quanta per second, will have a certain value, being able to make more massive the BH. So, the BH acquires thermal energy (in addition to other electromagnetic radiations) from the surrounding Universe, so *Planck's grains*, *quanta* of electromagnetic radiation, transfer mass, their own *equivalent-mass*, to the atoms of the BH, resulting, in the long term, in a decrease of the overall temperature of the BH, and making its Specific Heat become negative (Puccini,2010,c). This is in perfect agreement with Eq. (48), since the mass *m* value is in the denominator.

2.6.3 The Dark Energy

The *Dark Energy* (DE) is a mysterious, un-eliminable energy distributed, as a fluid, evenly throughout the whole Universe. The nature of the *Dark Energy Particles* (*DEP*) is unknown.

DE appears to be associated with *vacuum* in space. Just the omnipresent *quantum vacuum energy* is the key element to help us understand the characteristics, profile and properties of *DEP*.

In accordance with data from Planck Satellite surveys it can be established that the baryonic matter, that is the common ordinary matter, represents 4.9% of *critical density*, that is only 4.9% of the sum total of the mixture of matter and energy the cosmos is made of (European Space Agency), (Planck Collaboration,2014). Thus, the invisible energy-mass left, or *Missing Mass* (MM), corresponds to 95.1% of the cosmic mass. In its turn, the MM is divided in Dark Mater (DM) and Dark Energy (DE). Again in compliance with data from the Planck satellite, DM constitutes 26.8% of this cosmic mixture of matter and energy. Further, since the Universe is *flat*, it has a *critical density* equal to the unit (Ω=1): consequently, the remaining 68.3% consists of *Energy Density*, also not detectable, thus defined as *Dark Energy* (DE).

"But which energy? It is supposed to be an energy, discovered in recent years, called *vacuum energy*, which causes an accelerated expansion of space, while it was always expected that the Gravity Force would decelerate the expansion. Two groups of researchers, the American Supernova Cosmology Project and the Australian High Red Shift Supernova Search Team (Rees) (Perlmutten), surprisingly found that the expansion of the universe has not slowed down, due to its own gravity, but it has accelerated. This means that there is a force acting against gravity. The energy that causes the acceleration of the expansion is called *vacuum energy* and, since energy and matter are equivalent, it probably provides that 73% density necessary to bring the density of the universe to the critical value, compatible with the observations that establish that the universe is *flat* "(Hack).

Let us try to better understand what "vacuum" and *vacuum energy* mean. At this regard, we read: "The quantum revolution has shown us why the old concept of vacuum as an empty box was unsustainable. From then on, the vacuum was simply the state that remained when everything that could be removed from the box had been removed. This state was by no means the absence of anything: it was only the lowest possible energy state. There was always something remaining: an energy of emptiness that permeated every fiber of the universe. It is never possible to achieve a perfect vacuum. A concept confirmed by the evident impossibility of extracting all the atoms from the vessel to the last. Any small perturbation or attempt to intervene on the vacuum would increase its energy. Newton was convinced that

a means "more rare and thin than air" must still be present in the vessel in which the void was made: Newton was ahead of his time. The omnipresent, un-eliminable *vacuum energy* was revealed and proved to have a tangible physical presence. Einstein showed that the universe could contain a mysterious form of vacuum energy. The Uncertainty Principle (UP) and quantum theory have revolutionized the concept of vacuum. Saying that in a box there are no particles, that it is completely free from any mass and energy, is in contrast to the UP, as it assumes to have complete information on the motion at any point and on the energy of the system at a given instant of time. With Quantum Theory it emerged that the last surprise offered by the UP was shown as what was called Zero Point Energy"(Barrow), meaning that it will never be possible to completely empty a container, but there will always remain an irreducible fundamental energy, which can never be completely eliminated. This limitation, indeed, reflects the reality of the UP, since if we know the position of an oscillating particle, its motion and therefore its energy are uncertain. In reference to this context, Hack adds: "Let's imagine to consider a region of space and take away all matter, radiation and every other kind of substance. The resulting state is called *vacuum*, (which is something different from null). The *vacuum* has the lowest energy of any other state, but not necessarily zero. According to Relativity Theory, every form of energy influences the gravitational field, and therefore the energy of the vacuum becomes an important ingredient. It is believed that the vacuum is the same throughout the universe, and consequently the energy density of the vacuum is called *cosmological constant* (Λ). While matter can be thickened or dispersed during the evolution of the universe, Λ is a property of the space-time. With expansion the matter density decreases. If the matter is the main component in the Universe, expansion will be decelerated. Whereas if Λ prevails, the energy density will be constant and the expansion rate will reach a constant value. It is said that such a universe is accelerating, because the speed of alienation of galaxies increases continuously. Observations of some *supernovae Ia*, 10 billion light years away, showed that 10 billion years ago the expansion was decelerated, and therefore gravity was prevalent; then the expansion and the consequent reduction of matter density made the energy of vacuum prevail over gravitational energy. These tests are a well-defined picture of our universe: plane and infinite, in accelerated expansion, which today is 71 Km/sec per megaparsec. A megaparsec is 3.26 million light years, and therefore every second a megaparsec becomes 71 Km longer" (Hack).

In short, this antigravity counter-pressure, exerted by the energy of vacuum, also for many others physicists, is equivalent to the DE, which Hack points to as a 5th Fundamental Force, corresponding to cosmological density. That is, "in the Universe there is another mysterious force, never directly observed, called '*vacuum energy*' or '*negative pressure*', or simply '*strange energy*': this force is opposed to the force of attraction of gravity, accelerating the expansion of the Universe"(Aczel).

For what concern the *vacuum energy*, it should be specified that "in classical physics the vacuum is identifiable with the absence of energy. In contrast, in the Quantum Fields Theory (QFT), the Heisenberg Uncertainty Principle prevents a measure of the vacuum state energy from giving exactly a zero value. Because of the Uncertainty Principle the number of particles contained in the vacuum state cannot be null, but it is forced to undergo random fluctuations: the *quantum vacuum* must therefore be imagined as a dynamic state, rich in all the particles - called *virtual* - which are produced due to unavoidable quantum fluctuations" (Urbano). To this purpose, Barrow writes: "The *quantum vacuum* can be conceived as a sea made up of elementary particles of all types and their antiparticles, which appear and disappear continuously. We focus our attention only on the Electro-Magnetic Interactions: there will be a great ferment of electrons and positrons. *Electron-positron pairs* materialize from the quantum vacuum and then immediately they annihilate each other, disappearing. If the electron and positron have mass (m), Einstein formula ($E = mc^2$) tells us that their "creation" requires an energy (E) of $2 \cdot mc^2$, which must be borrowed from the vacuum"(Barrow). This implies that the vacuum, the *quantum vacuum*, contains a fair amount of energy, since it is able to lend it!

Briefly, the laws of Quantum Mechanics (Hongxuan Wang) tell us that the *apparently* empty space is full of particles of every kind, which appear and immediately disappear, generating a repulsive force very similar to that which would be generated by the cosmological constant (Λ).

In this respect, we read: "The cosmological constant, or *lambda force* (Λ), is an incumbent presence, with its ability to act on everything, although not affected by the motion and the presence of other matter: it is not affected by anything. It is an ubiquitous form of energy, which remains when everything that can be removed from the universe is removed. It is like a strange fluid, which pressure is equal to the opposite of its energy density: a negative pressure, producing a repulsive gravitational effect"(Barrow). We can still read: "Λ behaves like an energy, a very particular energy, characterized by always having the same mass-energy identity at any point in space and at any time. The mysterious component appears as a fluid that exerts pressure, and

this pressure results to have a value equal to its energy density, but with the sign changed, that is *negative*. If we try to quantify the mysterious fluid, we come across the second disconcerting truth: its presence, even if due to that very small value of Λ, about 10^{-29}g/cm^3, is such as to represent ≈70% of the total content of the universe. Against all expectations, Λ is already the undisputed sovereign of our destiny! "(Pizzuti).

Moreover, in the NASA captions we find: "DE is a truly bizarre form of matter, or perhaps a property of the vacuum itself, that is characterized by a large, *negative pressure*. DE is the only form of matter that can cause the expansion of the universe to accelerate, or speed up" (NASA). And 'interesting to note that the DE and the Dark Matter (DM) are opposed: "the DM tends to restrict the cosmos, since it exerts a gravitational action, while the DE tends to make it expand more rapidly. The composition of the DE is still very mysterious. The Universe and its destiny are regulated by two contrasting factors: the DM that thickens around the galaxies and the DE that permeates the whole space. The DM is like a rubber band that tends to tighten (due to the gravitational action between the galaxies), while the DE is like a spring that pushes outwards, producing an expansion of the whole space: it is a pull spring, a *cosmic arm wrestling*" (Bignami). To this purpose, Hack points out: "The primordial plasma was subject to two opposing forces:1) Gravity Interaction (GI) and 2) *Radiation Pressure* (or *Photonic Pressure*). The former tends to compress the gas until the *Photonic Pressure* reverses its motion, producing elastic oscillations" (Hack).

In sum, "in the universe, at the beginning, the aggregating, braking impulse, exerted by the DM, prevailed for about 8 billion years (this is demonstrated by the study of the very distant Supernovae). After which it was the DE, hidden in the empty space, to begin to make its expansive thrust feel even more, accelerating the expansion of the Universe and the speed of departure of the galaxies. Today the action exerted by the DE dominates: it is like a push that opposes gravity. DE is the energy of empty space, it is uniformly spread throughout the space, but it is very diluted: an atom of DE per cubic meter of space"(Bignami). This so sparse concentration of the DE can be valid for the exterminated sidereal spaces, but we believe it is quite different in other contexts, in other spaces. "The DM and the DE have common characteristics: they are invisible, very abundant and are found everywhere, but while the DM is distributed in the universe in a non-homogeneous way, the DE fills the cosmos in a homogeneous way and uniformly fills the whole space"(Casas).

A proof of the existence of DE could be represented by the Sachs-Wolfe Effect (Sachs1967), accounted for by the *blue-shift* which the *cosmic microwave background* meets when it crosses the strong gravitational fields generated by large masses of matter: this energy gain is a direct sign of the existence of DE.

In short, what is the DE? DE is the *quantum vacuum energy*. But soon would be asked: what is its nature? It is not know! In order to identify the DE, there are three most followed hypotheses:

1) The *Cosmological Constant* (Λ), which represents a constant energy density filling the whole space homogeneously. That is, according to this theory, DE is considered as an intrinsic and fundamental energy of space, identified with the Λ. Since energy and mass are correlated, in compliance with the equation $E=mc^2$, General Relativity predicts that this energy will have a gravitational effect, sometimes called *vacuum energy*, since it represents just the energy density of the vacuum. The Λ can be formulated to be equivalent to the radiation of the empty space, or the vacuum energy. In fact, with the Λ we refer to the presumed intrinsic energy of the empty space, an energy that exerts a *negative pressure* (equal to its energy density) on the contents of the space, thus causing the acceleration of cosmic expansion. At this regard, Barrow specifies: "Λ *Strength* is similar to a vacuum energy, on a cosmic scale. It is the cosmic vacuum energy that provides the repulsive contribution of force Λ"(Barrow).

2) *Scalar Fields*, such as *Quintessence* and *modules*, i.e. dynamic quantities. Some theorists have named this "quintessence," after the fifth element of the Greek philosophers. *Quintessence* is a new kind of dynamical energy fluid or field, which energy density can vary in time and space (the contributions of the Scalar Fields that are constant in space are usually included also in Λ). Scalar Fields that change in space can be difficult to distinguish from Λ, since the change can be extremely slow. Moreover, from the equations of General Relativity it emerges that gravity depends not only on mass (and energy) but also on *pressure*. Thus, the DE derives from a type of matter, to which, since we ignore what it is, have been assigned the name of *quintessence*. Hence, along with this theory, *Quintessence* (*Q*) shows characteristics different from those attributed to Λ. In fact, unlike the latter, *Q* is a *Scalar Field*. There is no evidence of the existence of the *Q*, but it has not even been ruled out. It predicts an acceleration of the slightly slower expansion, in fact it is believed that with *Q* the energy density varies, though very little, whereas with the Λ it is constant.

3) The *ΛCDM Model* is a theory which indicates the Friedmann-Robertson-Walker model for the

Universe, with the *cosmological constant* (Λ) and *Cold* Dark Matter (DM): hence the acronym ΛCDM. So, in agreement with one of the prevailing theories, referable to the Standard Model, the very presence of the DE, with its effects, could be represented just by the Λ. This model of DE, in fact, is referred to as the Standard Model of Cosmology and represents the simplest model able to better reproduce the observations of the cosmology of the Big Bang (Vittorio).

The constituent elements of this model are: 1) Λ; 2) the Cold DM; 3) the common baryonic matter, that is atoms, as well as neutrinos, photons, etc...

Moreover, it is of particular importance to bear in mind that "at the basis of all cosmological models there is the theory of General Relativity. To reconcile the general relativistic equations with a wide range of observations, including the *cosmic microwave background*, the Standard Model of Cosmology includes the intervention of two unknown components: 1) an attracting material, known as *cold dark matter* (CDM), which, unlike ordinary matter, does not interact with light. 2) a form of repulsive energy, known as DE, identifiable with Λ, responsible for the currently accelerated expansion of the universe. Together with the ordinary matter we know, these two components were essential to explain the cosmos. But these are exotic components: we still do not know what they really are"(Sefusatti).

2.6.3.1 Electromagnetic Radiation'S Compressibility Limit

At this regard Feynman, one of the most expert in the secrets of light, writes: "We may give one example of the kinetic theory of a gas, one which is not used in chemistry so much, but is used in astronomy. We have a large number of photons in a box in which the temperature is very high. The box is, of course, the gas in a very hot star. The sun is not hot enough; there are still many atoms, but at still higher temperatures in certain very hot stars, we may neglect the atoms and suppose that the only objects that we have in the box are photons. Now then, a photon has a certain momentum ***P***, which is a vector. This ***P*** is the x-component of the vector ***P*** which generates the *kick*, and twice the x-component of the vector ***P*** ($2\boldsymbol{p}_x$) is the momentum which is given in the kick. Thus we find that the *Pressure* (*P*) is:

$$P = 2n\boldsymbol{p}_x v_x \qquad (52),$$

where n is the number of atoms in the volume *V*, and v_x indicates the number of collisions, that is n=*N*/*V* (*N* is the total number of atoms). Then, in the averaging, it becomes n times the average of $\boldsymbol{P}_x v_x$ (the same factor of 2) and, finally, putting in the other two directions, we find:

$$PV = N\frac{\boldsymbol{p}\cdot\mathbf{v}}{3} \qquad (53).$$

That is the pressure times the volume is the total number of atoms times 1/3 (***P***·**V**), averaged.

Now, for photons, what is ***P***·**V**? The momentum (***P***) and the velocity (**V**) are in the same directions, and **V** is the speed of light, so this is the momentum of each of the object, times the speed of light. The momentum times the speed of light of every photon is its energy (E): E=***P***c, so these terms are the energies of each of the photons, and we should, of course, take an average energy, times the numbers of photons. So we have 1/3 of the energy inside the gas:

$$PV = \frac{U}{3} \text{ (photon gas)} \qquad (54),$$

where *U* is the total energy of a monoatomic gas. *U* is equal to a number of atoms times the average kinetic energy of each. So we have discovered that the radiation in a box obeys to the law:

$$PV^{4/3} = C \qquad (55),$$

where *V* is the volume and *P* is the *Pressure* of the photonic gas. So we know the *Compressibility* (*C*) of the radiation! That is what is used in an analysis of the contribution of *radiation pressure* in a star, that is how we calculate it, and how it changes when we compress it"(Feynman 1965a).

We must make a reflection: the latter equation gives us a limit, beyond which the radiation cannot be further compressed. And why? Radiation is energy, let's say it is ethereal, it is made up entirely of photons, ie massless particles. Furthermore, like all bosons, there can be a large number of photons, even in a very limited space, since the Pauli Exclusion Principle (Pauli) does not act on bosons. Consequently the Eq. (55) should have almost no limit at all. Instead it is not so: but then, what's underneath? In our opinion, the *Planck's grain*, the photon *equivalent-mass* places a limit on the Compressibility of radiation: it is a manifestation of the antigravity action, of the *Repulsive Force* exerted by DE.

2.6.3.2 Possible Profile Of The Dark Energy Particle (*Dep*)

As Randall reminds us, "unlike matter, DE exerts a negative pressure on the environment. The positive pressure, as we are accustomed to understand it, would exert an action that would lead to an implosion of the structure of the Universe, whereas a negative pressure would lead to an accelerated expansion. The most natural candidate to explain the negative pressure exerted by DE is Einstein's *cosmological constant* (Λ), which represents an **Energy Of Pressure** that permeates the Universe, but not attributable to matter. The term "DE" is therefore a more general term, used to account for a certain relationship between energy and pressure: as Λ requires, but only in an approximate way. Today, DE is the dominant component of the Universe. This is all the more remarkable, since the density value of the

DE is extremely small. DE has played a dominant role only in the last few billion years; whereas at the beginning of the evolution of the Universe the radiation was first dominant, then the matter. But radiation and matter, spreading out in a gradually increasing volume, have been diluted; the density of DE, however, remained constant, despite the expansion of the Universe. In the life time of the Universe so far, the energy density associated with radiation and matter has decreased so much that the DE, which is not dispersed, has ended up taking over, giving impetus to expansion, accelerating it. In the end, the Universe will be reduced to contain practically nothing, apart from the *energy of the void*"(Randall). In fact, "DE can deal with some properties of the void, with the interaction of emptiness with electromagnetic fields" (Bignami).

Moreover, Rovelli wondering: "What happened before the Big Bang (BB)? In the Loop Theory, which combines Quantum Mechanics (*QM*) and General Relativity, based on the proposal by Martin Bojowald, who applies the Loop theory equations to cosmology, we come across a surprising result: the history of the Universe continues backwards over time and does not stop at the BB, but goes further back: the BB was a rebound (*bounce*) from a previous contraction (or Big Crunch). This 'bounce', says Bojowald, is due to the density of the contraction material, which when it becomes high comes into play the *QM* producing a kind of Repulsive Force (not entirely dissimilar to the repulsive force of quantum origin that prevents electrons from falling on the atomic nucleus), or *'quantum-gravitational'*, which bounces the contraction universe, thus giving rise to expansion, to the BB. In fact, the universe expands from a central region, from a very limited space, to very high density. Proof of this is the *cosmic microwave background* which is spread throughout the universe and is a direct trace of the great initial warmth of when the cosmos was very compressed. Near the BB the matter is so dense, entering a region where the *QM* can not be neglected "(Rovelli).

In keeping with this concept, indeed, Ashtekar described with an elegant mathematical formalism that the quantum properties of space-time bring out something new: a repulsive force, which would have produced the rebound (bounce) of our universe, manifested with the BB, consequent to the violent Big Crunch of the previous universe (Ashtekar).

For us this repulsive force is a direct and clear consequence of the limit to the compressibility of both matter and radiation. For the latter, the limit is expressed precisely by the equation (51). So, the same BB would be the first child of this *repulsive force* triggered by *Radiation Pressure* (or *Photonic counter-Pressure*) which may represent the DE (Puccini2019,c).

We can still read: "Most of the universe is filled with *stuff* whose identity remains a mystery. The value of DE is nothing but the tail of a greater mystery: why is the energy that pervades the Universe so small?"(Randall). Namely because, in our opinion, the particle carrier DE, or DE Particle (*DEP*), coincides with the light quantum, or photon, which *minimal* energy, or *Zero Point Energy*, corresponds to Planck's constant (*h*). She goes on: "If the quantity of DE had been greater, it would have been preponderant with respect to the energy content of radiation and matter, already in the early stages of evolution of the Universe, with the result that its structure (and with it life) would not have had time to form. Moreover, no one knows what it is due, even before, the great energy density that triggered *inflationary phase* and nourished it"(Randall). As we believe "the great energy density that triggered *inflation*" (Randall) could coincide, along with Rovelli, Bojowald and Ashtekar, with the *repulsive force* (of quantum origin), corresponding to the DE, which prevents electrons from falling on the atomic nucleus, which we can identify with the *Radiation Pressure* or *Photonic counter-Pressure*. This repulsive force, or *counter-force*, in fact, may have generated the *bounce* of the Big Bang and triggered the *inflationary phase*. That the *Inflationary Expansion* was born and sustained by an *anti-gravitational force*, conveyed by very high energy γ photons (therefore a real *Photonic counter-Pressure*), we have already communicated and discussed it to a "Progress in Electromagnetics Research" Symposium, held in Cambridge (Ma) in 2010 (Puccini,2010,b).

In this respect, Amendola writes: "According to Quantum Fields Theories the constant Λ is an intrinsic property of the void and there is no obvious reason to believe it is null. Quite the opposite: this *vacuum energy* of should have a great value, such as to immediately make the whole universe explode or collapse. Risky accounts, let's face it, but indicative that there is something profound in Λ that we are missing completely "(Amendola).

Unless we try to consider the fact that Λ, i.e. DE, is nothing but an expression of photonic energy: the same "that permeates the apparent intra-atomic vacuum" (Randall) or the exterminated sidereal spaces (Rees) (Perlmutten), in the form of *Radiation Pressure* or *Photonic counter-Pressure* and that, therefore, the *DEP* can be identifiable with the Planck constant! Moreover, according to Amendola "DE, or *Quintessence*, resembles Λ, but it is not exactly constant and, therefore, its density varies slowly over time and may even fluctuate and thicken slightly in space"(Amendola).

Randall says: "From Quantum Mechanics we know that vacuum (the state for which we should not have permanent presence of particles) is actually filled with ephemeral particles that suddenly appear in existence and then immediately disappear. These particles of short existence can have any energy, so great that the gravitational effects are no longer negligible"(Randall). This leads us further to believe that the DE does not have a constant energy density, that is, equal everywhere and at all times. After all, assuming in our opinion that the DE is *Photonic Pressure* (sometimes excessively compressed), even in the same space the energy of the *DEP* can be significantly different: it depends on the energy impressed, given to Planck constant, that is, it depends on the *momentum* (***P***) of the *DEP*, i.e. the photon considered. In fact, just to do an example, very simple and verisimilar, the quantum fluctuations of the vacuum continuously generate particles (and relative antiparticles) "of significantly different energies"(Randall).

It is considered that "DE is a hypothetical form of elastic energy, repulsive, of an unknown nature, that pervades space. A few billion years ago, when the matter became more rarefied with expansion, and its gravitational attraction weakened, the repulsive force induced by DE took over. It has been hypothesized that the role of the DE has become so relevant because of its repulsive action, such as to lacerate the matter even in its most intimate structures"(Treccani). This is in full agreement with our concept above. Indeed, if the DE corresponds to the *Radiation Pressure*, it means that it is also present within the intra-atomic space, between the nucleus and the orbiting electrons: therefore with time it could move them away, increasing the effects of its repulsive force, until it breaks and disintegrates even atoms! These our concepts are confirmed by what is written by Randall: "The intra-atomic space swarms of electromagnetic radiation"(Randall). She adds: "DE does not aggregate like conventional matter, it does not get rare with the expansion of the Universe, but it keeps its density constant. This form of energy was initially proposed by Einstein: he called it the *universal constant*, but later on physicists called it *cosmological constant*. We want to understand better what DE is: if it is only that kind of background energy, that Einstein proposed at first, or if it is a new form of energy, subject to temporal variations. Or is DE something absolutely unexpected and unpredictable, which we are not even able to conceive?"(Randall).

In other words, DE is a sort of intrinsic energy of the space. The best value estimated by the Perlmutten *team*, for Λ, is $\approx 10^{-29}$ g/cm^3 (Perlmutten). As it is known, however, the problem is that most Quantum Fields Theory provide a huge value for Λ: up to 120 orders of magnitude more. Then other physicists have thought of DE as a *Quintessence* called 'phantom energy', that is a field that pervades space-time and can take different values, in different points. This goes along with our hypothesis, according to which the *DEP* is represented by *light quanta* belonging to different electromagnetic fields, according to the operating places, and according to their energy. In this way most of the DE's theories would be unified.

In short, in our opinion, the various properties and characteristics of the DE are not all unified in one of the theories listed (or other not mentioned, as less supported by theorists), but more or less distributed among the theories exposed. That is, the DE can correspond to the Λ, as well as to the vacuum energy, as well as exerting negative pressure, or *anti-gravity counter-pressure* (these are the 3 basic concepts of the first theory). But at the same time we think that Λ energy density is not at all constant, it has different values. Both in relation to the energetic value of the energy sources, and as regards the space, i.e. the place where it is performing its action, and as regards the time of its detection (in relation to the wavelength with which the *DEP* is traveling). We believe that if the DE was represented by the *Scalar Fields*, it would have different energy densities, depending on the context in which it is located: in the intra-atomic vacuum, or in the intergalactic vacuum, for example, depending on the source. We also don't agree with the possible constancy over time of the value of Λ. Because as with the expansion of the Universe, the values of the density of matter and of radiation have changed (i.e. decreased), likewise the energy density of the DE must be diminished because, we think **De Is** nothing else than a kind of ***Photonic Pressure*** and exerted precisely by *Planck's grains*. What we support can be found in the inexorable lengthening (proportionally to the expanding of the Universe) of the wavelength (λ) of the initial *electro-magnetic radiation*, passing from extremely energetic γ rays (Puccini,2010,b) to the very weak *cosmic microwave background* that currently permeates the whole Universe. Hence, we are not reluctant to the concept that the DE in some circumstances may coincide with the *Quintessence*, i.e. with a kind of 5th Fundamental Force, which can be expressed in various ways and different operating contexts.

2.6.3.3 Operating Sites Of Dark Energy

As we all know Λ represents a force of repulsion among the masses, able to act only between huge masses and over very great distances. But we do not think it always works this way. We have clear evidence that the DE also acts on very short, intra-atomic distances, since it is considered to coincide with the energy of vacuum, vacuum also present inside the atom and represented by an electromagnetic

(EM) field (Randall), as to say: by a *photonic field*. At this regard we have various examples of probable operating contexts of the DE, often very different from each other, both in terms of the extent of the space in which it operates, and with regard to the intensity of the energy with which it operates, and with regard to the methods and times in which it carries out its action.

A) Exterminated Sidereal Spaces: the most well-known context in which the DE is supposed to carry out its *repulsive action* is represented by the exterminated sidereal spaces in which, with deep surprise, in 1998 an acceleration of the expansion of the Universe was found (Rees) (Perlmutten). This acceleration has been attributed to a repulsive, anti-gravity action most likely carried out by an elusive, mysterious, impalpable form of energy, called DE. According to the calculations of Perlmutten, the energy density of this *repulsive force*, or DE, is ~ 10^{-29}g/cm^3. Yet, despite this very small value, the DE represents as much as 68.3% of the entire mixture of mass-energy permeating the cosmos (European Space Agency. In this context, DE has carried out its action for exterminated distances and since the Big Bang! (Puccini,2019,b).

B) Big Bang: in keeping with Rovelli, Bojowald and Ashtekar itself, the Big Bang (BB) represents the oldest context of the repulsive action, antigravity, explained by the DE. That is, the BB is the effect of a *bounce* from a previous contraction (Big Crunch). *Bounce* due to the progressive increase in the density of the matter-energy in contraction, by an overwhelming Gravity Force, such as to reach a compression and density limit, until the Quantum Mechanics intervenes and triggers a real explosion. In this context the situation is completely reversed (compared with the context **A**): at the time of the BB the space in which the DE operates is not the entire Universe, but a very limited space. Also regarding the time we are at the antipodes. In the context A, indeed, the DE is operative from ≈13820 thousand years. At the time of the BB, instead, the action of the DE lasts only fractions of billionths of a second. Moreover, the energy intensity of the DE shows abysmal differences: compared to the modest one of the context A (7 orders of magnitude lower than the energy of visible light), the energy with which the DE triggered the BB must have been far greater than that carried by the most energetic γ photons (Puccini,2010,b).

C) Inflationary Phase: as for the *Inflationary Phase* (Guth), the differences compared to the BB are really minimal: the space has just a little expanded, the energy intensity of the DE has decreased slightly and the duration of action of the DE has just lengthened (even if we are talking about fractions of a millionth of a second longer) (Puccini,2019,d).

D) Stellar Cores: another context in which the DE operates, the *Radiation Pressure* in our opinion, is represented by a trial of strength that goes on uninterruptedly in the depths of the stellar *cores* between the Gravity Interaction (GI) and the DE. In fact, the well known *Arm Wrestling*, which has been going on since the beginning of time between the GI and the *Radiation Pressure*, may represent another operating mode of the DE. This *Arm Wrestling* is represented by a trial of strength that goes on uninterruptedly in the depths of the stars between GI and DE. In short, the gravity (GI) and the *Radiation Pressure* of the photons can *fight* for a long time as it happens in the star's core. At this regard, from an authoritative source, we read: "In ordinary stars such as our Sun, the inward force of gravity is balanced by the outward hydrodynamic pressure of the hot gasses and, to a lesser extent, by the **Radiation Pressure Of Photons**" (Natl.Acad.Sci.USA). Thus, the Planck's quanta contribute to counterbalance the huge gravitational pressure which pushes from the outward external layers of the star to the internal layers. In order to perform this action, this compression, the *Planck's grains* have to "base it on something", as though they had an equivalent mass (equivalent to the energy value of the Planck's quantum divided c^2). Thus, it could be the *equivalent mass* of lots of billion of billion. of *light quanta*, which summed up may contribute, together with the "hydrodynamic pressure of the hot gases", to prevent the Sun from collapsing or the collapse of the other stars, at least for a long time (Puccini,2019,a). It's like saying that *h*, the *Planck constant*, exerts a mechanical action, probably a mass effect acting as "*counter pressure*" to the considerable GI expressed by the remarkable gravitational mass which inexorably pushes towards the inside of the star (Puccini,2018,b). Hence, let us come now to short and very short distances which the DE, or *Photonic Counter-Pressure* in our opinion, should operate too.

E) Intra-Atomic Spaces: at this regard we would like to quote the so-called *N-N Force* or *Levy Interaction* (Levy). It is a *repulsive force*, which prevents the excessive approach of 2 nucleons, indicated as N-N. As it is known, indeed, the particles cannot approach each other beyond a given distance (d_o), below which a repulsive force appears: the Levy Interaction. In this respect, Wigner and Eisenbud write: "There is experimental evidence that the Strong Interaction is repulsive at a very small distance among the nucleons. A particular potential, which was originally proposed on the bases of nuclear forces mesonic theory, and that gives a fairly good description of the *systems with two bodies*, is the Levy Interaction. This force is intensely repulsive at very short distances. Between two nucleons, the Levy

Interaction is strongly repulsive from distances (d_o) equal to"(Eisenbud):

$d_o < 0.532 \cdot 10^{-13}$ [cm] (56).

To this purpose, Pacini states: "Among the nucleons, regardless of their charge, there is a very powerful attractive force, the Strong Interaction, which prevails on the *Coulomb Force* (repulsive between protons) when the distance between the two interacting nucleons is $\leq 10^{-13}$ [cm], that is 1 *fermi.* But by compressing the nucleons enough, the force becomes repulsive again! In fact, the intervention of this force places a limit on the further reciprocal approach of the nucleons, limit corresponding to ~ 0.30 *fermi*, beyond which there is a *saturation barrier*"(Pacini), that is an electromagnetic radiation (EMR) *barrier*, in our opinion, which represents the DE, which is *Radiation Pressure*. Well, we think that this *barrier* consists of a multitude of light quanta thickened and crammed together, but without exceeding "the limit of '*compressibility of the radiation*"(Feynman, 1965a) imposed by the equation (55), although the photons are bosons, so they aren't subject to the Pauli Exclusion Principle (Pauli). We believe that *the secret* of the consistency of this *barrier*, which raises a wall so compact, to be able to counteract the intense Strong Interaction (which would inexorably tend to join the nucleons), resides in the even though minuscule mass-energy density *h* conferred to photon, the Planck's Constant.

However, one might ask: how is the presence of the light quanta justified within the atom? They should be the remitted photons trapped in the 'recombination' phase, which occurred ≈ 380000 years after the Big Bang (BB) (Hack), when the photon energy fell to <13.6 eV. A confirmation of this concept is provided by the atomic explosions, which emit in the atmosphere an amazing quantity of light, really blinding (whose average energy is 2.48 eV), in addition to other EMR_s. In this way, with the 'recombination', that is with the formation of atoms, probably a large number of Planck's grains are incorporated too, no longer able to break the link between the electron and the proton in a hydrogen atom (whose binding energy is 13.6 eV). In our comfort, Randall writes: "The intra-atomic space is full of photons" (Randall).

Shortly, this *repulsive force* that acts within the atom, already signaled by Levy, could represent and show another mode of action, and of operational place, of DE, corresponding to a *Photonic counter-Pressure*. Hence, in this different *modus operandi*, the DE carries out its action conveyed by sufficiently energetic Planck's quanta, demonstrating in this way that the energy density of the DE vary according to the context in which it operates.

F) Intra-Nuclear Spaces: to this purpose Pacini points out: "But there is more: to be convinced of this *Repulsive Force*, which acts as 'repulsive', as for trains, between the two particles, we should think that without it, the atomic nucleus would not hold up and would tend to shrink more and more"(Pacini). This Pacini's statement gives a primary and absolute value to the DE. In effect, without the anti-gravity balancing action of this *repulsive force*, which we identified as a *Photonic counter-Pressure*, the world would not be as it is! (Puccini,2019,c).

G) Intra-Nucleonic Spaces: and' interesting to emphasize that what happens inside the atomic space, as previously described, can also occur in the nucleus and even inside a nucleon, that is in the intra-nucleonic space. In fact, "this mysterious antigravity repulsive energy, or 5th Force, should also act against the gluons, thus succeeding in overriding the Strong Interaction when the quarks (Q_s) tend to get too close to each other, that is when they almost touch each other, but not really: that is there is always some space between the Q_s. The space is apparently empty, but actually it is occupied by the *thickness* of the 5th Force" (http/quibo.it/quark). Well, in our opinion this "*thickness*" can be represented by a large number of Planck's grains, probably too crowded each other, crushed by the Q_s in progressive approach (by the Strong Interaction or *gluon force*) until they can no longer be compressed further and can no longer be in an increasingly narrow space. Nevertheless, this is in complete disaccord with the Pauli Exclusion Principle (Pauli), along with which all the bosons can thicken in infinite quantities. At least for the photons, we must think that there is a limit for the Exclusion Principle, a limit imposed by the equation (55).

In this context, the presence of light's quanta, even within the nucleons (where they prevent Q_s from hitting each other), dates back to the primordial *nucleosynthesis* (which, started 3 minutes and 46 seconds after the Big Bang). In fact, with this process, many highly energetic photons were trapped inside the nucleons. As Weinberg reminds us, indeed, "in the primordial universe there were ≈1.1 billion photons for each nucleon" (Weinberg,1977).

The possible demonstration of what we support is provided, this time, by the nuclear explosions, which free a lot of light, similar to the atomic explosions, as well as an abundant emission of highly energetic radiation. Hence, when the distance between the Q_s is reduced to ≈0.30 fm (Pacini), it is the *thickness* of this 5th Force interposed between the Q_s to act like a buffer.

Well, also from this context we deduce that, without the work and the intervention of the DE, the structure of ordinary matter would not have been as it is, or it would not have been there at all!

H) Intra-Nucleonic Spaces And *Asymptotic Freedom*: in such circumstances, the repulsive action of the DE, that is the *Photonic counter-Pressure* in our opinion, performs those tasks attributed to *asymptotic freedom*. Notoriously, the *Quarks Asymptotic Freedom* phenomenon is characterized by a certain movement independence of the quarks (Q_s) but only for very short distances. This comes from the fact that when Q_s are very close together, the Strong Interaction (SI) almost completely loses its strength. Why? It could be assumed that this is a consequence of the *shielding and masking effects* in their turn supported by the congruous and elegant mathematical formalism of the Quantum Chromo-Dynamics, sufficient on its own to explain the phenomenon (Gross) (Politzer). The calculation concerns the determination of the transferred high *momentum* trend, q^2, of the actual constant of a non-Abelian theory as the Quantum Chromo-Dynamics.

The result shows that the actual constant, g^2, *asymptotically* tends to zero as q^2 increases:

$$g\,(q^2) \approx \frac{c}{\log\,(q)^2} \to 0\ (q^2 \to \infty) \qquad (57).$$

The interactions between Q_s, extremely intense at the energies and *moment* transferred from the order of q^2 ~1 GeV^2, decrease in intensity and tend *asymptotically* to a situation in which the Q_s behave as if they were free: a property admirably defined *asymptotic freedom* of the SI.

Besides we wonder: what is the objective, physical, *concrete* reality that underlies it?

What is the exact *physical* mechanism for which the SI strength is not homogeneous throughout its action radius? Or: how can Q_s, alone, without any help, have enough strength and power to get rid of the extremely intense *grip* exercised by the SI?

Unless there is the intervention of some other phenomenon, currently unknown, completely unrelated to the SI. Then, one might wonder: is it possible that there is something between the Q_s, which at first goes unnoticed, but when the particles gather each other excessively this *something* begins to be *felt*, showing a clear and energetic repulsive action? But if so, what is it?

We think that in the *asymptotic freedom* it is not the SI to loose strength, but it is overwhelmed by another force, a *Repulsive Force*, quite distinct from it, and that, in certain peculiar circumstances, proves to be even more powerful than the SI itself (Puccini,2019,e).

In short, when the distance between the Q_s is too small, for us may be the *thickness* of the *force* (a sort of 5th Force) interposed between the Q_s to act as a buffer, triggering, like a spring, (thus we talk about the DE also as an elastic force) a repulsive action, of mutual removal of the Q_s.

In this respect, we read: "The DE, that is, this mysterious repulsive energy antigravity, or 5th Force, should also act against the gluons, thus succeeding in overriding the Strong Interaction when the Q_s tend to get too close to each other, that is when they almost touch each other, but not really: that is there is always some space between the Q_s. The space is apparently empty, but actually it is occupied by the *'thickness'* of the 5th Force"(http/quibo.it/quark).

Well, we believe that this *thickness* behaves in a similar way to the Pacini's *saturation barrier* which very likely is interposed between nucleons within the intra-nuclear space. Namely, we thought that the *thickness* is represented by a large number of Planck grains, probably too crowded each other, crushed by the Q_s in progressive approach (by the SI or *gluon force*). And this *thickness* of the *repulsive force*, probably interposed between Q_s, may represent just the physical substrate responsible for the peculiar *asymptotic freedom* phenomenon (Puccini,2019,d), (Puccini,2020,b).

Briefly, we believe that this *repulsive force*, or DE, or *Quintessence*, is represented by a multitude of light's quanta that, crammed into an increasingly narrow space, and not further compressible, begin to exert an *expansive counter-pressure*. It is as there was something in the intra-nucleonic space, which reveals the effects of his presence only when the Q_s gather excessively. It is as if this *something* could not be further compressed among Q_s too close together, starting to perform a *counter-pressure*, like a repulsive force. Therefore, in the end, the Q_s can no longer be compressed further and can no longer be in an increasingly narrow space. This is in disaccord with the Pauli Exclusion Principle (PEP), along with which all the bosons can thicken in infinite quantities. At least for the photons, we must think that there is a limit for the PEP, a limit imposed by the Eq. (55).

Furthermore, the hypothesis that there may be something else inside the gluon field is not pure fantasy. According with Barrow, the seemingly empty space is full of electromagnetic (EM) radiation (Barrow,2000); it's like saying that the so-called *vacuum* always contains, and in any case, an EM field, that is a Maxwell's field. At this regard, Penrose says: "Maxwell EM field delivers energy. For $E=mc^2$, it must also have a mass. Maxwell's EM field is therefore also matter! Now we must certainly accept this notion" (Penrose,2004). It is pleonastic to specify that Maxwell's EM field is constituted and operated by *Planck's grains*.

Moreover, we know that the intra-hadron space is not completely empty, it contains the *proton sea* (Randall). Maybe in addition to the repulsive *photonic barrier*, these virtual Q_s and $\bar{Q}_s$ (that is to say with a very short life), of which *proton sea* swarms,

contribute to the repulsive action emerging among Q_s too close together, and therefore counterbalancing the SI's action for excessively short distances. It is like saying that the so-called *shielding effect* is not mediated by immaterial, evanescent particles, but by real quantum objects.

We reiterate: it may also appear as an unlikely hypothesis, but we cannot exclude it with certainty. If we integrate this phenomenon, the explanation will be more exhaustive and complete, to better understand why the action of SI weakens almost completely for too short distances between Q_s (despite its very intense strength) (Puccini,2020,b). In this way, we try to embody the possible physical real structure that could be at the bottom of the peculiar *asymptotic freedom* phenomenon, already masterfully illustrated, from a mathematical point of view, by Gross, Wilczek and Politzer.

By concluding, there are still several examples of *Photonic Pressure*, but without an associated *counter pressure*. That is to say, *without the repulsive action*, so far described, which represents the primary characteristic of the DE. Thus, they do not appear as classifiable phenomena among those managed by the DE.

2.7.4 Possible *Dep* 'S Values

For all the above reasons, we assume that the DE is conveyed by light quanta, i.e. photons, also of different energies, engaged in various tasks, sometimes peculiar and/or unusual, whose common denominator is represented by the impossibility of being compressed and thickened beyond a determined limit (Puccini,2019,b). As to say that the Dark Energy Particle (*DEP*) corresponds to the light quantum, the Planck's grain! Obviously, this value is not constant, but varies with the oscillation *frequency* that accompanies the Planck constant (*h*), according to the *Plank's postulate*, $E=h\,v$, as shown by Eq. (7).

As concerns the value of the *inertial* and *dynamic* mass of light quantum, we can compare, for example, our calculations with those of Penrose, or Perlmutten's, inherent different contexts.

As regards Penrose, in his masterful volume, "The Road to Reality", on page 641 He writes: "The mass of photon, if not 0, should be $<10^{-20}$ electronic masses for good observational motives" (Penrose,2004). Well, the mass of the electron is $9.1\cdot10^{-28}$ grams, so if the photon is $<10^{-20}$ electronic masses, we have: $9.1\cdot10^{-28-20}$ [g]. Thus, in accordance with Sir Roger Penrose a light quantum, i.e. a photon, which is not massless must have a mass very close to $< 9.1\cdot10^{-48}$ [g].

Penrose's calculations, among the greatest living mathematicians, are completely superimposable on ours: $7.372\cdot10^{-48}$ [g], as shown in Eq. (32). This is of great honor for us and greatly comforts us.

As concerns Perlmutten, the surprising accelerated expansion of the Universe has been attributed to a repulsive, anti-gravity action most likely carried out by a mysterious, elusive form of energy, called *dark energy* (DE). In this case, along with the calculations of Perlmutten *team*, the energy density of this *repulsive force*, or DE, is $\approx10^{-29}$g/cm^3.

This value should represent the energy density of the intergalactic and interstellar DE particle (*DEP*). These *DEP*, in our opinion, *should* correspond to light quanta of different wavelengths which, in this context, should be represented by the *cosmic microwave background* (*CMB*) (Penzias). As known, the *CMB* wavelength (λ) is $\approx$7.35 [cm]: they are microwaves, that is Planck's grains with very low energy.

Let's see what the *CMB energy-mass density* is. The particles are mostly in motion so that, in the same way as the photon, to calculate the density value of the *DEP* mass-energy, we must analyze its momentum (***P***): $\boldsymbol{P}=h/\lambda$ (as shown in equation 12). Hence, in those circumstances in which the *DEP* have a wavelength (λ) superimposable to that of the *CMB*, the ***P*** of the *DEP*, indicated with DEP_p, will be:

$$DEP_p = \frac{h}{\lambda} = \frac{6.626\cdot10^{-27}[\text{erg}\cdot\text{s}]}{7.35[cm]} \qquad (58),$$

that is: $$DEP_p = 0.9014965\cdot10^{-27}\,[\text{g}\cdot\frac{cm}{s}] \qquad (59),$$

i.e.: $$DEP_p = 9\cdot10^{-28}\,[\text{g}\cdot\frac{cm}{s}] \qquad (60).$$

As it can be easily seen, these values are very similar to those calculated by Perlmutten, inherent the intergalactic DE ($\approx10^{-29}$g/cm^3); how to say, in our opinion, that this value also represents the *energy-mass density* of the intergalactic *DEP*.

This finding could represent an indirect counter-proof that the *DEP* can coincide with the light quanta, whose λ varies according to the context in which they operate.

We have proposed, in fact, that DE may also be present within the nuclear space (there it represents the *N-N Force* or Levi's Interaction (Levy), as to say the Pacini *saturation barrier* (Pacini) and within the nucleonic space, where the DE may create an incompressible *physical barrier* that prevents Q_s to further get closer, probably representing the physical substrate underlying the peculiar *Q_s asymptotic freedom* phenomenon (Puccini,2019,e).

It is interesting to highlight that in these last circumstances the energy carried by *DEP* would be much more intense (compared to the intergalactic DE), so that the respective λ would be much shorter than *CMB* wavelength. That is the λ of the involved *DEP* (or light quantum, according to our hypothesis)

should vary in line with the considered context. Besides, this inconstancy in the *energy-mass density* value of the DE (and thus of the *DEP*), consequent to the variability of its λ, is in perfect harmony with Weinberg's concepts which, to make ends meet with the Anthropic Principle, assumes that the *vacuum energy* (or DE) took different values in different domains of the Universe (Weinberg 1987).

In short, the *counter pressure* triggered by DE most likely represents the most immediate physical and real manifestation of an (*auxiliary*) *force* or *potential energy* that appears on occasion when circumstances require it. That is, contrary to the 4 Fundamental Forces, it is as this *potential* 5th Force, initially present as *vacuum energy* represented essentially by "*electro-magnetic fields* swarming of photons"(Randall) and continuously exchanged by electrons and *ephemeral* positrons, (generated by the *quantum vacuum*, according to Barrow), was *taking shape*, structuring in case of necessity, when the compressive action exerted by the Gravity Interaction becomes excessive, particularly intense, we could say *overwhelming*, until a counter-reaction takes place, i.e. the *Photonic counter-Pressure* (Puccini2019,c).

It is very interesting to emphasize that, in full compliance with the *theme* of our paper, to trigger this *counter-pressure*, for us is the mass-energy density of a very compact wall of Planck's grains, no further compressible, compressed up to the limit point dictated by the mathematical formalism expressed in Eq. (55), after which the repulsive action is immediately triggered.

"An atom is mostly empty, but within this vacuum there is of course an electromagnetic field, although virtually no real matter is present"(Puccini,2017,b), but there is energy: the so-called *vacuum energy*, which is none other than DE, which is actually represented by "the light quanta continuously exchanged between electrons and nucleus"(Randall).

What Randall affirms appears to us as an indirect confirmation, but very authoritative, of our hypothesis: the so-called *vacuum energy*, that is DE, is nothing transcendental and mysterious, nothing but a form of *Photonic Pressure* and the particle that carries this DE is probably the Planck's grain. The *quantum vacuum*, indeed, is one of the key elements to help us understand the characteristics, properties and structure of the DE Particles (*DEP*), for us represented in the last analysis by light quanta, but not all and not always of the same energy and, likely, not photons of the optical band, this is the keystone: the DE is represented by a *Photonic Counter-Pressure*, or *negative pressure*, then expansive, repulsive, antigravity, exerted by Planck grains *no further thickened and compressible*.

Most likely, the DE is nothing more than the sum of the common *photonic energy* of a considerable number of light quanta, often inexorably more and more compressed and amassed by the Gravity Interaction, until, as Eq. (51) indicates, it reaches a limit of *incompressibility* of the electromagnetic radiation. At this point, by each individual photon, an energetic repulsive action triggers, which, adding to each other by the Overlap Principle (Glenn), act in unison as a *counter-pressure* (or *negative pressure*): just as the *Radiation Pressure* or *Photonic Counter-Pressure* works.

2.7 Non Zero *H* Value In General Relativity

As we all know, the great revolution of General Relativity was that of geometrically expressing the role of gravity in a space where mass-energy was present. Einstein, indeed, starting from the *principle of equivalence*, already postulated in Newton's theory (1687), states that the presence of mass-energy induces the curvature of space-time, since the trajectory of a light ray in the presence of a gravitational field is not straight. "Einstein's equations for the gravitational field are the model for the equations of our universe; they account for the interaction of geometry with matter, that is, they allow the determination of the metric in the presence of matter"(Giammaria). These are 10 linear differential equations of the 2nd order to the partial derivatives, having as unknown the components of the *metric tensor* g_{ab}: they describe the geometry of the space-time and its curvature, placing them in relation with the *density of matter-energy* and the *pressure*, using the *energy-momentum tensor* (T_{ab}). In effect, "in the relativistic theory of gravitation it is first of all important to specify that the sources of the gravitational field are both the density of energy, the density of the flow of energy, and the density of the impulse flow (*momentum*). These three quantities form a single tensor type object which is the energy-momentum tensor (T_{ab}) which measures the mass density of matter and, at the same time, fully describes the properties of matter" (Giammaria).

Therefore, Einstein field equation binds the *metric tensor* (g_{ab}) to the *energy-momentum tensor* (T_{ab}), being dependent on the state of matter and therefore not an absolute magnitude, but a dynamic field that must satisfy an equation. So the first Einstein's Field Equation is:

$$R_{ab} - \tfrac{1}{2} R g_{ab} = -8\pi G\, T_{ab} \qquad (61),$$

where G is the gravitational constant, while the 8π, as Penrose remind us "comes from the fact that we are dealing with *density*, rather than single particles. The sign – depends on the fact that the acceleration is inward, inducing a *reduction in the volume* in the deviation of the geodesics to which the equation

originates. The *source of gravity* (i.e. the source of the volume reduction), instead of simply being equal to 4πG multiplied by the mass density (in the sense of the mass-energy term in T_{ab}) is now 4πG multiplied by the mass density plus the sum of the pressures in the material, in 3 mutually perpendicular directions (deriving from other components of T_{ab}). The only essential difference between the geometry of the curved space-time (which Einstein needed) and the Riemannian geometry, for which the Ricci-Curbastro tensile calculus had been introduced (in the four-dimensional case) was the *sign change*, which was required in passing from the locally Euclidean structure of the Riemannian spaces to the locally Minkowskian structure required by a relativistic space–time"(Penrose,2002). With the Eq. (61), indeed, Einstein "replaced both the gravitational field of Newton and Poisson with the *Riemann metric tensor* (R_{abcd}), and the matter density of the gravitational fields of Newton and Poisson with the *energy-momentum tensor* (T_{ab})" (Aczel).

When Einstein completed his *field equation* he was firmly convinced that he could use it to describe an isotropic, homogeneous but static universe. Yet, "Einstein's equations showed that a static universe is unstable and would collapse on itself under the action of gravity. To avoid collapse Einstein postulated the existence of a *force* that opposed gravity (in order to maintain the static universe): he called it *cosmological constant*"(Hack) and inserted it with the symbol Λ in his field equation (Einstein,1917):

$$R_{ab} - \frac{1}{2} R g_{ab} + \Lambda\, g_a = -8\pi G\, T_{ab} \qquad (62).$$

As it can be seen, Λ appears to multiply the metric tensor g_{ab}, so that locally its modest (repulsive, anti-gravity) effect was negligible, while its action on cosmological scales could be appreciated.

The modification made by Einstein to his equation, indeed; "was carefully calibrated, so as to preserve those important physical characteristics that a meaningful equation must possess. The change had to have very little effect on local phenomena, such as the motion of the planets, but very pronounced for the great distances. Thus he cleverly manipulated the geometry of the Universe, so as to fit it with the equation"(Aczel).

Well, with this *move* Einstein tried to restore the stillness to his model of the Universe, which was the accepted view at the time. So, for Einstein, "the concept of gravity as an attractive force is also valid on a cosmic scale for all known forms of energy and for matter. At the same time, Einstein's theory of gravitation also allows the existence of forms of energy with different properties, which produce repulsive gravity, just as seem to work the DE"(Puccini,2019,b). At this regard Hack states: "Einstein's equations showed that a static universe is unstable and would collapse on itself under the action of gravity. To avoid collapse, Einstein postulated the existence of a force opposing the Gravity Interaction (so as to maintain the static universe): the *cosmological constant* (Λ)" (Hack).

This suggests that already in Einstein's first field equations, easily contradicted by Friedmann (1922), something was missing that, in our opinion, is not the cosmological constant, but rather the *Planck constant*: this would be *the quantization of General Relativity* and, in a certain sense, also a Quantum Gravity (Puccini, 2019,a), since the General Relativity is closely connected to the value of gravity (the Gravity Interaction remained outside the Standard Model precisely because the link with the Quantum Mechanics was not found). Thus, considering the de Broglie formula: $\boldsymbol{P}=h/\lambda$, in Eq. (58) instead of Λ we could introduce the value of the *momentum* (***P***) of the considered Electro-magnetic Radiation, or *Radiation Pressure,* that is h/λ:

$$R_{ab} - \frac{1}{2} R g_{ab} + \frac{h}{\lambda} g_{ab} = -8\pi G\, T_{ab} \qquad (63),$$

where λ indicates the wave length of the involved *DEP* (or light quantum), which should vary according to the context considered (as previously described). This *inconstancy* in the value of the DE (and therefore of the *DEP*), consequent to the variability of its λ, is in perfect harmony with Weinberg's concepts which, to make ends meet with the *Anthropic Principle*, assumes that the *vacuum energy* (or DE) took different values in different domains of the Universe (Weinberg,1987).

Thus, we could assert that we did not make any *apparently* significant change to the Einstein field equation, since the *h* we introduced is also a constant (whose value is well known), while the other parameter is a *lambda* too. However, here is the substantial difference: the *lambda* (Λ) introduced by Einstein indicates just a *constant*, representing an energy value, small, but not at all defined (value that for some theories is not even fixed, constant).

With our model, conversely, the *lambda* (λ) expresses with extreme precision the value of the wavelength of the particle transmitting the DE in the considered circumstance. Moreover, it is easy to deduce that in our model the value of λ is not constant at all, but varies according to the energy density of the particle (*DEP*) involved, which we can assimilate to a Planck's quantum, i.e. a photon, and which varies according to the *context* in which it operates.

3. Conclusions

To conclude, for all the above reasons, the DE is conveyed by *Planck's grain*, i.e. light quanta, also of different energies, engaged in various tasks, sometimes peculiar and/or unusual, whose common denominator is represented by the impossibility of being compressed and thickened beyond a determined limit. Briefly, the *counter pressure* triggered by DE most likely represents the most immediate physical and real manifestation of an (*auxiliary*) *force* or *potential energy* that appears on occasion when circumstances require it.

In other words, contrary to the 4 Fundamental Forces it is as this *potential* 5th Force, initially present as *vacuum energy,* represented essentially by *electro-magnetic fields* swarming of photons (continuously exchanged by electrons and *ephemeral* positrons, generated by the *quantum vacuum*), was *taking shape*, structuring in case of necessity, when the compressive action exerted by the Gravity Interaction becomes excessive, particularly intense, we could say *overwhelming*, until a counter-reaction takes place, i.e. the *Photonic counter-Pressure*.

We believe that, to trigger this *counter-pressure*, is the mass-energy density of a very compact wall of Planck grains, no further compressible, compressed up to the limit point dictated by the mathematical formalism expressed in equation (55), after which the repulsive action is immediately triggered, anti-gravity, as due to *a request for space that is failing*.

That's like saying that, at last, the *Planck's radiation corpuscles*, i.e. the photons, are saved in time: otherwise in the various circumstances described they would be inexorably crushed and, maybe, destroyed by the Gravity Interaction.

What saves them is the limit to their *compressibility*, elegantly illustrated by equation (55).

In short, digging deep, this *mathematical* limit in our opinion is closely related to a *physical* parameter: the real structure of a light quantum, the photon, whose *soul* is represented by the energy-mass value of the Planck's constant, *h*.

It is a truly infinitesimal value, but multiplied by million and millions of times it can acquire a real physical consistency with related effects that cannot be reset.

Furthermore, still the Planck constant (precisely through its infinitesimal mass multiplied by the frequency of the light quantum to which it belongs) may represent the *mathematical* solution to the Yang-Mills *mass gap problem* (Yang,1954) without resorting to the *Renormalization* or to the Brout-Englert-Higgs Mechanism (Englert), (Higgs), (Guralnik), but simply inserting its value in all the equations of Perturbation Calculus, Quantum Fields Theory and Yang-Mills Theories (Puccini2019d).

It is clear, indeed, that if we insert this infinitesimal energy-mass value (however $\neq 0$) instead of massless photons in all these equations, subsequently all *divergences*, that is all zeros and infinities, would suddenly disappear. Hence, the limits imposed by the *Spontaneous Symmetry Breaking* disappear so that there is no longer any need to deny the mass to the Nuclear Forces bosons (Puccini,2017,c), including the Yang-Mills ***B*** *quantum* (Yang,1954), i.e. the boson of the Strong Nuclear Interaction.

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8/20/2020