DARK ENERGY PARTICLE IS the PHOTON

Antonio PUCCINI
Neurophysiologist of Health Ministry, Naples-Italy

ABSTRACT

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, for us represented ultimately by photons (Ps) but, likely, not Ps of the optical band.
Probably DE is the sum of the common *photonic energy* of a lot of Ps, often inexorably amassed and thickened by the Gravity Interaction, until the radiation cannot be further compressed.
These concepts are elegantly confirmed by the equation: $PV^{4/3} = C$. Consequently, from each individual P triggers an energetic repulsive action, which, summing up (by the Overlap Principle), acts in unison as a *counter-pressure*. To trigger this *counter-pressure*, is the mass-energy density of a very compact wall of Ps, no further compressible.
DE is ubiquitously widespread both within intergalactic and intra-atomic space, between the nucleus and the orbiting electrons: the latter is a space notoriously swarming of Ps.
In our opinion, DEP are conveyed by Ps, also of different energies, engaged in various tasks and operating contexts, sometimes peculiar and/or unusual, whose common denominator is represented by the impossibility of being compressed beyond a determined limit.
In short, DE is represented by a *Photonics Counter-Pressure*, or *negative pressure*, that is expansive, repulsive, anti-gravitational, exerted by Ps *no further compressible*. As well-known in fact, Ps are not ethereal and dimensionless particles. Ps are the *Planck grains*, equals to:
$6.626 \cdot 10^{-27}$[erg·s] $\cdot 10^{n}$ [c/s], where *n* indicates the number of oscillations per second of a single P.

1.INTRODUCTION

1.1 The MISSING MASS

As is well-known, at the beginning of the 30's Fritz Zwicky noticed that peripheral stars rotating around the centre of a galaxy have such a speed that the Gravity Interaction(GI) should not be able to keep them into orbit. In fact, Zwicky wrote: "E. Hubble has shown recently that the correlation between the apparent velocity of recession and the distance is roughly linear, corresponding to 500 Km./sec. per 10^6 parsecs. Large deviations occur for the nearest nebulae, which may be attributed to their peculiar motions. The relative shift of frequency $\Delta\upsilon/\upsilon$ representing the velocity of recession is apparently independent of the frequency. The available range in the spectrum is not very large, however. No appreciable absorption or scattering of light can be related to the above shift of spectral lines. The optical image of an extragalactic nebula seems to be as well defined as can be expected from the resolving power of the telescopes. Extrapolating from Hubble's relation to objects in our own galactic system, the velocity of recession would become so small (5 Km./sec. for 10.000 parsecs) that it would escape observation. The theoretical considerations proposed by the author in the following made it probable that an appreciable effect should also be observed in our galaxy"[1].
Zwicky assumed the existence of an invisible mass-energy on which the GI acted. He hypothesized the existence of a *missing mass* (MM). An invisible mass-energy whose gravitational effect adds to the visible matter's. In this way account balanced[2]. Margherita Hack adds: "By studying the motion of the galaxies within the Comae Berenices (321 million light years away), Zwicky, in order to justify the rotation speed (which was not allowed by the overall mass of cluster), deduced the presence of a greater quantity of mass, represented by an invisible, not detected matter. As for the Virgin Cluster, also for Comae Berenices Zwicky - in 1933 - found that the mass, indicated by the motion of the galaxies (members of the Cluster), was far greater than the mass that could be deduced counting them. It was another proof of the existence of a large quantity of non-luminous, not detectable, invisible matter: the MM"[3]. We learn from Giacconi and Tucker: "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. Such differences between the observed mass and the gravitational mass were already noticed by Oort in 1941 and Schwarzchild in 1954. However most astronomers ignored the problem until late 70's. Things changed radically when new optical instruments were developed as well as more powerful X and radio telescopes"[4]. New instruments allowed Vera Rubin and her stuff at the Carnegie Institute to measure orbital speeds far away from the centre of a galaxy. They obtained accurate evaluations of mass galaxies. Using the *Doppler effect* technique, they learned that the mass calculated from orbital speeds is much bigger than the mass inferred from the optical image of the galaxy[5]. Rubin said: in spiral galaxies the ratio between MM and luminous matter is 10 to 1. Apparently galaxies are immersed in a halo of invisible matter. "These results were confirmed by radio observations, showing that galaxy invisible halos must contain about ten times more mass than what can be seen in the visible and radio waves. Apparently this MM is hidden in a kind of shape which so far we have not been able to observe.

One of the most spectacular examples of invisible halos was showed around the big elliptic galaxy M87 by Fabricant and Gorenstein, and by Forman and Jones (at Harvard-Smithsonian Centre for Astrophysics). The data were collected with the X ray counter from *Einstein*” [4].
The phenomenon, initially highlighted by Zwicky, was later found everywhere. For example, "it had already been noticed with the telescopes that spiral galaxies, like our Milky Way, rotate at much faster speeds than expected. Indeed, in the exterior, the stars rotate at 700.000 kilometers per hour, at this speed the centrifugal force should make the stars run away in all directions "[6]. Also recent observations have showed that the motion of both the galaxy and the stars in the galaxies, is to be imputed to a quantity of mass-energy significantly bigger than what can be detected with the optical band or other electromagnetic radiations [7].

1.2 PLANCK SATELLITE

X and radio frequency surveys confirm the results: non observable mass, or MM, is ≈95% than the total mass of the Universe. The ordinary visible mass is only ≈5% than the total mass. This is confirmed by accurate satellite surveys. In fact, very sophisticated instruments have been built, such as those allocated on the Planck satellite, which has studied the *cosmic microwave background* (CMB) with such precision that has offered us even more accurate data on the composition of the Universe [8]. With Planck the quantitative values of the ingredients of the Universe have changed. From Planck 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 that composes the cosmos, compared to 4% of the data collected from the previous satellites. Therefore, the invisible energy-mass left, or MM, corresponds to 95.1% of the cosmic mass. In its turn, the MM is divided in Dark Mass (DM) and Dark Energy(DE).
To this purpose Capaccioli writes: "DM is *Matter* because it is capable of exercising a GI, similar to that of ordinary bodies, made by the heavy particles of atomic nuclei, the baryons. It is *Dark* because this 'new thing' seems to be completely indifferent to photons: it does not produce nor absorbs light, and when the two meet, each one keeps going on his way. DM must have a different nature from things we know are made, both in heaven and on Earth. Theoretical and experimental physicists have worked hard to find the responsible particle of an ingredient, which though dark, might have played a crucial role in allowing the baryons of the primordial cosmic soup to concentrate on stars and galaxies: no dark matter, no party, one could say. Unfortunately, however, the hunt has not yet yielded any result. The game is still open "[9]. Therefore: what is the invisible mass of the universe (DM) made of? We don’t know. “Cosmological considerations seem to exclude that the DM is under the shape of a normal baryonic matter”[4]. Probably the DM is made up of particles formed before and immediately after the Inflationary Phase [10] [11] [12].
Again according to data from the Planck satellite, DM constitutes 26.8% of this cosmic mixture of matter and energy (instead of 23%). Besides,“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) (compared to the previously estimated 73%).

2. DISCUSSION

2.1 PRIMORDIAL UNIVERSE

As Hack reminds us “The primordial plasma was subject to two opposing forces:1) Gravity (GI) and

2) *Radiation Pressure* (or *Photonics Pressure*). The former tends to compress the gas until the Photonics Pressure reverses its motion, producing elastic oscillations. Since compression heats the plasma, it results in the warmer and colder regions observable in the CMB, shown by the presence of two peaks. Since both the baryonic matter and the DM are subject to the GI, while only the baryonic matter is subject to radiation pressure, it is possible to determine from the properties of the peaks that the baryon matter is ≈4% of the critical density and the DM ≈23%. On the other hand, the fact that the universe is flat means that the critical density must be equal to 1. It follows that the remaining 73% consists of energy density "[3]: the so-called 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 GI would decelerate the expansion. Two groups of researchers, the American Supernova Cosmology Project and the Australian High Red Shift Supernova Search Team [13] [14], surprisingly found that the expansion of the universe has not slowed down, due to its own gravity, but it is 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* "[3].

2.2 VACUUM ENERGY

Let's try to better understand what "vacuum" and *vacuum energy* mean. "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"[3]. This antigravitational 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 [3]. Therefore, "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 "[15].

Hawking writes: "besides matter, the universe can contain *energy of the vacuum*, the energy present also in an apparently empty space" [16]. In fact, as known, in the description of physic systems, vacuum is considered as the minimum energy state, or *Zero Point Energy* [17], which only in some cases corresponds to the *almost* total absence of particles or waves. "It was thought that the interstellar and inter-galactic spaces were expanses of vacuum, but then with the theory of quantum fields(QFT) it was stated that space is never really empty, but is pervaded by quantum fields present everywhere: the various particles are, in fact, *excited states* of these fields. Space appears empty when the fields are at the lowest energy level, whereas space comes alive with visible matter and energy when the fields are excited. Wheeler said: empty space is not empty, but it is the kingdom of the richest and most surprising Physics. For Hawking, DE is the central problem of Physics "[18].

Barrow states: "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 (ZPE) "[19], 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 reflects the reality of the UP, since if we know the position of an oscillating particle, its motion and therefore its energy are uncertain.

As it is known the UP establishes that there are pairs of *complementary properties* that cannot be measured simultaneously with unlimited precision. The energy and the average life of a particle constitute one of these *complementary pairs*: "if you want to know everything about the energy of a particle, you must renounce to any information on its half-life. In other words, the UP states that the product of the uncertainties of these two variables is always greater than h/2π:

$$\Delta_E \cdot \Delta_T > h / 2\pi \qquad (1),$$

where Δ_E indicates the uncertainty of the energy, Δ_T the uncertainty of the particle lifetime and h is the Planck's constant. Any particle or observable physical state must satisfy the inequality expressed by equation (1). It is a precondition for observability"[19].

In this regard Feynman say: "No one has ever found (or even thought of) a way around the UP. So we must assume that it describes a basic characteristic of Nature"[20].

Hawking states: "UP is a fundamental, inescapable property of the world" [21].

Barrow adds: "The entity of the *uncertainty* is precisely the ZPE. This means that the concept of vacuum must be reconsidered in some way, since it can no longer be associated with the idea of null or empty space. The idea of the ZPE was originally introduced by Planck in 1911, proposing that the emission of radiation occurs in *discrete quanta*, while the absorption can take place continuously for any quantity. The system has an energy (E) of:

$$E = h\,\nu \qquad (2),$$

where h is the Planck's constant and ν is the frequency of the considered radiation"[19].

2.2.1. Quantum vacuum

Still with regard to 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 UP prevents a measure of the vacuum state energy from giving exactly a zero value. Because of the UP 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"[22]. As Barone reminds us "the vacuum has energy and is the site of continuous fluctuations, which produce virtual quanta (that is, of very short life). The theoretical study of the vacuum is the object of the QFT. The *quantum vacuum* is a mine of interesting phenomena: the generation of antimatter (antiprotons and antineutrons, first of all), the multiple production of particles, the annihilation reactions"[23].

Barrow adds: "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(EM) 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. "[19]. This implies that the vacuum, the *quantum vacuum*, contains a fair amount of energy, since it is able to lend it! [24]. "If the time lapse, during which the particles exist (before annihilating again), is so short as to violate the UP, that is if:

$$\Delta_E \cdot \Delta_T < h / 2\pi \qquad (3),$$

then these electron-positron pairs will be *undetectable*: this is why they are called *virtual pairs*. On the contrary, if before annihilating each other, and disappearing, they live long enough for the equation (1) to be satisfied, the particles will be *observable*: in this case we talk of *real couples*. The creation of virtual couples seems to be a violation of the Energy Conservation Law. Nature allows us to violate this law, provided that no one can grasp it on the fact: this is guaranteed on condition that the energy is returned fairly quickly. In short, it is convenient to conceive the condition of virtuality as a sort of agreement for the *energy loan*. Thus, the quantum vacuum is populated by a set of virtual electron-positron pairs that continually appear and disappear. One wonders: since these virtual couples are unobservable, why do not we ignore them? At this point we reconsider our two electrons that are about to interact: their presence determines an important change in the quantum vacuum. Electric charges of opposite sign attract each other and therefore, if we place an electron in the vacuum populated by virtual pairs, the positively charged virtual positrons are attracted to the electron. That is, the electron has produced a separation of virtual pairs and is therefore *wrapped* in a cloud of positive charges. This process is called *polarization of the vacuum*. Its effect is to create a positively charged screen around the bare negative charge of the electron. Another electron approaching will warn, not the entire negative electrical charge of the electron placed in the vacuum, but the milder effect of the *shielded* charge, and will be more weakly widespread than it would happen if the vacuum polarization was absent "[19].

It is interesting to point out that "this effect changes if we vary the energy, both of the environment and of the incident electron. If the electron approaches rather slowly, it will not penetrate deeply into the shielding cloud of positive charges and will be weakly deflected. But if it approaches with a higher energy, it will penetrate deeper into the screen and feel the effect of a greater share of the entire electron charge at its center. Therefore, the incident electron will be deflected more drastically than less energetic particles. Thus, the effective intensity of the electromagnetic(EM) repulsion force between two electrons

depends on the energy at which it takes place: as energy increases, the interaction becomes more intense. It's like playing with woolen-lined billiard balls: if the balls hit flat, they will just bounce, as they are protected by wool coatings; but if they are collided at high speed, the padding will have little effect and the balls will bounce with great force. The trend is clear: the more the environment energy grows, the more effective the electromagnetic interaction (EMI) becomes. As energy increases, the incident particle 'sees' more and more closely the bare charge of the point-like electron behind the virtual positron cloud, and is deflected more"[19].
In short, the laws of Quantum Mechanics 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).

2.3 GENERAL RELATIVITY'S FIELD EQUATIONS

As known "in Newtonian space-time there are two separate geometries: a three-dimensional for space and another one-dimensional for time, hence the disjunctive definition of two distances: a spatial (d_s) and a temporal (d_t). Relativistic space-time, on the other hand, contains only one geometry that combines both space and time, so as to define the temporal space interval (d_s^2) which is the invariant interval under general transformations of coordinates "[25], which fix the distance between two points, or rather (since we are dealing with Relativity, where the 3 spatial coordinates are closely related to the temporal coordinate) it is more appropriate to say: the distance between 2 *events*. For a flat space-time (Minkowskian) like the one considered in the Special Relativity, the invariant in Cartesian coordinates (d_s^2) is so defined:

$$d_s^2 = c^2\, dt^2 - dx^2 - dy^2 - dz^2 \qquad (4),$$

where only the temporal coordinate (d_t) has the positive sign, while the 3 spatial coordinates have the sign -. "The great revolution of General Relativity was that of geometrically expressing the role of gravity in a space where mass-energy was present, no longer adopting Newton's vision of gravitational force, but that of Einstein. The latter, in fact, starting from the *principle of equivalence*, already postulated in Newton's theory, 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, so the curves that minimize the distance (d_s), in a space where mass-energy is present, are not straight lines, as happens instead in a flat space "[25].
Therefore, along with the *principle of equivalence* of Galileo-Newton, every gravitational field can be described, locally, by a metric expressed, precisely, by the *metric tensor* g_{ab}, which allows to express the distance between two points infinitely close (in any coordinate system) and to determine the intrinsic properties of the space. The curved space of Riemann has a geometry characterized by two structures: a *metric* one, expressed just by the *metric tensor* g_{ab}, and a *similar* one, determinable starting from the metric tensor following the definition of the Christoffel symbols: $\Gamma^{\mu}_{\alpha\beta}$. The *metric tensor* takes on a dual role: it describes the geometry of the space, defining its distances, as well as acquiring a *physical meaning*, thanks to its relationship with the gravitational potential. Thus, in the formulation of General Relativity, the metric completely determines, through the symbols of Christoffel, the geometric and kinematic properties of the curved space-time.
"To get to the heart of Einstein's gravitational theory we must address the problem of geometry dynamics, that is, the interaction of geometry with matter, expressed by Einstein's field equation. 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 "[25]. 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}). Thus, Einstein field equation binds the metric tensor to the energy-momentum tensor, being dependent on the state of matter and therefore not an absolute magnitude, but a dynamic field that must satisfy an equation.
"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"[25].
In turn, a fundamental element for mathematically describing the concepts of General Relativity is the *Riemann curvature tensor* (R_{abcd}), used by Einstein to measure distances in curved spaces, whose subscribed indices "refer to all possible modes in which the geodetic deviation could be measured" [26]. Furthermore, the Riemann tensor characterizes the dependence of *parallel transport* from the chosen path and gives a quantitative measure of the curvature of the space. By contracting the Riemann tensor indexes we obtain the curvature tensor (of space-time), or *Ricci-Curbastro tensor* (R_{ab}) which, by further contraction, leads to R, called *scalar of curvature*, or *Ricci's*: it is a single
average total quantity. So Einstein's field equation is:

$$R_{ab} - \frac{1}{2}\, g_{ab}\, R \;= -8\pi G\, T_{ab} \qquad (5),$$

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})" [26]. It is useful to bear in mind that" 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"[26]. In fact, with the equation (5) 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}) "[15].
It is important to keep in mind that when Einstein completed his field equation he was firmly convinced that he could describe through it an isotropic, homogeneous but static universe.
Yet, as Hack points out: "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*"[3] and inserted it with the symbol Λ in his field equation [27] :

$$R_{ab} - \frac{1}{2}\, g_{ab}\, R + \Lambda\, g_{ab} \;=\; -8\pi G\, T_{ab} \qquad (6).$$

As can be seen, Λ appears to multiply the metric tensor g_{ab} , so that locally its modest (repulsive, anti-gravitational) effect was negligible, while its action on cosmological scales could be appreciated. In fact, the modification made by Einstein to his equation "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. He also used the non-Euclidean nature of his space: whose curvature was expressed by 10 quantities, corresponding to the 10 metric tensor coefficients *g* of the four-dimensional space-time; therefore Einstein retouched each of these 10 quantities of a quantity Λ, very small. Thus he cleverly manipulated the geometry of the Universe, so as to fit it with the equation" [15]. 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, meaning both the baryonic matter and the DM. Consequently, General Relativity contemplates that the expansion of the universe slows down at a rate determined by the density of matter and the energy contained therein, at least for those to which an attractive gravitational action can be associated, as is traditionally known "[25]. At the same time, Einstein's theory of gravitation also allows the existence of forms of energy with different properties, which produce repulsive gravity.

2.4 COSMOLOGICAL CONSTANT

As it is known "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"[19]. In other words "Λ has many mysterious properties: the most important is that it is a form of energy that does not dilute with expansion, but which, in fact, remains constant. This is a consequence of another unusual feature: its strong negative pressure. In General Relativity, pressure exerts a force of gravity, just like mass: being negative, the resulting force accelerates expansion (instead of slowing it down like ordinary matter and DM); it is therefore a sort of anti-gravity, absolutely homogeneous (so it can not be modeled at will to make it anti-stars, anti-planets and anti-gravity engines). An immediate consequence of its value independent of time is that Λ will continue to accelerate expansion forever (even when the density of matter and radiation will have fallen to imperceptible levels). The data do not yet allow to establish if Λ is the only possible explanation "[28].
Furthermore, "Λ behaves like an energy, a very particular energy, characterized by always having the same mass-energy identity, about 10^{-29}g/cm^3 at any point in space and at any time. This translates into an impressive object, which creates *copies of itself* as the Cosmos expands, so as to fill in equal measure all its parts. Not only that: 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, 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! "[29]. We read: "Λ could be interpreted as the energy density of the vacuum, which according to the Quantum Mechanics assumes a certain non-zero value. We wonder: is the observed acceleration *exactly* the one predicted by a Λ? If not, if we could identify small discrepancies between the observed cosmic evolution and that predicted by the hypothesis of a contribution due to a *constant* energy density, we would be forced to actually consider new forms of energy, or alternative theories of gravity, and we would probably also have some indication of the direction in which to direct theoretical research"[30]. Barrow

points out: "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 [19].

2.5 DARK ENERGY(DE) PROFILE

DE is a mysterious, unknown energy, ubiquitously widespread in the cosmos, but not directly detectable. It represents 2/3 of the entire mass-energy density contained in the Universe. DE and 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*. 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 (GI). **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"[6]. 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. In short, "compared to the DM, the puzzle of the DE appears even more intricate" [18]. Moreover, "differences in the distribution in the Universe between DM and DE are emphasized: the DM has a non-homogeneous distribution, while the DE presents a homogeneous distribution in the cosmos. The Euclidean character of the global geometry of the Universe is confirmed to a high degree of precision. Furthermore, the current structure of the Universe derives from physical processes occurring within its first 10^{-35} seconds of life. We are facing an impressive *capacity for the memory of Nature*"[31].

Casas adds: “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. Although its energy density is really miniscule (in the volume of the earth there are ≈7 mg of DE), the fact that it spreads over large apparently empty spaces of the cosmos causes its total contribution to be very significant, ≈68% of the contents of the universe. It is a strange form of energy, of which we do not know the origin, nor the reason of its greatness. The DE is not only mysterious, but it is also problematic, in the sense that it is very difficult to place it in a natural way within the current patterns of modern physics: we do not know its origin, nor if it is exactly a constant. What is the physical effect of the DE? The equation (6) confirms that the Universe continues to expand (as we observe), but we now know that this expansion accelerates with time. This happens because Λ produces a *gravitational repulsion*.

The equations of General Relativity presuppose that gravitational forces are not only generated by matter and energy, but also by the *pressure* exerted by them. The novelty, compared to the equation of Newton's gravitation, lies in the fact that there is no gravitational attraction, but *gravitational repulsion.* This is a *negative pressure*"[32]. In fact, "while normal matter and DM create a positive pressure, DE creates a *negative pressure* that generates repulsive gravity (rather than attractive), with consequent acceleration of cosmic expansion. A universe made up only of normal matter cannot expand, since gravity is always

an attractive force, and not even by adding DM we come to a *flat* universe. The observation of accelerated expansion presupposes the presence in the universe of an additional form of matter "[33].
According to Bhattacharjee "DE is a field of energy, or a property of unknown space, capable of opposing gravity, which would explain the acceleration of the expansion of the observed space" [10].
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"[34].
"DE is a form of invisible energy, unknown and repulsive, that does not form structures, does not dilute with the expansion of the Universe, and does not interact with ordinary matter" [35].

2.6 DE's THEORIES

We read: "We know very little about DE: it has to be homogeneously distributed, it has a very low energy density (as in mass) (about $7 \cdot 10^{-30}$ g/cm^3), it does not interact with fundamental forces, if not with gravity "[36]. Let's briefly analyze the main theories to explain the DE.

2.6.1 DE corresponds to Cosmological Constant (Λ)

According to this theory that identifies Λ with DE, Λ represents a constant energy density that fills the whole space homogeneously. That is, DE is interpreted as an intrinsic and fundamental energy of space, identified with the Λ. Since energy and mass are correlated according to 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. "With the Λ we refer to the presumed intrinsic energy of the empty space, an energy that exerts a negative pressure on the contents of the space, thus causing the acceleration of cosmic expansion" [36]. The Λ, in fact, shows the effects of a *negative pressure*, equal to its energy density, and therefore accelerates the cosmic expansion. The reason why Λ has negative pressure can be seen from classical Thermodynamics.
"The term cosmological constant (Λ) is mathematically equivalent to a term of *vacuum energy*. It was Lemaitre who realized this equivalence. Subsequently Zel'dovich related this term with the *quantum vacuum*. This gives an elegant interpretation of Λ in terms of quantum vacuum effects. Unfortunately, calculating the numerical value of this vacuum energy density, it turns out, with great embarrassment, that it also differs by 120 orders of magnitude compared to what is obtained from the observations. It is, as Hawking said, the biggest failure of a physical theory. From the observational point of view, Λ has a well-measured and concordant value among various experiments "[37]. The enormous value of the energy-mass density of Λ, emerging from the Quantum Fields Theories calculations, is a big unsolved problem.
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 leads 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* "[38].

2.6.2 ΛCDM Model

According to 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 theory is the ΛCDM, which indicates the Friedmann-Robertson-Walker (FRW) model for the universe, with Λ and *Cold* DM: hence the acronym ΛCDM. This model of DE 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[39]. 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 ...

As known, "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* (CMB), 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"[40].

2.6.3 DE corresponds to *Quintessence* (*Q*)

In order to understand the nature of DE, as an alternative to the *cosmological constant* model, cosmologists have proposed many other interesting hypotheses. "From the equations of General Relativity it emerges that gravity depends not only on mass (and energy) but also on pressure. The DE, therefore, derives from a type of matter, to which, since we ignore what it is, we have assigned the name of *quintessence*"[33]. According to this model, *Quintessence* (Q) shows characteristics different from those attributed to Λ. In fact, unlike the latter, Q is a *Scalar Field*. The field must be very light so as not to form material structures, having a high Compton wavelength.

According to this theory, also called the *Scalar Fields*, that is Q and modules, i.e. dynamic quantities, Q is a dynamic field, whose energy density can vary in time and space (the contributions of the Scalar Fields that are constant in the space are usually also included in the Λ). The Λ can be formulated to be equivalent to the radiation of the empty space, or the energy of the vacuum. *Scalar Fields* that change in space can be difficult to distinguish from Λ, since change can be extremely slow[33]. 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.

A proof of the existence of DE could be represented by the Sachs-Wolfe Effect (1967) [41], represented by the *blue-shift* which the CMB meets when it crosses the strong gravitational fields generated by large masses of matter: this energy gain would be a direct sign of the existence of DE.

It is hypothesized that "DE is a new kind of fluid energy or physical field, which pervades all space" [42]. Thus, it can not be excluded that this "physical field" isn’t similar to the electromagnetic fields permeating the *apparent vacuum*, described by Barrow, and therefore teeming with photons (Ps). "Some

theorists, considering it the 5^{th} Fundamental Force, have called it *Quintessence*, which differs from Λ by its dynamic character, that is variable in time and space. By definition, however, Λ is constant and fixed. But even this theory fails to explain what DE is, how it interacts and why it exists. A different explanation of how energy purchases space comes from Quantum Mechanics, which explains that the 'empty' space, on the other hand, is full of particles and virtual antiparticles that incessantly form and annihilate in infinitely short times. These fluctuations of the void give it an energy, and therefore a mass, which would produce anti-gravitational effects determining the acceleration of the expansion of the universe. But when we try to calculate the quantity of energy, we get a huge value, completely out of measure and devoid of physical sense. Thus, we know that DE
exists, but we know nothing of its nature, nor how it originated and evolved "[42].
"One of the fundamental questions is why the vacuum should have an associated energy. The quantum fields theory (QFT) predicts a presence of virtual particles having a very short in existence and then they disappear. These virtual particles could be related to the repulsive force of the DE. The vacuum energy needed to produce the observed cosmic acceleration is about 1 joule per cubic kilometer of space; the simplest version of the QFT, on the other hand, provides a value of about 120 orders of magnitude higher than that observed to date. Therefore there are still many open problems. For example, there may exist unidentified particles acting in the direction of astronomical observations. The theorists also devised alternative forms of DE. New theories of gravity have been created, similar to Einstein's general relativity, but which generate repulsion on very large scales. Others have postulated a kind of fluid that fills the space, called *Quintessence* (Q), which behaves a bit like *cosmological constant* (Λ), but changes slowly in density. Whatever the answer to the initial question, the fact remains that DE is the key to opening a window on an almost completely unexplored region of fundamental physics. Finding the answer can not only change our vision of reality, but also predict the ultimate destiny of the universe "[43]. So "there is the possibility that the DE coincides with the Q, which traces accelerated expansion back to the presence of *variable scalar fields in time and space*" [36]. This represents a substantial difference in behavior and mode of action between Q (or 5^{th} Force) and Λ.
In short, "it is as if, at the base of the accelerated expansion of the universe, there was a repulsive force, a kind of anti-gravity, uniformly distributed in space. Quantum Mechanics predicts that the vacuum is not exactly empty, but full of virtual particles (which appear and disappear) and therefore possesses an intrinsic form of energy. However, there is still no satisfactory theory that can explain what it actually is, and what it derives from, this energy, called precisely DE, which causes the acceleration of the Universe, or whether it is related, and in what way, to that which determined the initial inflationary phase. Other scholars opt for a 5th (fundamental) Force, called *Quintessence*: a sort of *quantum field*, endowed with repulsive gravity "[44].
Yes, the DE could coincide precisely with a quantum field, in our opinion pervaded by photons(Ps). Various alternative hypotheses emerged to the energy of the void, but none has yet succeeded in imposing itself on the others.

2.6.4 *Modified Gravity*

Another possibility has been proposed: "The acceleration of the expansion of the universe is due, in fact, to a new *dark force*, able to exert its force directly on matter, just like Gravity Interaction (GI), the Electro-Magnetic Interaction (EMI), or the 2 Nuclear Forces. This 5^{th} Force would be almost indistinguishable from gravity, so much so that it was also called *Modified Gravity*. The consequences of a *Modified Gravity* could be innumerable: the entire epic of the Universe should be rewritten taking

into account a new powerful factor, well beyond the simple Λ"[28].
As it is known "the recent announcement of the first observation of a fusion between two neutron stars, recorded both through gravitational and electromagnetic waves emitted by the event Gw 170817 (i.e. dating back to 7 August 2017), has literally opened a new window of observation of the universe. The fusion of the two neutron stars shook for a brief moment the surrounding space-time, giving rise to an impulse of gravitational waves, which traveled in space for 130 million years before being detected on Earth by Ligo and Virgo interferometers. The fusion also produced a series of electromagnetic(EM) waves, including a first, intense, gamma-ray glow, detected by the Fermi and Integral satellites almost simultaneously with the gravitational waves, just two seconds later. The fact that gravitational and EM waves have arrived almost together after such a long journey in space represents, among the innumerable things, an important test for the different theories currently underway to explain the DE"[45]. In fact, a recent study by Ezquiaga and Zumalacárregui [46] highlighted the possible precariousness of various theories regarding the nature of DE. "The two authors explain how the simplest theories such as the *cosmological constant* came out of this test. This and other similar and derivative theories assume that the DE is constant both in space and time, influencing gravitational and EM waves in the same way, as is clear from their simultaneous detection. However, even some more complicated or 'exotic' theories can hold proof of the fusion between neutron stars. For example, the so-called *massive gravity* (which assigns a mass to a hypothetical elementary particle called a graviton) may be correct if the graviton has a very small mass. Finally, the researchers note how a whole class of theories, generally known as *scalar-tensor theories*, are placed in serious difficulty by the observational evidence gathered during the fusion event. Einstein-aether, MOND-like, Galileon and Horndeski are some of the theories that would need some adjustments to avoid being rejected "[45].

2.7 *PHOTONICS PRESSURE* (or *RADIATION PRESSURE*)

The equations of General Relativity presuppose not only that the gravitational effect is generated by matter and energy, but also by the *pressure* exerted by the latter [32].
Let's analyze with Feynman the so-called *Radiation Pressure*: "When light is shining on a charge and it is oscilling 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. Evidently it is that the light's force (*F*) on a particle, in a magnetic field (*B*), is given by:

$$F = q\mathbf{v}\mathbf{B} \qquad (7),$$

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 $1/c$:

$$F = q\,(\boldsymbol{vE})/c \qquad (8).$$

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 *Pushing 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:

$$F = (dW/dt)\,/c \qquad (9).$$

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

$$E = h\,v \qquad (10).$$

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* ($\boldsymbol{p}$) :

$$\boldsymbol{p} = E/c = hv/c \qquad (11).$$

The direction of the *momentum* is, of course, the direction of propagation of the light. So, to put it in the vector form: $E = h\,v \qquad \boldsymbol{p} = hv/c \qquad (12).$
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" [47].
Thus, the *Photonics Pressure,* or *Radiation Pressure* (by many physicists identified with the 5th Force or *Quintessence*, and by as many with the Λ) plays a repulsive action, frankly and exclusively repulsive. Yet, one wonders: where does the photons (Ps) take all this *strength,* able to counteract, even for a long time, the compressive action of large masses of gravity? It is really surprising, since Ps, although particles, are considered massless: therefore as inconsistent particles, devoid of their own structure, ie ethereal particles. Let's deepen the topic.

2.8 On the ZERO MASS of PHOTON

The equation (10) shows the energy(E) of a light-particle. The energetic values of each photon(P), without considering its oscillating frequency, corresponds to the Planck's constant(h), which is just an energetic value, corresponding to $6.626 \cdot 10^{-27}$ [$erg \cdot \sec$]. The P, of course, goes with the speed of light, this value (c) is know too, it is 299792.458(± 0.4)Km/sec [48].
Let's now consider the equation related to the Principle of Equivalence Mass-Energy(MEEP):

$$E = mc^2 \qquad (13).$$

That's how Einstein commented upon his MEEP: "The value of the considered mass refers to the value of an *inertial mass"* [49]. Let's apply equation(13) to the P, keeping in mind that one of the three parameters is well known, that is c, the speed of the P in the vacuum. The 2° parameter is the Energy of the P which is described by equation(10). Besides, as Chandrasekhar reminds us "it is useful to consider a fundamental consequence of the quantum nature of the matter: the lowest energy possible for a system cannot be null, that is zero, but it needs to have a value different from zero, it is called *Zero Point Energy*(ZPE)"[50]. On the other hand, still for the MEEP, to an "energetic" particle, carrying energy, forces etc., should correspond a *mass equivalent* to the energy carried, divided c^2[51]. To this purpose, Feynman writes: "Energy and mass differ just for a factor c^2 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 $E = m$"[47]. Since there is no zero energy, for the ZPE, there should not be any particle carrying energy, with a zero mass. 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* [17]. Thus, in the case of a P at the *inertial state,* that is when it interacts with another particle, so it stops running, at least for that infinitesimal moment it will oscillate much less. We will never be able to know how much! We will never be able to know with *accuracy* how much an interacting P can oscillate, that is what could be the number of oscillations [c⁄s] in that moment. Let's indicate this unknown value with 10^n[c⁄s],which is an *uncertainty factor*. The P stops running when hitting another particle, as it happens during a *measurement*, so it will not oscillate as when it was running, though it never stops running completely: it is the *Heisemberg Uncertainty Principle* to deny it, since in this case we would know simultaneously the *position* and the *momentum* of the particle [52][53]. Thus also in the inertial state the oscillating frequency (v) of the P 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). Thus, if we want to consider the Energy of the P in its *inertial state*, indicated with E_o, we should have:

$$E_o = h\cdot v = h\cdot 10^n \text{ [c/s]} \qquad (14),$$

$$E_o = 6.626\cdot 10^{-27}\text{[erg·s]} \cdot 10^n \text{ [c/s]} \qquad (15),$$

hence:

$$E_o = 6.626\cdot 10^{-27+n} \text{ [erg]} \qquad (16).$$

This should be the Energy value of a P at an inertial state. We may say its *minimal energy value*; as we can see this value is not easy to determine, rather, it is *undetermined*, as stated by the Quantum Mechanics. As the *erg* value is expressed in [$g\cdot cm/s^2\cdot cm$], that is in [$g\cdot cm^2/s^2$], we have equation (17):

$$E_o = 6.626\cdot 10^{-27+n} \text{ [g·cm}^2\text{/s}^2\text{]} \qquad (17).$$

In this way we can have information, with a certain approximation, about the 2nd parameter of equation (13), referred to the P. Hence we can easily have the 3rd parameter, the *equivalent rest-mass* or *equivalent inertial mass* (m_o) of the P:

$$m_o = E_o/c^2 = 6.626\cdot 10^{-27+n}\text{[g·cm}^2\text{/s}^2\text{]}/(2.9979)^2\cdot 10^{20}\text{[cm}^2\text{/s}^2\text{]} \qquad (18),$$

Let us calculate this value following the *cgs* system:

$$m_o = [6.626\cdot 10^{-27+n}/(2.9979)^2]\cdot 10^{20} \cdot \text{[g·cm}^2\text{/s}^2\text{]} / \text{[cm}^2\text{/s}^2\text{]} \qquad (19),$$

and we have:

$$m_o = [6.626/(2.9979)^2]\cdot 10^{-27-20+n} \text{ [g·cm}^2\text{/s}^2\text{]·[s}^2\text{/cm}^2\text{]} \qquad (20)$$

$$m_o = [6.626/(2.9979)^2]\cdot 10^{-47+n} \text{ [g]} \qquad (21),$$

which follows:

$$m_o = 0.7372 \cdot 10^{-47+n} \text{ [g]} \qquad (22),$$

that is:

$$m_o = 7.372 \cdot 10^{-48+n} \text{ [g]} \qquad (23).$$

What we get is that the *inertial mass* of the P corresponds to 10^{-48+n} grams. Thus, if the value of *n*f of *n* w that is one oscillation per second, m_o would be 10^{-48}[g].Whereas if *n* was 10^3 oscillation per second, we would have $m_o = 10^{-45}$[g]. Of course in all cases it is an extremely value, but it is ≠ 0. Besides, as we know, one of characteristics of the P is to travel most of the time, so it also it al a *momentum* (***p***).

2.9 The *MOMENTUM* (*p*) of PHOTON

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”[54]. Feynman chases: “Each photon has an energy and a *momentum* (***p***)”[47]. This ***p*** is represented in the de Broglie’s formula[55]:

$$\boldsymbol{p} = h/\lambda \qquad (24),$$

where λ is the wave length of the considered photon(P) (or other particles). The mean wave length of a P in the optical band corresponds to $\sim 5\cdot 10^{-5}$ [cm] [56] and its ***p*** is:

$$\boldsymbol{p} = 6.626\cdot 10^{-27}\text{[erg·s]}/5\cdot 10^{-5}\text{[cm]} \qquad (25),$$

$$\boldsymbol{p} = 6.626 \cdot 10^{-27} \text{ [g·cm}^2\text{/s]} / 5\cdot 10^{-5}\text{[cm]} \qquad (26),$$

$$\boldsymbol{p} = 1.325\cdot 10^{-22} \text{ [g·cm/s]} \qquad (27).$$

Let’s see how *heavy* an electron is: its mass corresponds to $9.1\cdot 10^{-28}$ g, comparing these values, emerges that a running P is much heavier than an electron.

In short, other than P massless! It is the opposite: with these masses carried out by Ps we can better understand, and justify the light pressure action or “photonics pressure”, or radiant pressure. In this respect, Feynman adds: “An Electro-Magnetic Field has waves, which we call light; it turnss out that light also carries a momentum (p) with it, so when light impinges on an object it carries in a certain amount of p per second. This is equivalent to a force, because if the illuminated object is picking up a certain amount of p per second, its p is changing and the situation is exactly the same as if there were a force on it. Light makes a pressure by bombarding an object; this pressure is very small, but with sufficiently delicate apparatus it is measurable”[47]. This phenomenon is interpreted as an “energetic” phenomenon of the Ps (it would be only energy without mass).
We are talking about a pressure action, so it should not be unreal to think it is something ”real”, material, concrete, to produce the pressure effect. That is, 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.

2.10 COMPRESSIBILITY of ELECTRO-MAGNETIC RADIATION

Let’s analyze with Feynman, one of the most expert in the secrets of light, the *Compressibility of the Electro-Magnetic Radiation*(EMR): “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 $\boldsymbol{p}$, which is a vector. This $\boldsymbol{p}$ is the x-component of the vector $\boldsymbol{p}$ which generates the *kick*, and twice the x-component of the vector $\boldsymbol{p}$ ($2\boldsymbol{p}_x$) is the momentum which is given in the kick. Thus we find that the *Pressure* (*P*) is:

$$P = 2n\boldsymbol{p}_x v_x \qquad (28),$$

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 times the average of $\boldsymbol{p}_x v_x$ (the same factor of 2) and, finally, putting in the other two directions, we find:

$$PV = N\,(\boldsymbol{p}\cdot\mathbf{v})\,/3 \qquad (29),$$

That is the pressure times the volume is the total number of atoms times 1/3 ($\boldsymbol{p}\cdot\mathbf{v}$), averaged.
Now, for photons, what is $\boldsymbol{p}\cdot\mathbf{v}$? The momentum($\boldsymbol{p}$) and the velocity($\mathbf{v}$) are in the same directions, and $\mathbf{v}$ 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):
$E=\boldsymbol{p}c$, 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:

$$PV = U/3 \text{ (photon gas)} \qquad (30),$$

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:

$$PV^{4/3} = C \qquad (31),$$

(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”[47].
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 (Ps), ie massless particles. Moreover, like all bosons, there can be a large number of Ps, even in a very limited space, since the Pauli Exclusion Principle (PEP) does not act on bosons. So equation (31) should have almost no limit at all. Instead it is not so: but then, what's underneath? For us, the P mass places a limit on the Compressibility of radiation: it is a manifestation of the DE, of the 5^{th} Force. Rovelli adds: "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 CMB 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 "[57].

In line with this concept, 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 [58].

In our opinion 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 (31). So, the same BB would be the first child of this *repulsive force* triggered by *Radiation Pressure* (or *Photonics counter-Pressure*) which, in our opinion, represents the DE.

2.11 POSSIBLE IDENTIKIT of the DARK ENERGY PARTICLE (*DEP*)

The laws of QM combined with the laws of Relativity tell us that empty space is not empty at all, but full of latent particles, which appear and immediately disappear, generating a repulsive force very similar to that generated by Λ.

"No one has ever seen these particles directly, but it has been observed that they actually exist, since they leave a tangible sign on ordinary matter, such as of altering the energy levels of atoms "[33]. Probably the Ps of intra-atomic electro-magnetic(EM) field, mentioned by Randall [38], could supply energy to the orbiting electrons, causing them to jump on a more energetic orbit (but returning immediately in their previous orbit). To this purpose, Barrows specifies: "The non-null value of the Planck constant (*h*) is important for the stability of matter. In the impacts between the atoms and the EM radiation, the value of *h* is large enough to take a rather strong '*stroke*' to push the electrons to the immediately higher permissible level "[59].

As it is known, h identifies with Planck grain, with the quantum of light, that is with photon(P). And yet, a massless P is capable of inferring such a stroke, besides giving "stability to matter" [59].

Unless the P is not so massless.

We do not know the origin of the DE. As Casas reminds us "DE is a kind of energy that fills space, is associated with space: we can imagine it as a field that fills the cosmos in a homogeneous way, even though its energy density is really miniscule" [32]. This is in perfect agreement with our hypothesis, according to which the particle carrier the DE, or *Dark Energy Particle*(DEP) could be identified with P. It is hypothesized that "DE is a new kind of fluid energy or *physical field*, which pervades the whole space, and whose effects on the expansion of the Universe are opposed to those of normal energy and matter "[42]. Thus, it cannot be excluded that this field, this "physical field" cannot be similar to a field teeming with Ps, in the same way as the intra-atomic field. Bignami adds: "DE can deal with some properties of the void, with the interaction of emptiness with EM fields" [6].

To this purpose, Baldo Ceolin states: "The electron forms an inseparable unit with the field of Ps with which it interacts. The interaction between 2 electrons is represented as the continuous emission of Ps by an electron and with the absorption of Ps by the 2nd electron. That is, the electron, as a particle with electric charge, is the source of an EM field that we can conceive as a set of Ps, and this forms with the particle the same inseparable unit, in the sense that the particle is thought as continuously interaction with its own field through a continuous process of emission and reabsorption of Ps. A similar description also applies to the proton as a particle with an electric charge. Furthermore, the protons and neutrons interact through the field of nuclear forces, which keep the protons and neutrons together to form the nuclei: the proton and the neutron are therefore sources of the nuclear field, in the same way that the electron is the source of the EM field. As the EM field is considered constituted by a set of Ps, so the nuclear field is considered made of a set of particles called π mesons. According to Maxwell's theory, if you have two electrons 1 and 2, placed at a certain distance from each other, the force acting on the electron 1 is transmitted by the EM field created by the electron 2, and vice versa. That is, EM field is the intermediary that transmits force between the 2 particles. Also according to the classical theory of Maxwell, all charged particles, when accelerated, emit and absorb EM radiation (that is, Ps). On the other hand, as it is known, according to quantum conceptions, **this field of radiation must be thought of as a set of Ps**, which means that electrons can emit or absorb Ps. The **electrons form an inseparable unit with the field of Ps** with which they interact "[60].

What has just been reported makes us think of the so-called *perturbative equations*, in which interacting electrons are often involved with their own or others Ps (as described by Baldo-Coelin). It is easy to understand why in the equations of the *perturbed* systems, as in those of the Quantum Electro-Dynamics(QED), before the *Renormalization*, absurd values were constantly coming out. In fact, given the *inseparable unity electron-Ps*, one could just respectively multiply or divide the value of the mass of the electron (or some other parameter) for the *zero* value attributed to the mass (or better: to the mass-energy density) of the P, to result in zero or infinite.

On the contrary, if instead of a massless P, instead of snubbing the Principle of Mass-Energy Equivalence, we multiply or divide by a P having a mass-energy density corresponding to $7.372 \cdot 10^{-48+n}$[g], where *n* indicates the oscillations per second (i.e. the frequency) of the P involved (as equation 23 shows), both the zero and the infinites disappear as if by magic!

Furthermore, "if virtual particles emerging from empty space can change the properties of atoms, they can also affect the expansion of the universe. Physicists have shown that the energy of virtual particles should act exactly like the one associated with a Λ. However, there is a complication: according to direct observations the DE coming out of the vacuum is 0, or it is very small, nevertheless, according to the calculations, the quantum fluctuations of the vacuum would generate an energy, which value is 10^{120} (120 orders of magnitude) greater than that observed. If these calculations were true, real, the universe should expand so fast that the light emitted from our computer desktop could never reach our eyes. Instead, the fact that not only can we see the distance to which the computer is placed, but even up to the most remote regions of the universe, puts an even more stringent limitation on the energy of the void, which must be almost 120 orders of magnitude lower than the aforementioned estimate. A similar discrepancy between theory and observation has become today the most delicate and urgent problem of physics, behind which lies a decisive turning point in our understanding of the macro- and microscopic world "[33]. At this regard, Amendola adds: "According to Quantum Fields Theories (QFTs) 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 "[28]. Wrong calculations, wrongly set, most likely. The reality, the evidence deny these calculations dramatically. 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 or the exterminated sidereal spaces) in the form of *Radiation Pressure* or *Photonics counter-Pressure* and that, therefore, the DEP is identifiable with P! Let's reiterate: maybe the error in the calculations is in continuing to consider the P massless, with all the related algebraic consequences, such as multiply or divide by a value considered = 0.

Randall says: "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?"[38]. Precisely because, as we believe, the particle carrier DE, or *DEP*, coincides with P, which *minimal* energy, or Zero Point Energy(*ZPE*), corresponds to Planck's constant (*h*). Randall adds: "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 *inflation* and nourished it"[38]. Randall’s statement (awarded, among other things, of the Honorary Citizenship of Padova, just as Hawking, Weinberg and Witten) can provide a winning asset to our hypothesis. We also believe that 'that large amount of energy' could coincide, in agreement 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 [57] [58], which we can identify with the *Radiation Pressure* or *Photonics 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 Ps (therefore a real *Photonics counter-Pressure*), we have already communicated it to a "Progress in Electromagnetics Research" Symposium, held in Cambridge (Ma) in 2010 [12].

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" [28]. Randall writes: "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 "[38].

This leads us further to believe that the DE does not have a constant energy density, that is, equal everywhere and at all times. On the other hand, assuming in our opinion that the DE is *Photonics 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 the Ps, or acquired by the Ps; that is, it depends on the momentum of the *DEP,* i.e. the P 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" [38]. Randall points out: "Therefore, the *vacuum energy* receives a considerable contribution from extremely energetic particles, much greater than we would expect, if we consider the evolution time of the Universe. However, to have the Universe appear as we see it, the value of the vacuum energy should, instead, be astonishingly small, 120 orders of magnitude smaller than we would assume, on the basis of quantum-mechanical considerations. The question of the depletion of the energy density of the DE, and why so diverse energy sources provide such similar contributions, still await a response. According to some physicists the value of the vacuum energy is incredibly unlikely (i.e. considered too low), however any other value, just greater, would have prevented the formation of the galaxies and our existence. This reasoning is based on the *anthropic principle*. The explanation of the value of DE is perhaps the
greatest mystery with which cosmologists and particle physicists are confronted today "[38].
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 "[61]. This is in perfect agreement with our concept above. In fact, 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!
"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 it something absolutely unexpected and unpredictable, which we are not even able to conceive? "[38].
In short, among the various proposals put forward by physicists and cosmologists, in order to identify the DE, there are two hypotheses most followed: 1) The Λ, which represents a constant energy density that fills the whole space homogeneously. 2) *Scalar Fields*, such as *Quintessence* and *modules*, i.e. dynamic quantities: ***Quintessence* is a dynamic 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).
The Λ can be formulated to be equivalent to the radiation of the empty space, or the vacuum energy. Scalar Fields that change in space can be difficult to distinguish from Λ, since change can be extremely slow.
As it is known, "When the volume of the universe doubles, the density of matter is halved, while the DE should remain almost unchanged. When Feynman developed the Quantum Electro-Dynamics, he realized that even the vacuum has its own well-defined energy, caused by the virtual particles that are formed continuously. In fact, the *uncertainty principle* states that the energy and duration of a phenomenon can not both be zero. Therefore absolute vacuum cannot exist, since in it energy and duration of phenomena would be null. What we believe 'emptiness' is actually a frightening bubbling of particles (virtual, since they are not detectable for their very short, ephemeral life) interacting globally with ordinary matter, giving life to the acceleration of the cosmos. In short, the **DE is a sort of intrinsic energy of space**: 'the price of peace to have space'. The best value estimated by Perlmutter, for Λ, is $\approx 10^{-29}$ g/cm^3. The problem is that most QFTs 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"[62]. This goes along with our hypothesis, according to which the DE is represented by Ps belonging to different photonic or electromagnetic fields, according to the operating places, and according to their energy. In this way most of the DE's theories would be unified.

We believe, probably, that 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. In our opinion, 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, has different values. Both in relation to the energetic value of the energy sources, both 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 DE 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, **for us, the DE is** nothing else than ***Photonics Pressure*** (as illustrated by Hack [3]). 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 [12] to the very weak CMB that currently permeates the Universe. Therefore 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, in our opinion, can be expressed in various ways and different operating contexts.

2.12 CONTEXTS and OPERATING MODES of DE

Widespread opinion is that "Λ represents a force of repulsion among the masses, able to act only between huge masses and over very great distances" [62]. However 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 [38] and represented by the electromagnetic field (Randall [38]), as to say: by a *photonics field*.

In short, 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.

1) 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 [13] [14]. This acceleration has been attributed to a repulsive, anti-gravity action most likely carried out by a mysterious, elusive, impalpable form of energy, called precisely DE. In this case, according to the calculations of Perlmutten [14] the energy density of this *repulsive force*, or DE, is ~ 10^{-29}g/cm^3. Yet, despite this very small value, the DE arrives to represent as much as 68.3% of the entire mixture of mass-energy that permeates the cosmos. It is interesting to point out that, in this example, DE has carried out its action for exterminated distances and since the Big Bang (BB)!

2) According to Rovelli, Bojowald and Ashtekar itself, the 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) [57] [58]. *Bounce* due to the progressive increase in the density of the matter-energy in contraction, by an overwhelming Gravity Interaction(GI), such as to reach a compression and density limit, until the Quantum Mechanics(QM) intervenes and triggers a real explosion (as described in paragraph **2.10**). In this context the situation is completely reversed (compared to context **1**): at the time of the BB the space in which the DE operates is not the entire Universe, but a very limited space, even less than a point according to Lemaitre [63]. Also regarding the time we are at the antipodes. In the first example the DE is operative from ~ 13820 thousand years, at the time of the BB 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 first example (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 Ps[12].
3) As for the *Inflationary Phase*, however, 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).
4) 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 GI and DE. The gravity (GI) and the *Radiation Pressure* of the Ps can *fight* for a long time as it happens in the star's core. 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**" [64]. Thus, the photons (Ps) 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, Ps have to "base it on something", as though they had an equivalent mass (equivalent to the energy of the Planck's grain, the light quantum, divided c^2). That is, it could be the equivalent mass of lots of billion of billion.. of Ps, 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[65]. Ps therefore have a mechanic effect, 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[66].
Let's come now to short and very short distances which, we believe, the DE, or *Photonics Counter-Pressure*, should operate too.
5) To this purpose, we would like to quote the so-called *N-N Force* or *Levy Interaction*[67]. It is a *repulsive force*, which prevents the excessive approach of 2 nucleons, indicated as N-N. It is known, in fact, that the particles cannot approach each other beyond a given distance (d_o), below which a repulsive force appears: Levy Interaction (LI) [67]. Wigner and Eisenbud point out "There is experimental evidence that Strong Interaction (SI) is repulsive at a distance very small among the nucleons. A particular potential, which was originally proposed on the bases of the mesonic theory of nuclear forces, and that gives a fairly good description of the *systems with two bodies*, it is LI. This force is intensely repulsive at very short distances. Between two nucleons, LI is strongly repulsive from distances (d_o) equal to "[68]:

$$d_o < 0.532 \cdot 10^{-13} \text{ [cm]} \qquad (32).$$

As Pacini reminds us: “Among the nucleons, regardless of their charge, there is a very powerful attractive force, the SI, 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*"[69], an electro-magnetic(EM) radiation *barrier* , in our opinion, which represents the DE, which is *Radiation Pressure*. In other words, we believe that this *barrier* consists of a multitude of Ps thickened and crammed together, but without exceeding the limit of '*compressibility of the radiation*' [47] imposed by the equation (31), although the Ps are bosons, so they aren’t subject to the Pauli Exclusion Principle (PEP).
We believe that *the secret* of the consistency of this *barrier*, which raises a wall so compact, to be able to hold off the intense SI (which would inexorably tend to join the nucleons) resides in the even though minuscule mass-energy density *h* conferred to P, the Planck's Constant.
However, at this point, one might ask: how is the presence of the Ps justified within the atom? They should be the remitted Ps trapped in the 'recombination' phase, which occurred ~ 380000 years after the BB [3], when the Ps 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 EM radiations. In short, with the 'recombination', that is with the formation of atoms, probably a large number of Ps 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 swarms of Ps”[38].
Thus, 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, that is, from *Photonics counter-Pressure*. Therefore, in this different *modus operandi*, the DE carries out its action conveyed by sufficiently energetic Ps, thus demonstrating, therefore, that the energy density of the DE vary according to the context in which it operates.
6) Pacini adds: "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"[69]. This statement gives a primary and absolute value to the DE: without the anti-gravity balancing action of this *repulsive force*, which we identified as a *Photonics counter-Pressure*, the world would not be as it is!
7) 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-nucleon space. We read, in fact, that "this mysterious repulsive energy antigravity, or 5th Force, should also act against the gluons, thus succeeding in overriding the SI when the quarks (Qs) 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 Qs. The space is apparently empty, but actually it is occupied by the 'thickness' of the 5th Force"[70]. We think that the *thickness* is represented by a large number of Ps, probably too crowded each other, crushed by the Qs in progressive approach (by the SI or *gluon force*), thus in the end they can no longer be compressed further and can no longer be in an increasingly narrow space. This is in disagreement with the PEP, according to which all the bosons can thicken in infinite quantities. At least for the Ps, we must think that there is a limit for the PEP, a limit imposed by the equation (31).
In this context, the presence of the Ps, even within the nucleons (where they prevent Qs from hitting

each other), dates back to the primordial *nucleosynthesis*, which, started 3 minutes and 46 seconds after the BB [56]. In fact, with this process, many highly energetic Ps were trapped inside the nucleons. The 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.

Thus, when the distance between the Qs is reduced to ~ 0.30 fm [69], it is the *thickness* of this 5th Force interposed between the Qs [70] to act as a buffer, triggering, like a spring, (therefore we talk about the DE also as an elastic force) a repulsive action, of mutual removal of the Qs.

We believe that this 5th Force, or *Quintessence*, is represented by a multitude of Ps that, crammed into an increasingly narrow space, and not further compressible, begin to exert an *expansive counter-pressure.*

It is interesting to note that, in such circumstances, the repulsive action of the DE, that is the *Photonics counter-Pressure*, performs those tasks attributed to *asymptotic freedom*.

Moreover, 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!

In the described circumstance, the operating spaces, the energy intensity and the reaction times of the DE are, on the whole, superimposable to those described in the **5**th context. Moreover, there are contexts similar to the one described in point **4**), since they are characterized by a long arm wrestling between the GI and a very intense *repulsive force*. This struggle also takes place in the depth of the stellar core, where the *Photonics counter-Pressure* is integrated "by the outward hydrodynamic pressure of the hot gasses" [64].

The difference can emerge when the star rating is ≥ 8 solar masses (☼).

8) At this regard, Asimov writes: "In *white dwarfs* the average star density is 130000 times the platinum's. In the common matter almost all the volume of the atom is 'empty' space, but if subjected to enormous pressure, the subatomic particles may be forced to approach each other, forming a super-dense mass. Nevertheless, the subatomic particles maintain a sufficient distance to allow them to move freely, so that this dense matter still behaves like a gas, which in 1925 Fowler, due to its peculiar and anomalous behavior, defined *degenerate gas*. After a few years, Landau specified that even the core of the common stars contains this *degenerate gas*"[71]. To this purpose, "taking advantage of the insights developed by both Fermi and Dirac, it is inferred that, in an ordinary gas, the pressure decreases parallel to the decrease of temperature, since the degree of thermal agitation of the atoms decreases. On the contrary, in the case of *degenerate matter*, this does not occur, because of the very high density. In fact, when the particles are extremely close to each other, there are effects of the Quantum Mechanics(QM) that induce a kind of repulsion between the particles. In other words, a form of *counter-pressure* opposes to the gravity, like an anti-gravitational pressure, which in turn is related to two basic principles of QM[72]: the Uncertainty Principle (UP)[52] and the PEP[73]. In this respect, we read: "When fermions of the same type (electrons or neutrons, for example) have the same energy and also the same quantum numbers, then the state of matter is defined as *degenerate*: in this case particles cannot approach arbitrarily small distances, because they can never be exactly in the same state. The only possibility of satisfying the PEP is to maintain a certain distance between them: then the *degenerate fermions system opposes to any further compression*: thus the *degenerate pressure* is born, which acts in the opposite direction to gravity "[74]. Therefore, even when the compression and density are very marked, "*there remains a certain distance between one fermion and the other*" [74]: that is, there is still some space around each fermion. In short, the PEP helps us to understand the *space-geometric* distribution that fermions with the same quantum parameters can and must assume, but does not provide us with an exhaustive explanation on why these inter-fermionic spaces should persist forever. We have learned, precisely from the vacuum energy, that spaces cannot be completely empty, but they contain a field of energy: mostly it is electromagnetic fields, teeming with Ps [38]. On the other hand it is more than likely that these spaces must contain something that constitutes the "barrier" that interacts with the excessive, further approach between fermionic particles. It is very likely that these spaces are packed, full of Ps not further compressible (just as imposed by equation 31).

Here then all adds up: it is not the *Fermi pressure*, as saying the *degenerate gases of electrons or neutrons* to oppose the GI, but a multitude of Ps cluttered, all piled right in the spaces interposed between fermions. Thus, it could be inferred that these spaces were not imposed and arranged by the PEP, but by the energy density of an increasingly numerous and compact multitude of Ps. It follows that even in such circumstances, in our opinion, the DE would not be identified also with the *counter pressure* attributed unintentionally to the degenerate matter, but would coincide, again, with the *Radiation Pressure*: or *Photonics Counter-Pressure*, managed by the large number of Ps, massed and compressed in the very restricted inter-fermionic spaces, forcibly granted by the PEP to these Ps.

As known, according to the QM, the simple fact of confining particles in a sphere of radius (r) implies that these particles are provided with a *momentum* ($\boldsymbol{p}$):

$$\boldsymbol{p} \geqq \hbar/r \qquad (33),$$

where ħ is the *rationalized* Planck constant. At this *momentum* corresponds a *pressure* [72]. In turn, the PEP establishes that 2 identical fermions will never have the same quantum numbers and occupy the same *phase space* cell. Therefore, if each the two fermions with lower energy have a $\boldsymbol{p}$, as described by equation (33), the next pair will have: $\boldsymbol{p} \geqq 2\,\hbar/r$, and so on. Thus, the average *momenta*, brought by the particles, are greater than if they were all in the *fundamental state*. This gives rise to a pressure that increases more than linearly with respect to the number of particles [72]. In this regard, it cannot be excluded that equation (33) can also be applied to P (although it is a boson), being P a particle, a *Planck's grain*, and provided with *momentum*.

Asimov writes: "In 1924 Eddington had observed that the interior of all the stars had to have a very high temperature. Given the large mass of a star, its GI is immense. To avoid the collapse of the star, this immense force must be counterbalanced by an equal internal pressure, due to heat and radiation energy "[71], ie from *Radiation Pressure*. Maiani adds: "In 1930 Chandrasekhar realized that the PEP of electrons gas could provide enough pressure to counteract the gravitational attraction and support the star. Why the electrons? Both because they are much lighter than the nucleons, and because they have more extensive quantum effects "[75]. Then, when the nuclear fuel is over, the outer layer of the star collapses on the central core. Based on Chandrasekhar calculations, if in that phase the collapsed star has a mass ≤1.44 ☼ (Chandrasekhar *mass limit*), the gravitational collapse is stopped by the *Radiation Pressure* (or *Photonics counter-Pressure*) and by the *counter-pressure* exerted by the *degenerate electrons* which make the stellar core, to which a *white dwarf* will remain, over time. The *limit mass of Chandrasekhar* (M_{Ch})[76] is determined as follows:

$$M_{Ch} \approx (3\sqrt{2\pi}/8)\,(\hbar c/G)^{3/2}\,[(Z/A)\cdot 1/_{\mu}\, m_p]^2 \qquad (34),$$

where ħ is the *rationalized* Planck's constant, c is the speed of light in the vacuum, G is the constant of universal gravitation, Z is the atomic number, A is the atomic mass, m_p is the inertial mass of the photon(P), μ indicates the number of nucleons. With Z/A=0.5, we have M_{Ch}=1.44☼ [77].

This *pressure* holds the GI star if the mass is <M_{Ch}, and the star will end peacefully as *white dwarf* [71]. Otherwise, if at this stage the stellar mass results >M_{Ch}, things will be different. What happens is that, in the stars with mass >MCh, once the iron is formed, the stellar nucleo-synthesis stops, since the iron is not meltable. Therefore, once there is no more fuel, hence no more thermonuclear reactions, the GI takes over: the star begins to contract, with a significant and progressive increase of the temperature (T), pressure and density, so that Ps acquire energies of the MeV order. It happens, in fact, that "T in the stellar *core* increases progressively, where the *Radiation Pressure* grows proportionally to the 4^{th} power of T. That is, when T doubles, the *Radiation Pressure* increases by 16 times, making more and more fragile the balance between gravity and *Radiation Pressure*, until, in the end, the repulsive effect prevails and the star explodes in a Supernova [71]. This very vertiginous increase in the energy of the *Photonics counter-Pressure* is accompanied by another form of pressure, the so-called *Fermi pressure*, whose *counter-pressure* action is able to support the weight of masses less than about 3 ☼, until the gravitational contraction ceases [69]. In the end, therefore, what remains of the old stellar *core* of the exploded Supernova, is a tiny celestial body, with a diameter of 10-15 Km, on average, of which only one cm^3 weighs about 200 million tons: a Neutron Star was born.

Whereas, if the mass exceeds the Tolman-Oppenheimer-Volkoff *limit* [78][79], equal to ~ 2.5-3 ☼, the gravity of the *neutron star* can no longer be balanced by the *neutrons degeneration pressure* (or *Fermi pressure*) and by the *Photonics Pressure*. The Tolman-Oppenheimer-Volkoff *limit* has a certain approximation, especially regarding the lower limit. The uncertainty in the value reflects the fact that the *Equations of State* for the *extremely condensed matter* are not known, that is to say, the Equation of State of the *degenerate neutrons* is not yet well defined (also because we should calculate the contribution given by the *Photonics counter.Pressure*). Thus, the gravitational contraction proceeds even more quickly and violently, since the greater gravitational mass creates even more marked pressure and density conditions than in the *neutron stars*. Therefore, it also goes towards the inexorable collapse, with subsequent explosion. Both during the final phase of the contraction and in the explosive phase, the conditions for the nucleosynthesis of all the heaviest elements of the iron are created, up to uranium: *explosive nucleosynthesis*. The exploded Supernova, however, this time creates a different astral body: a Black Hole.

There are still several examples of *Photonics 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. Therefore, they do not appear as classifiable phenomena among those managed by the DE.

A) In this regard, we quote an example of *Photonics Pressure*, but without the repulsive component. As Feynman reminds us: “The light makes a *pressure* when it collides with an objects. It is a very small pressure but it can be measured with extremely sensitive instruments” [47]. This phenomenon is interpreted as an “energetic” phenomenon of the Ps (it would be only energy without mass)[80]. We are talking about a *pressure action*, but not a *counter pressure*: there is no repulsive or antigravitational effect. Similarly, it has been reckoned that the pressure solar rays have on Earth is 1 mg/mt^2. The effect of this pressure induced by solar rays, known as “*solar wind*”, can be observed in the cosmos, when this “wind” gives an impulse to the surfaces it hits. It deflects, in the opposite direction, the comet’s tail. Chandrasekhar says: “The energy of the solar light is converted in kinetic energy of the electrons, in the current produced by solar battery. In the same way its *momentum* pushes the comets’tail in the opposite direction of the sun”[50].

B) Other known phenomena ascribable to the light pressure action are the *photo-electric effect*[81], the *Compton effect*[82] and the *Raman effect* [83]. In these phenomena the P *pushes away* the hit electron from its orbit: it seems to be a *mechanical effect* produced by the light [84]. Though these phenomena cannot be interpreted as repulsive effects.

C) We find an other example of *Photonics Pressure* in the so-called *Casimir Effect* [85]. What happens is that two metallic plates, placed at a short distance one opposite the other, reflect (back and forth) in the intermediate space. If we consider the light as Ps, it is as though some of them were excluded in the space between the plates. The effect is that there will be more Ps outside than between the plates. It will be possible to observe a certain pressure of the external Ps which pushes the plates one against the other. Casimir effect gives us a very clear example of the Ps power, which apparently have a clear "mass effect" since they have a mechanic force on the metallic plates.
These last examples, as mentioned, do not show the effects of a repulsive action, of a *Photonics counter-Pressure*, for which they are not attributable, in our opinion, to the DE. The DE, in fact, is first of all as a *repulsive force*, a force that opposes gravity: it is the *antigravity* (called, in fact, *negative energy*).

2.13 DARK ENERGY's *STATE EQUATIONS*

As it is known, with *Equation of State* (EOS) we mean a mathematical relation between two or more variables of State of a physical system, such as pressure (P), volume (V), temperature (T), or density (ρ), mass (M), energy (E). The relationships between these variables define the thermodynamic state of a system and, as a general scheme, can be represented as follows [61]:

$$f(P,V,T) = 0 \qquad (35).$$

Starting from this equation, it is possible to calculate, for known values of P and T, for example, the volumetric properties of a fluid, as well as, by using rigorous relationships derived from Thermodynamics, properties that cannot be directly measured, such as entropy or the energy of the considered system.
Measuring EOS for DE is one of the greatest efforts of observation cosmology.
Since the Universe can be considered as a perfect fluid, it is useful to "introduce a relationship that binds the density of energy (ρ) and the pressure (P) of each of the components of the universe" [86]. This report provides the elements to draw a first draft for the construction of the EOS of the DE:

$$P = \omega\, \rho\, c^2 \qquad (36),$$

where c is the speed of light in the *vacuum*, and ω is a dimensionless number, whose value varies according to the type of mass-energy that is considered. With the General Relativity, and according to the Principle of Equivalence Mass-Energy ($E=mc^2$) of the Restricted Relativity, "the value of ρ (rho) enjoys the contribution of several terms: the mass density of the baryonic matter, the mass density of the Dark Matter(DM) and the mass-energy density of the Electro-magnetic(EM) Radiation "[86]. In fact, the parameter ρ "represents the total energy density of the Universe in all its forms" [25]. It is customary to set $c = 1$ in equation (36). Therefore, taking into account the contribution of each individual component, the EOS (36) can be rewritten as follows:

$$P = \sum_i \omega_i\, \rho_i \qquad (37),$$

where the sum (Σ_i) includes all the components. In fact, the index i indicates the possible types of matter-energy in the universe: 1) common or baryonic matter; 2) DM; 3) radiation; 4) a possible energy of the vacuum or a *scalar field*.
Specifically, the EOS for the DE can be represented as follows:

$$\omega_{DE} = P_{DE}/\rho_{DE} \qquad (38),$$

that is:

$$\omega = P/\rho \qquad (39),$$

or:

$$P = \omega\, \rho \qquad (40).$$

The latter EOS illustrate "a useful report from which to describe and verify the properties of DE carried out by the various models of DE and thus choose which ones can be considered effectively valid" [87].

Equation (40) represents the EOS of DE "writable for the idealized universe as a fluid; a mathematical relationship between the pressure (P) and the energy density (ρ) of all that fills the universe. The possibility of giving such a simple expression to the EOS of the DE that permeates the Universe, lies in the fact that the cosmos, as seen in some models of the DE, is presented as a very diluted fluid and this allows to greatly simplify the relation between the density of energy and the pressure of what constitutes it, otherwise much more articulated as for the condensed states of matter.
In the EOS of the DE, illustrated by equation (40), the parameter ω is a dimensionless number whose value is specific to each form of matter-energy that is considered. In fact written in a more explicit form the EOS for our universe is:

$$P = \sum_{\omega} P_{\omega} = \sum_{\omega} \omega\, \rho_{\omega} \qquad (41),$$

where the parameter ω, being a specific number for each different component, can be used as an index to distinguish it "[25].
In short, to solve the cosmological equations, we need to trace the EOS which, in the circumstance, must connect the two variables of state P and ρ, as expressed by equation (40). It seems to us of considerable importance that these two variables are inter-correlated also in the equation of the energy tensor-*momentum* (T_{ab}):

$$T_{ab} = (P + \rho)\, \mathrm{Ui}\, \mathrm{Uj} - P\, g_{ab} \qquad (42),$$

where U is the quadrivelocity, ρ is the (total) energy density and P is the (isotropic) pressure in the resting reference, that is the Robertson-Walker moving one. The energy-momentum tensor is assumed to be (for simplicity and consistency with the Cosmological Principle and with what is observed experimentally) that of a perfect fluid, i.e. a continuous medium that has no cutting efforts (viscosity) [88]. Now let's review the possible EOS of the DE.
1) In the case that the DE coincides with the cosmological constant (Λ), one should have:

$$P_{\Lambda} = -\rho_{\Lambda} \qquad (43),$$

from which we obtain that $\omega_{\Lambda} = -1$. That is, in our universe Λ is a component that has a negative pressure producing, therefore, an expansion [25].
2) In turn, the ΛCDM model provides the simplest explanation for the DE, considering it the energy of the vacuum to which to associate a parameter ω = –1, despite suffering from the problems of *coincidence* and fine-tuning.
Instead, in other theoretical models about the possible nature of DE, "it happens that ω_{DE} varies over time. It follows that a first objective for the study of the DE is to identify possible deviations of ωDE from the value –1, in order to find out whether it is identifiable or not with Λ. In fact, the combination of the results of many projects carried out in this perspective has led to the achievement of the restriction of the values of ω_{DE} to an interval corresponding to:

$$-1.097 < \omega_{DE} < -0.858 \qquad (44),$$

assuming a constant EOS for DE "[87].
3) The theoretical model of *Quintessence* tries to explain the existence of DE through the presence of a dynamic scalar field (Φ) to associate a slowly variable EOS over time. This model, therefore, is described by an EOS with parameter ω not constant, but variable over time, of the type $\omega = \omega(a)$, where a is the scale factor (acceleration). Therefore ω can oscillate for the whole range of allowed values, with consequent variability also for its energy density (ρ). Therefore, the EOS describing the DE, interpreted according to the *Quintessence model*, will correspond to:

$$\omega = P_{\Phi}/\rho_{\Phi} = [(\Phi^2/2) - V(\Phi)] \,/\, [(\Phi^2/2) + V(\Phi)] \qquad (45).$$

With the assumption of tracing solutions, the *Quintessence model* meets with the evolutionary history traced by the ΛCDM model, not incurring in incongruities with the experimental data, relative to the past history, and thus trying to solve the *problem of coincidence*. However, similar to the ΛCDM model, the *Quintessence model* also continues to suffer from a fine-tuning problem on potential energy [25]. In a variant of this model, called *k-essence model*, "the non-canonical term of kinetic energy in the Lagrangian can explain the recent acceleration without the need for an *ad hoc* potential energy. The existence of a tracing solution would solve the problem of *coincidence*, still remaining unexplained, even in this model, the so small value of the vacuum energy"[25].
However, this problem does not exist, considering that the Dark Energy Particle(*DEP*) can be identified with photon(P), whose energy density is almost zero, as shown by the equation (23).

3. CONCLUSIONS

As Randall reminds us: “As for the world of the atom, probably the most amazing thing is that the atom essentially consists of empty space. The atomic nucleus has a radius of more than 4 orders of magnitude smaller than that of the electronic orbits. The volume of the nucleus is $\approx 10^{-12}$ of the volume of the whole atom. An atom is mostly empty, but within this vacuum there is of course an Electro-Magnetic(EM) Field, although virtually no real matter is present"[38], but there is energy: the so-called *vacuum energy*, which is none other than DE, which is actually represented by the Ps continuously exchanged between electrons and nucleus.
What Randall affirms appears to us as an indirect confirmation, but very authoritative, of our hypothesis, and of the core of this work: the so-called *vacuum energy*, that is DE, is nothing transcendental and mysterious: nothing but a form of *Photonics Pressure* and the particle that carries this DE is probably the P.
The *quantum vacuum* 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 Ps, but not all and not always of the same energy and, likely, not Ps of the optical band. In short this is the keystone: the DE is represented by a *Photonics Counter-Pressure*, or *negative pressure*, then expansive, repulsive, anti-gravitational, exerted by Ps *no further thickened and compressible*.
Randall adds: "The measure of certain gravitational effects indicates the presence of something that is even more mysterious than DM: it is what is called DE. This DE that permeates the Universe is very similar to the energy that precipitated *inflation*, but today its density is much smaller than the energy that long ago presided over inflation"[38]: we pass, in fact, from γ Ps of an unimaginable energy [12], to very weak microwaves. This is in perfect agreement with our hypothesis, both regarding *inflation* and DE: it is a very significant confirmation that DE can be constituted by Ps!
The concepts just reported by Randall, are in full agreement with what was proposed by Alan Guth. With his 'Inflationary theory', Guth hypothesized that **a negative pressure field**, similar in concept to DE, could have led an *Infiationary Fhase* in the primordial Universe [11]. Inflation postulates that a repulsive force, qualitatively similar to DE, has caused a huge and exponential expansion of the Universe immediately after the BB. However, the inflation must absolutely have taken place at a much higher energy density than the energy density of the DE we observe today. It has not been described if there is a relationship between DE and Inflation. However, in our opinion, the relation does exist: they are both conveyed by electro-magnetic radiation, but with extremely different energies [12].
These concepts are not in disagreement with what Amendola reported, so "as primordial cosmic

inflation may have been induced by a "particle", or rather by a field, called *inflatone*, so the recent acceleration could be due, instead that to Λ, to the hidden work of a field / particle called DE or *Quintessence* (again Aristotle!) or simply: *scalar field*. Like all fields, it extends and spreads throughout the space and has its own dynamics. **Like all particles, DE has a mass too**"[28].

It is just what we stating: the particle that should carry the DE, i.e. the *DEP*, must have a mass, corresponding, in our opinion, right to the dynamic-mass carried out by the interested photon's *momentum* [89] .

P is a particle too, a particle of light, so we think that the photo-kinematics does not involve only energy (as the energy of P), but also mass (the *masked mass* of the photon), in full respect of Einstein's Principle of Mass-Energy Equivalence. Why a *masked mass*? In order to respect the well known Bohr Complementarity Principle[90], according to which a particle can show itself only with one of two "aspects": wave or particle. These parameters are "complementary", similarly to the complementary parameters of Uncertainty Principle: energy-time, or position and momentum of a particle. The more accuracy we have in knowing a parameter, the more uncertain the measure of the complementary corresponding parameter will be. Thus, the more information we have about the wave aspect of the P, the less, in the same moment, we have of its particle aspect. Therefore, according to Complementarity Principle, if the P is in motion we can catch its kinetic energy, adding it to its main base energy, but we will never be able to have news, simultaneously, about its corpuscular characteristics. From the P in motion (wavelike aspect) we can have news about its energy, but we can never check its mass. Whereas when the P interacts, it slows almost completely its run, however without stopping completely: Uncertainty Principle would not allow it to. Thus the P will stop showing its wavelike appearance and will show us its corpuscular one, allowing us to determine its mass (in case it has some!). In short, only when the motion almost stops (and its wavelike aspect disappears) the P will be able to show its corpuscular appearence. Only then, as a corpuscle, the P will show us, at last, its probable mass: maybe indirectly, showing us the probable mass-effects or mechanical effects [91].

One way say: it is wrong! The P is always in motion, so it will never show us its corpuscular aspect, and thus its possible mass. On the contrary, we believe that the P *wears* his corpuscular appearance, only in the very brief instant in which it interacts. In support of what we claim, there are several examples of *mass-effect*, or gravitational effects induced by P. It is possible to mention the photo-electric, Compton and Raman effects, previously discussed.

We read from Hack: "The density of radiant energy (Ps) present in today's Universe is ~ 10 times > of the density of matter" [3]: this reflects the relationship in nature between DE and ordinary matter and is in perfect agreement with our hypothesis, according to which the DE is identified with the *Radiation Pressure*.

As previously mentioned, Hack reported that "the *primordial plasma* was subjected to two opposing forces in an arm wrestling: gravity (GI) on one side and the *Radiation Pressure* (or *Photonics Pressure*) on the other. The first tends to compress the gas until the *Photonics Pressure* reverses the motion, producing elastic oscillations "[3]. We believe that *Radiation Pressure*, that is *Light Pressure*, coincides with DE, governing all actions and effects, all its behavior. So, one may wonder: why, and according to what mechanisms the "*Photonics Pressure* reverses the motion" [3] blocking the further "gas compression" [3], as in the primordial Universe ≈1/3 made of neutrinos and ≈2/3 of Ps [56]? In our opinion it is the further *incompressibility* of the particles constituting this very hot gas, this plasma, to block the compression exerted by the GI.

In short, when density becomes excessive, and the spaces between the particles are extremely reduced,

the *consistency* of Ps comes out, which, let us keep in mind, are also corpuscles, granules of PlancK. Without considering the frequency of the involved P, it still remains its ***h***, which is **not zero**, but $6.626 \cdot 10^{-27}$[erg·s]. Of course, it is a very small, infinitesimal value. However if we think that in a very small space there can be crammed into billions and billions (the Exsclusion Principle allows it [73]), it is formed over time, under the compressive action, continuous and inexorable of the GI, as a *buffer of Ps* that, in our opinion, becomes progressively more and more *incompressible*.
In this regard, equation (31) shows the limit value of the *radiation Compressibility*, from which we infer that beyond that value the effects of the *incomprehensibility of the light*, of Ps, come out. Thus the repulsive action takes over, that repulsive, anti-gravitational force, represented, governed and managed by *Radiation Pressure*, as to say by the *Photonics counter-Pressure*. On the other hand, to further contribute to the intensity and manifestation of this *force* there is one of the properties that characterize the electromagnetic waves: the *Overlap Principle*, which allows to sum up, one by one, the single effects of each P [92] present in these apparently empty spaces, that is, in these electromagnetic fields.
In short, it is this *Repulsive Force*, in our opinion, to represent the *Lambda Force* (or the *cosmological constant*), the *Quintessence* (or 5th Force), the ΛCDM Model: how to say the DE.
At this regard Chandrasekhar adds: "let’s consider a crystal, in which the attractive and repulsive forces are balanced. If we stretch the crystal the distribution of electric charges changes, and the attractive force dominates; whereas, if we compress the crystal, the repulsive action will prevail "[50]. Something similar happens with the DE, the 5th Force, as if, when the distance between contiguous particles, too compressed and thickened, decreases, a repulsive spring takes, a spring which for us is represented as a *cushion of Ps* no further compressible.
As Barrow writes "there is a basic level of electro-magnetic oscillation in space after all that can be removed has been removed: the remaining void represents the state of *Zero Point Energy* (ZPE) available" [19]. However, as known, the electro-magnetic (EM) oscillation presupposes, throughout the space (only *apparently* empty), the presence of the Ps. It is a *conditio sine qua non*: P is the protagonist of these *empty spaces*, it is the main actor in the scene describing the EM oscillation. There can never be EM oscillation without the involvement of the Ps.
Hawking adds: "According to the famous Einstein equation, $E = mc^2$, the ***vacuum energy* has mass**" [16] This mass is represented, for us, by the *mass-equivalent* of the Ps [51] present in the vacuum [19] [38]. Hawking goes on: "Therefore, having mass, the vacuum energy has a gravitational effect on the expansion of the universe; but, quite singular, the effect of the vacuum energy is opposite to that of matter. Matter slows down expansion and eventually stops it and inverts it, whereas vacuum energy acts like the *cosmological constant*. The energy of the vacuum is so close to zero that until recently it was not easily detectable "[16].
What Hawking states is in accordance with our calculations about the *mass-equivalent* of P, $7.372 \cdot 10^{-48}$[g]: values really close to zero. These findings, although we continue to consider the P as massless, should not create perplexities, also because they should appear congruous, both from a mathematical and a physical point of view.
To this purpose, it seems very interesting to quote what Penrose writes: "Actually, the mass of P, if not zero, it should be $<10^{-20}$ electronic masses"[93]. The mass of the electron is $9.1 \cdot 10^{-28}$g, so if the P is $<10^{-20}$ electronic masses, we have: $9.1 \cdot 10^{-28-20}$[g]. Thus according to Penrose a P which is not massless must have a mass very close to $< 9.1 \cdot 10^{-48}$ [g].
Penrose's calculations, among the greatest living mathematicians, are completely superimposable on ours: $7.372 \cdot 10^{-48}$ [g]. This is of great honor for us and greatly comforts us.

We should also consider that these values describe the *inertial mass* of the P, exactly corresponding to the so-called *Zero Point Mass* (ZPM) [94]. According to Einstein's *mass-energy equivalence principle* (MEEP)[95], and in agreement with Chandrasekhar [50], the ZPM is equivalent to the ZPE [17] [50]. This is why, according to our hypothesis, also the ZPM of *DEP*, indicated with DEP_{ZPM}, has very low values:

$$DEP_{ZPM} = 7.372 \cdot 10^{-48+n}[g] \quad (46),$$

where *n* indicates its oscillation frequency per second. Obviously, the minimal DEP_{ZPM} corresponding to the minimal oscillation per second of this particle; that is with n=0, it is: $10^n = 1$. However, the particles are mostly in motion so that, in the same way as the P, to calculate the density value of the *DEP* mass-energy, we must analyze its momentum (***p***), $\boldsymbol{p}=h/\lambda$ (as illustrated in equation 24), where *h* is the Planck constant and λ is the wave length of the considered *DEP*. Thus, in those circumstances in which the *DEP* haves a λ superimposable to that of the *cosmic microwave background* (CMB) initially detected by Penzias and Wilson [96] [56], corresponding to 7.35 [cm], the ***p*** of the *DEP*, indicated with $DEP_{\boldsymbol{p}}$, will be:

$$DEP_{\boldsymbol{p}} = h/\lambda = 6.626 \cdot 10^{-27}[erg \cdot s]/7.35[cm] \quad (47),$$

that is:

$$DEP_{\boldsymbol{p}} = 0.9014965 \cdot 10^{-27}[g \cdot cm/s] \quad (48),$$

i.e.:

$$DEP_{\boldsymbol{p}} = 9 \cdot 10^{-28}[g \cdot cm/s] \quad (49).$$

As if in this case, the value of the *DEP* mass-energy density is just above the *Planck constant*'s. Of course, in all other possible circumstances the λ of the *DEP* will certainly be shorter, which will consequently correspond to a *momentum* (***p***) obviously greater. This value, corresponding for example to that of a P of the optical band, is represented in equation (27). Instead, if the λ of the *DEP* is just shorter, e.g. 10^{-6} [cm], that is superimposable to an ultra-violet P, we have:

$$DEP_{\boldsymbol{p}} = 6.626 \cdot 10^{-27}[erg \cdot s]/10^{-6}[cm] \quad (50),$$

that is:

$$DEP_{\boldsymbol{p}} = 6.626 \cdot 10^{-21}[g \cdot cm/s] \quad (51).$$

Of course, these values, much greater than the mass of the electron, rise by various *orders of magnitude* if the considered *DEP* has a λ superimposable to that of a γ P.

In short, these last equations show values of mass-energy density, attributable to *DEP*, also considerable and such as to justify their intense repulsive action, of variable intensity, in our opinion, from one circumstance to another (as shown in the equations).

As Weinberg reminds us: "34 minutes and 40 seconds after the Big Bang, 31% of Energy Density of the universe is supplied by neutrinos and antineutrinos, and 69% by photons" [56]. That is the 2/3 of the energy spread in the entire Universe was contained in the Ps: yet they are mass less! Despite the Equivalence Mass-Energy.

We consider it of considerable importance that these values and relationships have remained unchanged even in the current Universe [56]. In fact, Weinberg states: "At the beginning of the universe there must have existed (and still exist today) ~ 1.1 billion Ps per nuclear particle" [56].

In our opinion this represents a particularly significant datum, as it is in perfect agreement with our thesis: DE = *Photonics counter-Pressure*, or *Radiation Pressure*.

Weinberg adds: "In the CMB there is currently a nuclear particle for every billion of Ps"[56].

In short, we find it really worth noting the fact that the energy density, found by the Planck satellite, relative to the mysterious DE, and corresponding to 68.3% of the mass-energy distributed in the Universe, is completely superimposable to the value (69%) of the percentage of Ps diffused in the cosmos, now as then.

In closing, the most up-to-date satellite evidence and surveys show us two irrefutable findings: 1) The density of the entire mass-energy quantity distributed in the cosmos is represented, since the primordial universe, for 69% by Ps. 2) The Planck satellite, from the analysis of the CMB, has realized that just this mixture of mass-energy permeating the Universe is represented for 68.3% by a type of energy not yet identified: the DE.

Well, these percentage values, perfectly overlapping, represent in our opinion a bewildering confirmation, supported by the findings: that 68.3%, assigned to the DE, must be, instead, attributed to that same percentage (69%) of the entire mass density energy distributed in the Universe, and fully represented by the Ps, both now and then.

We believe, that is, that the DE does not correspond to anything transcendental or *exotic*: no!

The DE, most likely, is nothing more than the sum of the common *photonic energy* of a considerable number of Ps, often inexorably more and more compressed and amassed by the GI, until, as equation (31) indicates, it reaches a limit of *incompressibility* of the Ps. At this point, by each individual P, an energetic repulsive action triggers, which, adding to each other (by the Overlap Principle), act in unison as a *counter-pressure* (or *negative pressure*): just as the *Radiation Pressure* or *Photonics Counter-Pressure* works.

As Hack pointed out, "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 GI (so as to maintain the static universe): the *cosmological constant* (Λ) "[3]. This suggests that already in Einstein's first field equations, easily contradicted by Friedmann [97], 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, since the General Relativity is closely connected to the value of gravity (the GI remained outside the Standard Model precisely because the link with the Quantum Mechanics was not found). Thus, in equation (6) instead of Λ we could introduce the value of the *momentum* of the considered Electro-magnetic(EM) Radiation, or *Radiation Pressure*, that is *h/λ*:

$$R_{ab} - \frac{1}{2}\ g_{ab}\ R + \frac{h}{\lambda}\ g_{ab}\ =\ -8\pi G\ T_{ab} \qquad (52),$$

where λ indicates the wave lenght of the involved *DEP* (or P), which should vary according to the context considered. 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*, presupposes that the *vacuum energy* (or DE) took different values in different domains of the Universe [98].

We could therefore say 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. But 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). On the contrary, with our model the *lambda* (λ) expresses with extreme precision the value of the wavelength of the particle transmitting the DE in the considered circumstance. 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 P.

In the case of the expansive acceleration of the cosmos detected in 1998, the responsible DE, permeating the sidereal spaces, would have an energy density, according to Perlmutten [14], of ~10^{-29} [g/cm^3].

It is interesting to note that these values are superimposable to ours! In fact, under these same circumstances, if the λ of the considered *DEP* is identifiable with that of the CMB initially detected

[96], that is 7.35cm, the value of the energy density (mass) carried out by the *DEP*, calculated on the basis of his momentum, as illustrated in equation (49) corresponds to $9 \cdot 10^{-28}$ [g·cm/s].
This should represent a truly definitive confirmation of our hypothesis that, we repeat, tends to identify the energy density of the mysterious DE with the energy density of the myriad of Ps, involved in creating *the Radiation Pressure* or *Photonics Counter-Pressure* .
In conclusion, for all the above reasons, the DE is conveyed by Ps, 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.
In short, the *counter pressure* triggered by DE most likely represents the most immediate physical and real manifestation of a (*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* 5^{th} Force, initially present as *vacuum energy,* represented essentially by *electro-magnetic fields* swarming of Ps (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 GI becomes excessive, particularly intense, we could say *overwhelming*, until a counter-reaction takes place, i.e. the *Photonics counter-Pressure*.
To trigger this *counter-pressure*, is the mass-energy density of a very compact wall of Ps, no further compressible, compressed up to the limit point dictated by the mathematical formalism expressed in equation (31), after which the repulsive action is immediately triggered, anti-gravity, as due to *a request for space that is failing*.
It is like saying that, eventually, Ps are saved in time: otherwise in the various circumstances described they would be inexorably crushed and, maybe, destroyed by the GI.
What saves them is the limit to their *compressibility*, elegantly illustrated by equation (31).
Thus ultimately, in our opinion, the P is the *Dark Energy Particle.*

4. REFERENCES

1**)** Zwicky F., “On The Red Shift Of Spectral Lines Through Interstellar Space”, Proc. Natl. Acad. Sci.U.S.A.,Vol.15, 10, 773-779 (1929).
2) Zwicky F., “How far do cosmic rays travel?”, Phys.Rev.,43,147-148 (1933).
3) Hack M., “Dove nascono le stelle”, Sperling & Kupfer ed.,Milano,131-133,164-170-177 (2004).
4) Giacconi R and Tucker W.H., “The X-Ray Universe. The Quest for Cosmic Fire from Black Holes to Intergalactic Space”, 1985 by Riccardo Giacconi and Wallace Tucker; Mondadori ed., (Milano),170-179 (2003).
5) Rubin V.C. and Ford K.W. “Rotation Of The Andromeda Nebula From A Spectroscopic Survay Of Emission Regions”, Astrophys.J.,159,379-403 (1970).
6) Bignami L., “Materia ed Energia Oscura”, Focus, Mondadori Ed., Milano,178,152-160 (2007).
7) Puccini A., “The Missing Mass in the Universe May Be Represented by the Dynamic-mass of the Photons”, Session 3P1:Optics and Photonics, Proceedings of Progress in Electro-magnetics Research Symposium ,Cambridge (Ma), USA, 816-818, July 5-8 (2010).
8) European Space Agency (ESA): Planck and the Cosmic Microwave Background, https://www.esa.int/Our_Activities/Space_Science/Planck/Planck_and_the_cosmic_microwave_background
9) Capaccioli M., “I Cacciatori della Materia Oscura”, Il Mattino (Napoli),174,14 (2017).

10) Bhattacharjee Y., “The Universe”, National Geographic, Italian edition,4,42-67 (2014).
11) Guth A., “Inflationary universe: A possible solution to the horizon and flatness problems”, Physical Review D, Vol.23,N°2,347-356 (1981).
12) Puccini A., “The Inflationist Expansion of the Universe Was Conducted by Very High Energy Photons”, Session 3P1:Optics and Photonics, Proceedings of Progress in Electromagnetics Research Symposium, Cambridge (Ma), USA, 819-822, July 5-8 (2010).
13) Rees A. et al. “Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant", The Astronomical Journal,116,3,1009-1038 (1998).
14) Perlmutten S. et al., “Measurements of Omega and Lambda from 42 High-Redshift Supernovae", The Astrophysical Journal , 517, 2, 565-586 (1999).
15) Aczel A. D., “God’s Equation”, ©Amir D. Aczel 1999,Four Walls Eight Windows ed., New York; il Saggiatore ed., Milano, 25,138,141,175 (2000).
16) Hawking S., “The Universe in a Nutshell”, ©2001 by Stephen Hawking; Mondadori ed., Milano,100-101 (2002).
17) Puccini A., “About the Zero Point Energy, Zero Point Mass, Zero Point Temperature and Zero Point Motion in the Subatomic World and Photonics”, *Proceedings* of Progress in Electromagnetics Research Symposium, Suzhou, China, 1169-1171,Sept. 12-16 (2011),.
18)) Ferris T., “Materia ed Energia Oscura”, National Geographic (Ed. per l’Italia),1,74-89 (2015).
19) Barrow J.D.,“The Book of Nothing”, ©John D. Barrow 2000,1st published by Jonathan Cape 2000; Mondadori Ed., Milano,16,17,99,132,133,198-200,237-240,279,282,313,348 (2001).
20) Feynman R.P., “The Feynman Lectures on Physics. Vol.3: Quantum Mechanics”,©1965, 1989 Californian Institute of Technology (Caltech); Zanichelli Ed., Bologna, vol.3,1-11 (2001).
21) Hawking S., “A Brief History of Time”,©1988 by Stephen W. Hawking, Bantam Books, U.S. and Canada; Rizzoli Ed., Milano, 73 (1993).
22) Urbano A., “La ricchezza del niente. L’energia del vuoto quantistico”, INFN, http:/www.asimmetrie.it/tags/tag/energia-oscura
23) Barone V., “Il sollievo della semplicità”, in Enrico Fermi “Atomi Nuclei Particelle”, Bollati Boringhieri Ed., Torino, LXVI (2009).
24) Puccini A., “On the Bosons’Range of the Weak Interaction”, Journal of Advances in Physics, Volume14,Issue 3, 5865-5868 (2018).
25) Giammaria P., “Il problema dell’Energia Oscura”, Tesi di Laurea in Fisica, Univerità di Roma, relatore A. Melchiorri (2013).
26) Penrose R., “The Einstein Equation of General Relativity”, in “It Must be Beautiful. Great Equations of Moderne Science”; Granta Publications, London, © Graham Farmelo,2002; Il Saggiatore ed., Milano, 276-279 (2005).
27) Einstein A.,"Kosmologische Betrachtungen zur allgemeinen Relativitaetstheorie”, Sitzung. der Königlich Preussischen Akademie der Wissenschaften, Berlin, part 1,142–152 (1917).
28) Amendola L., “Costante Cosmologica, Energia Oscura ed Espansione dell’Universo”, INFN, http:/www.asimmetrie.it/tags/tag/energia-oscura
29) Pizzuti L., “L’Energia Oscura, storia di una costante inspiegabile”, http:/www.tomshw.it/energia-oscura-storia-una-costante-inspiegabile
30) Sefusatti E., MEDIA INAF: Notiziario on line dell’Istituto Nazionale di Astrofisica, Italy http;/www.media.inaf.it/2017/07/21/energia-oscura
31) Firmani C., “I lati Oscuri dell’Universo: la materia e l’energia”, INAF,

Osservatorio Astronomico di Brera, Milano (2007).
32) Casas A., “La Materia Oscura. L’elemento più misterioso dell’universo” ,RBA Contenidos Editoriales S.A.U., Spagna 2015; RBA Italia, Milano,136-140,57-58 (2015).
33) https:/www.cosediscienza.it/materia-ed-energia-oscura
34) http:///map.gsfc.NASA.m_uni/uni_101bb2.3.html
35) Trotta R., ”Modello di concordanza”, Newton, RCS Ed., Milano,10,95 (2009).
36) http:/spazio-tempo-luce-energia.it/energia-oscura
37) Gruppuso A. interviewed by Sandri M. in “100 anni di Lambda”, MEDIA INAF, Astronomia, Fisica News, 12/7/2018, http://www-media.inaf.it/2018/07/12/100-anni-di-lambda/
38) Randall L., “Knocking on Heaven’s Door”,© Lisa Randall 2011-2012; il Saggiatore ed. (Milano), 386-389, 92-93,442,381 (2012).
39) Vittorio N., “Dalla costante Cosmologica all’Energia Oscura”, INFN, Roma, January 25 (2017).
40) MEDIA INAF, Redazione “L’eredità di Planck”,2018,http://www.media.inaf.it/18/07/17/planck
41) Sachs R.K.,Wolfe A.M., “Perturbations od a Cosmological Model and Angular Variations of the Microwave Background”,Astrophys.J.,147,73 (1967).
42) https://www.dissensiediscordanze.it/lindecifrabile-mistero-della-materia-energia-oscura
43) Di Sia P., “L’energia oscura dell’universo: una panoramica. Il mistero dell’energia oscura”, http://universo.it/2016/12/16/energia-oscura-delluniverso-una-panoramica
44) http:/xoomer.virgilio.it/fisica_moderna/InflEspansione.htm
45) Parisini S., “Un po’ di luce sull’energia oscura”, MEDIA INAF, Astronomia News,19-12-2017, http://www-media.inaf.it/2017/12/19/merging-energia-oscura/
46) Ezquiaga J.M., Zumalacárregui M., “Dark Energy After GW170817: Dead Ends and the Road Ahead”, Physical Review Letters,119,251304 (2017).
47) Feynman R.P., “The Feynman Lectures on Physics”. Vol.1 ,©1965,1989 California Institute of Technology (Caltech);Zanichelli Ed., Bologna,vol.1 34-5,10,16,17; 17-7; 10-13;39-8 (2001).
48) Achenbach J., “La Luce“, National Geographic, Italian edition, Milano,10,8 (2001).
49) Galison P.,L’equazione del Sestante: $E=m\cdot c^2$ in “It Must be Beautiful. Great equations of Moderne Science”; Granta Publ.,London,2002; il Saggiatore ed.,Milano,119 (2005).
50) Chandrasekhar B.S., “Why Things Are the Way They Are”, Cambridge Universit Press,1998; Il Saggiatore ed., Milano, 72-73,304,65 (2004).
51) Puccini A., “The Equivalent Rest-mass of Photon” (Session 2P2: Electromagnetic Theory and Design on the Optical Dispersive Materials, Invisible Cloak and Photonic Crystals). *Proceedings* Progress in Electromagnetics Research Symposium, Marrakesh, Morocco,723-725,Mar.20-23 (2011).
52) Heisemberg W.,“Uber den anscauliken Inhalt der Quantentheoritschen Kinematik und Mechanik“, Zeitschrift fur Physik,Vol.43,172-198 (1927).
53) Puccini A., “Uncertainty Principle and Electromagnetic Waves”, Journal of Electromagnetic Waves and Applications,Vol.19,7, 885-890 (2005).
54) Fermi E. “Argomenti pro e contro l’ipotesi dei quanti di luce”, Nuovo Cimento,3,201-206 (1926).
55) de Broglie L., “Ondes et quanta”, Comtes Rendus, Vol.177, 507-510 (1923).
56) Weinberg S., “The First Three Minutes. A Modern View of the Origin of the Universe”,© 1977 by S.Weinberg; Mondadori Ed.(Milano),75,65,79,27,136,131,109,127 (1977)
57) Rovelli C., “Così è rinato l’Universo”, il Sole 24 ore, 276,33 (2011).
58) Ashtekar A., “Gravity, Geometry and the Quantum”,arXiv:gr-qc/0605011v2 14 Jul 2006
59) Barrow J.D., “The Constants of Nature. From Alfa to Omega”,©2002 John D. Barrow, Jonathan

Cape 2002; Mondadori Ed.,Milano,293 (2003).
60) Baldo Ceolin M., Introduction, in Yang C.N., “Elementary Particles”, Princeton University Press, New Jersey 1961; Boringhieri Ed., Torino,IX-XI (1969).
61) Treccani Enciclopedia, “Energia Oscura”, in “Lessico del XXI Secolo”.
62) http:/www.fmboschetto.it/tde4/costcosmologica.htm
63) Lemaitre G.,“Un Univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques”, Annales de la Société Scientifique de Bruxelles, vol. 47, 49-59 (1927).
64) Nat’l Academies Press, The National Academy of Science, USA, “Nuclear Physics. Chapter 5: Nuclear Astrophysics”,111(1986).
65) Puccini A., “Correct Quantum Gravity is a Mechanical Effect Induced by Dynamic-Mass of Light’s Quanta”, viXra.org., Quantum Gravity and String Theory, 1712.0546 (2017).
66) Puccini A., “Light Quantum Induces the Measurement Paradox”, Journal of Advances in Physics, Vol.15, 6039-6055 (2018).
67) Levy M.M., “Meson Theory of Nuclear Forces and Low Energy Properties of the Neutron-Proton System”, Phys.Rev.,88,725-738 (1952).
68) Eisenbud L. and Wigner E.P., “Nuclear Structure”,Princeton University Press, N.J.,1958; Boringhieri Edizioni Universitarie,(Torino),40-41 (1960).
69) Pacini F., ”L’Universo”, Editori Riuniti,Roma,158,280-289 (1982).
70) http:/www.quibo.it/atosi/quark/confin.htp
71) Asimov I., “Asimov’s New Guide to Science”,©1984 by Basic & ooks, Inc.; Mondadori Ed., Milano,57,59,64 (1986).
72) www.Fe.INFN.it/florenti/courses/astrophysics/07/Supernovae
73) Pauli W., "Über den Zusammenhang des Abschlusses der Elektronengruppen im Atom mit der Komplexstruktur der Spektren", Zeitschrift für Physik, **31,** 765–783 (1925).
74) Lesch H., “Physic fur die Westentasche”,© Piper Verlag GmbH, Munchen 2003; Ponte alle Grazie Ed., Milano,105-106 (2007).
75) Maiani L.,“Fusione nucleare nelle stelle di grande massa”, Fermi Lectures 10, INFN Rome, 15^{th} Jan. (2015)
76) Chandrasekhar S., “The Maximum Mass of Ideal White Dwarfs”, Astrophysical J.,vol.74, 81-82 (1931).
77) Marani A:, “Stelle di Neutroni”, Tesi di Laurea in Matematica e Fisica ,Università di Bologna (2008).
78) Tolman R.C., “Static Solutions of Einstein’s Field Equations for Spheres of Fluid”, Phys.Rev.,55,374, 364-373 (1939).
79) Oppenheimer J.R., Volkoff G.M., “On Massive Neutron Cores”, Phys.Rev.,55,374, 374-381 (1939).
80)) Puccini A., “The Momentum of Luminous Photon Can Explain the Mistery of the Scission of The Water Molecule, Fundamental Event in the Clorophyllose Photosynthesis”, *Proceedings* of Progres in Electromagnetics Research Symposium, Moskow, Russia, 353-357,August 19-23 (2012),
81) Einstein A., “On a heuristic viewpoint concerning the production and transformation of light”, Annalen der Physik, vol.17,132-148 (1905).
82) Compton A,”A Quantum Theory of the Scattering of X-rays by light Elements”, Phys.Review, vol.21, 5,483-502 (1923).

83) Raman C.V., Krishnan K.S.,”A New Type of Secondary Radiation”, Nature,121,501-502 (1928).
84) Puccini A., “Light Weighs”, Progress in Electromagnetics Research B,Vol.8,161-177 (2008).
85) Casimir H.B.G., “On the attraction between two perfectly conducting plates”, Proc. Kon. Ned. Akad. Wetensch. B51, 793-795 (1948).
86) Alberti A., “Modelli di Energia Oscura”, Tesi di Laurea in Fisica, Relatore M. Pietroni, Università di Padova (2013).
87) Schiavone F.M., “Misure delle Distanze in Cosmologia ed il problema della Dark Energy”, Tesi di Laurea in Fisica, Relatore E. Piedipalumbo, Università di Napoli Federico II (2017).
88) Marra V., “Le Costanti fondamentali e la loro variazione indotta da uno Scalare Cosmologico”, Tesi di Laurea in Fisica, Relatore A.Masiero, Correlatore F.Rosati, Università di Padova (2004).
89) Puccini A., “The Momentum of Photon May Explain the Measurement’s Paradox in the Subatomic World” (Session 1A2: Electromagnetic Theory and Design on the Optical Dispersive Materials, Invisible Cloak and Photonic Crystals).*Proceedings* of Progress in Electromagnetics Research Symposium, Suzhou, China,1169-1171 Sept. 12-16 (2011).
90) Bohr N., ”The Quantum Postulate and the Recent Development of Atomic Theory", Nature. 121, 580–590 (1928).
91) Puccini A., “About the Zero Mass of Photon”, Progress In Electromagnetics Research, *PIER* 55, 117–146 (2005).
92) Glenn R., “Overlap Principle”,Center for High Pressure Research SUNY Stony Brook,NewYork, USA (2004), http://www.journey.sunysb.edu/ProjectJava/Wavelnt/
93) Penrose R., “The Road to Reality”, 2004 ©Roger Penrose; RCS ed., Milano, 641 (2005).
94) Puccini A.,“Quantum Gravity is Induced by a Mechanical Effect Elicited by Momentum of Light’s Quanta”, Asian Journal of Science and Technology,Vol.10,Iss.1,9206-9220 (2019).
95) Einstein A., “Ist die Tragheit eines Korpers von seinem Energieinhalt abhangig?”, Annalen der Physik,Vol.18,639-641 (1905).
96) Penzias A.A., Wilson R.W.,”A Measurement of Excess Antenna Temperature at 4080 Mc/s“, Astrophysical Journal,142,419-421 (1965).
97) Friedmann A.,”Über die Krümmung des Raumes”, Zeitshrift fur Physik,,10,1,377-386 (1922).
98) Weinberg S., “Anthropic Bound on the Cosmological Constant”, Phys. Rev.Lett.,59, 22, 2607-2610 (1987).