DARK MATTER PARTICLE IS

A NEUTRAL ELECTRON

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Abstract

Cosmological observations showed that the ordinary matter, or ordinary visible mass, is only ≈ 4% of the total mass of the Universe. Non observable mass, or *missing mass*, is ≈ 96% of the total mass, of which ≈23% is invisible matter, or *Dark Matter* (DM). Cosmological considerations seem to exclude that the DM is under the shape of a normal baryonic matter. Therefore, the *Dark Matter Particle* (*DMP*) very probably is a lepton particle.

The *DMP* was formed in the first fractions of second after the Big Bang. In order not to contradict the value of the *critical density* of the universe ordinary matter, the *primordial nucleosynthesis* can have generated only light elements and particles. *DMP* has existed since the Big Bang, this means it is a very stable particle. Moreover, since it does not emit and does not reflect light, and it never interacts with ordinary matter or with other *DMPs*, it implies that it is insensitive to Electro-Magnetic and Nuclear Interactions, therefore it is a neutral particle.

Thus the *DMP* is a stable, light, neutral, non-interacting lepton.

It was supposed to be a neutrino but, still in relation to *nucleosynthesis*, the value of its infinitely small mass, i.e. ≤0.01 electronic masses, contradicts the value of *critical density*. For opposite reasons, even WIMPs cannot identify with *DMP* (the value attributed to their mass is excessive: ≥ 100 proton masses).

Therefore we may think of an electron, but they carry electric charge, and highly react with the surrounding matter. It does not work. Unless we assume the *DMP* can equally identify with an electron, but without the electric charge: a neutral electron (e°).

According to Majorana's mathematical formalism, the mathematical substrate in support of the e°, leads to consider it as a *self-conjugated spinor,* where the *charge conjugation* may give it a certain stability and make it unable to interact.

The physical substrate is represented by the lack of a ***R*** *process* on the e°. Consequently, it will never, or almost never, undergo a Wave Function Collapse, so it will not be traceable as a common particle, but, according to Quantum Mechanics, it keeps travelling as a wave, undisturbed, *delocalized*, and propagating as a superimposition of quantum states.

Introduction

It is known that the problem of the *Dark Matter*(DM) was first issued by Fritz Zwicky. In fact, at the beginning of the 30's Zwicky noticed that peripheral stars rotating around the centre of a galaxy have such a speed that the Gravity Interaction(GI) should not be able to keep them in orbit. Zwicky writes: "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 on which the GI acted. He hypothesized the existence of a *missing mass* (MM). An invisible mass whose gravitational effect adds to the visible matter's. In this way account balanced[2]. In fact, as Hack reminds us: "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, a DM. 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 DM"[3]. We learn from Giacconi and Tucker: "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 DM 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 the mass 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]. Giacconi and Tucker add: “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”[4].

Though "Zwicky's discovery was ignored"[6], it seems to us necessary to quote, in his honour, what Casas writes: "Zwicky was an authentic genius, precocious for the time he lived" [7]. This makes us remember his contemporary: Ettore Majorana. "In addition to his DM pioneering studies, he was also the first astrophysic to assume that the supernovae were explosions of stars, leaving behind the remains of a neutron star. He was also the first to think that galaxy clusters could function as *gravitational lenses*"[7] [8].

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 "[9]. 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 significantly bigger than what can be detected with the optical band or other electromagnetic radiations[10]. X and radio frequency surveys confirm the results: non observable mass, or MM, is ≈96% than the total mass of the Universe. The ordinary visible mass is only ≈4% than the total mass. This is confirmed by accurate satellite surveys, which highlighted "2 peaks in the Universe of the first phase, from which it can be established that the baryonic matter is ≈4% of *critical density* and DM ≈ 23%. Since the Universe is *flat*, it has a *critical density* equal to the unit (Ω=1): consequently, the remaining 73% consists of *Energy Density*"[3], also not detectable, thus defined as *Dark Energy* (DE).

Discussion

It's good to say that, according to some thinking (modified Newtonian dynamics or MOND hypothesis), the DM does not exist: it is an 'optical illusion', because on large distances, the

GI works abnormally. Instead, "it is just the *gravitational lens* method to have indeed allowed us to verify that the DM of the Universe is 5-6 times more abundant than ordinary matter, in total agreement with the estimates made with the orbit method. Then, the *gravitational lens* provided overwhelming evidence that DM is really there, and is not an optical illusion. In addition, studying in depth the fluctuations of the *bottom fossil radiation*, or *cosmic microwave background* (CMB) coming from the Universe, one can deduce the existence of DM and its abundance" [7].

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 "[6]. Therefore: what is the invisible mass of the universe (DM) made of? The hadronic matter is only about 4% of the total mass. "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 immediately after the Inflationary Phase [11] [12] [13]. Bhattacharjee adds: "The DM was needed to hold together the galaxies that were forming. The GI coming from only known ordinary matter was not enough"[11]. Casas states: "According to the Big Bang theory, when the universe was a few seconds old, its temperature was some billion degrees; it was so high that the atom constituents (protons, neutrons, and electrons) were disconnected and moved at great speed. Many photons, neutrons and other particles were also present. It was then that the right conditions of density and temperature occurred so that a phenomenon called *nucleosynthesis* occurred, whereby a portion of protons and neutrons fused to form complex atomic nuclei, e.g. helium. However, an important part of the original protons, i.e. hydrogen nuclei, remained unbundled. This constitutes the confirmation of the theory. The abundance of light elements in the cosmos provides the most obvious witness to what happened when the Universe existed for a few minutes. To calculate the production of elements of the primordial universe, it is necessary to use the value of an important magnitude: the *density* of the ordinary matter of the universe. Calculations reveal the abundance of light elements, which are strikingly similar to the observed abundance. This means that DM (6 times more abundant

than ordinary) can *not* be an ordinary matter that, for some reason, we have not been able to detect, e.g. small asteroids wandering for interstellar space. If DM was ordinary matter, the authentic *density* of ordinary matter would not be what we observe, but 7 times greater. Thus, the calculations of primordial *nucleosynthesis* regarding the abundance of light elements do not coincide with observations. The abundance of light elements indicates that, basically, there is no ordinary matter other than what one really can observe. Therefore DM must be something else"[7], and at the same time it must really exist. "The DM cannot be the dark version of the luminous one, that is, it is not electromagnetic radiation, but a genuinely new ingredient of the cosmos, so abundant to excel in mass all that we call matter. Thus, DM is the true holder of the Universe GI, the creator of galaxies, the referee of their inner dynamics: hunting is not closed"[14].

So what can be the identikit of the *X Particle* that constitutes the DM?

1) First of all this *X Particle* is not a fantasy: it must really exist, just because there are numerous clues to support the real presence in the cosmos of this DM. One could just mention the *gravitational lens* effect and the analysis of the CMB fluctuations. Besides, "in 2004 Hubble satellite photographed a titanic collision between two 'clusters of galaxies', forming a ring-shaped DM halo, twenty-five times the Milky Way: this is the first glimpse of DM" [9].

2) It is particularly important that this *X Particle* exists since the first minutes after the Big Bang: that is, it was born with the first protons, neutrons, electrons, photons and neutrinos. If it has existed since the dawn of time, it means unambiguously that the *X Particle* must be particularly stable.

3) If a particle remains stable, unmodified for almost 14 billion years, undoubtedly it implies that there cannot be a lighter particle in which the *X Particle* may decay. So the circle tightens.

4) These *X Particles* are copiously present in the Universe, but distributed in a homogeneous way. "They are not just out there, but here too, among us" [7].

5) Another fundamental feature of the *X Particle* is that it interacts very little with ordinary matter: indeed, we suspect that it does not interact at all. Only the effect of the GI can put it, so to speak, in evidence.

6) The *X Particle* does not interact even with similar particles, that is, of its very nature. That's right: it does not even interact with another *X Particle*. We have this evidence by observing the Bullet Cluster: it is a pair of clashes of collided galaxies, at 3 million light years. "The Chandra X-Ray satellite has found massive aggregates of hot gas at the center of Mass, attributing it to the collision between ordinary material clouds. However, analyzing the

Bullet's gravitational field, two massive mass concentrations have been found. One for each of the interacting clusters, farther away from the center of the collision, deducing that the ordinary materials structures of the 2 clusters were clashing and melting while the two loads of DM, even more massive, just crossed the disaster area, without interacting, intact and imperturbable "[15]. This is a giant collision: the 2 clusters have been colliding for hundreds of millions of years, and their centers have already crossed about 150 million years ago; they are now moving away. It can be noted that "both gas clouds are moving away, each one to one side. In addition to gas clouds, there are single galaxies. The extraordinary thing is that the latter are not in the same position as the first, but moved. They are further from the center, compared to the clouds themselves. Why galaxies are not in the same position as gas clouds? Because interfering with each other, the 2 gas clouds create friction and consequently stop each other. However, the galaxies are so far apart within each cluster that the two galactic swarms cross almost without touching and therefore their movement is not restrained. That's why they are further then gas clouds. The collision has had the effect of separating galaxies from the gas clouds in each cluster! In addition, the observation of the x-ray emission allowed to verify that, in fact, the matter contained in the gas is much abundant than single galaxies', as it is usual to think. Moreover, the temperature of the gas clouds is much higher than the usual one. This is due to the frustration caused by the clash. This friction is also the cause of the strange *bullet* shape, of the dx cloud. Moreover, clusters produce the effect of the *gravitational lens*. In short, most of the matter in the clusters is not in the gas clouds. So the MOND hypothesis cannot be considered valid since, without the DM, the clear spots would have to appear in the same area as the gas clouds, since that is the area where the most common mass is. It is currently thought that Bullet Cluster represents the most obvious and direct evidence of DM's existence, as well as giving further clues on its nature. In fact, not only does the DM interact very little with ordinary matter (hence its invisibility), but very little with itself too"[7].

7) The *X Particle* of DM cannot be a common baryonic particle, that is, identical to what common ordinary matter and atomic nuclei are made, "otherwise calculations of primordial *nucleosynthesis* would contradict the data resulting from observations"[7]. Giacconi and Tucker point out: "Cosmological considerations tend to exclude that MM is in the form of normal baryonic matter. According to the theory of the Big Bang, the universe began to expand from a warm and dense state. In the first expansion minutes all deuterium (heavy hydrogen) was formed in the universe. The amount of deuterium that was formed is closely related to the conditions prevailing at that initial stage. If the *density* of the mass had been too

high, all deuterium would have become helium"[4]. In short, it seems more appropriate to think that "DM must be composed of particles not yet known" [16].

8) This *X Particle* is invisible and has never been identified so far. Being invisible means that it is a particle that does not emit, absorb nor reflect visible light.

9) An immediate consequence of what is stated in point 8 is that it can be inferred that the DM Particle does not react to the Electro-Magnetic Interaction at all: can we think it is free from electric charge, that is, neutral? The circle tightens further, almost inexorably. Bignami states: "The requirements that the DM must have are massive particles and no electric charge" [17].

10) Another peculiar feature of this particle is the abundant amount that is diffused in the cosmos, indeed it is the most widespread particle in the Universe. It alone represents ≈ ¼ of the whole mass present in the world. In fact, even though "99% of the atoms of the Universe are hydrogen and helium atoms" [4], we refer to ordinary matter, which represents only ≈4% of the total mass. The abundance of *X Particle* has some implications. "Let's point out that starting from the study of primordial *nucleosynthesis*, we were able to explain the abundance of light elements. So let's look for a particle (or group of particles) that has the characteristics mentioned"[7]. We have already mentioned that this *X Particle* has the same age as the Universe, so it already existed at the time of *nucleosynthesis*, and in abundant quantities. It came to us intact, and in very large quantities, which would have not been easy if it had been a heavy particle or with a certain mass, since it would have already decayed in a lighter particle. Therefore, especially in relation to its considerable abundance, it seems more appropriate and probable that it is a lightweight particle, according to the value of *critical density*. But then, with this further clue, with the latter *retouching*, we could also say that the look of our elusive particle is almost complete.

What is this particle? According to the current opinion, three are the main candidates: WIMP, axion, neutrino.

A) WIMP: It is not known what the DM is made of. It is thought that it is made of weakly interacting massive particles (WIMP). Massive particles (100 times heavier than a proton) which interact very little with the matter, even less than neutrinos. It may also be a super symmetric particle, or something else. WIMP are being searched at the Gran Sasso and in particle accelerators: they are the same technologies used to detect a neutrino. However no definite result has been obtained so far. Actually, we think that the mass of WIMP is too much to be compatible to represent the *DM Particle*. There are two main reasons: 1) It would have been very difficult for a very large particle, covering nearly ¼ of the total mass diffused in the Universe, and weighing ≈100

proton masses, to pass the primordial *nucleosynthesis* phase and reach the present times. We know, in fact, that *nucleosynthesis* is just "able to explain the abundance of light elements" [7]. 2) Besides, the abundance of such massive particles would have overly increased the *critical density* value and made it incompatible.

B) Axion: "It was hypothesized in the 80's in order to solve a theoretical problem of the Standard Model (SM) inherent in the structure of Strong Interaction (SI)" [7]. It is believed they formed in the early moments of the Universe. Their mass should be more or less superimposable on neutrinos'. It reacts very weakly to ordinary matter too. In our opinion, axion's mass is too small to identify with the *X Particle*. In addition, contrary to the WIMP, with the axion the opposite phenomenon occurs: its excessively modest mass would not be enough to reach the correct value of the *critical density*.

C) Neutrino: As it is known, at first SM considered the neutrino (ν) as massless. Then, after the experiment of Superkamiokande, a mass was assigned to ν, though very little: something between 1 million and 100 millionth the electron's mass; according to others it was approximately ≤0.01 electronic masses (the next lighter particle). It is believed that most *ν* come from the very first moments of the Big Bang, forming a *background of neutrinos* (v_s) that fills the cosmos, similar to the CMB (made of photons). Although v_s seem to have a small mass, it is still not enough to consider that they may represent the DM. Casas states: "However, ν cannot coincide with DM. First of all, because when computing the ν cosmic bottom, which comes from the Big Bang, ν is not sufficient to constitute a 23% *critical density* (i.e. the DM density). To achieve this percentage, ν should be much heavier than they are"[7], unless they match another particle, still neutral, but more massive.

We are back to square one. What is the *DM Particle*? From the various profiles listed above, it is possible to get some essential elements that could help us frame it, drawing a first sketch of the identity of this *X Particle*:

1) First it must be a very stable particle (since it has the same age as the Universe!). First consequence: it must be the lightest elementary particle of its class or family of particles, as there can be no lighter particle in which it decays. Second consequence: it must therefore be a lightweight particle, without any doubt.

2) It is not a baryonic particle, but this does not exclude that it may be a lepton particle. Moreover, these are the two main classes of half-integer spin particles, so if the *X Particle* is not a baryon, then it must be a lepton. Mesons, in their turn, though hadrons, belong to the boson category (spin whole or nil), i.e. transmitters of the Fundamental Forces, and certainly the *X Particle* will not belong to this category of particles. Unless we admit it belongs to a

category of particles completely unknown, but it seems unlikely, especially considering we can find the solution with a particle belonging to the known families.

3) This particle continuously demonstrates that it never interacts (only in very rare occasions) with ordinary matter, nor with *DM Particles* themselves.

4) The *X Particle* is *Dark* just because it does not emit, absorb and does not reflect visible light; this implies that it has nothing to do with electrical charges and Electro-Magnetic Interaction. Indeed, with its behavior it proves to be insensitive to Nuclear Interactions too. Thus it should not carry any *charge*: neither electromagnetic, nor strong, neither color nor weak. The only Force to which the *DM Particle* (*DMP*) has turned out to be sensitive is the GI, but only for large scales, astronomical scales (that is, when considering abundant quantities, and all together, of that *Particle*).

Ultimately, therefore, we know it is a particle with the following characteristics:

1) stable; 2) not at all reactive; 3) light; 4) a lepton particle; 5) with any type of charge, completely neutral.

Well, looking around, the only lightweight and stable lepton we can find is the electron (the ν has already been excluded, as outlined above, for the various reasons found in Literature). Yet the electron satisfies only 3 demands, 3 characteristics over 5. It is a very reactive particle and, in addition, it carries electric charge. However, we do not seem to see any other particle, among the known ones or more likely, which meets more requirements than the electron to represent the *X Particle*. How can we solve this puzzle? Maybe we can try "a desperate remedy", as Pauli wrote in the famous letter to the participants of the Congress of Physics in Tubingen to safeguard all Conservation Laws in the disintegration of the neutron [18]. In our case we can try a "desperate remedy" too. Our "remedy" meets the five *DMP* requirements, without substituting the proposed type of particle. It is possible to think of a chargeless electron, i.e. neutral: e°.

It could be said: e° does not exist, this is an invention! The only known electrons are those carrying an electric charge: e^- and e^+. Yet even the ν, when suggested by Pauli, was an invention. Moreover the ν was a particle totally unknown. Indeed, it was forced to introduce in Physics, *compulsorily*, a new family of particles, with their own characteristics, and with presumed properties quite different from the other elementary particles known at the time. The e°, instead, refers to one of the fundamental particles more widespread in nature, even if only those electrically charged are known. In addition, a not negligible result, with the e° it is not necessary to invent a new category of particles to be added to the Standard Model (SM), maintaining the symmetry of the SM. One might replicate: why not consider ν as *DMP*,

instead of e°? We have already mentioned the various reasons, widely available in literature, explaining why the ν cannot not be the right candidate to represent the *X Particle*. The main one is its limited mass.

On the other hand the disintegration of the neutron, or negative β-decay (βd^-), shows that the energy value attributable to ν corresponds to <5.8 eV (many A.A. attribute to ν an infinitely smaller mass). Why this limit? This limitation was inferred from the observations of Supernova 1987A, for which it had been assumed that the mass of the electronic ν (ν_e) was <5.8 eV[19]. Why? Because the neutrinos(ν_s) of this supernova arrived on Earth a few hours before the visible light; so they "must have traveled at a speed very close to that of light. Since lighter particles travel faster than heavier ones, scientists have concluded that the mass of ν is very small"[20]. Besides, in the 1920s, analyzing the βd^-, a remarkable energy gap emerged, between 511 and 782 eV (based on our calculations) [21]. For some years it was not possible to find a solution until Pauli proposed ('a desperate remedy') the assumption that the emission of a 3rd particle without electric charge could compensate for this gap. Later Fermi called neutrino (ν) this third particle, emitted with βd [22] [23] [24]. Indeed, as *nucleosynthesis* does not allow ν to represent *DMP*, because of its very small mass, for the same reasons we believe that just one ν cannot fill the energy gap of the βd: we would need one hundred or more of these ν! On the contrary, considering that the third particle emitted with βd is accelerated at relativistic rates (as Fermi himself states [25]), in our opinion just one e° would be enough to compensate the energy gap, thus safeguarding the Laws of Conservation of Mass and Energy and at the same time safeguarding the Law of Conservation of Electric Charge and Angular Momentum, including the Lepton Number Conservation (considering that, as imposed by the βd^- itself, it is a right-handed (↑) anti -e°, i.e. ē°↑ [21].

Let's try to figure out whether the e° is able to meet the other two requests of the *X Particle*, which the electrically charged electron failed. Well, one is immediately satisfied, because the e° is free of electric charge. There is one last obstacle to overcome, so that the e° can represent the inescapable and invisible corpuscle, called *DMP*. In order to overcome this latter obstacle, the particle we propose must behave in an opposite way to its twin particles provided with electric charge. It is just a charge to make the difference, and what a difference! Therefore, while electrically charged electrons are very reactive, both with ordinary matter, and with other electrons, on the contrary we need to understand what the physical peculiarities that make e° poorly reactive (or not at all reactive) both with common matter and other e° are.

Only by finding a plausible and probable solution to this question, we can propose the e° as the particle identifiable with the *DMP*.

In short, it is as if the deprivation of the electric charge produced, in one of the most widespread particles in the world, some particular and truly surprising properties. Yet other known neutral particles, belonging both to the fermion and boson category, behave normally, that is they interact easily with common matter, including particles identical to themselves. Therefore, it seems that the electron is only one, when free from electrical charge, to acquire a very peculiar behavior which makes it invisible, reserved and elusive. But what most surprises us, is its incredible longevity. In fact, if e° really corresponded to the mysterious *X Particle* of DM, then as it can be inferred from *nucleosynthesis*, it would have the same age as the Universe. In short, we would have a particle that, without interacting with anything, was as indestructible, as well as, we could say: *pseudo-eternal*. But then we wonder: what makes it invulnerable, like the gods of Olympus? What's behind it? What can be the intimate, deep and mysterious physical mechanisms, and the underlined mathematical formalism that make it so special?

Finally, we recall some sophisticated mathematical equations, specifically elaborated to describe the behavior of electrons, and later integrated with other equations: these latter formulated with reference to neutral particles, first of all electrons.

We may say that everything starts with Schrodinger. He had long been thinking of de Broglie's happy intuition of.

It is known that de Broglie suggested, without experimental data, to give particles the same property as waves. He gave each particle a its own wave length depending only on the *momentum* of the particle itself [26]. Any particle with a *momentum p* seems to be something periodic, oscillating as a wave, with a universal relation between the wave length of the particle, indicated by λ, and modulus *p* of its *momentum.* In this way we have the formula:

$$\lambda = h/p \qquad (1).$$

where *h* is Planck's constant. The question, wave or particle, can be solved with the Quantum Mechanics (QM) leaving to the particles – rather, to *quantum objects*(QO) - a *wave function* (WF) of their own, indicated with ψ, which describes correctly both their wave and particle character. The WF is a *mathematical function* which depends on time (*t*) and on the position (*x*) of the particle it is referred to[27]. According to the QM, "we are not able to say that a quantum system, before being observed, has well defined properties, since we cannot know them"[28]. Thus, starting from de Broglie's formula, see Eq.(1), Schrodinger worked out the

wave equation for the electron. The energy of electrons is expressed by the Hamiltonian (H) described by Schrodinger equation (2):

$$H = p^2 / 2m + V_{(x,t)} \quad (2),$$

where *m* is the mass of the electron, *p* its *momentum*, *V* expresses the potential energy of the electron, which *argument (x,t)* reveals its space-time coordinates[29][30]. It seems to us particularly interesting to point put that this equation describes the wave function (ψ) of the electron when the particle is not disturbed, that is when any *measurement* is carried out, it stays in its natural state: it *lives*, as a QO [31]. Thus it occupies a volume, it is *spread* in the space which is allowed to it (it is *delocalized*), and it is represented by *superimposed quantum states*: it tends to behave as a wave. This is the *phase of linear evolution* ***U*** [32][33]. However, Schrodinger's equation does not start from Einstein's relativistic mechanics, but from Newton's old mechanics. Dirac was not satisfied: "The new quantum mechanics, when applied to the problem of the structure of the atom with point-charge electrons, does not give results in agreement with experiment" [34]. Therefore Dirac "starts looking for a more accurate equation for electrons, based on relativistic mechanics" [35]. We report the Dirac wave equation for the electron[34][36]:

$$[\, Y^{\mu} (i\, \delta/\delta\, x^{\mu} - eA_{\mu}\,(x)) + m]\;\; \Psi(x) = 0 \quad (3).$$

With reference to this equation Wilczek states:"It describes the behavior of the wave function $\Psi(x)$. It has 4 components: $\Psi_{e}\uparrow(x), \Psi_{e}\downarrow(x), \Psi_{p}\uparrow(x), \Psi_{p}\downarrow(x)$. Each of them is a function whose value depends on the space and time, as indicated by the *argument* (*x*). Dirac considered these values *complex numbers*, which square magnitude gives an opportunity to find the kind of corresponding particle: up spin electron, down spin electron, up spin positron or down spin positron, at the space- time given point. In modern interpretation the values are operators which create electrons or destroy positrons. μ *should* have a value of 0,1,2,3, representing the time and the 3 directions of space, and add up the contributions of all values. The derivative $\delta/\delta x°$ measures how quickly the wave function changes over time, while others derivatives measure how quickly it changes in different spatial directions. *A(x)* fields are the electromagnetic potentials. They specify the electric and magnetic field felt by the electron. The electron charge is -e. It specifies the intensity of its response to those fields. The mass of the electron is *m*. Dirac's innovation was to introduce Y matrices. They allowed Dirac to formulate an equation in which space and time appeared on an equality basis, however, forcing him to introduce a wave function with 4 components"[35]. Wilczek adds: "Dirac's equation correctly predicts that the electrons have a spin and behave like small bar magnets.

The equation contains solutions describing a way in which ordinary atoms can spontaneously annihilate in a flash of light in a split second. A spectacular result was the prediction that there had to exist a new particle with the same mass of the electron, but of opposite charge, and able to annihilate an electron transforming it into pure energy. Now the *bad news*: Dirac's equation has four components; that is, it contains 4 separate wave functions, to describe the electrons. Two components have an attractive and direct interpretation, describing the two possible directions of the spin of an electron. The other two, on the contrary, showed several problems. In fact the two extra equations contain solutions with *negative energy* (and with both spin directions) "[35]. In this regard Klein writes: "the *negative energy states*, emerged from the interpretation of Dirac electron's equation wave, *repelled* many physicists, above all Pauli, Heisenberg and Majorana"[37]. Ettore Majorana wrote his latest work inspired by Dirac equation: "Symmetric Theory of Electron and Positron". In the abstract he states: "Making use of a new quantization process, the meaning of Dirac equations is somewhat modified and there is no longer any reason to speak of negative-energy states nor to assume, for any other types of particles, especially neutral ones, the existence of antiparticles, corresponding to the "holes" of negative energy "[38]. The author writes: "We limit ourselves to the description of a quantization procedures for the matter-waves, which is the only important case for applications, at present; this method appears as a natural generalization of the Jordan-Wigner method, and it allows not only to cast the electron-positron theory into a symmetric form, but also to construct an essentially new theory for particles not endowed with an electric charge (neutrons and the hypothetical neutrinos). Even through it is perhaps not yet possible to ask experiments to decide between the new theory and a simple extension of the Dirac equations to neutral particles, one should keep in mind that the new theory introduces a smaller number of hypothetical entities, in this yet unexplored field "[38]. Majorana adds: "It is well known that one can eliminate the imaginary unit(i) from the Dirac equations with no external field:

$$[W/c + (\alpha,p) + \beta mc]\Psi = 0 \qquad (4),$$

with an appropriate choice of the operators α and β (and this can be done in a relativistically invariant fashion). We shall, in fact, refer to a system of intrinsic coordinates such as to make eq. (4) real, keeping explicitly in mind that the formulae we shall derive are not valid, without suitable modification, in a more general coordinate system. Denoting, as usual, with σ_x, σ_y, σ_z and ρ_1, ρ_2, ρ_3 two independent sets of Pauli matrices, we set:

$$\alpha_x = \rho_1 \sigma_x; \quad \alpha_y = \rho_3; \quad \alpha_z = \rho_1 \sigma_z; \quad \beta = -\rho_1 \sigma_y; \qquad (5);$$

dividing eqs. (5) by $-h/2\pi i$ and defining $\beta' = -i\beta$, $\mu = 2\pi mc/h$, we obtain the real equations:

$$[1/c\ \delta/\delta t\ -(\alpha,grad) + \beta'\ \mu]\ \Psi = 0 \qquad (6).$$

As a consequence, eq.(4) separates into two independent set of equations, one for the real and one for the imaginary part of Ψ. We set $\Psi = U + iV$ and consider the real equations (6) as acting on U "[38]:

$$[1/c\ \delta/\delta t\ -(\alpha,grad) + \beta'\ \mu\ ]\ U = 0 \qquad (7).$$

It is of considerable importance to highlight this Majorana record with reference to Eq. (7):

"The behaviour of U under space reflection can be conveniently defined keeping into account that a simultaneous change of sign of U has no physical significance, as already implied by other reasons. In our scheme:

$$U'(q) = RU(-q) \qquad (8),$$

with $R = i\ \rho_1\ \sigma_y$ and $R^2 = -1$. Similarly, for a time reflection:

$$U'(q,t) = i\rho_2\ U(q,-t) \qquad (9).$$

It is remarkable, however, that the part of formalism which refers to U (or V) can be considered, in itself, as the theoretical descriptions of some material system, in conformity with the general methods of quantum mechanics. The fact that this reduced formalism cannot be applied to the description of positive and negative electrons may well be attributed to the presence of the electric charge, and it does not invalidate the statement that, at the present level of knowledge, equations related to the *anti-commutability relations* constitute the simplest theoretical representation of neutral particles. The advantage of this procedure, with respect to the elementary interpretation of Dirac equations, is that there is now no need to assume the existence of antineutrons or antineutrinos"[38] meant as distinct antiparticles from the respective particles. Compared to the *Weyl Spinor*, also with 2 components, i.e. with 2 degrees of freedom (that is, with 2 spin orientations), but massless, as Majorana states in his model "in the place of massless quanta, we have particles with a finite rest mass and also for them we have two available polarization states. In the present case, as in the case of the electromagnetic radiation, the half-quanta of rest energy and momentum are present, except that they appear with the opposite sign, in apparent connection with the different statistic. They do not constitute a specific difficulty, and they must be considered simply as additive constants, with no physical significance. Similarly to the case of light quanta, it is not possible to describe with eigenfunctions the states of such particles. In the present case, however, the presence of a rest mass allows one to consider the *non relativistic approximation*, where all the motions of elementary quantum mechanics apply, obviously. The non relativistic approximation may be useful in the case of the heavy particles (neutrons)" [38].

It emerges, therefore, that the particle considered in these equations, now known as *Majorana Particle*, or *Majoran Spinor* or *Fermion* (also, just as *DMP*, elusive) requires two basic conditions: 1) it must be neutral; 2) it must be massive.

Edoardo Amaldi too, like Majorana, one of *the boys of via Panisperna* (as well as the first chief of the CERN in Geneve), writes: "Dirac relativistic theory, is based on Dirac equation which is completely symmetrical to the sign of the charge of the considered fermion; but this symmetry is partly lost in the subsequent development of the theory that describes the vacuum as a situation in which all the states of negative energy are occupied, as well as all the free positive energy. The excitement of a fermion from one of the negative state energy to a positive one leaves a gap with positive energy, which can be interpreted as the anti-fermion. In this way the process of excitation of a fermion, from a state of negative energy to one of positive energy, is equivalent to the creation of a couple fermion-antifermion. This asymmetric approach brings as a consequence also the need to erase, without any *sound justification of principle*, some infinite constants due to negative energy states, as, for example, the electric charge density. These drawbacks are avoided in the theory proposed by Majorana, in which he proposes a new representation of the Dirac matrices $Y\mu$ (μ = 1,2,3,4), which has the following properties:

A)Unlike what happens in the original Dirac's representation, in Majorana's representation the 4 Y_μ matrices have the same reality properties of the four-vector $\chi_\mu \equiv r,ict$; or, if one takes all the real space-time coordinates, associated with a pseudo-Euclidean metric, all four are real "[39]. Also, as Recami notes: "the algebra $R(4) \cong R_{3,1}$ introduced by Majorana is quite different from the algebra $C(4) \cong R_{4,1}$ introduced by Dirac. We observe, *en passant*, that the algebra of Majorana is one of two algebras naturally associated to Minkowski space (the second being $R_{1,3} \cong H(2)$, where *H(2)* is the algebra of quaternionic matrices 2x2)"[40]. Amaldi continues:

"B) In this representation, Dirac's equation relating to a free fermion is with real coefficients, thus its solutions are broken into a real part and an imaginary one, each of them meets separately the mentioned equation. But each of these real solutions, just as a consequence of its reality, has two very important properties: the first is that it gives rise to a quadruple vector with zero electric charge. It follows that the real solutions of Dirac's equation must correspond to fermions free of both electric charge and magnetic moment. The second result of the reality of the fermionic field Ψ is that the corresponding field operator must be Hermitian, so that its degrees of freedom are halved and there is no more distinction between fermion and antifermion. Majorana in his work suggested that the neutron or neutrino, or both

particles, were corpuscles of this type that is neutral corpuscles identified with the corresponding anticorpuscles"[39].

This is the great novelty emerging from Majorana's mathematical formalism, showing us a mathematics that precursors the times. Against any prediction, like the a rabbit emerging from the conjurer's cylinder, from Majorana equations appears a neutral particle which identifies with its antiparticle. In Dirac's equations particle and antiparticle are two distinct entities, whereas Majorana equations show that a neutral particle and its antiparticle are the same particle. This peculiarity is represented mathematically by ***C***, which indicates the so-called *charge conjugation*. Therefore Majorana particle is a *self-conjugated* spinor, i.e. it identifies with its antiparticle. "The spinor, or spinorial object, is an essential mathematical concept, a marvellous idea of remarkable importance: an essential mathematical significance for quantum physics of fundamental particles such as electrons, protons, and neutrons. Common solid matter would not exist without the consequences of this idea. What is a spinor? Basically it is an object that, after a rotation of 2π, turns into its opposite. Spinorial objects represent the wave functions of fermions, never those of the bosons. Indeed the term spinor always means one particle with spin ½, i.e. a fermion and never a boson. The spinor is represented by a 2-component wave function Ψ_A, thus the index $_A$ takes values 0 and 1, i.e.: $\{\Psi_0(x), \Psi_1(x)\}$ [32].

In this regard, let's group the most salient features of the Majorana Spinor (S_M):

Majorana's Spinor is a 2 component spinor, i.e. it has two degrees of freedom, consisting always in the same spin orientation for the particle (levorotatory: ↓), and antiparallel for the respective antiparticle (dextrorotatory: ↑), namely: $\Psi(S)\downarrow$; $\Psi(S^-)\uparrow$,where S is the spinor and S^- the anti-spinor. It is incompatible with a conserved charge, since the Majorana equation requires that its spinor has neither electric charge nor magnetic moment, but it must have a mass different from zero: $m\neq0$. According to Majorana such a spinor should coincide with "particles with no electrical charge (neutrons or hypothetical neutrinos)"[38]. It could also likely coincide with another neutral particle, not yet identified (most likely because of its very low interope with ordinary matter). As Barbieri says: "Majorana starts from the symmetry between electrons and positrons, ***C***. As he tries to overcome it he stumbles in the idea of a *self-conjugated spinor*" [41]:

$$S^-_M = \boldsymbol{C}(S) = S_M \qquad (10),$$

where S_M and S^-_M indicate *Majorana's spinor* and its antiparticle, which has not yet been identified: it must be massive and free of electric charge. In turn, ***C*** indicates the *charge conjugation*. What does it mean? It means that the *Majorana spinor* (which can be

represented by a neutral particle) identifies with its antiparticle; they are the same particle: one is the mirror image of the other, just as described by Eq.(10) or by Majorana through Eq.(8). The mirror image shows the same particle, but with a spin rotating in the opposite direction. That is, the particle has always a rotating spin in one direction, and the so-called antiparticle, on the contrary, revolves in the opposite direction. That is a *self-conjugated* particle, we can think of a ballerina who makes the pirouette in front of the mirror: in the mirror she sees herself, but she is turning in the opposite direction.

In short, the special thing emerging from Majorana equations is that there is no distinction between particle and respective antiparticle, at least as regards neutral particles (those electrically charged are distinguished for at least the opposite charges). This peculiarity is precisely mathematically represented with ***C***. In this regard, Penrose writes: "The operation that replaces each particle with its antiparticle is denoted by ***C***. A physical interaction that is invariant with respect to the replacement of the particles with their antiparticles (and vice versa) is called ***C***-invariant. The spatial reflection (specular reflection) is denoted by **P** (which stands for *parity*). Weak Interactions are not invariant neither with respect to **P**, nor with respect to ***C***, but they are invariant with respect to the *combined* operation ***C*****P** (= **P*****C***). We can assume that ***C*****P** is performed by an unusual mirror, in which each particle is reflected in its antiparticle. We note that ***C*****P** operation causes a left-handed particle is reflected in its right-handed antiparticle"[32]. It seems interesting to point out that this dovetails with the model of *Majorana spinor* inherent neutral particles and the "hypothetical ν"[38]. It is very important, in our opinion, that Majorana himself leaves doors open to other particles, provided they are neutral (and massive).

We suspect that this *charge-conjugation* may be the determining factor, both of the peculiarity of Majorana's equations, and of the structural support of our model. On the other hand, if we are not mistaken, we do not find that Mathematics shows us other *self-conjugated* particles, apart from Majorana Spinor, even though for a long time it was supposed that it could correspond just to ν. Therefore it was assumed that ν was self-conjugated. Then, replacing ν at Majorana Spinor in Eq. (10), we have:

$$\bar{\upsilon} = \boldsymbol{C}(\nu) = \nu \qquad (11).$$

As in Eq.(10), concerning the Majorana Spinor, in Eq. (11) too we find that "the hypothetical ν"[38] identifies with its antiparticle ($\bar{\upsilon}$); they are the same particle: one is the mirror image of the other, just as described by Majorana through Eq.(8). The mirror image shows the same particle, but with a spin rotating in the opposite direction. That is, the particle has always a rotating spin in one direction, and the so-called antiparticle, on the contrary,

revolves in the opposite direction (just as when we see a rotating ball in front of the mirror: it is the same object). We can really say that the Majorana *self-conjugated Spinor* model was prophetic. In fact, just 30 years later, as we all know, it was shown that in weak interactions(WI_s) there is *violation of Parity*, just as Lee and Yang had predicted [42]. In that regard Penrose reminds us that Madame Wu "examined the distribution of the electrons emitted by the radioactive core of cobalt 60, finding a clearly asymmetrical relation to reflection between this and the directions of the spins of the nuclei of cobalt. This finding was puzzling, because it had never been observed an asymmetric mirror image phenomenon into a fundamental physical process! The *chiral asymmetry*, arises from the fact that in a mirror for a left-handed helicity particle it appears similar to the same particle with right-handed helicity, and *vice versa*. Each of these is converted in the other in a *specular reflection*. (In more conventional terminology, γ_5 changes sign for reflection, so that the roles of the parties of left-handed and right-handed helicity of the electron wave function, $(1-\gamma_5)\Psi$ and $(1+\gamma_5)\Psi$ are exchanged). In this way, the *non-invariance* of WIs, with respect to the *reflection*, has resulted in the fact that only the levorotatory electron is subject to WI. The same thing can be said for the neutron when undergoing a spontaneous βd^-, so as for the resulting proton. It is only the levorotatory neutron and the levorotatory proton to take part in the weak decay process. The ν too is particularly interesting in this respect. Only if the ν has a levorotatory helicity it is subject to WI or it could be created in a weak interaction process. Therefore ν_s are particles with levorotatory helicity. In the case of the electron's antiparticle, i.e. the positron, it will be the right-handed positron to be subject to WI. A similar observation also applies to the antiproton, the antineutron and anti-Quark. It could also apply to $\bar{\upsilon}$. The notion of antiparticle is valid both for bosons and for fermions, whereas Pauli Principle only applies to fermions, thus the point of view of *Dirac's sea* cannot apply to bosons. The pion with positive charge (the meson π^+), for example, which is a boson, has an antiparticle which is the pion with negative charge (the meson π^-). Actually, several bosons are their own antiparticles: it is the case of the photon and even the neutral pion (the meson $\pi°$) "[32]. It seems very important to note that what Penrose wrote confirms what emerges from Majorana equations where, especially in the case of an electrically neutral particle, this, placed in front of a mirror, you identifies with its antiparticle: i.e. particle and neutral antiparticle differ only in the spin, which are antiparallel! Obviously, according to Majorana, this is particularly true for the "hypothetical ν "[38]. Consequently the ν identifies with the $\bar{\upsilon}$, just as shown in Eq. (11). The only difference, in fact, is in the helicity: ν_s are always left-handed and $\bar{\upsilon}_s$ are always right-

handed. Eq.(10) could represent the *fermion* or *Majorana spinor*, as it corresponds to the "*self -conjugated spinor* in which Majorana had fallen"[41]. This is true both whether the 3rd particle emitted in βd corresponds to the ν, and in case it is another particle, i.e. e°. According to the latter possibility, the Eq. (11) should be well represented:

$$\bar{e}° = \boldsymbol{C}(e°) = e° \qquad (12).$$

The ***C***(or *charge conjugation*) given in Eqs.(10), (11) and (12) represents precisely the symmetry properties as expressed by these equations.

In short, this striking *symmetry* between the particle and its antiparticle, mathematically expressed by the *charge conjugation* (***C***), and jumped out of Majorana's equations as a prestigious game, seems to us the *common denominator* that joins the 3 particles, singly represented in the Equations (10), (11) and (12). And the most interesting thing, in our opinion, is that all three particles only in very rare cases interact with common matter, or with identical particles. In fact, Majorana's particle has not been found yet, as well as the hypothetical ν, and the possible e° (which in our view could represent the only neutral lepton instead of ν) [21].

We think that there are many possibilities that the very low inter-interactivity of the considered 3 particles is a consequence of the *symmetry*, the *charge conjugation* that characterizes them.

This is the fifth missing requirement: that is a possible physical-mathematical explanation why these particles do not interact. Moreover, this was also the last obstacle to overcome, in order to be able to propose the identification of the e° with the *DMP*. Also the latter is closely associated with the mentioned three particles by his proven inaccessibility, non-interactivity with matter. Besides, there are no other known or hypothesized particles having this same peculiarity. In short, it is as if Majorana, with its sophisticated mathematical formalism, provided the solution to solve our enigma. Thus, as the *charge-conjugation* between the particle and its antiparticle can bring together three other particles that have never been detected, unresponsive (the ν itself has never been detected directly but indirectly through the Cherenkov Effect induced by the third particle emitted by βd [43] [44]), we also think it possible and suggestible that Majorana equations are extensible also to *DMP*. In this case we have:

$$anti\text{-}DMP = \boldsymbol{C}\,(DMP) = DMP \qquad (13).$$

Observing the latter equation, it is immediately apparent that it is perfectly superimposable to Eqs. (10), (11) and (12): what changes is only the subject, the protagonist, or the particle

considered. Well, it's as if these 4 subjects were superimposable, interchangeable, that is, identifiable with each other, as a single particle, all of them with very low ability to interact.
In short, the fact *DMP* does not interact may come from the application of Majorana equations, that is, it could be this peculiar *charge conjugation* to make the *DMP* elusive. We wonder, in fact, what intimate physical-chemical mechanism is related to this Mathematics, able to make invulnerable and elusive Majorana Fermion, as well as the e° and the *DMP*. It could be assumed that these *self-conjugated* particles may be wrapped in a shell that separates them and isolates them physically from the surrounding world.
However, it is not possible to go much further: Quantum Mechanics (QM) would not allow us. After all we are at subatomic dimensions, too small for the human eye. Unfortunately, we can only try to infer, to imagine how things go, but without any certainty: QM does not allow us to have any accurate or approximate information about the real state of a *quantum object* (QO), that is, a sub-atomic particle, or its morphological and structural configuration. QM tells us that the wave or particle aspects are not at all outlined: the *square of the modulus* of the $|\psi|^2$ has to be interpreted as the *density of probability* to find the particle, its *quantum state*, in one of the several possible positions. "It is more likely to find the particle where its WF(ψ) is maximum in absolute value; so the probability to find the particle in the space is 1, that is $||\psi|| = 1$(100% of probabilities), where:

$$||\psi|| = \int_E{}^3 |\psi(x)|^2 \, dx^1 \wedge dx^2 \wedge dx^3 \qquad (14),$$

that is the integral of $|\psi|^2$ on all the space gives the total probability to find the particle in a place of the tridimensional physical space, with coordinates x^1, x^2, x^3. Thus, the WF is *normalized.* As we know, with the WF of a single particle the 'rule' is the quantity $||\psi||$, defined as the integral of $|\psi(x)|^2$ on all the space the particle can occupy. The *normalization* request makes us exclude the WFs of the *momentum states*, indicated with:

$$\psi = e^{i\mathbf{P}\bullet\mathbf{x}/\hbar} \qquad (15),$$

since $|\psi|^2=1$ throughout the infinite space, so that the previous integral, being equal to the total volume of the space, diverges"[32]. Besides even we had the right tools to see these particles, what happens is that as soon as we try everything changes. The Eq.(15) describes the *momentum state* of the WF(ψ) of the QO we are examining. The *momentum* is not localised, it is uniformly distributed throughout the occupable space (*i* is the imaginary unit and ħ Planck's constant rationalized = $h/2\pi$). Thus, "since the integral diverges" [32], we have to consider the integral of the *momentum states* as unrealizable idealizations: that is as Penrose

says “it is not possible to carry out a *measurement* (M) of the WF of the *momentum state”*[32]. Thus, it is thought that all Ms are reduced to *position* Ms.

What happens is that as soon as we try to observe a QO, as to say as soon as we try to make a M, everything changes: it is the so-called *Measurement's Paradox* (MP) [27].

Let’s examine as in the mathematical formalism of QM a M of a quantum system must be represented: a ‘measurable quantity’ of a quantum system is represented by a certain kind of operator ***Q***, called *observable.* Examples of *observables* are the ‘dynamic variables’: i.e. the *momentum (p)* and the *position (x)* of the particle we wish to examine. The theory requires that an *observable* ***Q*** is represented by a *linear operator* ***L***, so that its action in Hilbert space (**HS**) is to make a linear transformation of **HS**. According to the rules of QM the result of a M, related to an *operator* ***(Q)***, is always one of the two *self states*: this is the *jump* of the *quantum state*, indicated as *Wave Function Collapse* (WFC)[31]. Miller reminds us: “Whatever the state before the M, it *jumps* in one of the ***Q*** self states, as soon as the state (that is the particles in exam) is measured. After the M the state gets a definite value for the *observable* ***Q***, precisely the *self value q*”[45]. When the *observable* ***Q*** is measured on the state $|\psi>$ (where ψ indicates the WF), the rule is that the *probability* tells us that the state *jumps* from $|\psi>$ to one of the ***Q*** *self states*: $|\phi>$, for example. The *jump* of the WF, or WFC, induced by any kind of M, is represented as follows:

$$|<\psi|\phi>|^2 \qquad (16).$$

This is not true, of course, for the macroscopic world. In this regard Miller adds: “If we want to make a M, as to detect the position of a falling ball, we have to see or photograph, that is we need to *light* it up. In order to do so we have to hit it with light beams, that is with a number of photons: however the photons hits do not modify the trajectory of the ball, nor its velocity. Thus, both the *position* and the speed or *momentum* of the ball can be determined at the same time, with all the precision and accuracy we wish. Let’s see what would happen if the ball was a single electron. According to QM the falling electron can be in any position, since its WF is *diffused* throughout the space (the ball, instead, is localised since the beginning). It doesn’t have any sense to wonder where the electron is, until a M is carried out, i.e. taking a picture of it: in this case we need to light it up, at least with a light quantum, which becomes part of the M system. The interaction of the single light quantum (1 photon) with the electron, localises it in that moment”[45], at the same time we have induced a particular phenomenon of the QM: the WFC. The contact of a single photon with the electron in exam can collapse its *quantum state*, its WF[31]. Well, the interaction between the M system (that is also a single light quantum) and the examined physical system (the electron)

induces the ***R*** process: that is the *reduction* of the electron WF (which was *diffuse*, till a moment before the M), so now it tends to converge to a certain, well defined, region of the space. That is "among all the possible positions which the electron WF can occupy, as a *diffused* wave in all the space, the M process chooses one. Thus, with the M, the *quantum state* of the electron is transformed from being potentially in any position to being in a well defined position"[45]. The Uncertainty Principle tells us that the cost of this localization is an enormous *uncertainty* about the *momentum* of the electron"[45],[46],[47].

We wonder: what kind of mechanism can be concealed behind the observation, behind the M, behind this kind of interactions? No one knows. Miller states "both Schrodinger equation and the other QM fundamental equations remain mute!" [45].

However, what seems important is that "the WF does not evolve along with Schrodinger equation, after the M" [48]. Whereas, when we carry out the M, the QO, its WF, concentrates in a well specific point in space appearing as a corpuscle. What happened is that with the M, it took place a *Reduction* of the *state vectors* (***R*** process), that is the WFC of the electron. In this regard we agree with Penrose following the "***R*** objective Theory" which considers ***U*** and ***R*** real physical processes. "It is clear that the WF is something more *real* than a simple *probability wave*"[48]. Physicist wondered what was the role of the observer in the M process of a physical system. Bohr suggested that it does not exist a reality independent by the M apparatus: it is not possible to trace a clear separation between the behaviour of the observed particle and the instrument of M. A physical theory can describe physical phenomenon only if it includes an experimental content, the observation, the M, which make these phenomena show (though there are modified).

QM does not provide us with any useful information on any QO, inherent in its *phase of linear evolution* ***U***, that is, referable to the whole time it lives and travels undisturbed, *delocalized*, and propagating as a superimposition of quantum states. The ***U*** *Phase* persists until one tries to interact with the QO, i.e. with the particle, i.e. when one tries to measure it. In this case, as reported earlier, the measured QO immediately meets a *quantum jump*, as reported by Eq. (16), resulting in the *collapse* of the wave function (ψ) of the examined QO (WFC), whereby the particle undergoes *Reduction of the state vectors* (***R*** *process*).

This is the main point: only during the ***R*** *Process*, extremely short, we can *pick up* the particle. Only during the ***R*** *Process* the QO, its WF, concentrates in a well specific point in space appearing as a corpuscle: now it is *localized*, just as a corpuscle. In short, it is particularly important to note that whenever a subatomic particle interacts with the surrounding matter, its WF faces a *quantum jump*, passing immediately from the ***U*** *Phase* to

the ***R*** *Process*: this creates a drastic change of the QO behaviour (from undulating-like to corpuscular-like). Obviously this should also apply to the considered 4 particles, i.e. ν, *Majorana Particle*, e° and *DMP*. We wrote 'should apply' instead of 'applies' because it is logically inferred that since they do not interact with matter, none of the 4 particles will ever undergo a ***R*** *Process*, and therefore not even the WFC. They will remain in their ***U*** *Phase*, continuing to wander through the cosmos, uncontested and undisturbed, since the night of the times, invisible and inaccessible, as ghost particles.

The novelty, in our opinion, is just this: we may have found the physical explanation for which we cannot see the considered particles. Since they do not interact with anything, they will never undergo a ***R*** *Process*, so we will never be able to see them as a corpuscle, but they will continue to wander as waves, *delocalized*, unidentifiable for long time.

We could say that in this way we have completed the solution of the 5th requirement: the physical-mathematical explanation why these particles do not interact. In fact, Majorana's equations provide the mathematical substrate to provide a plausible explanation of their non-interactivity with any kind of matter, probably through *charge conjugation* and the peculiar symmetry between the particle and its antiparticle, as if it kept them firmly and mutually bound. In turn, the technical explanation from a physical point of view consists in the failure to implement the ***R*** *Process*, so the considered particles will never be visible nor traceable.

At this point we can make a meditation. As mentioned above, comparing Eqs. (10), (11), (12) and (13), they are identical to each other, with the exception of the subject, that is, the particle being considered. But if such equations are completely superimposable, it may also apply to subjects, so they might be considered as the same particle: that is, as a single particle valid for all 4 equations. What is the particle then? First of all we must keep in mind that none of them has ever been directly identified or detected: which also applies to *ν*.

A basic point might be that every time it was considered that *ν* had been detected, they were always *indirect detection* thanks to traces left by a *ghost particle* never detected *de visu*. It is the detection of the impacts' effects, such as the Cherenkov Effect (*CE*), to prove the existence of *ν*, although it might be another particle to induce the *CE*[43][49]. In Nature the *CE* is only elicited by electrons. The electrons of the atmospheric molecules, hit by cosmic rays at high altitude, are accelerated at very high speed, so emitting those photons that give consistency to the so-called *Cherenkov Light*[44]. One thing we can be certain about the results of all *indirect detection* of the *ν*: they only show the *traces* left by a *ghost particle*, that is, the 3rd particle released with the βd_s , a particle never directly identified. In favor of our hypothesis, that in βd what is released is a e° instead of a *ν* (more precisely an ē° in βd^- and

an e° in the βd^+), is the fact that the main detection techniques of ν all use the *CE*: a phenomenon *naturally* induced by electrons[21]. So it's no wonder if it is still an electron, this time without electric charge, to induce the various *CEs* highlighted during the *surveys* carried out by Reines and Cowan [50], or at the Superkamiokande, or the Subdury Neutrino Observatory (SNO), or elsewhere. Then, comparing Eqs. (11) and (12) with its particles, it seems more likely to consider the e° instead of ν.

Proceeding by exclusion, and comparing Eqs. (10) and (12), it emerges that *Majorana Particle* may also be interchangeable with e°. In this case too, we prefer to take as reference point the closest to a family of known particles, i.e. e° [51]. In this way we do not need to try to figure out in which particle class to include Majorana Spinor or even invent a new particle family (whenever possible).

The combinations, identifications between e°, ν and *Majorana Particle*, are not surprising since from Maiani's Fermi Lectures we learn: "In Pati and Salam Grand Unified Theory (GUT), based on the group O(10), there is a heavy ν, which may be a *Majorana Particle*, violating the Lepton Number Conservation. The inevitable consequence is that the βd neutrinos should be *Majorana Particles* too" [52] [53] [54].

It really is a very strong confirmation of our hypothesis.

It is known that the βd was formulated by Fermi [24] :

$$N \rightarrow P + e^- + \bar{\upsilon} \qquad (17),$$

where *N* is the neutron, *P* is the proton, e^- is the electron with a negative electrical charge and $\bar{\upsilon}$ is the antineutrino. Therefore, if we put in this equation a *Majorana Particle* (the antiparticle namely) as reported by Maiani instead of the $\bar{\upsilon}$, the Law of Lepton Number would be violated. On the contrary, as we reported, comparing Eqs.(10) and (11), it emerges that *Majorana Particle* may be interchangeable with e°. Therefore, if we replace the *Majorana anti-Particle* with ē° [51], it is safeguarded the Law of Conservation of the Lepton Number too.

In this regard, from our βd model, we have [21] :

$$N \rightarrow P + e^- + \bar{e}° \qquad (18).$$

In this new model of βd^- are safeguarded all Conservation Laws. Moreover, let us not forget that Salam and Glashow are among the creators of the Standard Model (SM) : therefore, it should not cause excessive scandal that the mass of the ν corresponds to the electron's mass. In our opinion, indeed, the "heavy ν, which may be a *Majorana Particle*"[52][53] is a neutral lepton, namely a e°: which is *self-conjugated* too (just as the *Majorana Particle*).

Finally, there is the main particle of our work: the *X Particle* or *DMP*. Comparing Eqs. (12) and (13), it also appears that the *DMP* is interchangeable with e°. Even then, trying to consider the *DMP* as a separate particle, distinct from e°, it would be really difficult to find a new particle family in which to allocate it. Therefore, it will be simpler, even in the case of the *DMP*, to take the e° as its point of reference since, as comes from Eqs. (12) and (13), one may identify with the other, as if they were equivalent.

Conclusions

Probably there remains an unresolved problem. Since the particles we have taken into consideration do not interact with matter, nor with Nuclear Interactions (Weak and Strong Interaction), nor with Electromagnetic Interaction, how do they gain mass? According to SM all particles have a null intrinsic mass. The problem can be solved by postulating the existence of a *complex scalar field* permeating the space: the Higgs Field(HF). According to SM only left-handed particles tend to interact, to mate with this HF, acquiring an energy at rest which is not null, which for almost all respects is analogous to a value of mass at rest, then describable as a parameter mass. As it is well known the mechanism just described is the so-called Higgs Mechanism(HM) [55] [56] [57]. Our calculations show a very small range of HB action, exactly $9.8828 \cdot 10^{-16}$ [cm] [58]. The HM is valid for left-handed particles, in contrast *anti-DMP* and ē° are right-handed, so they are insensitive even to WI's action. For the same reasons, since they are not sensitive to the *weak charge*, *anti-DMP* and ē° cannot acquire mass through HM. Yet it is the real enigma: how does *anti-DMP* (or for it the ē°) acquire mass, and in what quantity? At this point, it seems necessary a new Physics, still to be understood, capable of describing in what ways, and through which mechanisms, an anti-lepton without electric charge, and insensitive to the weak charge (being right-handed) can equally acquire mass, without using HM, at least as it is currently described. Unless we think there may be another type of HM, in this case interacting with neutral right-handed antileptons, so that even these can gain mass, and *without breaking the symmetry*. Under such circumstances the ῡ temporary acquisition of mass, would *overshadow symmetry*. In this case, it would be necessary to understand whether those leptons can get mass through one Higgs Boson, or there are two distinct Higgs Bosons, one of which would interact selectively with right-handed leptons. Randall states: "We have no certainty about the precise set of particles involved in the HM. For example if the *breaking of the electroweak symmetry* was to be attributed to 2 Higgs fields, rather than to one. However, there are other models that

hypothesize more complex *Higgs sectors*, with even more articulated consequences. For example: Supersymmetric models provide higher number of particles in the Higgs sector. In that case we would always expect to find a Higgs Boson, but its interactions should be different from those deducible by a model that includes only one Higgs particle "[59]. However, we think that the same problem also involves the respective particles, namely the *DMP* and e°, since, while being potentially sensitive to WI (being left-handed), do not actually react with WI. Thus they cannot acquire the mass through the modes described by SM. This shows the possibility that they and *v* can be considered similar to a *Majorana self-conjugated spinor*.

It would mean that the mass of these particles is generated by a new Physics mechanism, such as, for example, the *see-saw mechanism*, where a right-handed particle, with significant Majorana masses, is inserted. Thus, if right-handed particle is very heavy, it produces identical left-handed particle with very small mass, inversely proportional to the heavy mass. The two particles are therefore in a sort of swing (*see-saw*) between *masses* and *forces*, which always brings the smallest mass up [60]. Thus, if the *see-saw mechanism* was to be real, it could largely justify the mass we attributed to the supposed $\bar{\upsilon}_e$, that is, that of a e°, or another *self-conjugated particle*. Yet, one might object: why the *e°* has never been detected, even accidentally? Electron decay products emerge continuously in the *colliders*! But it is clear: the crucial difference lies in the fact that we are talking about electrons without electricity charge, they do not interact with matter for all the same reasons ν_s do not interfere . In addition, the 3rd particle emitted with βd^- is right-handed. This *see-saw mechanism* seems to us quite similar to the *zig-zag mechanism* of Penrose [32].

We have reported the *see-saw* mechanism, since it is one of the most followed to justify the mass of these particles, when it is required a different way from the HM. Actually it seems to us easier and more likely that the considered particles gained mass immediately before the primordial *nucleosynthesis*, preserving it intact since then.

It also seems interesting to note that from Majorana equations, see Eq. (9), emerges that the considered particle (namely Maiorana's Spinor, but very probably it also applies to other *self-conjugated* particles) is also symmetric with time, i.e. it can travel both directions of the time flow: forward as particle, or backward as antiparticle (in this it is completely superimposable to Feynman Spinor). This further feature gives these unbreakable particles, including in our view the e° and the *DMP*, a sense of immortality, of eternity.

Besides, if the DM diffused in the universe corresponded, as *DMP*, to the e°, it would be a lightweight particle with a mass of at least 511 eV, this being the value of the *Zero Point*

Mass of an electron [61]. If we consider that this particle represents ≈ ¼ of the total mass of the Universe, then the *critical density value* (Ω) should be: Ω> 1.

This is something very important since it would drastically alter the destiny of the Universe, which would sooner or later slow its expansion till a standstill and then probably start a process of contraction. According to the current forecasts, the Universe will continue to expand forever, thinning more and more, until its disintegration and disappearance of all celestial objects, molecular and atomic aggregates. Leaving behind probably only elementary particles that cannot decay into lighter particles, i.e. up Quarks and electrons. Whereas, with the *DMP* represented by the e°, we have a completely different situation. In fact, the e° with its mass (multiplied by a very large number of particles: 10^9 for each nucleon widespread in the Universe) would alter the value of the *critical density* of the Universe. In this way our universe could match the 1st model of Friedmann universes [62][32]. As Hawking reminds us "a remarkable feature of the 1st Friedmann Universe Model is that within it the universe is not infinite in space, yet space has no boundaries. The gravity is so strong that the space folds over itself"[63].

Anyway, this DM enigma is really intriguing. In this regard Rubbia says: "We are close to a new Copernican Revolution, because the discovery of DM has a tremendous meaning: it leads us to a 'Physics Reinterpretation'. Finding out what the DM is made of will also require a rethinking of Physics, as we know it and perhaps will allow us to trace cosmological symmetries, so far only hypothesized.

From a cosmological point of view we know that the hadronic matter is only a small fraction of the total, since the DM is measured by gravitational methods and we can be sure of its existence. However this does not clearly explain what this matter is, a matter which is not produced by nucleosynthesis. Is it an elementary particle? A WIMP or a *supersymmetric particle*? Or something else? The main question is if this matter is detectable only gravitationally or it has electroweak couplings with the matter we know. Only in this case we might be able to study it experimentally, causing collisions between the DM and ordinary matter. Conversely all our experiments would give negative results. It will be necessary to build many other detectors, because the inability to register collisions may also depend on the size of the experiment. One thing is certain: the hunt is open"[64]. We can infer that the e° is not in contrast with what Rubbia assumed.

There is one more important consideration to be made. From Majorana's mathematical formalism we have that each *self-conjugated* particle is made of a particle and its corresponding antiparticle: that is, half is matter (although it is not ordinary matter but DM)

and the other half is antimatter! Therefore, considering that these particles represent ≈ ¼ of the whole matter diffused in the cosmos, automatically, *with one stroke*, we found 1/8 of the antimatter distributed in the cosmos, and so far completely concealed! It seems to be a really significant result. But there is one more thing to consider: matter particles and antimatter coexist peacefully together. Certainly, this peaceful coexistence may well be valid for particles without electric charges.

Many A.A. are perplexed in accepting a clear distinction between matter and antimatter. Yang states: "There is of course the question of why it is necessary, in order to have symmetry, *combine* the operation of exchanging matter and antimatter with a mirrored reflection. The answer to this question can be achieved only through a deeper understanding of the relationship between matter and antimatter. Currently such an understanding is not glimpsed "[65]. We could say, comforted by mathematicians results achieved by Majorana, that the matter coincides with the antimatter, with the difference that in the neutral particles the rotation of the spin changes, and the charged particles changes too, or at least the electric charge. That is, the matter could not be so much different from antimatter, although it makes a lot of their clash effect, with instant annihilation of the particles. But this annihilation process could simply be a result of the clash between two opposite charges. On the other hand the concept of antimatter is a consequence of the interpretations of Dirac's equation on the electron which was proposed by Dirac himself in 1931. What had emerged consisted in the representation of an electron with a positive electric charge, that is opposite to that of the common electron: for this reason was considered as antimatter, although it was just the same particle, but with opposite electric charge. Weinberg writes: "Dirac's theory claimed as his greatest triumph the prediction of the existence of the positron, the electron's antiparticle, which was discovered a few years later in cosmic rays. From the point of view of Quantum Field Theory there is, however, no reason why a spin ½ particle should have a distinct antiparticle. In some theories half-integer spin particles are antiparticle of themselves, even though so far none of them has been found "[66]. Among these theories cited by Weinberg there could be *Majorana's fermion or spinor*, particularly applicable to neutral particles, where the particle identifies with its respective antiparticle. In this regard, Wilczek says: "In his short career, Ettore Majorana made several profound contributions. One of them, his concept of 'Majorana fermions' - particles that are their own antiparticle -is finding ever wider relevance in modern physics"[67]. Weinberg adds: "At that time it was still unclear that Dirac's equation had nothing to do with the need for antiparticles. When an equation is so successful as Dirac's, it can never be just wrong. It may not be valid for the reason supposed

by its author, may fail in new contexts, and may also not have the meaning that the author attributed to it. We must always be open to reinterpretations of these equations, but the great equations of modern physics are a permanent part of scientific knowledge"[66]. Penrose adds: "One should not really think that an antiparticle is something totally distinct from a particle. In the context of modern Quantum Field Theory, you do not need to present things in Dirac's original way (apparently asymmetric). Antiparticles are as particles as the particles of which are the *antiparticles*"[32]. Moreover, Majorana composed his last work (as he set forth in the Abstract) in order to propose a different mathematical interpretation of Dirac's equation and the resulting concept of *antimatter*, at least with regard to the neutral particles[38]. Klein adds: "Majorana in his last work, the most profound and even the most prophetic, proposes an unprecedented way of conceiving the bond between matter and antimatter. For Dirac the particles were subject to be some states, called of negative energy. These states are in infinite numbers and form *Dirac's sea*. However, such particles are not directly observable. For Majorana things are different. He processes a theory of neutral particles in which no more negative states are used. In his model neutral particles, free of charge (neutron and ν), are necessarily identical to their same antiparticles. More specifically, neutral particles must have their mirrored image as antiparticles. These particles are called 'Majorana', although today no one has yet determined their existence. In the context of the 1930s, a theory such as that proposed by Majorana was out of the way, and it was hard to imagine, also because of an absolutely original mathematical formalism that rests on unusual abstract symmetries for physicists of the time. The few who were aware of it remained troubled. Dirac's theory, better known and certainly more affordable, became in a short time the reference theory: to every particle of matter, even without electricity charge, corresponds an anti-particle which is not identical"[68].

In short, since the Eq.(13) coincides with Eq.(12), we have that the *DMP* may correspond to a e°. Besides, bearing in mind these equations show a *neutral self-conjugated particle*, that is particle and antiparticle are identical, with the only difference that the first is always left-handed (↓), while the second is always right-handed (↑), we can simplify it further in the following way:

$$e^{\circ}\downarrow \equiv \bar{e}^{\circ}\uparrow \qquad (19).$$

As it can be seen, Eq.(19) shows a perfect symmetry: both when it refers to the represented particle, and when it refers to the underlying *DMP*, we think it can be identifiable with a *self-conjugated* e°.

DMP would be represented as follows:

$$DMP°\downarrow \equiv anti\text{-}DMP°\uparrow \qquad (20).$$

Just this symmetry may represent the basic point expressed by the Majorana's mathematical formalism to explain one of the main features of these particles: they do not interact. Besides, since these ghost particles do not have the ***R*** *Process* and do not undergo the *collapse of their own wave function* (WFC), they will never, or almost never, be traceable, and continue to wander over the cosmos.

References

1) Zwicky F., "On The Red Shift Of Spectral Lines Through Interstellar Space", Proc.Natl.Acad.Sci.U.S.A.,1929,Vol.15,10,773-779.

2) Zwicky F., "How far do cosmic rays travel?", Phys.Rev.,1933,43,147-148.

3) Hack M., "Dove nascono le stelle", Sperling & Kupfer ed.,Milano,2004,131-133.

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), 2003,170-179.

5) Rubin V.C. and Ford K.W. "Rotation Of The Andromeda Nebula From A Spectroscopic Survay Of Emission Regions", Astrophys.J.,1970,159,379-403.

6) Capaccioli M.,"I Cacciatori della Materia Oscura", Il Mattino (Napoli),2017,N.°174,14.

7) Casas A., "La Materia Oscura. L'elemento più misterioso dell'universo" ,RBA ed., Milano, 2015,34,53,89,65-70,96,57-58.

8) Zwicky F., "On Collapsed Neutron Stars", Astrophys.J.,1938,11,522-525.

9) Bignami L., Focus, Mondadori ed.(Milano), 2007, N.°178,152-160.

10) Puccini A., "The Missing Mass in the Universe May Be Represented by the Dynamic-mass of the Photons", Session 3P1: Optics and Photonics, Progress in Electromagnetics Research Symposium Proceedings ,Cambridge (Ma), USA, July 5-8, 2010, 816-818.

11) Bhattacharjee Y., "The Universe", National Geographic., Italian edition, 2014,4,42-67.

12) Guth A., "Inflationary universe: A possible solution to the horizon and flatness problems", Physical Review D,Vol.23,N°2,1981,347-356.

13) Puccini A., "The Inflationist Expansion of the Universe Was Conducted by Very High Energy Photons", Session 3P1: Optics and Photonics, Progress in Electromagnetics Research Symposium Proceedings ,Cambridge (Ma), USA, July 5-8, 2010, 819-822.

14) Capaccioli M., "La Materia Oscura", Il Mattino (Napoli),2016,12,29,17.

15) Ferris T., "Dark Matter and Energy", National Geographic, Italian edition,2015,1,74-89.

16) Magrini M., Nova,Il Sole 24ore,(Milano),2012,N.°194,44.

17) Bignami G.,Interviewed by Ranzini G.,Focus, Mondadori ed.(Milano),2012,239,9,70.

18) Pauli W.,Letter to partecipants of the Conference in Tubingien(1930),Septiem Conseil de Physique Solvay, 6th December 1930.

19) Vissani F., "La Domanda di Majorana", Ithaca: Viaggio nella Scienza,2015,VI,47-57.

20)Mirizzi A., "Neutrini e Supernovae", Ithaca: Viaggio nella Scienza,2015,VI,69-74.

21) Puccini A., "Neutral Electron Instead of Neutrino: A New Beta-Decay Model", viXra.org, Nuclear and Atomic Physics : 1706.0202

22) Fermi E., "Tentativo di una teoria dell'emissione dei raggi β",La Ricerca Scientifica , 4, 1933,491-495.

23) Fermi E., “Tentativo di una teoria dei raggi β”, Il Nuovo Cimento,1934,11,1-19.
24) Fermi E., “Le ultime particelle costitutive della materia”, 22° Meeting Società Italiana per la Propensione delle Scienze(SIPS), Bari 13/10/1933; ProceedingsSIPS,Roma 1934,.2,7-14.
25) Fermi E., “Atomi Nuclei Particelle”, Boringhieri Ed.(Torino) 2009,23.
26) de Broglie L., « Ondes et quanta », Comptes rendus, 1923,Vol.177,507-510.
27) 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, Progress In Electromagnetics Research Symposium Proceedings, Suzhou, China, Sept. 12-16, 2011, 1169-1171.
28) Zeilinger A.,“Einsteins Schleier. Die neve Welt der Quantenohysik“, 2003,Verlag C.H. Bech H.G., Munchen, Einaudi ed.(To), 2005,18.
29) Schrödinger E.,“Quantisierung als Eigenwertproblem”,Annal.der Physik,1926,79,361-376.
30) Schrödinger E., "An Undulatory Theory of the Mechanics of Atoms and Molecules", Phys. Rev.,1926,Vol.28, N.°6, 1049–1070.
31) Puccini A., “A Mechanical Effect Induced by Electromagnetic Radiation May Explain the Wave Function Collapse of a Quantum Object”, Session 2P2: Electromagnetic Theory and Design on the Optical Dispersive Materials, Invisible Cloak and Photonic Crystals, Progress in Electromagnetics Research Symposium Proceedings , Marrakesh, Morocco, Mar. 20-23, 2011, 726-728.
32) Penrose R., “The Road to Reality”, ©2004 Roger Penrose; RCS Libri ed.(Milano) , 2005, 205, 789, 782,786,634-638,717-722.
33) Puccini A.,“Anderson Transition May Be Induced by the Self Collapse of the Electron Wave Function”, Progress in Electromagnetics Research Symposium Proceedings, Moskow, Russia, August 19-23, 2012, 348-352.
34) Dirac P.A.M., “The Quantum Theory of the Electron”,Proc. R. Soc. Lond. A: 1928, 117, 610-624.
35) Wilczek F. in “It Must Be Beatiful. Great Equations of Modern Science“, Granta Publications, London, ©Graham Farmelo,2002;Il Saggiatore Ed.(Milano),2005,194,367-368.
36) Dirac P.A.M., “The Quantum Theory of the Electron. Part II”, Proc. R. Soc. Lond. A, 1928, 118,351-361.
37) Klein E.,“Il etait sept fois la revolution”,2005 ed.Flammarion; Cortina ed.(Milano),2006, 119-120.
38) Majorana E. ,”Teoria Simmetrica dell’’Elettrone e del Positrone”, Il Nuovo Cimento,1937, Vol.14, 171-184.
39) Amaldi E., “Ettore Majorana, a 50 anni dalla sua scomparsa“, Il Nuovo Saggiatore, 1988, 4, 13-26.
40) Recami E., “Ettore Majorana: l’opera scientifica edita e inedita”, Proceedings del XIX Congresso Nazionale di Storia della Fisica e dell’Astronomia,Italy,1999,Il Nuovo Saggiatore, 1999, Vol.15,14-28.
41) Barbieri R, “Majorana e la moderna fisica delle particelle”,Physical Meeting, Naples (Italy), 14/6/2012.
42) Lee T.D. and Yang C.N., ”Question of Parity Conservation in Weak Interactions”, Phys.Rev.,1956,104,254-258.
43) Cherenkov P.A., “Visible emission of clean liquids by action of ϒ radiation”, Doklady Akademii Nauk SSSR, 2,451,1934.
44) Puccini A., “Why Gamma Photons Induce Cherenkov Effect”, Progress in Electromagnetics Research Symposium Proceedings, Moskow, Russia, August 19-23, 2012, 343-347.

45) Miller A.I., Erotismo,estetica e l'equazione d'onda di Schrodinger,in "It Must be Beautiful. Great Equations of Moderne Science"; Granta Publ.,London,2002;il Saggiatore ed.,Milano,2005,186-187.
46) Heisemberg W.,"Uber den anscauliken Inhalt der Quantentheoritschen Kinematik und Mechanik", Zeitschrift fur Physik, 1927, Vol.43,172-198.
47) Puccini A., "Uncertainty Principle and Electromagnetic Waves", Journal of Electromagnetic Waves and Applications,2005,19,7,885-890.
48) Penrose R., La riscoperta della gravità. L'eaquazione di Einstein della relatività generale, in "It Must be Beautiful. Great Equations of Moderne Science"; Granta Publ., London,2002; il Saggiatore ed.,Milano,2005,293.
49) Puccini A., "Quantum Mechanics Suggests that Photons with Different Energy Do Not Travel at the Same Speed", Session 2P2: Electromagnetic Theory and Design on the Optical Dispersive Materials, Invisible Cloak and Photonic Crystals, Progress in Electromagnetics Research Symposium Proceedings, Marrakesh, Morocco, Mar. 20-23, 2011, 729-733.
50) Reines F. and Cowan C.L., "The Neutrino", Nature, vol.178, 446-449, September 1,1956.
51) Puccini A., "Majorana Particle is a Neutral Self-Conjugated Electron", viXra.org, Nuclear and Atomic Physics: 1707.0064.
52) Maiani L., "Fermi Lectures 24. Scenari per la Bariogenesi. Leptogenesi", INFN, Roma, 20 marzo 2014.
53) Pati J., Salam A., "Lepton number as the fourth 'color'", Phys.Rev.D,10,1974,275-289.
54) Georgi H., Glashow S., "Unity of All Elementary-Partcle Forces", Phys.Rev.Lett.,1974, 32, 8, 438.
55) Englert F. and Brout R., "Broken Symmetry and the Mass of Gauge Vector Mesons", Phys.Rev. Lett.,13,321-323,1964.
56) Higgs P.W., "Broken Symmetries and the Masses of Gauge Bosons", Phys.Rev.Lett.13,508-509 , 1964.
57) Guralnik G.S., Hagen C.R. and Kibble T.W.B., "Global Conservation Laws and Massless Particles", Phys.Rev.Lett.,13,585-587,1964.
58) Puccini A., "On the Higgs Boson's Range", viXra.org, Quantum Physics:1705.0250
59) Randall L., "Knocking on Heaven's Door",© Lisa Randall 2011-2012; il Saggiatore ed. (Milano) 2012, 292, 307.
60) http:/www.torinoscienza.it/dossier/majorana e_il_mistero_della_materia_nell_universo 26256.html
61) Puccini A., "About the Zero Point Energy, Zero Point Mass, Zero Point Temperature and Zero Point Motion in the Subatomic World and Photonics", Progress In Electromagnetics Research Symposium Proceedings, Suzhou, China, Sept. 12-16, 2011, 1169-1171.
62) Friedmann A., "Uber die Krummung des Raumes", Zeitschrift fur Physik, 1922,Vol.10,377-386.
63) Hawking S., "A Briefer History of Time",©2005 by Stephen Hawking; RCS Libri ed.(Milano), 2005, 77-78.
64)) Rubbia C., interviewed by Nova-Sole 24 ore (Milano), 2013, 24, 4.
65) Yang C.N., "Elementary Particles", Princeton University Press, New Jersey,1961; Boringhieri ed.(Torino),1969,77-78.
66) Weinberg S. in "It Must Be Beatiful. Great Equations of Modern Science",Granta Publications, London, ©Graham Farmelo,2002;Il Saggiatore Ed.(Milano),2005,347-351.
67) Wilczek F.,"Majorana returns", Nature Physics, 2009,5,614-618.
68) Klein E.,"Il etait sept fois la revolution",2005 ed.Flammarion; Cortina ed.(Milano),2006,119-120.