NEUTRONIZATION EQUATIONS

Antonio PUCCINI

Neurophysiologist of Health Ministry, Naples - Italy

ABSTRACT

With the *neutronization* protons(*P*s) and electrons($e^-{}_s$) fuse together to form neutrons(*N*s) and release *electronic neutrinos*(ν_e):

$$e^- + P \rightarrow N + \nu_e \qquad (1).$$

This is possible because the electron in the *neutronization equation* is equipped with a very high energy, just provided by a collapsing star, or by a neutron star. In those extreme conditions electrons become *relativistic*, since they acquire a ≈200MeV energy, so as to fill the conspicuous energy gap between *N* and *P*.

However, Eq.(1) appears incomplete because it does not explain the *ex abrupto* appearance of the ν_e. One may wonder: how was it produced?

As it is known matter and antimatter particles are always produced as a couple. Where is the antiparticle of ν_e, i.e. the $\bar{\upsilon}_e$, not represented in Eq.(1)?

In our opinion, Eq.(1) implies some intermediate steps not represented.

A phenomenon associated with *neutronization* is *photoannihilation*, characterized by the *materialization* of the electromagnetic radiation(γ), with consequent production of pairs, such as:

$$\gamma \rightarrow \bar{\upsilon}_e + \nu_e \qquad (2).$$

If we enter Eq.(2) in Eq.(1), we have:

$$e^- + P \rightarrow e^- + P + \gamma \rightarrow e^- + P + \bar{\upsilon}_e + \nu_e \rightarrow N + \nu_e \qquad (3),$$

that is:

$$e^- + P + \bar{\upsilon}_e + \nu_e \leftrightarrow N + \nu_e \qquad (4),$$

i.e.:

$$e^- + P + \bar{\upsilon}_e \leftrightarrow N \qquad (5).$$

From Eq.(5) it emerges that to *N* corresponds a *compound* of 3 particles, i.e. a *multiplet*:[e^-, *P*, $\bar{\upsilon}_e$]. This is in agreement with *Spin Statistics*, as well as with Quantum Mechanics, since the *relativistic electron* has an energy>140MeV. Furthermore, let's try to read Eq.(5) in reverse:

$$N \rightarrow e^- + P + \bar{\upsilon}_e \qquad (6).$$

It is surprising: Eq.(6) shows exactly the decay products of *N*, corresponding precisely to the famous Fermi equation describing the *N decay*, providing a counter-test to Eq.(5)

1. INTRODUCTION

As it is known, with the term "*neutronization*" we mean the process, such as within a collapsing star, in which protons(*P*s) and electrons(e^-_s) fuse to form neutrons(*N*s) and release *electronic neutrinos*(ν_e):

$$e^- + P \rightarrow N + \nu_e \quad (1).$$

Observing Eq.(1), we immediately notice that, in order to compensate for the *gap mass* (Δ_m) between *N* and *P*, the e^- must be provided with a very high energy: just provided by a collapsing star. Thus, as can be seen, the *neutronization* is a peculiar phenomenon, as well as being of *vital* importance. In fact, after the *primordial nucleosynthesis*, all elements of the Periodic Table were formed through the *stellar neutronization*: from the 4^{th} to the 92^{nd}.

But a *relativistic* e^- is not enough to trigger the neutronization. No! Extreme environmental conditions are required, such as density (ρ) and very high temperatures (T). An intense ρ of the environmental context makes the particles very close to each other, trapped, and therefore easier to join each other, while a very high T is essential for the *baryogenesis*, i.e. for the *nucleonic synthesis*.

In fact, Weinberg writes [1] that the *threshold temperature* necessary for the *materialization* of a particle, i.e. for the transformation of energy into matter, must unequivocally be ≧ to the value obtained by dividing the *inertial energy*, or *zero point energy*[ZPE][2] of the considered particle, for the Boltzmann constant (*k*), equal to 0.00008617eV, for each Kelvin degree (°K).

It is thus obtained that while for the e^- (with ZPE = 0.511MeV) the *threshold temperature* corresponds to 5.93 billion °K, for the *nucleonic synthesis* (*baryogenesis*) really amazing temperatures are needed, which are obtained under very limited circumstances, sometimes only for short periods of time, equal to fractions of one millionth of a second, as soon after the Big Bang (*BB*). In fact, to obtain the formation of *P* (ZPE = 938.26 MeV) the *threshold temperatu*re corresponds to 10888 billion °K. Similarly, the creation of *N* (ZPE = 939.55 MeV) requires a *threshold temperature* of 10903 billion °K[1]. These are very high temperatures that, we could say, in nature are reached only in those situations of *singularities* [3] [4] [5], such as *BB* or *black holes* (BHs) [6] [7], or *neutron stars*: the latter are direct consequences of the collapse of a Supernova.

2. DISCUSSION

2.1 PRIMORDIAL NUCLEOSYNTHESIS

As it is known, with the *primordial nucleosyntesis*, which started only 3 minutes and 46 seconds after the *BB* [1], the lightest chemical elements were formed, namely only the first 3: hydrogen (H_1^1), helium (He_2^4) and lithium (Li_3^7), in addition to some isotopes related to these elements, among which deuteron (H_1^2) and helium-3 (He_2^3) [8]. This is because, since the "Hadron era" is over, now T is too low (~10^9 °K) for the *N synthesis*, so that those *Ns* left free tend to spontaneously decay in *Ps*. So the progressive lack of *Ns* does not allow us to move forward in the synthesis of heavier elements. In fact, observing the Mendeleev Table it is noted that there are no stable nuclei with *atomic mass*(A) = 8, so the *primordial nucleosynthesis* stops at Li_3^7, ending approximately within a couple of minutes.

2.2 STELLAR NUCLEOSYNTHESIS

Since then, it will have to go through several hundred million years, until the conditions of gravity, pressure, ρ and T are sufficient to see again a natural *N synthesis*, that is, a new *baryogenesis*. This occurs in the star *core*.

As Pacini reminds us "The fundamental process in the evolution of a star is the gravitational contraction of an abundant quantity of gas and dust. Under the influence of gravitational attraction, the mass of gas contracts progressively. Since the contraction releases gravitational energy, the gas that makes up the star is heating up, even for millions of years, until the central temperature has risen to several million degrees"[9]. Therefore, the high values of pressure and T reached at the level of the stellar *core* allow the triggering of thermonuclear reactions, with the ignition of the H:

$$4\, H_1^1 \rightarrow He_2^4 + 2e^+ + 2\nu_e + \gamma \qquad (2),$$

where γ indicates gamma photons, highly energetic. When all H of central regions has converted to He, the pace of nuclear reactions slows down due to lack of fuel. Then the star gases cool off, the pressure decreases and, as a consequence, gravity resumes the upper hand, so the star's core contracts.

2.3 CHANDRASEKHAR MASS LIMIT

"In 1930 Chandrasekhar realized that the Pauli Exclusion Principle (PEP) of e^-_s gas could provide enough pressure (even in the absence of sources of radiation and at T = 0) to counteract the gravitational attraction and to support the star. Why the e^-_s? Both because they are much lighter than the nucleons, and because they have more extensive quantum effects "[10].

As known, the nuclear fusion is hindered by electrostatic repulsion between the nuclei, which grows progressively and rapidly as the atomic number(Z) increases. Then, when the nuclear fuel is over, the outer layer of the star collapses on the central core. Based on Chandrasekhar calculations, if in that phase the collapsed star has a mass ~ ≤1.44 solar masses (☼) (Chandrasekhar *mass limit*), the gravitational collapse is stopped by the counter-pressure exerted by the *degenerate electrons* which make the stellar core, to which a *white dwarf* will remain, over time [11].

The *limit mass of Chandrasekhar* (M_{Ch}) is determined as follows:

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

where ħ is Planck's constant, *c* is the speed of light in the vacuum, *G* is the constant of universal gravitation, *Z* is the atomic number, A is the atomic mass, m_p is the inertial mass of the *P*, μ indicates the number of nucleons. With Z/A=0.5, we have M_{Ch}=1.44☼ [12].

After which since the helium fuel is finished, there is a central contraction, accompanied by a heating. Thus, by successive degrees, increasingly heavier elements will be formed, up to the iron (Fe_{26}^{56})[9]. It is calculated that to get to the synthesis of iron, stars with mass greater than 8 ☼ are needed [13]. For the synthesis of Fe temperatures $>10^9$ °K are necessary [12]. With Fe the standard *stellar nucleosynthesis* stops.

2.4 EXPLOSIVE NUCLEOSYNTHESIS

In fact, while "elements up to Fe are synthesized in the life of the stars (*stellar nucleosynthesis*), the heaviest elements are synthesized in the *Ns flow* of the supernovae final phase and therefore dispersed in the explosion of the supernovae themselves" [10]: *explosive nucleosynthesis*.

What happens is that, in the stars with mass >M_{Ch}, once the Fe is formed, the *stellar nucleo-synthesis* stops, since the Fe is not meltable. Therefore, once there is no more fuel, hence no more thermonuclear reactions, the gravity takes over: the star begins to contract, with a significant and progressive increase of the T, pressure and density(ρ), and the photons acquire energies of the MeV order. Thus, roughly all the nuclei of the natural elements, heavier than the Fe, are generated in the central regions of the star during the collapse of the core and the subsequent explosion.

It is necessary to bear in mind that when the ρ reaches the value of 10^{12}g/cm^3, e$^-$ have also acquired a huge amount of energy, they become *relativistic*, so that the minimum energy configuration of *P*s and *N*s changes, as energetic e^-_s violently struck against the *Ps* of Fe nuclei. *P*s are able to convert themselves to *Ns* through an *electron capture* process (*inverse β process, or β-decay*$^+$): in this way the *neutronization* process, represented by Eq.(1) is generated.

2.5 ELECTRON DEGENERACY

The keystone that supports *neutronization* lies precisely in the *degeneracy* of these *relativistic* e^-_s .
In fact, the small mass of the e$^-$ (relative to that of the *N* or the *P*) is of fundamental importance. The de Broglie wavelength (λ) is:

$$\lambda = h/\boldsymbol{p} = h/m\text{v} \quad (4),$$

where *h* is the Planck constant, ***p***, *m* and v are respectively the momentum, the mass and the speed of the considered particle. To fit an e$^-$ into the same size box as a *P* (that is, for it to have the same λ) requires that the smaller mass is balanced by a larger velocity, and hence a larger *kinetic energy* (E_{kin}). This energy is not thermal energy but *quantum degeneracy energy.* Ordinary nuclei have the luxury of storing their e^-_s in the much larger volume of the electronic orbits rather than in the crowded nuclear region. For ρ >> 10^6g/cm^3 the e^-_s are *relativistic* and the Fermi energy is: $E_f \approx 11.0$ MeV. Such high energies make *electron capture* favorable, even though it produces nuclei that are instable to *negative β decay* in laboratory. For the nuclei in the iron-peak, the *threshold energy*(Q) for *electron capture* is roughly[15]:

$$Q = 190 \text{ MeV} \quad (5).$$

In confirmation of this *threshold energy* by *relativistic* e$^-$, indispensable to induce the *neutronization*, we read: "In the collapsing star there are high T, corresponding to photons with energies of the order of MeV, so that nuclei dissociate and find e$^-$, *Ps* and *Ns* in a comparable number. In these circumstances, the typical *momenta* of fermions (e$^-$, *P* or *N*), are ≈200 MeV: a value superimposable to that shown in Eq.(5). Therefore what happens is that the *relativistic* e^-_s that collide with the *Ps* have enough energy to give: e$^-$+*P*→*N*+ν (see Eq.1), where the produced ν_s (subject only to the Weak Interaction) cross the star and run away freely, before the reverse reaction occurs [16] or *negative β decay* (*βd*$^-$):

$$N \rightarrow P + e^- + \bar{\upsilon}_e \quad (6),$$

where $\bar{\upsilon}_e$ is an electronic anti-neutrino. Therefore, under high densities the matter becomes a *degenerate gas* when the e^-_s are all stripped from their parent atoms. In the core of a star, once hydrogen burning in nuclear fusion reactions stops, it becomes a collection of positively charged ions, largely helium and carbon nuclei, floating in a sea of e^-_s , which have been stripped from the nuclei. *Degenerate gas* is an almost perfect conductor of heat and does not obey the ordinary gas laws. *White dwarfs* are luminous not because they are generating any energy, but rather because they have trapped a large amount of heat which is gradually radiated away. Normal gas exerts higher pressure when it is heated and expands, but the pressure in a *degenerate gas* does not depend on the temperature(T). When gas becomes super-compressed, particles position right up against each other to produce *degenerate gas* that behaves more like a solid. In *degenerate gases* the E_{kin} of e^-_s are quite high and the rate of collision between e^-_s and other particles is quite low, therefore *degenerate electrons* can travel great distances at velocities that approach the speed of light. Instead of T, the pressure in a *degenerate gas* depends only on the speed of the degenerate particles; however, adding heat does not increase the speed. Pressure is increased only by the mass of the particles, which increases the gravitational force pulling the particles closer together. Therefore, the phenomenon is the opposite of that normally found in matter where if the mass of the matter is increased, the object becomes bigger. On the contrary, in *degenerate gas*, when the mass is increased, the pressure is increased, and the particles become spaced closer together, so the object becomes smaller. *Degenerate gas* can be compressed to very high densities, typical values being in the range of 10^7g/cm^3. Anyway, there is an upper limit to the mass of an *electron-degenerate object*: the M_{Ch}.

2.6 NEUTRON STARS and BLACK HOLES

In fact, taking advantage of the insights developed by both Fermi and Dirac, it is inferred that, in an ordinary gas, the pressure decreases parallel to the decrease of T, since the degree of thermal agitation of the atoms decreases. On the contrary, in the case of *degenerate matter*, this does not occur, because of the very high ρ. In fact, when the particles are extremely close to each other, there are effects of the Quantum Mechanics(QM) that induce a kind of repulsion between the particles. In other words, a form of *counter-pressure* opposes to the gravity, like an anti-gravitational pressure, which in turn is related to two basic principles of QM: the Heisemberg Uncertainty Principle (HUP)[17][18] and the PEP[19]. According to the QM, the simple fact of confining particles in a sphere of radius (*r*) implies that these particles are provided with a *momentum* (***p***):

$$\boldsymbol{p} \geqq \hbar/r \quad (7).$$

At this *momentum* corresponds a *pressure* [16]. In turn, the PEP establishes that 2 identical fermions will never have the same quantum numbers and occupy the same *phase space* cell. Therefore, if each the two fermions with lower energy have a *momentum* (***p***), as described by Eq.(7), the next pair will have: $\boldsymbol{p} \geqq 2\ \hbar/r$, and so on. Thus, the average *momenta*, brought by the particles, are greater than if they were all in the *fundamental state*. This gives rise to a pressure that increases more than linearly with respect to the number of particles [16].

It happens, that is, that even with T=0 there is a pressure, the so-called *Fermi pressure*, whose counter-pressure action is able to support the weight of masses less than about 3 ☼, until the gravitational contraction ceases [9]. In the end, therefore, what remains of the old stellar *core* of the exploded Supernova, is a tiny celestial body, with a diameter of 10-20 Km, on average, of which only one cm^3 weighs about 200 million tons: a *Neutron Star* was born.

Whereas, if the mass exceeds the *Tolman-Oppenheimer-Volkoff limit* [20] [21], equal to ~ 2.5-3 ☼, the gravity of the *neutron star* can no longer be balanced by the *Ns degeneration pressure* (or *Fermi pressure*). The *Tolman-Oppenheimer-Volkoff limit* has a certain approximation, especially regarding the lower limit. The uncertainty in the value reflects the fact that the 'equations of state' for the *extremely condensed matter* are not known, that is to say, the equation of state of the *degenerate neutrons* is not yet well defined. Thus, the gravitational contraction proceeds even more quickly and violently, since the greater gravitational mass creates even more marked pressure and density conditions than in the *neutron stars*.

Therefore, it also goes towards the inexorable collapse, with subsequent explosion. In fact, the external parts of the stellar *core* in collapse *rebound* on the central *core* (incompressible) of *degenerate neutrons*, which form the *neutron star*. With the rebound a shockwave is created that propagates outwards and sweeps away the outer layers of the star, thus triggering the *supernova explosion* [13].This wave is pushed by the *thermal* ν_s, which carry a considerable fraction of the gravitational energy released. Only 1% of the released energy is observable (represented by the E_{Kin} of the shock wave and by the radiation), while the remaining 99% is taken away by the $\nu_{s,}$ just formed by the *neutronization* process.

Both during the final phase of the contraction and in the explosive phase, the conditions for the nucleosynthesis of all the heaviest elements of the Fe are created, up to uranium: *explosive nucleosynthesis*. The exploded Supernova, however, this time creates a different astral body: a BH.

Summing up, we have highlighted that *N synthesis* is only performed in particular conditions of gravity, pressure, T and ρ, as occurs with the *BB*, or during the *primordial nucleosynthesis*, or in the *stellar* and *explosive nucleosynthesis*, as in the processes of *neutronization* and *electron capture*.

2.7 NEUTRONIZATION

In short, the pressure of a *degenerate gas* depends just by the density(ρ). In fact, just when the ρ reaches a value of 10^7g/cm^3 the process of *neutronization* of matter starts, triggered by the remarkable E_{Kin} acquired by a free *degenerate electron*. Initially, the ν_e described in Eq.(1) succeed in escaping from the star with quite easily, but subsequently the ρ in the stellar core increases rapidly to become opaque to these same ν_s , which therefore remain trapped therein. Moreover, at high temperatures of the stellar core (T≈10^6 °K), the e^- e^+ pairs go to thermal equilibrium with ν_s and $\bar{\upsilon}_s$ of all *flavors*. With the progressive increase of ρ, in the contracting star the *neutronization* increases dramatically, while the number of *Ps* and $e^-{}_s$ decrease. Therefore, when ρ≈10^9g/cm^3 the stellar core starts to collapse.

Immediately after, when ρ≈10^{10}g/cm^3 Fermi energy exceeds *N–P mass difference*. As follows *inverse β decay*, also known as *positive β decay*(*βd*$^+$), becomes energetically preferable to normal *β decay*(*βd*$^-$). Then nuclei become very *N* rich: *neutronization.*

We have that the *neutronization* process is the direct consequence of the fact that an e^- so much energetic (*relativistic*) is able to give to the *P* its own E_{Kin} to gain that energy gap, corresponding to 0.78281 MeV, transported by the *N* [14]. Then, with the *neutronization* the $e^-{}_s$, compressed on the *Ps*, joint them forming *Ns* (and emitting ν_s) [22].

These $e^-{}_s$, moreover, benefit from an environmental context of very high pressure, such as to overcome the electric or Coulomb repulsion between e^- and *P*, so that these particles can more easily be pushed against each other to form *Ns*. As known, in normal matter it is just this Coulomb repulsion to prevent the compression of matter, but if the electric repulsion is missing, or is overwhelmed, the matter can be compressed up to 10^{14}g/cm^3, or more. In short, with the increasing contraction of the star the conditions of a complete *degeneration of the electrons* have been created, thus (as the PEP imposes) there have not been any *free states* a possible emitted e^- could occupy, which categorically prevents each *N*, as the one created in Eq.(1), to return to being a *P* [13]. It is like saying that $e^-{}_s$ and *Ps neutronize*, creating a *protostar of Ns*.

At a ρ of the order of 10^{14} gr/cm^3, i.e. one order of magnitude greater than the ρ of nuclear matter, 80% of the *Ns*, no longer bound within the nuclei, form a *degenerate gas*, so defined for its peculiar behavior [22].

2.8 NEUTRONIZATION EQUATIONS

Summarizing, we have that the energy acquired by a free *degenerate electron* is so high as to compensate and balance the *mass gap* between *P* and *N*, allowing the reaction illustrated in Eq. (1), and inhibiting the opposite one, which currently occurs under normal conditions, or 'low ρ' [22], known as *N disintegration*, or *N decay*, or *negative β-decay (βd⁻)*, illustrated by Eq.(6).

Let's analyze these equations.

As previously mentioned, Eq.(1) is congruous and *balanced*, due to the considerable energy acquired by e^- in these very particular environmental conditions.

On the contrary, Eq.(6) is not *balanced* at all. Why? For 2 specific reasons:

1) First of all because the environmental conditions are extremely different: Eq.(1) describes extreme situations of pressure and ρ, such as to induce the *neutronization*. Hence the e^- represented is *relativistic*, that is, provided with a very high energy, which reaches values up to 190-200 MeV, so as to compensate abundantly the *mass gap* between *N* and *P*.

Eq.(6), on the other hand, describes common environmental conditions, i.e. low ρ, whereby the e^- represented is also provided with common energy values, as it is not relativistic. It is an obvious consequence that this e^-, alone, that is, with its only energy, can never compensate for the conspicuous *energy gap* emerging from the Eq.(6): that's why Pauli added a 3rd particle to the *N decay*, or *βd⁻*.

2) The other motivation concerns the mass transported by the Pauli's 3rd particle, i.e. the $\bar{\upsilon}_e$. As it is known, in fact, the possible existence of ν, or 3rd particle, was hypothesized by Pauli to compensate for the remarkable *mass gap* emerging from the *N decay*:

$$N \rightarrow P + e^- \tag{8}$$

Let's evaluate the masses of the particles represented in Eq.(8). The *N* weighs $1.67492728 \cdot 10^{-24}$[g], while the *P* weighs $1.67262171 \cdot 10^{-24}$[g]; on its turn the e^- weighs $9.1093826 \cdot 10^{-28}$[g]. The mass difference between *N* and *P* corresponds to Δ_m ($0.00230557 \cdot 10^{-24}$[g]), that is $\Delta_m = 2.30557 \cdot 10^{-27}$ [g]. According to the mass-energy conversion factors, if we consider with Feynman that "1 MeV is about $1.782 \cdot 10^{-27}$[g]" [23], and follow the *cgs* metric system, we have:

$$(2.30557/1.782) \cdot 10^{-27}[\text{g}] = 1.29381 \text{ MeV/c}^2 \tag{9}$$

This is the value of the energy difference(Δ_e) between *N* and *P*::

$$\Delta_e = 1.29381 \text{ MeV} \tag{10}$$

The energy value expressed in Eq.(10) represents the maximum value of the energy spectrum ($\eta = E_{Max}$) of the β radiation emitted with *βd⁻*.

The minimum energy carried away by an e^- corresponds to 0.511MeV, thus the value of Eq.(10) is more than double than the energy of an e^- not particularly accelerated. With the decay of the *N*, instead, the *β ray*(that is an e^-) is accelerated to a very high speed, showing a marked E_{Kin}. Nevertheless, only in very limited circumstances, and coincidentally, the total energy carried away by the β radiation is able to compensate for the difference in mass-energy between *N* and *P*.

If we substract the *minimum energy* of an e^- from the energy value expressed by Eq.(10), we obtain the maximum value of the energy(*E*) that could be covered by the 3rd particle of the *βd⁻* **:**

$$E = 0.78281 \text{MeV} \tag{11}$$

This value exceeds the 53.1413% the energy of an e^- *at rest*. But it is worth pointing out that this is the maximum value the 3rd particle can reach (considering that at the same time the e^- is emitted too). This does not mean that it always has so much energy, rather the contrary. In fact in the value

expressed by Eq.(10) we must also consider the E_{Kin} of the β-ray, whose energy spectrum, as Fermi had reported [24], may also coincide with the entire energy value described by Eq.(10).
We wonder: can a single $\bar{\upsilon}_e$ compensate for the *energy* gap we find in Eq (11)? How heavy is a ν_e? Up until a few years ago it was considered even massless! Then, after the evidence for oscillation of atmospheric ν_s, carried out at the Super-Kamiokande [25], also the Standard Model had to recognize a mass at ν, though infinitesimal. Maiani states: "The current upper limits of the mass of the ν_s emitted with the *β-decay* are m_ν <2eV"[26], a value corresponding to <1/250000 of the electronic mass!
Therefore, to compensate for the *energy gap* still in force in Eq.(6), i.e. as the βd^- is represented, it would take more than 250000 $\bar{\upsilon}_e$! In short, there is still something not working in Eq.(6).
In fact, just to make the numbers work, the 3rd particle added by Pauli to βd^-, and indicated by Fermi with the name of ν, must have the same mass of e^-.
At this point it can be useful to analyze the basic requirements originally requested by Pauli and Fermi for the ν, i.e. for the 3rd particle or missing particle in the *N decay* or βd^-, defined by several authors as a *ghost particle*. Pauli writes: "Dear Radioactive Ladies and Gentlemen, I will explain to you in more detail, because of the "wrong" statistics of the N- and Li-6 nuclei and the continuous β spectrum, I have hit upon a desperate remedy to save the 'exchange theorem' of statistics and the law of conservation of energy. Namely, the possibility that in the nuclei there could exist electrically neutral particles, which I will call neutrons, that have spin 1/2 and obey to the exclusion principle and that further differ from light quanta in that they do not travel with the velocity of light. The mass of the neutrons should be of the same order of magnitude as the electron mass and in any event not larger than 0.01 proton mass. …But nothing ventured, nothing gained. Thus, dear radioactive people, scrutinize and judge. Your humble servant W. Pauli "[27],
Also Fermi, i.e. the author of the formulation of βd^- described with Eq.(6), reiterates the concept of Pauli: "We still have the problem of knowing the laws of forces acting between the particles making up the nucleus. It has indeed, in this regard, in the continuous spectrum of *β* rays, some clues that, according to Bohr, it would suggest that perhaps in these new unknown laws even the Principle of Conservation of Energy is not valid any more; unless we admit – together with Pauli - the existence of the so-called *neutrino*, that is a hypothetical electrically neutral particle having a mass of the order of magnitude of the electron mass" [28].
Therefore, these requests are essentially three: 1) the 3rd particle, or ν, is electrically neutral; 2) it has the same spin of the e^-; 3) it has the same mass of the e^- [27][28].
Well, why not to think immediately to the possible existence of a *neutral electron* (e°)?
All requests would be satisfied. It seems the most *logical* answer, and physically more than adequate to meet the demands of Pauli and Fermi. Even in this way the energy balance in the *N* disintegration is restored, thus safeguarding the Laws of Conservation of Mass and Energy and at the same time safeguarding the Law of Conservation of Electric Charge, Angular Momentum and Lepton Number[14].
Moreover, observing Eq.(1), the isolated ν_e is as if *it is not telling us its history*. We wonder: where does the ν_e come from, placed at the right member? In fact, it is well known that when a particle is created *from scratch*, i.e. when a new particle materializes, its antiparticle is simultaneously generated. Likewise, a fundamental rule of Physics states that "matter and antimatter particles are always produced as a couple"[29], it's unequivocal! And so: what happened to the relative antiparticle of ν_e, i.e. the $\bar{\upsilon}_e$, which is not represented in Eq.(1)? And where is the $\bar{\upsilon}_e$?

Just in compliance with the current physical rules, in our opinion Eq.(1) implies some *intermediate steps* in which, precisely, the $\bar{\upsilon}_e$ should appear.

At this regard, one of the phenomena that are very often accompanied by *neutronization* is the so-called *photoannihilation*, characterized by *materialzzation* of the electro-magnetic radiation (EMR), resulting in a *Production of Couples* (particle-antiparticle) [16], as:

$$\gamma \rightarrow \bar{\upsilon}_e + \nu_e \qquad (12),$$

where γ indicates a gamma photon, i.e. highly energetic radiation, being of nuclear origin. As these physical processes of *photoannihilation* and *Production of Couples* are frequently accompanied by *neutronization* processes[16], it may be more appropriate to describe them together.

For this reason, entering Eq.(12) in Eq.(1) we obtain:

$$e^- + P \rightarrow e^- + P + \gamma \rightarrow e^- + P + \bar{\upsilon}_e + \nu_e \rightarrow N + \nu_e \qquad (13),$$

namely:

$$e^- + P + \bar{\upsilon}_e + \nu_e \leftrightarrow N + \nu_e \qquad (14).$$

In this way, with these two intermediate steps, the previous Eq.(1), describing the *electron capture*, should be, in our opinion, more complete and congruous, since the possible steps through which the ν_e is generated are shown, which appeared *ex abrupto* to the right hand side of Eq.(1).

Besides, as it is known, according to the 1st Equivalence Principle (of Equations) we are allowed to subtract the ν_e present in the two members of Eq.(14), obtaining a new equation equivalent to the previous one:

$$e^- + P + \bar{\upsilon}_e. \leftrightarrow N \qquad (15).$$

Yet, from Eq.(15) something new emerges. In fact, it is easy to see that the *N* corresponds a *compound* of 3 particles: $e^- + P + \bar{\upsilon}_e$, i.e. a *multiplet* [e^-, *P*, $\bar{\upsilon}_e$].

Then, we would like to point out that the emerged *multiplet* is not a *forcing* at all. In our opinion, it comes from a more complete consideration of the "series of reactions that develop during the *Neutronization* processes, such as the *electron capture*"[16] described with Eq.(1), and "the *Couple Production* processes, including *photoannihilation*"[16], described within Eq.(12).

They are precisely these physical processes, such as the *photoannihilation* and the *Couple Production processes*, generated by the *materialization* of the EMR emerged with *electron capture*, which help us to better understand the *Neutronization* phenomenon in all its complexity. In fact, with the *photoannihilation* and the *materialization* of the EMR we have found the $\bar{\upsilon}_e$ which is missing in the *neutronization equation*, where only the ν_e is described, but without the counterpart. And where is the $\bar{\upsilon}_e$? The $\bar{\upsilon}_e$ is present in the left hand side of the Eq.(14) together with *P* and e^-, arranged in sequence, one after the other, to form that *multiplet*, represented by *N*. In this way, also implying the presence of a couple $\nu_e \bar{\upsilon}_e$ (generated by *photoannichilation*), and allocable to the 1st member of the *Neutronization Equation* (Eq.1), this equation becomes more appropriate and physically more valid.

Also, let's try reading in reverse Eq.(15):

$$N \rightarrow e^- + P + \bar{\upsilon}_e \qquad (16).$$

It is surprising: Eq.(16) shows exactly the decay products of *N*. In fact, this equation corresponds precisely to the famous equation describing the *N decay* or βd^- (Eq.6), formulated by Fermi in relation to the intuition of Pauli.

Furthermore, if we read this passage according to the direction indicated in Eq.(15), we have:

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

Reading Eq. (17) we infer that in an environmental context of extreme ρ, this *multiplet*, i.e. these 3 particles closely aligned with each other, without leaving the slightest space, would generate *N*.

But it is not possible, it will be said. A *N* incorporating an e^- would imply the presence of e^-_s within the nuclei. But this would conflict with the Quantum Mechanics (QM). In fact, as Maiani reminds us [30], if we bring into play the HUP an e^-, located within the radius (R) of the atomic nucleus, would have an energy ($\Delta_{\boldsymbol{p}}$) more than 100 times greater than that of *β-rays* (~1MeV):

$$\Delta_{\boldsymbol{p}} \approx \hbar/R \approx 140 \text{ MeV} \qquad (18),$$

where ħ is Planck's constant, written in the Dirac manner. In fact, according to the QM, simply placing particles in the sphere of radius R implies that these particles have a *momentum* ($\boldsymbol{p}$), as imposed by HUP, of: $\boldsymbol{p} \geqq \hbar/R$ [16]. The so-called *Klein paradox* is based on the same concept, so that, due to its high *momentum*, the e^- immediately runs away from the atomic nucleus. Klein was about to study electron scattering trying to cross a potential barrier. Klein's experiment clearly showed that if the value of the potential barrier is of the order of the e^- mass, this barrier is nearly transparent[31]. That is, the Klein experiment presented a quantum mechanical objection to the Rutherford *N model*, suggesting that an e^- couldn't be confined within a nucleus by any potential wall. For this reason, after more than a decade Rutherford hypothesis was rejected. He had imagined the *N* as made by the very close union of a *P* with an e^-, making a *neutral doublet*:

$$N = \left[P, e^- \right] \qquad (19).$$

Nevertheless, although the reality broadly confirmed that the *N* could be made at least as the *doublet* of Rutherford, it was appealed, *improperly* in our opinion, to the QM, rejecting the hypothesis that the *N* was a *compound particle*, but claiming that the *N* was an elementary particle. It means that it was not taken into account that all those physical processes that in Nature produce the *nucleonic synthesis or baryogenesis*, occur exclusively in extreme environmental conditions, where it is widely believed that most of the known physical laws would be less. Weinberg has emphasized widely that, in order to obtain the synthesis of a *P* or a *N*, the T must necessarily be $T \geq 10^{13}$ °K [1].
In short, it deals with really infernal environmental conditions, that is *singular*, as Einstein and many other authors defined them, pointing out, in fact, that in the presence of a *singularity* the physical laws would no longer be valid, or would not take place as usual.
Furthermore, it must be added that this particle, this *compound*, cannot have an internal space. In these circumstances "the e^-_s are so close to the *P*s that they merge with them and there is not even the smallest space between them" [33]. How could this *complex particle* have its own internal space, and thus its radius, given the likely null distance between e^- and *P*? Just think that in only one cm^3 of the *neutronic flux* (which is the core of a Neutron Star) there are 10^{22} *Ns*!
"In a normal atom the e^-_s are very far from the nucleus, and the atom is practically 'empty'. The enormous pressure in the Neutron Star is so great that it breaks the nucleus in *P*s and *N*s. Electrons are so close to the *P*s to merge with them, forming other *N*s. At this point the star is composed only by *N*s, so close that there is not even the smallest space between one and the other. The ρ is 10^{14} times a rock's: a teaspoon of this matter would weigh on the Earth as much as the entire human population "[33].
It may seem really ridiculous to keep talking about *N*'s radius in these spaces.
Moreover, it should remembered that the e^- described in Eq.(1), i.e. the *relativistic* e^- that determines the *neutronization*, hits the *P* with an energy of ≈200 MeV, i.e. much greater than the energy that the momentum of a *nuclear* e^- would acquire with the HUP (≈140 MeV), and frankly greater than the *energy gap* between *N* and *P*. This is why an e^- and a *P* can remain strictly bound for a long time: in the Neutron Stars, e.g. for several hundred million years.

Thus, in Nature the *N* is thus structured, that is, by the union of an e^- with a *P*: *baryogenesis docet*. Indeed, according to the model we proposed, from *P* would be captured also a $\bar{\upsilon}_e$.
One could still object: why $\bar{\upsilon}_e$ is always *captured*, whereas the ν_e (also present at the 1st member of Eq.14) is always let go? Why we sometimes do not have the opposite? It is simple: it is imposed by the Law of Conservation of the Lepton Number (L). Given that the *P*, being a baryon has L=0, this value will have to remain constant, through the whole course of the *electron capture* process. This process allows the *P* to *hook* tightly an e^-, the latter having L=1. It is easy to see that if the *electron capture* process stopped with the *capture* of only e^-, and so it is described (as shown by Eq. 1), the *N* coming from this union (e^- with *P*) , would have L=1 (as well as becoming a boson!). But it is absurd. It is impossible: *N* is a baryon, so it will always have L=0. So where is the mistake? In leaving the equation related to *electron capture* as it has been described. Instead, if we consider that a 3rd particle is also *captured*, things could adjust, provided that this particle has L = –1. But only an anti-lepton has L = –1. This is why the ν_e is let go (with it, moreover, *N* would come to L = 2), while the $\bar{\upsilon}_e$ is *captured*! This 3rd particle is exactly the same Pauli proposed in βd^- [27], which is just the inverse process of *electron capture*, called namely *inverse* βd (or βd^+). In addition, if composed of 3 particles *N* returns to be a fermion.
Finally, the *coup de grace* to Rutherford *neutral doublet* was inflicted by an experiment of Rasetti concerning the *nuclear Spin Statistics* of the nitrogen (N_7^{14}). Rasetti carried out a study of the Raman spectra of the nitrogen molecule, pointing out that N_7^{14} nuclei obeyed the Bose-Einstein statistics, as they showed integer spin [34]. Thus, experimental data were in open conflict with the *N model* prospected by Rutherford because, if we add 7 e^-_s in the nitrogen nucleus, we get to 21 fermions (*7Ps* settling + 7Ps linked to 7 *captured* e^-_s), that is an odd number, from which it turns out that nitrogen is a fermion, returning therefore in the *Fermi-Dirac Spin Statistics* (half-integer spin). But this is in stark contrast to Rasetti's experiment.
Now let's look at the Spin Statistics of the Nitrogen Core (N_7^{14}), considering *N* as *multiplet* (rather than *doublet*). This particular changes things. In fact, with the model of the *N multiplet*, we have that in the nucleus of nitrogen to the 7 base *Ps*, as a result of the e*lectron capture* process more 7 *Ps* are added, as well as 7 e^-_s and 7 $\bar{\upsilon}_e$.
So in the nitrogen nucleus we have as many as 28 half-integer spin particles (fermions). Thus, summing up, we have an even spin, which tells us that the nucleus of nitrogen behaves like a boson, in perfect agreement with the Rasetti experiment and, above all, according to reality.

3. CONCLUSIONS

Summarizing, regarding the possible existence of a *neutral electron* (e°), it could be said that the same results reached by a e° are obtained similarly even with a ν. And then: e° does not exist, this is an invention! The only known e^-_s 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, invented *from scratch*. 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 and further simplifying it (according to the *reductionist* approach preferably adopted in Physics)[35].

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.

To this purpose, we think necessary to emphasize that every time it was considered that the ν_s had been detected, they were always *indirect detections* thanks to traces left by a *ghost particle* never detected *de visu*, never directly identified. Generally, these indirect detections of the 3rd particle of the *βd⁻*, indicated as ν, are represented by the so-called *Cherenkov Effect* [36]. 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*.

In Nature the *CE* is only elicited by e^-_s [36][37]. That is the mark that distinguishes events sought is therefore a double coincidence in a pair of scintillators, separated by a time of a few microseconds. If instruments had revealed γ rays exactly of two energies provided, separated by suitable intervals, the investigators would have caught the ῡ. Thus, this was enough to believe to have found specifically and unequivocally the effects of the elusive ῡ.

With good conscience, this statement seems to us a *stretch* in the interpretation of the findings. That statement, in our view, requires a preconceived, a *dogma*: that the 3rd particle emitted with *βd⁻* must be only and unquestionably an ῡ, no other type of particle.

On the contrary, the minimal mass attributed to the $\bar{\upsilon}_e$, in our opinion, will never be able to solve the *mass gap problem* of the *N decay*.

A possible anti-neutral electron (ē°), instead, would have all the requirements to represent the 3rd particle of the *βd⁻*.

Furthermore, by integrating in the *neutronization equation* (Eq.1) the processes of materialization of the EMR with consequent *pair production*, described by Eq.(12), we obtain a more complete and congruous view of the processes of *neutronization*, as illustrated by Eq.(14). The latter equation and likewise Eq.(15), however, still remain *unbalanced* by the too small mass of the $\bar{\upsilon}_e$.

Instead, if for example we try to replace in Eq.(15) the $\bar{\upsilon}_e$ with the ē°, provided with a mass-energy between 0.511–0.78281MeV, we have:

$$e^- + P + \bar{e}^\circ \leftrightarrow N \qquad (20).$$

Moreover, ē° could probably also play a *cementing* role in favor of the stability of the possible *N composed*, or *N multiplet*, similarly to the task performed by *Ns* in favor of the stability of the atomic nucleus.

In this way, the Laws of Conservation of Mass and Energy are safeguarded too. The same applies to the reverse process, represented by the *N decay*, or *βd⁻*.

In fact, replacing the $\bar{\upsilon}_e$ with the ē° in Eq. (6), we have:

$$N \rightarrow e^- + P + \bar{e}^\circ \qquad (21).$$

Finally, as regards *Spin Statistics*, contrary to Rutherford *doublet*, the *multiplet* that could give rise to *N*, described by Eq.(17), would be in full agreement with the various principles of QM and with the Rasetti experiment.

4. REFERENCES

1) Weinberg S., "The First Three Minutes. A Modern View of the Origin of the Universe",©1977 by S. Weinberg; Mondadori Ed.(Milano),1977, 172-173,125,93,117.

2) 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.

3) Hawking, S., "A Brief History of Time",©1988 by Stephen W. Hawking, Bantan Books ed.; Rizzoli ed.,Milano, 67,1990.

4) Puccini A., "Correct Quantum Gravity is a Mechanical Effect Induced by Dynamic-Mass of Light's Quanta", viXra.org., Quantum Gravity and String Theory, 1712.0546, 2017.

5) Penrose R., "Gravitational collapse and space-time singularities", Phys.Rev.Lett.,14,3,57-59, 1965.

6) Hawking S.W., "Particle creation by black holes", Commun. Math. Phys., 43, 199-220,1975.

7) Puccini A., "About the Specific Heat of Black Holes" (Session 3P1: Optics and Photonics). Progress in Electromagnetics Research Symposium Proceedings , Cambridge (Ma), USA, July 5-8, 2010, 816-818.

8) Puccini A., "Dark Matter Particle is a Neutral Electron", viXra.org, Astrophysics, 1707.0364, 2017.

9) Pacini F., "L'Universo. Pianeti stelle galassie", Editori Riuniti, Roma, 280,286,287,1982.

10) Maiani L.,"Fusione nucleare nelle stelle di grande massa", Fermi Lectures 10, INFN Rome,15th Jan. 2015

11) Chandrasekhar S., "The Maximum Mass of Ideal White Dwarfs", Astrophysical J.,vol.74,81-82, 1931.

12) Marani A:, "Stelle di Neutroni", Tesi di Laurea in Matematica e Fisica ,Università di Bologna,2008.

13) Marconi A., "Fondamenti di Astrofisica ", Lesson 9, Anno Accademico 2010/2011, Dept. of Physics and Astronomy, University of Florence, Italy.

14) Puccini A., "Neutral Electron instead of Neutrino: a New Beta-Decay Model", viXra.org, Nuclear and Atomic Physics, 1707.0364, 2017.

15) Arnett D., Neutronization and Dissociation, in "Supernovae and Nucleosynthesis", David Spiegel ed.,1996.

16) www.Fe.INFN.it/florenti/courses/astrophysics/07/Supernovae

17)Heisemberg W.,"Uber den anscauliken Inhalt der Quantentheoritschen Kinematik und Mechanik", Zeitschrift fur Physik,Vol.43,172-198,1927.

18) Puccini A., "Uncertainty Principle and Electromagnetic Waves", Journal of Electromagnetic Waves and Applications, Vol.19, Issue 7, 885-890, 2005.

19) Pauli W., "Über den Zusammenhang des Abschlusses der Elektronengruppen im Atom mit der Komplexstruktur der Spektren", Zeitschrift für Physik, vol. 31, issue 1, 765-783, 1925.

20) Tolman R.C., "Static Solutions of Einstein's Field Equations for Spheres of Fluid", Phys.Rev.,55, 364-373, 1939.

21) Oppenheimer J.R., Volkoff G.M., "On Massive Neutron Cores", Phys.Rev.,55, 374-381, 1939.

22) de Grenet L., "L'evoluzione delle stelle"//archive.oapd.inaf.it

23) Feynman R.P,, "QED", ©1985 by Richard P. Feynman; Adelphi ed.(Milano),164,1989.

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

25) Fukuda S. et al., "Evidence for Oscillation of Atmospheric Neutrinos",Phys.Rev.Lett.,81,1562, 1888.

26) Maiani L., "La massa dei neutrini", Fermi Lectures 23, INFN, Rome, 26th March 2015.

27) Pauli W., Letter to partecipants of the Conference in Tubingien (1930), Septiem Conseil de Physique Solvay, 6th December 1930.
28) Fermi E., "Le ultime particelle costitutive della materia", 22° Meeting Società Italiana per la Propensione delle Scienze (SIPS), Bari 13/10/1933; Proceedings SIPS ,Roma 1934,Vol.2, 7-14.
29) http://scienzapertutti.infn.it/1834-0407-materia-e-antimateria
30) Maiani L., "Isotopes and nuclear electrons", Fermi Lectures 4, INFN, Rome, 27th November 2014.
31) Klein O., "Die Reflexion von Elektronen an einem Potentialsprung nach der relativistischen Dynamik von Dirac", Zeitschrift fur Physik, Vol.53,Issue 3-4,157-165,1929.
32) Sir E. Rutherford, "The Building up the Atoms", Proceed. of British Association,25/8/1920, "Engineering", 110,382,1920.
33) http://archive.oapd.INAF.it/Stelle_di_neutroni.html
34) Rasetti F, "Alternating Intensities in the Spectrum of Nitrogen", Nature, CXXIV, 792-793, 1932.
35) Randall L., "Knocking on Heaven's Door", ©Lisa Randall 2011-2012; il Saggiatore ed.(Milano), 256, 2012.
36) Cherenkov A., "Visible emission of clean liquids by action of ϒ radiation", Doklady Akademii Nauk SSSR, 2,451,1934.
37) Puccini A., "Why Gamma Photons Induce Cherenkov Effect", Progress in Electromagnetics Research Symposium Proceedings, Moskow, Russia, August 19-23, 2012, 343-347.