# From black-body radiation to gravity:

## why neutrinos are left-handed and why the vacuum is not empty

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**Summary**
Starting from a simplified survey of Fermi's neutrino theory, it is shown that the nuclear background energy in the vacuum is polarized by quarks, thereby not only explaining the narrow range of the strong interaction, but also giving an explanation for the left-handiness of neutrinos. Recognizing that such a vacuum polarization explains the cosmological dark matter and dark energy phenomena, it is hypothesized that the elementary constituents of the nuclear background energy and the cosmological background energy are the same. The hypothesis is supported by an assessment of the quark's "naked" mass.

Keywords: neutrino; Fermi constant; parity violation; dark matter

### *1. Introduction*

In the history of the development of the theory for particle physics described so far [1], the description of two dilemmas that have pre-eminently been decisive for the current Standard Model has been omitted still. Both dilemmas have to do with the neutrino, which in this text has not yet been described or barely described. The history of the neutrino begins with a misunderstood phenomenon from the years before 1930. One would expect in radioactivity, in which nuclear particles change state, the energy difference between the particle that has not yet decayed and the decayed particle is carried away by particles with a discrete energy value. This was clearly the case with alpha radiation carried by Helium atoms. Curiously, it was not the case with beta radiation carried by electrons. The spectrum of the electron beam turned out to be continuous rather than discrete, like illustrated in figure 1.

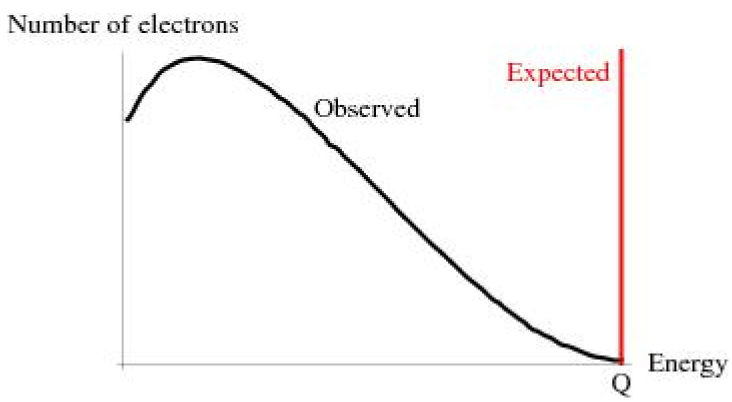


**Fig 1.** Expected density spectrum of the electron's energy in beta radiation (red) and the actually observed one (black).

That was already apparent 1914 from observations by James Chadwick (who became famous in 1930 for the discovery of the neutron) and others. It was a problem that led Wolfgang Pauli in 1927 to formulate a bold hypothesis which he did not dare to publish, but sighing posited in a letter to Hans Geiger and Lise Meitner [2]. Because, unlike some other scientists, including Niels Bohr, he did not want to doubt the law of energy conservation, he suggested in the letter the existence of a particle that eludes observation. That particle should be nearly massless, electrically neutral, and have half-integer spin. He called that particle "neutron", a name that was changed to neutrino after Chadwick's discovery of the neutron. It was Enrico Fermi who took Pauli's hypothesis seriously and in 1933 developed a theory for beta radiation based on the neutrino existence. Incidentally, the existence of the neutrino was not experimentally confirmed until 1956 by Reines and Cowan.

## 2. *Fermi's theory*

Fermi's theory is considered being the predecessor of the theory of the weak interaction carried by $W$ bosons. Fermi's model is conceptually simple, but rather complex in its implementation. For the purposes of this essay, a simplified representation will suffice, illustrated in the left hand part of Figure 2. This shows the decay of a neutron into a proton under

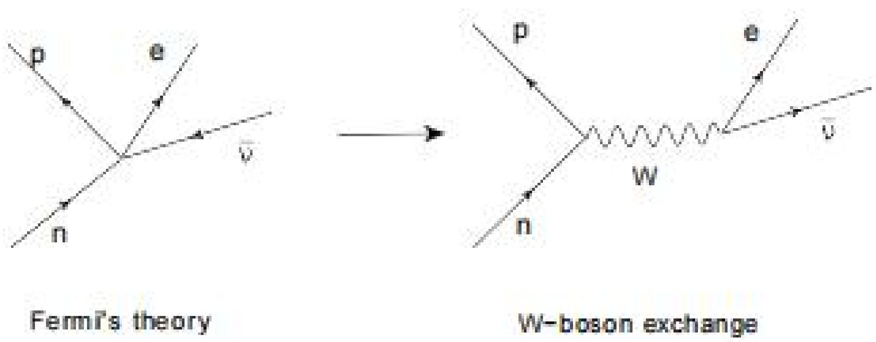


**Fig.2.** Fermi’s beta decay model with direct coupling versus decay by weak interaction boson..

release of an electron. To satisfy the conservation of energy, the energy difference $E_0$ between the neutron and the proton must be absorbed by the energy $E$ of the electron and the energy $p_\nu c$ of the neutrino moving at about the speed of light. To satisfy momentum conservation, the momentum $\mathbf{P}$ of the nucleon must be taken over by the momenta $\mathbf{p}_e$ and $\mathbf{p}_\nu$ of the electron and neutrino, respectively, so that

$$E_0 = E_e + p_\nu c \quad \text{and} \quad 0 = \mathbf{P} + \mathbf{p}_e + \mathbf{p}_\nu .$$

To explain the occurring energy spectrum of the electron, Fermi developed the concept of *density of states*. This is based on the assumption that fermions, such as the electron and the neutrino, despite their pointlike character, require a certain spatial space for their wave

function that does not allow a second wave function of a similar particle. That comes down to respecting the exclusion principle that was posited by Pauli in 1925 in the further development of Niels Bohr's atomic theory from 1913.
In a simple way, that spatial space is a small cube whose sides are determined by half the wavelength ( $L/2$ ) of the fermion. A volume $V$ contains $N$ fermions. So,

$$N = \frac{V}{(L/2)^3} = \frac{8}{(cT)^3} = \frac{8}{c^3}\frac{\omega^3}{(2\pi)^3} = \frac{8}{(\hbar c)^3}\frac{(\hbar\omega)^3}{(2\pi)^3}V .$$

For a particle in a relativistic state holds $\hbar\omega = pc$ . In that case, after differentiating,

$$\frac{\mathrm{d}N}{V} = \frac{24}{(2\pi\hbar)^3}p^2\mathrm{d}p.$$

A somewhat more fundamental derivation in terms of a spheric volume split up by solid angles $\mathrm{d}\Omega$ expresses this differential density of states as,

$$\frac{\mathrm{d}N}{V} = \frac{4\pi}{(2\pi\hbar)^3}p^2\mathrm{d}p \; .$$

The difference is about a factor of 2. The difference can be explained, because the roughly derived quantity admits two particles in the interval by taking into account a difference in spin. The differential density of states that can be attributed to the decay product of neutron to proton is equal to the product of the contributions of the electron and of the neutrino, so that

$$\frac{\mathrm{d}n}{V} = \frac{4\pi}{(2\pi\hbar)^3}p_e^2\mathrm{d}p_e\frac{4\pi}{(2\pi\hbar)^3}p_\nu^2\mathrm{d}p_\nu \, .$$

For the differentiated density of states holds,

$$\frac{1}{V}\frac{\mathrm{d}n}{\mathrm{d}E_e} = \{\frac{4\pi}{(2\pi\hbar)^3}\}^2\{p_e^2\mathrm{d}p_e\frac{\mathrm{d}}{\mathrm{d}E_e}p_\nu^2\mathrm{d}p_\nu + p_\nu^2\mathrm{d}p_\nu\frac{\mathrm{d}}{\mathrm{d}E_e}p_e^2\mathrm{d}p_e\}.$$

For the electron, which is not necessarily in a relativistic state, holds

$$p_e^2\mathrm{d}p_e = \frac{1}{c^3}(E_e - m_e c^2)^2\mathrm{d}E_e .$$

Since the neutrinos do not contribute to the spectrum of the electrons, the spectral density of the electrons can be calculated by integrating over the moments of the neutrinos. Hence,

$$\frac{1}{V}\frac{\mathrm{d}n}{\mathrm{d}E_e} = \frac{1}{4\pi^4\hbar^6c^3}\{(E_e - m_e c^2)^2\mathrm{d}E_e\frac{\mathrm{d}}{\mathrm{d}E_e}\int p_\nu^2\mathrm{d}p_\nu + (E_e - m_e c^2)^2\int p_\nu^2\mathrm{d}p_\nu \, .$$

Since the decay occurs from the nucleon in state of rest, the conservation law of momentums prescribes $|\mathrm{d}p_\nu| = |\mathrm{d}p_e|$. For the neutrino it then follows that,

$$p_\nu^2 \mathrm{d}p_\nu = \frac{1}{c^3}(E_0 - E_e)^2 \mathrm{d}E_e .$$

It will be clear that the first term in $\mathrm{d}n/\mathrm{d}E_e$ is infinitesimally small with respect to the second term and that therefore,

$$\frac{1}{V}\frac{\mathrm{d}n}{\mathrm{d}E_e} = \frac{1}{4\pi^4\hbar^6c^6}\{(E_e - m_ec^2)^2(E_0 - E_e)^2\} .$$

So here $\mathrm{d}n$ is the number of electrons per m$^3$ in an energy interval between $E_e$ and $E_e + \Delta E_e$. In terms of energy, therefore,

$\mathrm{d}W = (m_e\mathrm{c}^2)^2 V\mathrm{d}n$, so that

$$\frac{\mathrm{d}n}{\mathrm{d}E_e} = \frac{1}{(m_e\mathrm{c}^2)^2V^2}\frac{\mathrm{d}W}{\mathrm{d}E_e} \to \frac{\mathrm{d}W}{\mathrm{d}E_e} = (m_e\mathrm{c}^2)^2V^2\frac{1}{4\pi^4\hbar^6c^6}\{(E_e^2 - m_ec^2)^2(E_0 - E_e)^2 .$$

In ref. [3] is this expression written as,

$$\frac{\mathrm{d}W}{\mathrm{d}E_e} = \frac{G_F'^2}{2\pi^3}\{(E_e - m_ec^2)^2(E_0 - E_e)^2$$ , so that

$$\frac{G_F'^2}{2\pi^3} = V^2(m_e\mathrm{c}^2)^2\frac{1}{4\pi^4\hbar^6c^6} \to G_F' = \frac{V}{\sqrt{2\pi}}\frac{m_ec^2}{(\hbar c)^3} .$$

This can be done without loss of generality, as long as $G_F'$ it is not assumed a priori to be identical to the Fermi constant $G_F$ to be defined later. If we knew $V$, the constant $G_F'$ can be calculated. Since the calculation of the density of states assumes the spatial boundary of the wave function of the decay products, it is reasonable to assume that the volume $V$ is determined by the spatial boundary of the wave function that fits the energy from which the decay products originate, so that

$$V = (\frac{L}{2})^3 = (\frac{cT}{2})^3 = (\frac{c}{2}\frac{2\pi}{\omega})^3 = (\pi\frac{\hbar c}{\hbar\omega})^3,$$ and thus

$$G_F' = \frac{\pi^3}{\sqrt{2\pi}}\frac{m_ec^2}{(\hbar\omega_{np})^3} ,$$

In which $\hbar\omega_{np}$ the energy that determines the formation of the decay products. As illustrated in the right-hand part of figure 2, Fermi's point contact model has been revised after the

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discovery of $W$ bosons as carriers of the weak force, which is seen as the cause of the decay process. This insight led to the model shown in the right half. Zooming in on it shows that the neutron decay is caused by the change in composition of the nucleon from $udd \rightarrow udu$. This is shown in the left-hand part of figure 3. This picture is symbolic, because it suggests that the energy difference between a $u$ quark and a $d$ quark is determined by a $W$ boson, while we know that the free state energy of a boson is 80.4 GeV and there is only a 1.29 MeV mass difference between the $(udd)$ neutron and the $(udu)$ proton.

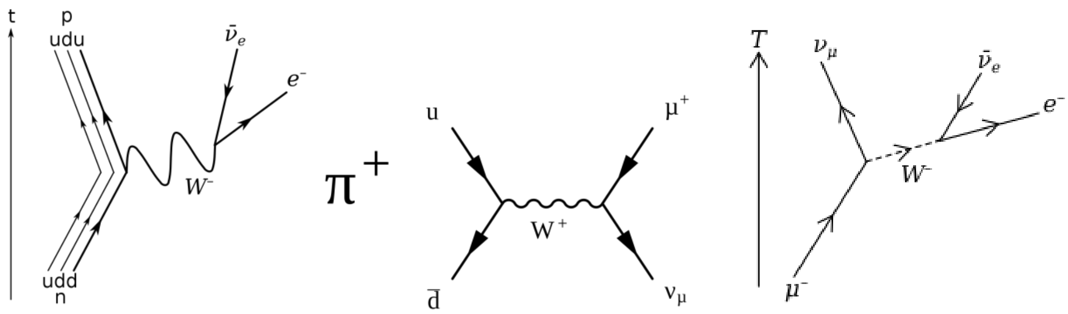


**Fig.3.** The symbolic representation of the weak decay process by the weak interaction boson

The figure in the middle gives a more realistic picture of the $W$ boson. A positive pion decays in its entirety via a $W$ boson into a (positive) muon and a neutrino. It is more realistic, because earlier in this essay we established that the pion moving at about the speed of light has a rest mass of 140 MeV, while it behaves relativisticly as 80.4 GeV prior to its decay into the muon's rest mass of 100 MeV plus a neutrino energy (that in the rest frame of the muon corresponds to a value of about 40 MeV). A (negative) muon in turn decays into electrons and antineutrons as shown in the right part of the figure. It will be clear from these figures that one $W$ boson is not the other. Only the middle image of figure 3 justifies its energetic picture. Hence, as discussed earlier in the essay, the 140 MeV rest mass of the pion is the non-relativistic equivalent of the 80.4 GeV value of the boson.

These considerations lead us to consider the decay process from pion to muon to be the most suitable one to calculate the constant $G'_F$ . Because the pion decays to a muon, the rest mass of the muon (= 100 MeV) takes the place of the electron before. The energy $\hbar\omega_{np}$ from which the decay product arises is the energy of the free state $W$ boson, so that

$$G'_F = \frac{\pi^3}{\sqrt{2\pi}} \frac{m_u c^2}{(\hbar\omega_W)^3} \; ; \; m_u c^2 = 100 \text{ MeV}; \; \hbar\omega_W = 80.4 \text{ GeV}.$$

This makes $G'_F$ = 2.38 $10^{-6}$ $\text{GeV}^{-2}$. This is about 4.6 x smaller than the PDG value of 1.106 $10^{-5}$ $\text{GeV}^{-2}$ for the Fermi constant. However, as noted above, $G'_F$ is not necessarily equal to $G_F$. What should hold, however, is the relationship between the half-life $\tau$ (in which half of a nuclear particle decays) and the integral $W_E$ of the decay spectrum,

$$\frac{1}{\tau} = \frac{W_E}{\hbar} \, .$$

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This expression shows that the lifetime of a nuclear particle is determined by the time it takes to build up the decay spectrum with the total energy value $W_E$ . Note that the expression resembles Heisenberg's uncertainty relation,

$$\Delta\iota \cdot \Delta W_E = \hbar .$$

In Fermi's theory, however, the expression is the elaboration of his "Golden Rule". That rule is based on a statistical analysis of the decay process, the details of which we will omit in this text. See [4], [5].

The relation takes on a simple form if the decay product is relativistic. This is the case with the decay of a muon into electrons, because in the major part of the spectrum $E >> m_e c^2$. In that case,

$$W_E = \frac{G_F'^2}{2\pi^3} \int_{m_e c^2}^{E_0} (E_e^2 - m_e c^2)^2 (E_0 - E_e)^2 \mathrm{d}E_e \approx \frac{G_F'^2}{2\pi^3} \frac{1}{5} E_0^5 \; ; \; E_0 = m_u c^2 \; .$$

The calculated energy density spectrum is shown in figure 4. The fifth-power shape, which relates the massive energy $mc^2$ of a nuclear particle to its decay half-life, is known as (Bernice Weldon) Sargent's law, as formulated empirically in 1933.

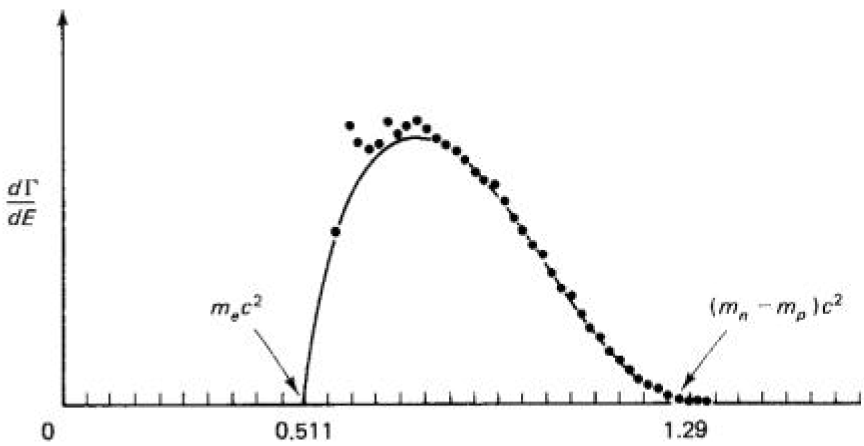


**Fig.4**. Electron energy distribution from neutron beta decay, calculated and experimental (dots).. Source: ref. [5,7].

Summarizing:

$$\frac{1}{\tau} = \frac{W_E}{\hbar} = (\frac{c}{\hbar c})W_E \; ; \; W_E = \frac{G_F'^2}{10\pi^3}(mc^2)^5 \; ; \; G_F' = \frac{\pi^3}{\sqrt{2\pi}} \frac{m_u c^2}{(\hbar\omega_W)^3} .$$

This result has a predictive value, because it allows to calculate the decay time of any nuclear radioactive particle from the reference values of, respectively, the weak interaction boson ($\hbar\omega_W =$ 80.4 GeV) and the massive energy of the muon ( $m_u c^2 =$ 105 MeV). The result thus calculated for the muon itself is $\tau_\mu$ = 2.56 x $10^{-6}$ s . This compares rather well with the experimentally established value $\tau_\mu$ = 2.2 × $10^{-6}$ s reported by the Particle Data Group (PDG) [6].

## 3. *Canonical theory*

The canonical theory is less predictive. Instead, the empirical established value of the muon's half life is invoked for giving an accurate value for Fermi's constant. The analytical model described in Griffith's book [5] gives as canonically defined result,

$$W = \frac{G_F^2}{192\pi^3} E_0^5 \ .$$

The factor 192 (= 2 x 8 x 12) is the result of integer numerical values that play a role in the analysis. In Griffith's book the factor $G_F$ is deduced as,

$$G_F = \frac{\sqrt{2}}{8}(\frac{g_W}{m'_W})^2 .$$

Herein $g_W$ is an unknown quantum mechanical coupling factor. In the Standard Model this is related to the weak force boson $m'_W$ and the vacuum expectation value $\Phi_0 = \mu_H / \lambda_H$ determined by the parameters of the background field , such that

$$2m'_W = g_W \Phi_0 .$$

This establishes a link between $G_F$ and $\Phi_0$ such that

$$\Phi_0^2 = (G_F\sqrt{2})^{-1} .$$

Unlike in the predictive model described in the previous paragraph, these relations do not allow to calculate the decay time $\tau_\mu$ of the muon. Instead, taking the experimentally measured result of this decay time $\tau_\mu$ (= 2.1969811 × $10^{-6}$ s ) as a reference, the quantities are numerically assigned,

$$G_F = 1.106\ 10^{-5}\ \text{GeV};\ \Phi_0^2 = (G_F\sqrt{2})^{-1} \approx (246\ \text{GeV})^2;\ g_W \approx 0.66.$$

For the sake of completeness it should be noted that in the weak force theory of Glashow, Salam and Weinberg (GSW), this coupling factor $g_W$ is further nuanced.

In the first part of the essay it has been noted that the structural model, as described in the first part of this essay, has a different definition for the coupling factor and what it is based on. Whereas in the Standard Model the coupling is defined as $2m'_W = g_W \Phi_0$ , in the

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structural model the semantics are somewhat different. In the latter model we have $g\Phi_0 = m'_W$ , in which $g$ is taken as the square root of the electromagnetic fine constant $g$ = (√137)$^{-1}$. This gives a different value for $\Phi_0$ . Under maintenance of the vacuum expectation relationship $\Phi_0 = \mu_H / \lambda_H$ , we have different values for the Higgs parameters $\mu_H$ and $\lambda_H$ . In both models, however, we have the same semantics for $\mu_H$ , because of its relationship with the Higgs boson ( $m'_H = (\mu_H \sqrt{2})\hbar c$ [1,5 p. 364]). This makes the value $\lambda_H$ different. In the first part of this essay it has been shown that maintaining an equal value for $\lambda_H$ as well imposes a different definition for $g_W$ such that $gg_W$ = (2√2)$^{-1}$.

## 4. *The second surprise*

The decay process due to weak interaction turned out to have a second unexpected surprise. One would expect that the spin of the electrons in the beta radiation does not favor a polarization direction. After all, there is no immediate plausible physical explanation why electrons in the beta radiation would in this respect not be on par. About 1956, Tsung-Dao Lee and Chen-Ning Yang began to doubt this on the basis of observations of the decay process of the kaon meson. In a scientific review [8] they concluded that the parity of the weak interaction should be questioned. Shortly afterwards, they approached Chen-Siung Wu with the question whether she could provide an experimental answer. Much to the surprise of many, she succeeded. She did so by analyzing the beta radiation released by the radioactivity of the Cobalt-60 atom and found that the electrons in the beta radiation have a left-handed spin. Afterwards, it could be established that this phenomenon occurs in all other decay processes determined by beta radiation. The weak interaction therefore turned out to be a force that, unlike the electromagnetic or the strong interaction, violates the parity of natural forces. The antineutrino that acts as a sister particle of the electron in the decay process, is therefore right-handed and so the the neutrino is left-handed. But whereas the spin of the electron can be influenced outside the decay process, there are no means to do so with the neutrino. Hence, the neutrino is always left-handed!

## 5. *Vacuum polarization*

But why? This question boils down to why the spin of the electrons becomes polarized in the decay process that produces beta radiation. It is not inconceivable that the energetic background field is responsible for this. But in what way can only be made plausible in a hypothetical way. In the first part of this essay it was posited that the quark is a Dirac particle with a special property. It is distinguished from the canonical type, such as that of an electron, in that both anomalous dipole moments are real. In an electron, one of the two (the magnetic) has a real value, but the other (the electric) has an imaginary value. From this a hadron model has been developed in which the quarks are bound together by polarization of the second dipole moment under the influence of a scalar quark potential. To explain the limited scope of the associated nuclear forces, the energetic background field, known in the Standard Model as the Higgs field, has been modeled as a field consisting of elementary polarizable dipoles. This background field limits the range of nuclear forces in a similar way to shielding the field of an electrical pointlike charge in a plasma of ions, as described by

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Debije and Hückel in 1923. With this model, a structural alternative to the Standard Model has been developed in the first part of this essay.

Apart from being a Dirac particle with two real dipole moments, owing to a particular set of gamma matrices, the quark has been shown being a particle whose potential is described with the Maxwell equations. The quark behaves like a magnetic monopole conceived by Eliahu Comay in his Regular Charge Monopole Theory (RCMT) [9,10]. This magnetoelectric theory is the dual form of the electromagnetic Maxwell theory. These magneto-electric fields are unable to influence the electromagnetic fields. Such a particle is therefore electromagnetically neutral. Let us now suppose that the neutrino is such a magneto-electric particle as well, possibly even with a canonic gamma matrix set, hence with a single real dipole moment only. If so, this dipole moment will be subject to polarization by the background field polarized by the quarks. It is conceivable that conservation of angular momentum extends over all angular momenta, i.e. not only over the dipole moments from ordinary electromagnetic origin, but also over the dipole moments of magneto-electric origin. Momentum conservation makes no distinction. If so, the polarization of electrons in the beta radiation is bound to the polarization of the antineutrinos. The neutrino's left-handedness is then no longer a mystery.

The vacuum polarization can be made clear by considering the quark as a magnetic RCMT monopole $Q_{qu}$ in a space charge field $\rho_D(r)$ consisting of small magnetic RCMT dipoles. In that case, the quark's static field can be written as a Poisson equation,

$$\nabla^2\Phi = -\mu_0\rho(r)\,;\;\; \rho(r) = Q_{qu}\delta^3(r) + \rho_D(r)\,.$$

An analysis of the energetic dipole background field to be explained below shows that $\rho_D(r)$ can be written as,

$$\rho_D(r) = \frac{\lambda^2}{\mu_0}\Phi(r)\;\;.$$

Applying it, the Poisson equation can be rewritten to

$$\nabla^2\Phi - \lambda^2\Phi = -\mu_0 Q_{qu}\delta^3(r)\,.$$

In the first part of this essay $\lambda$ has shown up as the decay parameter of the quark's potential field. Moreover, it has been established that this value in the Standard Model is related to the value of the Higgs boson ($\lambda = m'_H / 2\hbar c$).

The modification of Poisson’s equation is allowed by virtue of the relationship between the dipole moment density $\mathbf{P_d}$ and the space charge $\rho_D(r)$, [11],

$$\rho_D(r) = -\nabla\cdot\mathbf{P_d} = -\frac{1}{r^2}\frac{\mathrm{d}}{\mathrm{d}r}\{r^2 P_d(r)\}\;\;.$$

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Since in the static state eventually all dipoles within the range of the source will be polarized, the dipole moment density within this range is constant with value $P_{d0}$ . Hence,

$$\rho_D(r) = -\frac{2P_{d0}}{r} ,$$

and thus shows the same radial dependence as the regular potential profile at small $r$ . Hence,s

$$\rho_D(r) = \frac{\lambda^2}{\mu_0}\Phi(r) = \frac{\lambda^2}{\mu_0}\frac{\mu_0}{4\pi}\frac{Q_{qu}}{r} = -\frac{2P_{d0}}{r} \to 2P_{d0} = -\frac{\lambda^2}{4\pi}Q_{qu} .$$

It implies that the dipole moment density is fixed by the parameter $\lambda$ and the source strength $Q_u$ of the quark. Within the range of the source, the dipoles will be polarized, outside the source the dipole direction will no longer be directed, but will be randomly distributed by entropy in all directions. The number of dipoles per unit of volume will remain the same.

As a result of this process, in the immediate vicinity of a nuclear particle, such as the neutron, the vacuum is polarized. If the quark and neutrinos are RCMT Dirac particles and if the quark has two real dipole moments, the (anti)neutrinos in the decay process from neutron to proton will be polarized by the polarized vacuum particles. Under conservation of angular momentum, the electrons bound to the (anti)neutrinos will be polarized in the decay process as well. The polarization direction is unambiguously fixed. The polarization itself is the special phenomenon. Whether it makes the electrons left-handed and the antineutrinos right-handed is determined by an inherent property of the basic quark.

## 6. *Dark Matter*

Let us proceed by discussing the potential nature of the energetic background field. If an elementary component of the background energy is a Dirac particle of the special type indeed, then it has real RCMT dipole moments. The magnetic dipole moment $\mu_m$ depends on an unknown magnetic charge $q_m$ and an unknown small mass $m_d$ . So,

$$\mu_m = \frac{q_m}{2m_d}\frac{\hbar}{c} .$$

The energetic background field will contain an unknown amount $N$ of such particles per unit volume. With these quantities the density $P_{d0}$ can be expressed as

$$P_{d0} = \lambda^2 \frac{Q_m}{8\pi} = N\mu_m = N\frac{q_m}{2m_d}\frac{\hbar}{c} . \to \frac{q_m}{Q_m} = \frac{\lambda^2}{4\pi N}\frac{m_d c^2}{\hbar c} .$$

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We may relate this ratio to the ratio of $m_d$ to the "naked mass" $m_{qu}$ of the base quark according to,

$$\frac{q_m}{Q_m} = \frac{m_d}{m_{qu}}.$$

These last two expressions allow us to express the bare mass of the quark into,

$$m_{qu}c^2 = m'_{qu} = 4\pi N \frac{\hbar c}{\lambda^2} .$$

As noted above, the decay parameter $\lambda$ is related to the value of the Higgs boson. This value is derived in the frame of the pion. This frame flies almost at the speed of light. This imposes a relativistic correction on $\lambda$. To this end, we first write $\lambda$ as,

$$\lambda = \frac{m'_H}{2\hbar c} = \frac{m'_H}{m'_W}\frac{m'_W}{2\hbar c} .$$

We do so because we not only know the relativistic value $m'_W$ (80.4 GeV) of the weak force boson, but also its non-relativistic value, because (as described in the first part of this essay) this boson condenses as the rest mass of the pion ($m'_\pi \approx 140$ MeV). This allows to correct $\lambda$ to,

$$\lambda = \frac{m'_H}{2\hbar c} = \frac{m'_H}{m'_W}\frac{m'_W}{2\hbar c} \rightarrow \lambda_{corr} = \frac{m'_H}{m'_W}\frac{m'_\pi}{2\hbar c} .$$

The energy value of the “naked” quark mass then becomes

$$m'_{qu} = 4\pi N\hbar c(\frac{2\hbar c}{m'_\pi}\frac{m'_W}{m'_H})^2 .$$

If we knew the quark mass, the density $N$ of energy carriers per unit volume of the background energy could be calculated. On the other hand, if we knew $N$, we would be able to assess the quark’s “naked” mass.

Now it so happens that vacuum polarization is known in cosmology as well. There is an energetic background field that is responsible for the “dark matter” phenomenon. That dark matter causes objects at the edges of galaxies to orbit their kernels with a significantly faster orbital velocity than calculated by Newton's law of gravitation, even so by including corrections based on Einstein's Field Equation. In 1963, Mordehai Milgrom concluded that this in every known galaxy occurs to the same extent. In the absence of an explanation , he formulated an empirical adaptation to Newton's law of gravitation. This adaptation is characterized by an acceleration constant that is equal for all systems. Its value is $a_0 \approx 1.25$ x $10^{-10}$ m/s$^2$. In 1998, Vera Rubin reported another unexpected cosmological phenomenon. She concluded a more agressive expansion rate of the universe than the constant rate assumed on the basis of Einstein's Field Equation. Scientists reconciled the latter phenomenon with theory, by assigning a finite value to Einstein's Lambda ($\Lambda$) in the famous Field Equation, which until then had been assumed to have a value of zero. The consequence of this is that the universe must have an energetic background field. Based on cosmological observations of these two phenomena, it has finally been empirically established that the matter in the universe is divided up into three components $\Omega_B + \Omega_D + \Omega_\Lambda$ = 0.0486 + 0.210 +0.741 = 1, which are, respectively, the ordinary baryonic matter, the unknown dark matter and the unknown dark energy [12]. In [13], it is described how this relationship between these components can be theoretically determined.

The key to this is to revise the view that Einstein's Lambda is the cosmological constant as being a constant of nature. In Einstein's 1916 work on General Relativity, this quantity appears only as a footnote with the remark that an integration constant in the derivationn is set to zero. See the footnote on p. 804 in [14]. Steven Weinberg in 1972 valued this footnote and promoted this integration constant to the Cosmological Constant [15]. Strictly speaking, though, this quantity is a constant in terms of space-time coordinates. It may depend, in theory at least, on coordinate-independent properties of a cosmological system under consideration (a solar system, a galaxy, the universe) like, for example, its mass. In that case, only at the level of the universe it is justified to qualify Einstein's $\Lambda$ as the Cosmological Constant. In [13] the relationship is derived that,

$$\Lambda = \frac{1}{5}\frac{a_0}{M_B G},$$

in which Einstein's $\Lambda$ is found to depend on the gravitational constant $G$, the baryonic mass $M_B$ and on Milgrom's acceleration constant $a_0$. Moreover, it turns out that the latter depends on the relative amount of the baryonic mass $\Omega_B$ in the universe and on its Hubble age $t_H$ (13.6 Gigayears), such that

$$a_0 = \frac{15}{4}\Omega_B \frac{c}{t_H}.$$

This implies It that it is not Einstein's $\Lambda$ to be regarded as the true Cosmological constant, but that this qualification rather applies to Milgrom's acceleration constant. In this theory, the distribution of the three energy elements of the universe can be traced back to a background energy consisting of elementary components with a “gravitational” dipole moment $\mu_G = \hbar / 2c$. Within the sphere of influence of the baryonic mass these are polarized and are by entropy randomly oriented outside it.

Considering that both the nuclear background energy and the cosmological background energy may consist of elementary polarizable components, it would be strange if these components were not the same. The cosmology theory developed in [13] allows to determine the density $N$ of these particles as,

$$N = \frac{a_0}{20\pi G}\frac{2c}{\hbar} \approx 1.5\ 10^{14} \text{ particles per cubic nanometer.}$$

Although at the gravitational level this is an extremely high density, at the nuclear femtometer level ($10^{-15}$ m) sustaining the hypothesis seems falling short. Nevertheless, if $N$ is used to calculate the bare mass of the quark as deduced above, it turns out that

$$m'_{qu} = 4\pi N\hbar c\left(\frac{2\hbar c}{m'_\pi}\frac{m'_W}{m'_H}\right)^2 \approx 1.34 \text{ MeV},$$

which is a realistic value (to be discussed below).

The dilemma disappears by remembering that volumes should be considered at wavelength level. Anyhow, that is what Fermi's theory described earlier in this text has taught us. A mass of 1.34 MeV/$c^2$ corresponds to a De Broglie wavelength of 885 fm. That brings us to the picometer level. This is wide enough to explain the cosmological particle density at the nuclear level as well.

Summarizing: The “naked” mass of the archetype quark as derived in this text depends on six physical quantities. Two of them are generic constants of nature: the vacuum light velocity, and Planck’s constant. Two of them are particle physics related: the mass ratio of the Higgs boson and the weak interaction boson and the rest mass of the pion. Two of them are cosmological: the gravitational constant (a constant of nature) and Milgrom’s acceleration constant (poosibly a constant of nature as well).

## 7. Discussion

The value thus calculated is of the same order of magnitude as the “naked” mass for the quarks, derived in lattice quantum chromodynamics (lattice QCD) [16] from the rest masses of the pion and kaon as $m'_u$ = 2.3 MeV and $m'_d$ = 4.6 MeV for, respectively the $u$ quark and the $d$ quark. “Naked” mass has to be distinguished from “constituent” mass, which can be traced back as the distribution of the hadron’s rest mass over the quarks. Because these rest masses are mainly determined by the binding energy between the quarks, the relative large constituent mass hides the relative small amount of the true physical “naked” mass that shows up after removal of the binding energy component. Lattice QCD is based on the Standard Model with (the heuristic) gluons as the carrier of the color force, the (heuristic) Higgs particle as the carrier of the background energy and an interaction model based on Feynman's path-integral methodology. This methodology is based on the premise that in principle all possible interaction paths between the quarks in space-time matter and that the phase difference in transit time of “probability particles” (as a model of quantum mechanical wave functions) over those paths ultimately determines the interaction effect. Such paths can make more or less coherent contributions or completely incoherent contributions. In lattice QCD, the paths are discretized through a grid. This discretization is not by principle, but only intended to limit the computational work that is performed with supercomputers. The strength of this model is its unambiguity, because it assumes the application of the principle of least action to a Lagrangian (some authors therefore call Lattice QCD a “simple” theory). But it is also the weakness of the model, because the (now very complex) Lagrangian is “tuned” to all phenomenological phenomena observed in particle physics and has been given a heuristic mathematical formulation. It is quite conceivable that physical relationships have been remained hidden under a mathematical mask. A number of examples have been discussed in the two parts of this essay [1].

It might therefore well be that the definition of “naked” mass is model dependent. In the structural model the pion rest mass is the mass reference. In latice QCD both the rest mass of the pion and the rest mass of the kaon serve as reference (in the structural model it is shown that these two rest masses are interrelated). The lattice QCD “naked” mass values are validated from calculation of the proton mass, but, strictly speaking, this validation only shows the mass relation between the pion and the proton. In [17], it shown that the structural model is even more accurate in this respect, particularly taking into account its capability for an accurate calculation of the mass difference between a proton and a neutron. It is quite curious that in the PDG listing of quark masses, the formerly used constituent masses of the $u,d$ and $s$ quark are replaced by “naked” masses, while for the other quarks ($c,b$ and $t$) the constituent values are maintained. Another curiosity is the mass assignment to the $u$ quark and the $d$ quark in the same ratio as their presumed electric charge. This presupposes that the mass origin is electric. But why should it? And if so, why are these mass values not related by an integer factor with the mass of an electron?

The fact that two different models don’t yield exactly the same value for the indirectly determined unobservable "naked" mass of a quark does not necessarily prove the correctness or incorrectness of one the two. In neither of the two models the “naked” mass is used as “the first principle” for mass calculations, because the true mass reference is the rest mass of the pion. As long as comparable precisions are obtained, the value of the naked mass is irrelevant in fact. In the end, Occam's knife is decisive for making a choice.

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