ZITTERBEWEGUNG LEADS TO THE EXPLANATION OF A RECENT EXPERIMENT ON NEUTRINOS NOT EXPLAINABLE BY MEANS CHROMODYNAMICS

by

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Summary

The final bump in the Kurie plot found in the Troitsk neutrino-mass experiments corresponds to a finite value for the decay probability of a neutron into a proton and an electron with no neutrino. It is proposed that the angular momentum balance is satisfied by a zero-point field fluctuation (ZPF) that also leads to a finite probability for such process at the end of the Kurie plot. The three families of neutrinos are considered as trains of electromagnetic (e.m.) waves with different spectrum, caused by the variation of the spin-orbit radii. Neutrinos and ZPF would have therefore the same nature, the same angular momentum, and zero rest-mass. This new interpretation of neutrinos gives a hint for the solar neutrino deficit.

The problem of neutrino rest mass is one of the most important problems in elementary particle physics and, as a consequence, in cosmology. In general there are two possible experimental approaches to estabilish whether neutrinos are massive or not. The direct approach consists in studying the kinematics of the decays where a neutrino (or antineutrino) is supposed to be emitted. The indirect approach consists in looking for processes which are forbidden if neutrinos are massless. We restrict our attention to the result obtained in the direct way during the Troitsk experiments [1, 2], where the spectrometer facilities allowed one to observe details of the tritium beta spectrum at about 5-15 eV below the end point. At present, the lowest limit on the electron-neutrino mass was achieved by studying the shape of the tritium beta decay spectrum near its end-point. In fact, the decay of tritium ($n \to p^+ + e^- + \overline{\nu_e}$) provides a unique opportunity due to a low end-point energy (≈18.6 keV), a high specific activity, the lowest Z value and, moreover, the possibility of calculating most of the corrections for its superallowed spectrum. In addition to a significant reduction of the upper neutrino-mass limit, the experiments in Troitsk revealed the presence of an anomalous bump-like structure at the end of the beta spectrum.

We want to recall that the shape of the beta spectrum with non-zero neutrino (or anti-neutrino) mass can be expressed as [2]:

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$$W(E,Z) = A\,F(E,Z)\,E\,p\sum W_i(E_{0i}-E)\sqrt{(E_{0i}-E)^2-m_\nu{}^2c^4}\,, \qquad (1)$$

where A is a normalization constant, W_i the probability, E_{0i} the end point energy of the partial decay into the i-th final state, *F(E,Z)* the Fermi function, *E* and *p* the total energy and momentum of the electron, respectively.The effect of a non-zero neutrino (or anti-neutrino) mass emerges as a cutoff of the spectrum at the (E_{0i}-*E*) values equal to $m_\nu c^2$. The change in the curvature is particularly evident in the Kurie plot derivable from Eq. (1). Surprisingly enough, the curvature of the end point of Eq. (1) is opposite to that predicted for a positive $m_\nu{}^2$ value, i.e. it corresponds to a negative $m_\nu{}^2$ value. This strange results has been found by many other authors [3, 4] although the accuracy is much smaller than the Troitsk experiment's†. Some authors [4] have also found the same bump (near the end point of Eq. (1)) as clearly found in Ref. [1]. Actually, this bump is very strange and so far not theoretically justified, the only attempt being the one of Lobashev [2] who supposed an interaction with a cloud of neutrinos in our solar system requiring a too much high density of neutrinos. It seems that no reasonable explanation exists in standard chromodynamics (QCD). This difficulty discouraged some people and compelled to think that the observed bump is not physical but instrumental (in particular, this idea occurred during the discussions at TAUP 2001,as reported by F.Gatti). However, there is a series of experiments by Lobashev [2] and other authors [3, 4] who confirmed the existence of the bump. The acceptance of the physical existence would be different if a reasonable explanation could be given, obviously beyond standard QCD. This is that we do in the following.

In a seminar given in Milan, S. L. Glashow suggested that the experimental results of the Troitsk experiment implies a finite cross-section for the forbidden decay

$$n \to p^+ + e^-\,. \qquad (2)$$

In turn, the absence of the antineutrino in the right-hand side of Eq. (2) implies a violation of the angular momentum. In turn, this would imply a violation of Lorentz invariance of the kind examined by Coleman and Glashow [5]. Our suggestion is that the angular momentum conservation is satisfied by a zero-point field (ZPF) fluctuation. Actually, the ZPF corresponds to a half photon per normal mode, each "half" photon having angular momentum $\hbar/2$ (as that of a neutrino). Obviously, this proposal is based on the conviction that the ZPF is real and not virtual. Although not said by Glashow, reaction (2) implies a violation of the lepton number conservation law. We first justify the reality of the ZPF (also eliminating the relevant drawbacks), and then the violation of the lepton number.

In quantum electrodynamics (QED) the ZPF arises in second quantization from commutation rules. The ZPF can also be renormalized in the flat, pseudo–Euclidean space, so that some authors consider it as virtual. Without renormalization, the ZPF energy density would be infinite. But even if we truncate its power spectral density to the Compton frequencies of the heaviest discovered particles (the top quark), its effect on a free charged particle in vacuum would be catastrophic. In fact, as already shown by Einstein, the kinetic energy of a charged harmonic oscillator immersed in a stochastic electromagnetic (e.m.) field (as should be the fluctuations of the ZPF), should increase proportionally to time t [6]. However, as the velocity of the particle acquires a finite value with respect to the reference

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† During the Troitsk experiments a strange seasonal effect was also evidenced. Even if the authors [2] claim a correct stabilization of their electronic apparatus, we are still in doubt since the strongest variations occurred during the months when the power supply line was overloaded.

system S_0 for which the e.m. field is isotropic, a friction force $\boldsymbol{F}$ arises. As calculated by Einstein and Hopf [7], if *m* and *e* are the electron mass and charge, respectively, of the oscillator translating with velocity $\boldsymbol{V}$ having proper angular frequency ω_0, the friction force turns out to be expressed by

$$\boldsymbol{F} = -\frac{4}{5}\pi^2 e^2 \boldsymbol{V}\,(mc^2)^{-1}\left\{\rho(\omega_0) - \frac{1}{3}\omega_0 \left|\frac{d\rho}{d\omega}\right|_{\omega=\omega_0}\right\}, \tag{3}$$

where *c* is the speed of light and $\rho(\omega)$ the power spectral density of the e.m. stochastic field. In a cavity, equilibrium is reached if $\rho(\omega)$ is the Planck spectrum. But the spectrum of the ZPF is

$$\rho_0(\omega) = \left(\frac{\omega^2}{\pi^2 c^3}\right)\left(\frac{\hbar\omega}{2}\right), \tag{4}$$

where the first factor gives the modes density and the second factor the average energy per normal mode (the "half" photon). Substituting Eq. (4) into Eq. (3) gives $\boldsymbol{F}=0$, i.e. no friction force. Consequently, the kinetic energy should increase up to a huge value, only limited, in free space, by the cosmic background microwave (CBM) radiation at 2.728 K. The Einstein-Hopf Eq. (3) has been generalized by Rueda [8] so as to be applicable to a monopolar particle as a free electron. Now, calculations [9] show that an electron in a TV set should become a high energy cosmic ray. That is why some people consider the ZPF as virtual since,in order to find agreement with experiments, it must be eliminated by means of a renormalization.

Other authors, even orthodox electrodynamicists, have good reasons to consider the ZPF as real. It is the ZPF that causes the originally called "spontaneous"decays of the excited states and the radiative corrections, as the Lamb shift and the anomaly of the gyromagnetic ratio for electrons and muons. It is the Casimir effect [10] that mainly lends support to the reality of the ZPF. The attraction betweent two plates in vacuum with a force inversely proportional to the fourth power of their mutual distance *d*, is easily explained by the e.m. pressure of the ZPF on the outer faces of the two plates because the ZPF is screened inside them at least for wavelengths $\lambda \geq d$. The QED renormalization leaves the differences between the ZPF free value and the one modified by the boundary conditions inside the plates.

An awful problem in QED is that the ZPF is not renormalizable in a Riemannian space. Even if truncated at high frequencies, the introduction of ZPF in the stress-energy-momentum tensor (acting as a known source in Einstein's equations of general relativity) would predict a universe closed in few microns. The implied error is of 120 orders of magnitude [11]. The ZPF remains therefore the fundamental problem in both QED and general relativity.

A solution to the above problem comes from stochastic electrodynamics with spin [12]. The spin of a particle can not be thought of as a rotation of the particle around its own centre-of-mass axis because the angular momentum would be six order of magnitude smaller even if we take the speed of light *c* as the peripheral speed of the spherical particle with radius R and the maximum value for R allowed by the LEP scattering experiments [13]. Spin must rather be conceived as a motion of revolution at the speed of light of an almost point-like electron, according to the solution of the Dirac equation as given by Barut and Zanghi [14]. An interpretation of this motion as due to the self reaction has been recently given in a new theory assuming filaments as the ultimate constituents of both particles and fields [15]. Once one has this motion (called zitterbewegung by Schroedinger), he can derive the Schroedinger equation [16] and also special relativity which arises from the fact that one usually refers not to the actual motion of a particle but to the centre of its motion of revolution (that leads to the spin properties) [17]. The frequency ω_e of the electron spin motion is rather monochromatic and, since the universe is uniform on the large scale and in expansion, a uniform distribution of electrons with density N_e brings about a stochastic e.m. field whose power spectral density turns out to be given by [17]:

$$\rho_e(\omega) = \frac{N_e}{H} P_{rad} \frac{\omega^3}{\omega_e{}^4} \theta(\omega_e - \omega), \tag{5}$$

where H is the Hubble constant, P_{rad} the power radiated because of the spin motion, $\theta(x)=1$ for $x>0$ and $\theta(x)=0$ for $x<0$. As a percentage, the charged particles in the universe are practically electrons and the quarks up and down in protons and neutrons whose spin frequencies we denote by ω_u and ω_d respectively. Consequently, there are three ω^3 ramps, each truncated at the corresponding spin frequency. Finally, there are the quantum fluctuations at the Planck frequency ω_P so that the complete power spectral density of the real ZPF can be written as suggested in Ref. [18]:

$$\rho_e(\omega) = \frac{\hbar\omega^3}{2\pi^2 c^3}\left[\theta(\omega_e - \omega) + \frac{N_u}{N_e}\left(\frac{\omega_e}{\omega_u}\right)^2 \theta(\omega_u - \omega) + \frac{N_d}{N_e}\left(\frac{\omega_e}{\omega_d}\right)^2 \theta(\omega_d - \omega)\right] + \frac{\hbar\omega_e{}^4}{\pi^2 c^3 \omega_P} \exp\left[-\frac{(\omega-\omega_P)^2}{2\omega_P{}^2}\right], \tag{6}$$

where N_u and N_d are the average number densities of the up and down quarks, respectively. For $\omega < \omega_e$ the contribution to $\rho(\omega)$ is almost equal to one given by Eq. (5) and the central values of N_e and H (in the ≈30% present dispersion) lead to $\hbar\left(2\pi^2 c^3\right)^{-1}$ appearing in Eq. (6) [17]. Actually, it was proposed in Ref. [17] to use Eq. (5) in the reversed way, i.e. to obtain a relation between the Hubble constant H and the average density N_e of electrons in the universe so as to improve the knowledge of their true values. The $\rho(\omega)$ expressed by Eq. (6) is finite as well as its integration over ω from 0 to ∞. One of the drawbacks of a non-renormalized ZPF is therefore overcome.

The second drawback, i.e. the huge acceleration an electron should undergo from a real ZPF, is solved because of two reasons. The first one is that $\rho(\omega)$ strongly decreases at the end of any ω^3 ramp and its integration is finite so that the acceleration (due to Einstein-Boyer-Rueda mechanism [6]) of an electron is partially quenched. The second reason, much more important, is that the equation of motion, in non-relativistic approximation and neglecting the radiation, is still strongly different from Newton expression $m\boldsymbol{a}=\boldsymbol{F}$, and turns out to be given by [17]

$$m_* \boldsymbol{a} = (\boldsymbol{F} \cdot \hat{\boldsymbol{n}})\, \hat{\boldsymbol{n}}, \tag{7}$$

where $\hat{\boldsymbol{n}}$ is the spin axis unit vector and m_* the inertial mass when $\hat{\boldsymbol{F}} = \hat{\boldsymbol{n}}$ (indeed, in this case Eq. (7) reduces to $m_* \boldsymbol{a} = \boldsymbol{F}$). When $(\boldsymbol{F} \cdot \hat{\boldsymbol{n}}) = 0$ there is no net acceleration for the centre of the spin revolution since the curvature of the electron trajectory increases during half circle and decreases in the subsequent half circle. When an e.m. wave impinges on an electron, the electric field produces a velocity $\delta\boldsymbol{v} \propto \hat{\boldsymbol{n}}$ variation so that the additional acceleration due to the Lorentz force vanishes since

$$\delta\boldsymbol{F}_L \cdot \hat{\boldsymbol{n}} = \boldsymbol{e}\delta\boldsymbol{v} \times \boldsymbol{B} \cdot \hat{\boldsymbol{n}} \propto \boldsymbol{e}\, \hat{\boldsymbol{n}} \times \boldsymbol{B} \cdot \hat{\boldsymbol{n}} = 0. \tag{8}$$

Only when $\hat{\boldsymbol{n}}$ precesses $\delta\boldsymbol{F}_L$ is no longer zero. The Einstein-Boyer-Rueda mechanism of acceleration of an electron in the ZPF is strongly reduced since an electron with spin is only sensitive to the ZPF frequency roughly equal to its precession frequency. This mechanism can still justify the existence of the most energetic cosmic rays but the acceleration requires some thousand (or million) light years in the intergalactic space.

The solution of the above two drawbacks allows one to avoid the renormalization of the ZPF that, as already said, can not be renormalized in a Riemannian space. However, the awful drawback, affecting Einstein's equations of general relativity, remains. Here also the solution comes from the filament theory [15] that leads to a fully unified field theory of electromagnetism and gravitation. The gravitational field $\boldsymbol{E_g}$ turns out [18] to be proportional to the gradient of the number density N (per unit area) of the filaments. This new gravitational theory, intrinsically unified with electromagnetism, predicts [18] the same effects of general relativity up to the second order in GM/rc^2 for a spherical massive body but gives a zero effect for the ZPF since the space density of the ZPF is uniform in space so that its gradient vanishes. The presence of a real, non-renormalized ZPF has therefore no drawbacks even in a Riemannian space. Concluding the main part of our paper we can state that the ZPF is real, is necessary for QED, any normal mode of it has an energy $\hbar\omega/2$ and an angular momentum $\hbar/2$ so that it can stimulate the beta decay and cause a finite cross section for the decay of a neutron into a proton and an electron without neutrino, the angular momentum balance being satisfied with a ZPF fluctuation.

The justification of the lepton number violation is natural in our model (stochastic electrodynamics SED with spin). The same three elementary particles are considered to be an electron (or a positron) if in equilibrium (between radiated and absorbed power in its spin-revolution motion) with the first ω^3 ramp of Eq. (6), a μ meson if in equilibrium with the second ramp, a τ particle if with the third, and a $W^{\pm}$ vector boson if with the quantum gravity fluctuations (last term of Eq. (6)). It would therefore be explained why there are three families of leptons plus the massive exchange particles for the electroweak interactions (fully unified with electrodynamics in SED with spin). The three charged leptons (with their three antiparticles) would be the same particle with different radii R_s of their spin-revolution orbits. The equilibrium between absorption and radiation is satisfied only for the average value of a given R_s but when R_s increases, for instance with a factor 206, from the one of the μ meson to the electron's, there is a net wide spectrum of radiation we suggest to be the neutrino.In other words, electrons and the two kinds of quarks in a proton (at present the most numerous particles in the universe) bring about the ZPF normally, when they perform no transition from one to the other. A transition from a more energetic particle to another (that is from one having a small spin orbit radius R_s to another with a larger R_s) would be a neutrino emission (and vice versa an absorption in the opposite transition). Consequently, both the ZPF and neutrinos are e.m. waves, monocromatic for each mode of the ZPF and with a wide spectrum for neutrinos (that is why neutrinos have very small cross-sections). Concluding, ZPF and neutrinos have the same nature (e.m. waves) and the same angular momentum $\hbar/2$ so that they are fully interchangeable in the decay (2) that is actually

$$n \to p^+ + e^- + ZPF \tag{9}$$

near the end of the Kurie plot while for more energetic e.m. waves it is the usual $n \to p^+ + e^- + \overline{\nu_e}$. It is shocking to consider the ZPF acting as a lepton but the fact that its spin is $\hbar/2$ implies that it must be included in the Fermions. Actually, if it were a Boson it would undergo the Bose-Einstein condensation at T=0, as recently emphasized by Kakazu [19] . On the contrary, the ZPF has the spectrum given by Eq. (4) which is typical of a Fermion. Moreover, the neutrino helicity corresponds to either left-hand or right-hand polarization of the one of the two modes (for a given ω) of the ZPF. Concluding, the "complete" Eq. (9) satisfies both angular momentum and lepton number conservation, differently from the "incomplete" Eq. (2) suggested by Glashow.

If the above interpretation for the neutrino is correct, then there is a clear explanation of the solar neutrino deficit. An e.m. radiation is more or less absorbed when crossing a medium. If the medium is a collisionless plasma, there would be no absorption if the e.m. wave frequency is larger than the plasma frequency. If the collision frequency between the particles of the plasma is an appreciable fraction of the e.m. wave angular frequency ω, then there is an appreciable absorption, since the plasma becomes slightly resistive (while without collisions it is purely inductive). This is the case of the Sun where an absorption with a factor 2/3 (for the neutrinos crossing it) is quite reasonable for an e.m. wave having a spectrum between the electron and μ meson Compton frequency. All the neutrinos would have a zero rest mass and the solar deficit would not require the "ad hoc" assumed neutrino oscillations.

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