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Solar flares, solar neutrinos and ν_e-induced β-decays

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The evolution equation for the electron neutrino flux traveling in the Sun is examined. Consideration would hold for any standard model extensions having massive neutrinos. It is conjectured that the neutrino possesses both dipole magnetic and anapole moments while the solar magnetic field has twisting nature. Factors influencing on the electron neutrino flux, crossing a region of solar flares (SF's) are defined.

It is shown, that under passage of the electron neutrino flux through the region of the SF, three phenomena could be detected by the terrestrial observer. They are as follows: (i) decreasing the number of the electron neutrinos; (ii) appearance of the $\overline{\nu}_{eL}$- and $\overline{\nu}_{XL}$-neutrinos; (iii) reduction of the β-decay rate for some elements of the periodic table.

Decreasing the β-decay rates is explained by the hypothesis of the ν_e-induced β-decays. If this hypothesis holds then some nuclides with the ν_e-induced radioactivity could serve as real-time neutrino detectors.

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1. Introduction

At the end of 2002 as consequence of series of experiments with solar, atmospheric and reactor neutrinos the existence of the neutrino oscillations has been established. This, in turn, meant that the neutrino has a mass and the partial lepton flavor violation takes place. Neutrinos also find a use for solution of applied problems as evidenced by the application of antineutrino detectors for nuclear reactor monitoring in the "on-line" regime and the appearance of a neutrino geotomography [1]. All this puts forward the neutrino physics in the forefront of natural sciences. However, in spite of achieved progress, there are series of unsolved problems in the neutrino physics. Among these, for example, are: (i) the values of the neutrino dipole magnetic and anapole moments; (ii) the neutrino nature (Dirac or Majorana).

In this work we are going to present the basic concepts of neutrino physics. We shall consider the motion of the neutrino flux in condensed matter and a twisting magnetic field. Our treatment of the problem holds for any standard model extensions with massive

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neutrinos. The evolution equation of the neutrino system will be found. Mechanism of resonant conversions between different kinds of neutrinos will be explained. In conclusion we shall discuss the influence of the solar flares on the neutrino flux motion and show whether it is possible to predict powerful solar flares.

2. Neutrino electromagnetic properties

For neutrinos the connection between the flavor and mass eigenstate bases, $\Psi^f(x)$ and $\Psi^m(x)$, will look like

$$\Psi^f(x) = \begin{pmatrix} \nu_{eL}(x) \\ \nu_{\mu L}(x) \\ \nu_{\tau L}(x) \end{pmatrix} = \mathcal{U}\Psi^m(x) = \mathcal{U} \begin{pmatrix} \nu_1(x) \\ \nu_2(x) \\ \nu_3(x) \end{pmatrix}, \qquad (1)$$

with

$$\mathcal{U} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix}$$

,

where $c_{ik} = \cos\theta_{ik}$, $s_{ik} = \sin\theta_{ik}$, θ_{ik} is the mixing angle between the i and k neutrino generations, and δ is a CP-phase.

Neutrinos are neutral particles and their total Lagrangian does not contain any multipole moments (MM's). The appearance of them is caused by the neutrino interaction with the vacuum whose structure is governed by the choice of the model of electroweak interactions. For a Dirac neutrino the most general form of the matrix element for the conserved neutrino electromagnetic current J_μ^{em} is given by the expression

$$< \nu_i^D(p')|J_\mu^{em}|\nu_j^D(p) > = < \nu_i^D(p')|i\sigma_{\mu\lambda}q^\lambda[F_M(q^2) + F_E(q^2)\gamma_5] +$$
$$+ (q^2\gamma_\mu - q_\mu\hat{q})[F_V(q^2) + F_A(q^2)\gamma_5]|\nu_j^D(p) >, \qquad (2)$$

where $q = p' - p$, $F_M(q^2)$, $F_E(q^2)$, $F_A(q^2)$ and $F_V(q^2)$ are magnetic, electric, anapole and reduced Dirac formfactors. In static limit ($q^2 = 0$) $F_M(0)$ and $F_E(0)$ define dipole magnetic moment (DMM) μ_{ij} and dipole electric moment (DEM) d_{ij}, respectively. At $i = j$, $F_A(0)$ represents the anapole moment.

For a Majorana neutrino from the CPT invariance it is evident that all the formfactors, except the axial one F_A, are identically equal to zero. As regards non-diagonal elements, the situation depends on the fact whether CP-parity is conserved or not. For the CP non-variant case all the four formfactors are nonzero. When CP invariance takes place and the $|\nu_i^M>$ and $|\nu_j^M>$ states have identical (opposite) CP-parities, then $(F_E)_{ij}$ and $(F_A)_{ij}$ ($(F_M)_{ij}$ and $(F_V)_{ij}$) are different from zero.

The most sensitive and established method for the experimental determination of the neutrino DMMs is provided by direct laboratory measurements of electron (anti)neutrino-electron elastic scattering at low energies. At the moment the world best limit on neutrino DMM is coming from the GEMMA experiment [2]

$$\mu_{\nu_e} \leq 2.9 \times 10^{-11}\mu_B \qquad (90\% \text{ C.L.}). \qquad (3)$$

The theoretical predictions of the minimally extended standard model (MESM) are very far from upper experimental bounds. The diagonal and non-diagonal matrix elements of the neutrino DMM are determined by the expressions [3]:

$$\mu_{\nu_i} \equiv \mu_{\nu_i\nu_i} = \frac{3G_F m_e m_{\nu_i}}{4\sqrt{2}\pi^2}\left[1 - \frac{1}{2}\sum_a U^\dagger_{ia}U_{ai}\epsilon_a\right]\mu_B, \qquad (4)$$

$$\mu_{\nu_i\nu_{i'}} = -\frac{3G_F m_e}{16\sqrt{2}\pi^2}(m_{\nu_i} + m_{\nu_{i'}})\sum_a U^\dagger_{ia}U_{ai'}\epsilon_a\mu_B, \qquad (5)$$

where

$$\epsilon_a = \left(\frac{m_a}{m_W}\right)^2, \qquad a = e, \mu, \tau.$$

From these it follows

$$\mu_{\nu_i} = 3.2 \times 10^{-19}\mu_B\left(\frac{m_{\nu_i}}{1\ \text{eV}}\right), \qquad \mu_{\nu_i\nu_i'} \approx 10^{-4}\mu_{\nu_i}.$$

So, in the MESM the neutrino DMMs are negligibly small.

It will be recalled that the left right symmetric model LRM [4] predicts the neutrino DMM values close to the experimental bounds [5]. As far as the neutrino anapole moment (AM) is concerned, calculations fulfilled within the MESM give the results [6]

$$a_{\nu_e} \approx 8 \times 10^{-34}\text{cm}^2, \quad a_{\nu_\mu} \approx 14 \times 10^{-34}\text{cm}^2, \quad a_{\nu_\tau} \approx 17 \times 10^{-34}\text{cm}^2.$$

3. Equation of the neutrinos flux evolution

In two-flavor approximation ($\nu_e\nu_\mu$-mixing) for the stationary states, the evolution equation is

$$i\frac{\partial}{\partial t}\nu_i(\mathbf{r}, t) = \mathcal{H}\nu_i(\mathbf{r}, t), \qquad (6)$$

where $i = 1, 2$ and

$$\mathcal{H} = \begin{pmatrix} E_1 & 0 \\ 0 & E_2 \end{pmatrix},$$

In ultrarelativistic case ($|\,\mathbf{p}\,| \approx E$) $\mathcal{H}$ takes the view:

$$\mathcal{H} = |\,\mathbf{p}\,| + \frac{1}{2\,|\,\mathbf{p}\,|}\begin{pmatrix} m_1^2 & 0 \\ 0 & m_2^2 \end{pmatrix} = \mathcal{H}_d - \frac{\Delta m_{12}^2}{4\,|\,\mathbf{p}\,|}\sigma_3, \qquad (7)$$

where

$$\Delta m_{12}^2 = m_1^2 - m_2^2, \qquad \mathcal{H}_d = \left(|\,\mathbf{p}\,| + \frac{m_1^2 + m_2^2}{4\,|\,\mathbf{p}\,|}\right)I,$$

I is the unit matrix. In a one-dimensional case we have

$$z_i = v_i t \approx (1 - \frac{m_i^2}{E^2})t \approx t = z,$$

and evolution equation could be rewritten as follows:

$$i\frac{d}{dz}\nu_i(z) = \mathcal{H}\nu_i(z), \qquad (8)$$

where we have denoted $\nu_i(z, z) \equiv \nu_i(z)$.

Since the Lagrangians have been written in the flavor basis, then in all experiments we deal with the electron, muon, and tau neutrinos . For this reason, we should pass on to the flavor basis in the evolution equation

$$i\frac{d}{dz}\nu_l(z) = \mathcal{H}'\nu_l(z), \tag{9}$$

where the new Hamiltonian $\mathcal{H}' = UHU^{-1}$ is

$$\mathcal{H}' = \mathcal{H}_d + \frac{\Delta m_{12}^2}{4E}\begin{pmatrix} -\cos 2\theta_0 & \sin 2\theta_0 \\ \sin 2\theta_0 & \cos 2\theta_0 \end{pmatrix} \tag{10}$$

Accounting for the fact that $\mathcal{H}'$ does not depend on z, we find

$$\nu_l(z) = \exp\left(-i\mathcal{H}'z\right)\nu_l(0), \tag{11}$$

where

$$\nu_e(0) = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \qquad \nu_\mu(0) = \begin{pmatrix} 0 \\ 1 \end{pmatrix}.$$

By virtue of the fact that the quantity proportional to I in $\mathcal{H}$ leads to a common phase for all flavors and only the squared module of the wave function has a physical sense, then $\mathcal{H}_d$ in (10) may be omitted. Note that from Eq. (10) it follows

$$\tan 2\theta_0 = \frac{2\mathcal{H}'_{12}}{\mathcal{H}'_{22} - \mathcal{H}'_{11}}. \tag{12}$$

The inclusion of the neutrino interaction with matter particles will be the next stage of our analysis. The basic idea of our approach consists in the reduction of the totality of the neutrino interactions in matter to the motion in a field with a potential energy. Therefore, the interaction of the neutrino beam with matter is described by the interaction Lagrangian

$$\mathcal{L}_{int} = \mathcal{L}_{eff}^c + \mathcal{L}_{eff}^n = -\sum_l \nu_{lL}^\dagger(x)V_{\nu_l}\nu_{lL}(x), \tag{13}$$

where

$$V_{\nu_e} = \sqrt{2}G_F\left(N_e - \frac{1}{2}N_n\right), \qquad V_{\nu_\mu} = -\frac{1}{\sqrt{2}}G_F N_n,$$

and N_e (N_n) is an electron (neutron) density. Employing the expressions for the free and interaction Lagrangians we get

$$i\frac{d}{dz}\nu_l(z) = \mathcal{H}(z)\nu_l(z), \tag{14}$$

$$\mathcal{H}(z) = E + \frac{m_1^2 + m_2^2}{4E} - \frac{1}{\sqrt{2}}G_F N_n(z) + \frac{\tilde{M}^2}{2E}, \tag{15}$$

$$\tilde{M}^2 = \frac{1}{2}\begin{pmatrix} -\Delta m^2\cos 2\theta_0 + 2A & \Delta m^2 \sin 2\theta_0 \\ \Delta m^2 \sin 2\theta_0 & \Delta m^2\cos 2\theta_0 \end{pmatrix}, \qquad A = 2\sqrt{2}G_F E N_e.$$

The effective mixing angle of the neutrino in matter is given by the expression

$$\tan 2\theta_m = \frac{2\mathcal{H}_{12}}{\mathcal{H}_{22} - \mathcal{H}_{11}} = \frac{\Delta m^2 \sin 2\theta_0}{\Delta m^2\cos 2\theta_0 - A},$$

or

$$\sin^2 2\theta_m = \frac{(\Delta m^2)^2 \sin^2 2\theta_0}{(\Delta m^2 \cos 2\theta_0 - A)^2 + (\Delta m^2)^2 \sin^2 2\theta_0}. \tag{16}$$

So in matter with variable electron density the dependence of θ_m on N_e has a resonance character. When $A = \Delta m^2 \cos 2\theta_0$ the mixing angle in matter reaches its maximum value $\pi/4$. At the resonance point we observe a levels crossing phenomenon which is well known from quantum mechanics. Equaling corresponding diagonal Hamiltonian elements we get the condition at which the resonance transition $\nu_e \to \nu_\mu$ takes place

$$H_{11} - H_{22} = -\Delta m^2 \cos 2\theta_0 + 2A - \Delta m^2 \cos 2\theta_0 = 0.$$

Because $\mathcal{P}_{\nu_e\to\nu_\mu}$ is the quantity that is proportional to the differential cross section of the reaction $\nu_e e^- \to \nu_\mu e^-$, then at the resonance its behavior is described by the Breit–Wigner formula

$$\mathcal{P}_{\nu_e\to\nu_\mu} = \frac{\text{const}}{[N_e(z) - N_R]^2 + \Gamma^2} \tag{17}$$

where $\Gamma = \delta N_e$ is the resonance width being equal to $N_R \tan 2\theta_0$. Therefore, when moving the electron neutrino flux in matter with a variable density, the sharp increase of the transition probability between the neutrino states with different flavor states takes place. This effect is called Micheev-Smirnov-Wolfenstein (MSW) resonance.

Now we are going to consider an evolution of the neutrino system taking into consideration effects of neutrino interaction both with the solar matter and with its magnetic field. A magnetic field is characterized by geometrical phase, $\Phi(z)$, defined by

$$B_x \pm iB_y = B_\perp e^{i\Phi(z)}$$

and its first derivative $\dot\Phi(z)$. A magnetic field above and under a solar spot has non-potential character

$$(\text{rot } \mathbf{B})_z = 4\pi j_z$$

The data concerning centimeter radiation above a spot testify of a gas heating up to the temperatures of a coronal order. Thus, for example, at the height $\sim 2 \cdot 10^2$ km the temperature reaches the values of the order of 10^6 K, which results in a great value of solar plasma conductivity ($\sigma \sim T^{3/2}$). That allows to suppose, that j_z might be large enough in a region above a spot.

Let us consider Majorana neutrino system consisting of ν_{eL}, ν_{XL} and their anti-particles $(\nu_{eL})^c, (\nu_{XL})^c$. As $(\nu_L)^c$ are right-handed neutrino, further on we shall use for them following notions $\overline{\nu}_L$. The evolution equation for $\Psi^T = (\nu_{eL},\ \nu_{XL},\ \overline{\nu}_{eL},\ \overline{\nu}_{XL})$ will be

$$i\frac{d}{dz}\Psi = \mathcal{H}\Psi, \tag{18}$$

$$\mathcal{H} = \begin{pmatrix} \mathcal{H}_{\nu\nu} & \mathcal{H}_{\nu\overline{\nu}} \\ \mathcal{H}^\dagger_{\nu\overline{\nu}} & \mathcal{H}_{\overline{\nu}\overline{\nu}} \end{pmatrix},$$

$$\mathcal{H}_{\nu\nu} = \begin{pmatrix} \delta_c^{12} + V_{eL} + 4\pi a_{\nu_e\nu_e} j_z & -\delta_s^{12} + 4\pi a_{\nu_e\nu_X} j_z \\ -\delta_s^{12} + 4\pi a_{\nu_X\nu_e} j_z & -\delta_c^{12} + V_{XL} + 4\pi a_{\nu_X\nu_X} j_z \end{pmatrix},$$

$$\delta^{12}_{c(s)} = \frac{m_1^2 - m_2^2}{4E}\cos 2\theta_\nu (\sin 2\theta_\nu), \qquad V_{eL} = \sqrt{2}G_F(N_e - N_n/2),$$

$$V_{XL} = -\sqrt{2}G_F N_n/2, \qquad \mathcal{H}_{\nu\overline{\nu}} = \begin{pmatrix} 0 & \mu_{\nu_e\overline{\nu}_X} B_\perp e^{i\Phi} \\ -\mu_{\nu_e\overline{\nu}_X} B_\perp e^{i\Phi} & 0 \end{pmatrix},$$

$$\mathcal{H}_{\overline{\nu}\ \overline{\nu}} = \mathcal{H}_{\nu\nu}(V_{lL} \to -V_{lL}, j_z \to -j_z), \qquad X = \mu, \tau.$$

In Eq.(18) one should get rid of imaginary part in Hamiltonian. It is achieved by transformation to reference frame (RF), rotating at the same angle speed as a magnetic field. A Hamiltonian in this RF follows from the initial one by a replacement

$$e^{\pm i\Phi} \longrightarrow 1, \qquad V_{eL,R} \longrightarrow V_{eL,R} \mp \frac{\dot{\Phi}}{2}$$

Now we discuss the possible resonance conversions for left-handed electron neutrino. Equaling the corresponding diagonal elements of the Hamiltonian we get two resonance conditions:

(i) $\nu_{eL} \leftrightarrow \nu_{XL}$-resonance (Micheev-Smirnov-Wolfenstein (MSW) resonance), which is realized at the condition

$$\Sigma_{\nu_e\nu_X} = 2\delta_c^{12} + V_{eL} + 4\pi(a_{\nu_e\nu_e} - a_{\nu_X\nu_X})j_z = 0 \qquad (19)$$

with the transition width

$$\delta N_e(\nu_{eL} \to \nu_{XL}) \sim [(N_e)_R - 4\pi(\sqrt{2}G_F)^{-1}(a_{\nu_e\nu_e} - a_{\nu_X\nu_X})j_z] \tan 2\theta; \qquad (20)$$

(ii) $\nu_{eL} \leftrightarrow \overline{\nu}_{XL}$ resonance with flavor and spin flipping occurs at the condition

$$\Sigma_{\nu_e\overline{\nu}_X} = 2\delta_c^{12} + V_{eL} + V_{XL} + 4\pi(a_{\nu_e\nu_e} + a_{\nu_X\nu_X})j_z + \dot{\Phi} = 0, \qquad (21)$$

with the resonance transition width

$$\delta N_e(\nu_{eL} \to \overline{\nu}_{XL}) \sim \frac{2\mu_{\nu_e\overline{\nu}_X} B_\perp (N_e)_R}{2\delta_c^{12} + 4\pi(a_{\nu_e\nu_e} + a_{\nu_X\nu_X})j_z + \dot{\Phi}}. \qquad (22)$$

Note that the $\nu_{eL} \to \overline{\nu}_{eL}$-resonance is forbidden for Majorana neutrino because of $\mathcal{H}_{\nu_e\overline{\nu}_e} = 0$. In the case of Dirac neutrino we have

$$\mathcal{H}_{\nu\overline{\nu}} = \begin{pmatrix} \mathcal{H}_{\nu_e\overline{\nu}_e} & \mathcal{H}_{\nu_e\overline{\nu}_X} \\ \mathcal{H}_{\nu_e\overline{\nu}_X} & \mathcal{H}_{\nu_X\overline{\nu}_X} \end{pmatrix} = \begin{pmatrix} \mu_{\nu_e\overline{\nu}_e} B_\perp e^{i\Phi} & \mu_{\nu_e\overline{\nu}_X} B_\perp e^{i\Phi} \\ \mu_{\nu_e\overline{\nu}_X} B_\perp e^{i\Phi} & \mu_{\nu_X\overline{\nu}_X} B_\perp e^{i\Phi} \end{pmatrix},$$

and $\nu_{eL} \leftrightarrow \overline{\nu}_{eL}$-resonance is allowed at the condition

$$\Sigma_{\nu_e\overline{\nu}_e} = V_{eL} + 4\pi(a_{\nu_e\nu_e} - a_{\overline{\nu}_X\overline{\nu}_X})j_z = 0. \qquad (23)$$

In the MESM the resonances $\nu_{eL} \to \overline{\nu}_{eL}$ and $\nu_{eL} \to \overline{\nu}_{XL}$ have zero transition widths and, as a result, they are unobservable. The MSW resonance occurs before the convective zone while $\nu_{eL} \to \overline{\nu}_{XL}$ and $\nu_{eL} \to \overline{\nu}_{eL}$ resonances could take place only at upper layer of solar atmosphere in the sufficiently intensive magtic field.

4. Solar flares and related phenomena

The solar flares (SF) comprises the most powerful of all the solar activity events. The energy evolved during the SF could be as large as 10^{32} erg. It is now widely accepted that the magnetic field provides a main energy source of the SF's. A popular mechanism of the SF appearance [7] is based on breaking and reconnection of magnetic field strength lines of neighboring spots (the magnetic reconnection model — MRM).

By virtue of the MRM, a change of magnetic field configuration in a sunspots group of fairly opposite polarity might result in the appearance of an limiting strength line being common for whole group. Throughout the limiting line the redistribution of magnetic fluxes proceeds, which is necessary for magnetic field to have the minimum energy. The limiting strength line rises from photosphere to the corona. From the moment of this line appearance an electric field induced by magnetic field variations, causes current along the line, which due to the interaction with a magnetic field, takes a form of a current layer. As the current layer prevents from the magnetic fluxes redistribution, the process of magnetic energy storage of the current layer begins. Duration of appearance and formation period of the current layer (initial SF phase) varies from several to dozens of hours. The second stage has a time interval of 1-3 minutes. At this stage magnetic energy of sunspots transforms into kinetic energy of matter emission (at a speed of 10^6 m/s), into energies of hard electromagnetic radiation and into fluxes of solar cosmic rays. The concluding stage is characterized by existence of high temperature coronal region and can continue for several hours.

The high-power SF's can be especially destructive when they prove to be aimed at the Earth, hitting the planet directly with powerful charged particles. Such SF's are potentially dangerous for satellites, power grids and astronauts. It is obvious that the challenge is to predict the SF at the initial phase.

In recent years a number of articles, presenting evidence that some β-decay rates are variable, have been published. The hypothesis was offered that this changeability may be connected with variations of the solar neutrino flux — hypothesis of the ν_e-induced β-decays (see, for review, Ref.[8]). In so doing, variations of the solar neutrino flux could be caused by the SF's, changing Earth's orbit around the Sun, and changing in solar rotation. It should be recalled that for the first time the idea about variations of the solar neutrino flux which passes the region of the SF has been suggested in the works [9].

Let us centre on the case of the SF's. If the hypothesis of the ν_e-induced β-decays (Hν_eIBD) holds, that is, decreasing the β-decay rates is really caused by reduction of the solar neutrino flux, it is reasonable to suggest that $\nu_{eL} \to \overline{\nu}_{XL}$- and $\nu_{eL} \to \overline{\nu}_{eL}$-resonances happen strictly during the SF. After leaving from the solar surface the neutrino flux flies 150,000,000 km in a vacuum before it will reach the Earth. In this case weakening the electron neutrino flux is motivated by vacuum oscillations (VO's). Note, that VO's lead solely to $\nu_{eL} \to \nu_{XL}$ transitions. So, when the SF is absent a terrestrial detector records electron neutrino flux weakened at the cost both of the VO's and of the MSW resonance conversion. On the other hand, electron neutrinos flux passed the SF region in preflare period appears to be further weakened since it undergoes additional resonance conversions ($\nu_{eL} \to \overline{\nu}_{XL}$ and $\nu_{eL} \to \overline{\nu}_{eL}$), apart from the MSW resonance and VO's. Moreover, the ν_{XL}-neutrinos appearing in the MSW resonance, could also exhibit the resonance transition $\nu_{XL} \to \overline{\nu}_{XL}$.

Note, correlations between nuclear decay rates and annually changing Earth-Sun distances could be also explained by Hν_eIBD. But there, the ν_{eL} flux reduction owes its origin to the VO's only.

So, when the solar neutrino flux moves through the SF region in the preflare period, the $\overline{\nu}_{eL}$ and $\overline{\nu}_{XL}$ neutrinos appear. Then, terrestrial detectors could record these particles with the help of the reactions

$$\overline{\nu}_{eL} + p \to n + e^+ \tag{24}$$

$$\overline{\nu}_{\mu L} + p \to n + \mu^+. \tag{25}$$

Note, the reaction (24) is at the heart of the antineutrino detectors that are used for nuclear reactor monitoring in the on-line regime.

5. Conclusion

The evolution equation for the electron neutrino flux traveling in the Sun has been examined. Consideration carried general character, that is, it would hold for any SM extensions having massive neutrinos. It was conjectured that the neutrino possesses both dipole magnetic and anapole moments while the solar magnetic field has twisting nature. The resonance conversions of the electron neutrinos flux has been evaluated. For Dirac neutrinos these transitions are as follows: (i) $\nu_{eL} \to \nu_{XL}$ (MSW resonance); (ii) $\nu_{eL} \to \overline{\nu}_{XL}$; (iii) $\nu_{eL} \to \overline{\nu}_{eL}$. When neutrinos are Majorana particles we may detect only two resonance conversions: (i) $\nu_{eL} \to \nu_{XL}$; (ii) $\nu_{eL} \to \overline{\nu}_{XL}$. The MSW resonance may occur before the convective zone while $\nu_{eL} \to \overline{\nu}_{XL}$- and $\nu_{eL} \to \overline{\nu}_{eL}$-resonances could take place only at upper layer of solar atmosphere in the sufficiently intensive magnetic field.

It was shown, that under passage of the electron neutrino flux through the region of the SF, three phenomena could be detected by the terrestrial observer. They are: (i) decreasing the number of the electron neutrinos; (ii) appearance of the $\overline{\nu}_{eL}$- and $\overline{\nu}_{XL}$-neutrinos; (iii) reduction of the β-decay rate for some elements of the periodic table.

Decreasing the β-decay rates is explained by the hypothesis of the ν_e-induced β-decays. If this hypothesis holds then some nuclides with the ν_e-induced radioactivity could serve as real-time neutrino detectors. It goes without saying that, each of them possesses definite sensitivity relative to the variation of the solar neutrino flux. Therefore, we have to identify the nuclide having the maximum sensitivity and employ it to expand our understanding of both neutrino physics and solar dynamics.

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