Influence of solar flares on behavior of solar neutrino flux

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Abstract

Limiting ourselves to two flavor approximation the motion of the neutrino flux in the solar matter and twisting magnetic field is considered. For the neutrino system described by the 4-component wave function $\Psi^T = (\nu_{eL}, \nu_{XL}, \overline{\nu}_{eR}, \overline{\nu}_{XL})$, where $X = \mu, \tau$, an evolution equation is found. Our consideration carries general character, that is, it holds for any SM extensions with massive neutrinos. The resonance transitions of the electron neutrinos are investigated. Factors which influence on the electron neutrino flux, crossing a region of solar flares (SF) are defined. When the SF is absent a terrestrial detector records the electron neutrino flux weakened at the cost both of vacuum oscillations and of the MSW resonance conversion only. On the other hand, the electron neutrino flux passed the SF region in preflare period proves to be further weakened in so far as it undergoes one (Majorana neutrino) or two (Dirac neutrino) additional resonance conversions, apart from the MSW resonance and vacuum oscillations.

The hypothesis of the ν_e-induced decays which states that decreasing the beta decay rates of some elements of the periodic table is caused by reduction of the solar neutrino flux is discussed as well.

PACS number(s): 12.60.Cn, 14.60.Pg, 96.60.Kx, 95.85.Qx, 96.60.Rd.

1 Introduction

The solar flares (SF) represents itself the most powerful of all the solar activity events. The energy released during the SF is about $10^{28} - 10^{32}$ erg. It is now widely accepted that the magnetic field provides a main energy source of the solar activity including the SF's. Following observational results, theoretical studies began to focus on the role of magnetic field in producing the SF. A popular mechanism of the SF appearance is based on breaking and reconnection of magnetic field strength lines of neighboring spots

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(the magnetic reconnection model, for review, see [1]). At present this model has been considered to be one of the promising mechanisms for producing the SF, although a complete understanding of the relevant physics is still on the way.

Observations suggest that the field strength B_s of a big sunspots ($d \sim 2 \times 10^5$ km) could reach 10^4 Gs while their geometrical depth h is approximately 300 km. Then the total magnetic energy stored in such a sunspot with the volume $V = \pi d^2 h/4$ is

$$E_{mag} \simeq (B_s^2/8\pi)V \simeq 4 \times 10^{34} \text{ erg}, \qquad (1)$$

which is sufficient to produce even the largest flare, although only a small portion of this total energy can be used, that is, a large amount of energy is unavailable because it is distributed as the potential field energy. A magnetic field above sunspots is characterized by geometrical phase $\Phi(z)$, and its first derivative $\dot{\Phi}(z)$ where

$$B_x \pm iB_y = B_\perp e^{i\Phi(z)} \qquad (2)$$

(a coordinate system with the z-axis along the solar radius have been chosen). A magnetic field above and under a spot has non-potential character

$$(\text{rot } \mathbf{B})_z = 4\pi j_z \neq 0 \qquad (3)$$

(we are working in the natural system of units $\hbar = c = 1$). 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 the density of longtitudal electric current might be large enough in a region above a spot.

According to the magnetic reconnection model, a change of magnetic field configuration in a sunspots group of fairly opposite polarity might lead to the appearance of an limiting strength line being common for whole group. Throughout the limiting line the redistribution of magnetic fluxes takes place, 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 (an explosion phase of SF) 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 (SCR) which consist of protons $E_k \geq 10^6$ eV of nuclei with charges $2 \leq Z \leq 28$ and energy within an interval from 0.1 to 100 eV/nucleon and of electrons with $E_k \geq 30$ MeV. SCR became a source, on the Sun surface and later on the Earth atmospheres, of neutrons as well as secondary kaons and pions. Their following secondary rays, as muons $\mu^{\pm}$ and neutrinos and anti-neutrinos $\nu_\mu, \overline{\nu}_\mu$ as well as γ rays, and their final relic neutrinos $\nu_\mu, \overline{\nu}_\mu, \nu_e, \overline{\nu}_e$ are also released by the chain reactions

$$\pi^{\pm} \to \mu^{\pm} + \nu_\mu(\overline{\nu}_\mu), \qquad \pi^0 \to 2\gamma, \qquad \mu^{\pm} \to e^{\pm} + \nu_e(\overline{\nu}_e) + \nu_\mu(\overline{\nu}_\mu).$$

The existence and detection of these neutrinos were first predicted in Refs. [2].

The concluding stage (hot phase of SF) is characterized by existence of high temperature coronal region and can continue for several hours. The heating of dense atmospheric layers leads to an evaporation of large amount of gas, which favors a long-continued existence of a dense hot plasma cloud.

The high-power SF's can be especially destructive when they appear 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 clear that the prediction of the SF at the initial phase is a very important task.

In 1995-1996 the series of works in which the correlation between the SF's and solar neutrino flux have been published [3], [4],[5]. So, for the first time one was supposed to use the solar electron neutrinos for investigation of the solar flares. Of course the detection of the neutrino flux correlation with the SF will be possible only at the neutrino telescopes of the next generation where events statistics will increase on several orders of magnitude. However solving the problem comes from the other hand, namely, from area of nuclear physics. In recent years, a number of articles [6],[7],[8],[9] have been published presenting evidence that some beta decay rates are variable and this changeability may be connected with behavior of the solar neutrino flux — hypothesis of the ν_e-induced decays (see, for up-to-date review, Ref.[10]). For example, in 2006 J.Jenkins, monitoring a detector in his lab (1 μCi sample of ^{54}Mn), discovered [11] that the decay rate of ^{54}Mn

$$^{54}\mathrm{Mn} + e^- \to {}^{54}\mathrm{Cr}^* + \nu_e \to {}^{54}\mathrm{Cr} + \gamma + \nu_e \tag{4}$$

decreased slightly beginning 39 hours before a large SF of 2006 Dec.13. Since then, researchers have been examining similar variation in decay rates before SF's, as well as those resulting from Earth's orbit around the Sun and changes in solar rotation and activity. It should be noted that the changeability of the decay rate has been observed only for $\beta^{\pm}$ decay and electron capture processes.

The aim of this work is to demonstrate that, whether neutrino has Dirac or Majorana nature, in the standard model (SM) extensions decreasing the solar neutrino flux may occur in a preflare period. This, in its turn, allows to explain the reduction of the decay rate of some radioactive samples during the SF. In the second chapter we consider a neutrino flux motion in solar matter. In so doing we shall assume that the neutrino possesses the dipole magnetic and anapole moments. The possible resonant transitions which result in weakening the electron neutrino flux will be found. The third chapter is devoted to discussion of the obtained results.

2 The resonant conversions of the solar neutrinos

Let us find the evolution equation for the massive neutrinos in two-flavor approximation ($\nu_e\nu_X$-mixing, $X=\mu,\tau$) moving in the Sun. Not only do our consideration holds for SM extensions having only the ordinary (light) neutrinos ($\nu_{eL},\nu_{\mu L},\nu_{\tau L}$), but it also holds for SM extensions having heavy neutrinos ($N_{eR},N_{\mu R},N_{\tau R}$) being partners of the light neutrinos on the see-saw mechanism. The heavy neutrinos appearing in some SM extensions are much more heavier than the light neutrinos. For example, in the left-right symmetric model the lower bound on the heavy neutrino mass is approximately 100 GeV [12]. As a result, these neutrinos do not influence on oscillation picture of the solar neutrino whose energy lies in the interval

$$0.14 < E < 14 \text{ MeV}.$$

As we are limited only by two generations, we should consider a neutrino system consisting of ν_{eL},ν_{XL} and their anti-particles $(\nu_{eL})^c,(\nu_{XL})^c$, where c means an operation of charge conjugation. It should be noted that Majorana neutrino is also not an charge conjugation operator eigenstate due to a switching on of weak interaction. As $(\nu_{eL})^c$ and $(\nu_{eX})^c$ are right-handed neutrinos, in what follows we shall use for them both in Majorana and Dirac cases following notions $\overline{\nu}_{eL}$ and $\overline{\nu}_{XL}$ respectively.

For the case of the Majorana neutrino nature the evolution equation in a Schrodinger-like form takes the form

$$i\frac{d}{dz}\begin{pmatrix}\nu_{eL}\\ \nu_{XL}\\ \overline{\nu}_{eL}\\ \overline{\nu}_{XL}\end{pmatrix}=\mathcal{H}\begin{pmatrix}\nu_{eL}\\ \nu_{XL}\\ \overline{\nu}_{eL}\\ \overline{\nu}_{XL}\end{pmatrix}, \tag{5}$$

where

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

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

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

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

$$\mathcal{H}_{\overline{\nu}\;\overline{\nu}}=\mathcal{H}_{\nu\nu}(V_{lL}\to -V_{lL}, j_z\to -j_z),$$

i- and k-neutrino states, N_e and N_n are electron and neutron densities, respectively, θ_ν is a mixing angle in vacuum between mass eigenstates ν_1 and ν_2, V_{eL} (V_{XL}) is a matter potential describing interaction of the ν_{eL} (ν_{XL}) neutrino with a solar matter. The SM extensions with the extra gauge groups $SU(2)$ or $U(1)$ predict additional gauge bosons whose low bounds on masses lie in the region of 3 TeV and above. Therefore, when calculating the matter potential one may neglect their contribution to the matter potential.

When the neutrino is a Dirac particle $\mathcal{H}_{\nu\overline{\nu}}$ should be replaced by the expression

$$\mathcal{H}_{\nu\overline{\nu}} = \begin{pmatrix} \mu_{\nu_e\overline{\nu}_e} B_\perp e^{i\Phi} & \mu_{\nu_e\overline{\nu}_X} B_\perp e^{i\Phi} \\ \mu_{\nu_e\overline{\nu}_X} B_\perp e^{i\Phi} & \mu_{\nu_X\overline{\nu}_X} B_\perp e^{i\Phi} \end{pmatrix} \tag{6}$$

and assume V_{lL} equal to zero in the expression for $\mathcal{H}_{\overline{\nu}\ \overline{\nu}}$.

Before proceeding further we discuss the experimental bounds on the neutrino multipole moments (MMs) and compare them with theoretical predictions. The most sensitive and established method for the experimental investigation of the neutrino MMs is provided by direct laboratory measurements of (anti)neutrino-electron elastic scattering in solar, accelerator and reactor experiments. A detailed description of such experiments could be found in Ref. [13].

Let us take up first the dipole magnetic moments (DMMs) for Dirac neutrinos. The analysis of the recoil electron spectrum in the SuperKamiokande experiment gave [14]

$$\mu_\nu \leq 1.1 \times 10^{-10} \mu_B. \tag{7}$$

An upper limit on the neutrino DMM $\mu_\nu \leq 8.5 \times 10^{-11}\mu_B$ which was found in an independent analysis of the first stage of the Borexino experiment [15] results in the following bounds for ν_μ and ν_τ

$$\mu_{\nu_\mu} \leq 1.5 \times 10^{-10}\mu_B, \qquad \mu_{\nu_\tau} \leq 1.9 \times 10^{-10}\mu_B. \tag{8}$$

The neutrino interaction with the solar magnetic field could lead to the resonant conversion $\nu_e \to \overline{\nu}_e$. Using this effect produces the inequality [16]

$$\mu_{eff}(\nu_{^8B}) \leq (10^{-10} \div 10^{-12})\mu_B. \tag{9}$$

At the moment the world best limit on electron neutrino DMM is coming from the GEMMA experiment at the Kalinin nuclear power plant [17]

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

Note that the bounds on transit DMMs shall be obtained under observation of the processes

$$\nu_l + e^- \to \nu_{l'} + e^-, \qquad \overline{\nu}_l + e^- \to \overline{\nu}_{l'} + e^-, \qquad (l \neq l') \tag{11}$$

which proceed with the partial lepton flavor violation.

As far as a Majorana neutrino is concerned, the global fit of the reactor and solar neutrino data gives the following values for transition DMMs [18]

$$\mu_{12}, \mu_{13}, \mu_{23} \leq 1.8 \times 10^{-10}\mu_B. \tag{12}$$

The theoretical predictions of the minimally extended SM (MESM) are very far from upper experimental bounds [19]

$$\mu_{\nu_i} = 3.2 \times 10^{-19}\mu_B \left(\frac{m_{\nu_i}}{1\ \mathrm{eV}}\right), \tag{13}$$

and

$$\mu_{\nu_i \nu'_i} \approx 10^{-4} \mu_{\nu_i}. \tag{14}$$

So, in the MESM case the neutrino DMMs are negligibly small and are of no physical interest. On the other hand in alternative SM extensions the neutrino DMMs may have the values close to the experimental bounds. One such SM modification is the model in which, along with the light right-handed neutrinos, a charged scalar $\eta^{(\pm)}$ being $SU(2)_L$ singlet is introduced into a theory [20]. In this model the neutrino DMM could be as large as $10^{-11}\mu_B$. Similar value is also predicted by the left-right symmetric model [21].

We are coming now to the discussion on the anapole moment (AM). At neutrino mass neglecting the AM is associated with a neutrino charge radius (NCR) by the relation

$$a_{\nu_l} = \frac{1}{6} < r^2_{\nu_l} > . \tag{15}$$

Within the MESM the gauge-invariant result for the NCR has been obtained [22]

$$< r^2_{\nu_l} >= \frac{G_F}{4\sqrt{2}\pi^2} \left[3 - 2 \log \left(\frac{m_l^2}{m_W^2} \right) \right]. \tag{16}$$

It gave, in turn, the following numerical value

$$< r^2_{\nu_l} >= 4 \times 10^{-32} \text{ cm}^2. \tag{17}$$

Note that the NCR can be treated as an effective scale of the particle's size, which should influence physical processes such as, for instance, elastic neutrino-electron scattering. Then in order to take into account the contribution coming from the NCR to the cross section of this process the following substitution can be done

$$g_V \to \frac{1}{2} + 2 \sin^2 \theta_W + \frac{2}{3} m_W^2 < r^2_{\nu_l} > \sin^2 \theta_W. \tag{18}$$

Using this scheme, the TEXONO collaboration found [23]

$$-2.1 \times 10^{-32} \text{ cm}^2 << r^2_{\nu_l} > 3.3 \times 10^{-32} \text{ cm}^2 \qquad (90\%\text{C.L.}) \tag{19}$$

There are other limits on the electron neutrino charge radius as well. They are obtained: from neutrino neutral-current reactions [24]

$$-2.74 \times 10^{-32} \text{ cm}^2 < r^2_{\nu_e} > 4.88 \times 10^{-32} \text{ cm}^2 \qquad (90\%\text{C.L.}), \tag{20}$$

from solar experiments (Kamiokande II and Homestake) [25]

$$< r^2_{\nu_e} >< 2.3 \times 10^{-32} \text{ cm}^2 \qquad (95\%\text{C.L.}, \tag{21}$$

from an evaluation of the weak mixing angle $\sin^2 \theta_W$ by a combined fit of all electron neutrino elastic scattering data [26]

$$-0.13 \times 10^{-32} \text{ cm}^2 << r^2_{\nu_e} > 3.32 \times 10^{-32} \text{ cm}^2 \qquad (90\%\text{C.L.}). \tag{22}$$

The effects of new physics beyond the SM can also contribute to the NCR (see, for example, [27]).

Now we return to the evolution equation (5). Here one should get rid of an imaginary part in a Hamiltonian. It could be done by the transition to reference frame (RF), rotating at the same angle speed as a magnetic field. The expression for Hamiltonian in this RF follows from the initial one by the following substitution

$$e^{\pm i\Phi} \to 1, \qquad V_{lL} \longrightarrow V_{lL} - \frac{\dot{\Phi}}{2}. \tag{23}$$

Let us discuss the possible resonance conversions only for left-handed electron neutrino. In the case of the Majorana neutrino we have:
(i) $\nu_{eL} \to \nu_{XL}$ is the so-called Micheev-Smirnov-Wolfenstein (MSW) resonance, which is realized if the condition

$$\Sigma_{\nu_{eL}\to\nu_{XL}} = 2\delta_c^{12} + V_{eL} - V_{XL} + 4\pi(a_{\nu_e\nu_e} - a_{\nu_X\nu_X})j_z = 0 \tag{24}$$

is satisfied with the transition width

$$\delta N_e(\nu_e\nu_X) \sim [N_e(\nu_e\nu_X) - 4\pi(\sqrt{2}G_F)^{-1}(a_{\nu_e\nu_e} - a_{\nu_X\nu_X})j_z] \tan 2\theta_\nu, \tag{25}$$

where $N_e(\nu_e\nu_X)$ is an electron density at which the resonance takes place;
(ii) $\nu_{eL} \to \overline{\nu}_{XL}$ is the resonance with flavor and spin flipping which occurs at the condition

$$\Sigma_{\nu_{eL}\to\overline{\nu}_{XL}} = 2\delta_c^{12} + V_{eL} + V_{XL} + 4\pi(a_{\nu_e\nu_e} + a_{\nu_X\nu_X})j_z - \dot{\Phi} = 0 \tag{26}$$

with the resonance transition width

$$\delta N_e(\nu_e\overline{\nu}_X) \sim \frac{2\mu_{\nu_e\overline{\nu}_X} B_\perp N_e(\nu_e\overline{\nu}_X)}{2\delta_c^{12} + 4\pi(a_{\nu_e\nu_e} + a_{\nu_X\nu_X})j_z - \dot{\Phi}}. \tag{27}$$

When the neutrino is the Dirac particles the resonance conversion $\nu_{eL} \longrightarrow \overline{\nu}_{eL}$ takes place in addition to above mentioned ones. It occurs at the condition

$$\Sigma_{\nu_{eL}\to\overline{\nu}_{eL}} = 2V_{eL} + 4\pi(a_{\nu_e\nu_e} - a_{\overline{\nu}_e\overline{\nu}_e}j_z - \dot{\Phi} = 0. \tag{28}$$

Further on, for the sake of simplicity, we assume that the resonance localization places are situated rather far from one another, that is, the following conditions hold

$$N_e(k) + \delta N_e(k) < N_e(i) - \delta N_e(i), \tag{29}$$

where $i, k = \nu_e\nu_X, \nu_e\overline{\nu}_X, \nu_e\overline{\nu}_e$. Now we may consider them as independent ones. Then transition probabilities on resonances are given by the expression

$$\mathcal{D}_i = \exp\{-\gamma^i(z_i)F_i\}, \tag{30}$$

where $\gamma^i(z)$ is the adiabaticity parameter of i-resonance, z_i is the z-coordinate of i-resonance, and the F_i value depends on a kind of a resonance. In the most general case, F_i is dictated by the behavior of such quantities as $\dot{\Phi}(z), V_{lL}$ and j_z near the resonance. Assuming, that all these quantities are linear functions on z, we get $F_i = \pi/4$. It could be shown that the adiabaticity parameters are determined by the relations

$$\gamma^i(z) = \frac{8(\mathcal{H}_i)^2}{\sin^3 2\theta_i \left| \dfrac{d}{dz}\Sigma_i \right|}, \tag{31}$$

where

$$\sin^2 2\theta_i = \frac{2\mathcal{H}_i^2}{\Sigma_i^2 + 2\mathcal{H}_i^2},$$

and $\mathcal{H}_i$ is a non-diagonal element of Hamiltonian in Eq.(5), corresponding to an i-resonance transition.

3 Conclusion

The evolution equation for the electron neutrino flux moving in the Sun is investigated. Our consideration carries general character, that is, it holds for any SM extensions with massive neutrinos. We assume that the neutrino possesses both dipole magnetic and anapole moments while the solar magnetic field has twisting nature. The resonance transitions of the electron neutrino flux are found. For Dirac neutrinos these transitions are as follows: (i) $\nu_{eL} \to \nu_{XL}$ (MSW resonance); (ii) $\nu_{eL} \to \overline{\nu}_{XL}$ $(X = \mu, \tau)$; (iii) $\nu_{eL} \to \overline{\nu}_{eL}$. It should be stressed that in the minimally extended SM (MESM) the two resonances last mentioned have zero resonance transition widths and, as a result, they are unobservable. When neutrinos are Majorana particles we may detect only two resonance conversions: (i) $\nu_{eL} \to \nu_{XL}$; (ii) $\nu_{eL} \to \overline{\nu}_{XL}$. Again, within the MESM the latter has to be absent.

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. If the hypothesis of the ν_e-induced decays (Hν_eID) is the case, that is, decreasing the beta decay rates is really caused by reduction of the solar neutrino flux, then it is reasonable to suggest that $\nu_{eL} \to \overline{\nu}_{XL}$- and $\nu_{eL} \to \overline{\nu}_{eL}$-resonances happen strictly during the solar flare (SF).

After leaving from the solar surface the neutrino flux flies 150,000,000 km in a vacuum before it will reach the Earth. As this takes place, weakening the electron neutrino flux is motivated by the vacuum oscillations. It is well to bear in mind that vacuum oscillations lead solely to $\nu_{eL} \to \nu_{XL}$ transitions. So, when the SF is absent a terrestrial detector records the electron neutrino flux weakened at the cost both of vacuum oscillations and of the MSW resonance conversion. On the other hand, the electron neutrino flux passed the SF region in preflare period proves to be further weakened in so far as it undergoes one (Majorana neutrino) or two (Dirac neutrino) additional resonance conversions, apart from the MSW resonance and vacuum oscillations. It should be particularly emphasized that the above mentioned statement contradicts forecasts of the MESM and its confirmation will demand revision of this SM extension.

Note, that correlations between nuclear decay rates and the annually changing Earth-Sun distance reported for the first time in Ref. [6] could be also explained by the Hν_eID. But there, the ν_{eL} flux reduction is caused by the vacuum oscillations only.

Of course, establishing reasons of the ν_e-induced decays is one of the basic task of the contemporary physics which is so far from the ultimate answer. However, closeness of the typical solar neutrino energy and the nuclear binding energy per nucleon suggests following simple mechanism. Since a neutrino does not participate in strong interaction and has not electrical charge the bulk of the solar neutrinos penetrate unobstructed to nucleus. In so doing, neutrinos are not absorbed, while having given up a part of energy they pass through the nucleus. As a result, the decays of some elements of the periodic table become to be energy allowed. Therefore, if the Hν_eID is true, then we may state: some elements we belief that they are natural radioactive, in actuality, are artificial radioactive because of the solar neutrino flux bombardment.

Another consequence of the Hν_eID implies that nuclides with the ν_e-induced radioactivity could serve as real-time neutrino detectors. Of course, each of them possesses definite sensitivity relative to the variation of the solar neutrino flux. Therefore, we have to find the nuclide having the maximum sensitivity and use it to expand our understanding of both neutrino physics and solar dynamics.

It should be stressed that appearance of $\overline{\nu}_{XL}$ and $\overline{\nu}_{eL}$ in the solar neutrino flux could be detected with the neutrino telescopes as well.

In order to certainly prove the Hν_eID we must obtain the positive results using the well-controlled collider neutrino flux for irradiation of the radioactive samples.

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