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RESONANT ENHANCEMENT OF FLAVOR-CHANGING NEUTRINO INTERACTIONS[1]

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The resonant amplification of neutrino oscillations in the presence of flavor-changing neutrino interactions with matter is analyzed. It is shown that a significant ν-flavor conversion can take place even in the absence of neutrino mixing in vacuum. To account for the solar neutrino deficit, the strength of the new interactions should be $\sim 10^{-2} G_F$ and the resulting neutrino suppression and spectrum is similar to that in the ordinary MSW effect.

I discuss some extensions of the standard model where these interactions can be present, taking into account the experimental constraints that arise mainly from the induced leptonic rare decays.

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The solar neutrino problem, *i.e.* the persistent disagreement between the observed neutrino fluxes reaching terrestrial detectors (Davis ^{37}Cl experiment, Kamioka, SAGE) and the expectations based on the knowledge of the ν_e yield from the nuclear reactions taking place in the interior of the sun[1], seems to indicate that the neutrino properties differ from those present in the minimal standard model. In fact, most of the solutions proposed usually rely in non-standard ν properties such as masses, mixings, magnetic moments, etc.. Perhaps the most attractive explanation is the so called Mikheyev Smirnov Wolfenstein (MSW) effect[2], in which a small vacuum mixing is resonantly amplified by the effects of the solar medium, leading to a large ν-flavor conversion.

I will consider[3,4] two known extensions of the standard model where the neutrinos can not only be massive, but also have new interactions with the medium that can change their flavor. The study of the neutrino propagation in this context shows that even small strengths ($\sim 10^{-3} \div 10^{-1} G_F$) for these interactions can significantly affect the usual MSW mechanism and may even lead to a solution of the solar neutrino problem in the absence of vacuum mixings.

The models that I will consider are: *i*) the superstring inspired E_6 models, that contain in their superpotential the couplings

$$\lambda_{ijk} D_i^c L_j Q_k,$$

where L and Q are the standard lepton and quark doublets and D^c is a color triplet and isosinglet that appears as one of the exotic fermions in the 27 representation of E_6, and in this case is a leptoquark.[4] *ii*) the minimal supersymmetric standard model with the addition of the lepton number violating couplings[3] (broken R parity models)

$$\lambda'_{ijk} L_i L_j e_k^c + \lambda''_{ijk} L_i Q_j d_k^c,$$

where e^c and d^c are standard lepton and quark singlets ($i,\ j,\ k$ are generation indices).

These couplings induce new effective interactions of the neutrinos with matter mediated by leptoquarks (case *i*) or scalar quarks and leptons (case *ii*). For instance, in the E_6 model the interactions are with d_L quarks, leading to

$$-\mathcal{L} = \sqrt{2} G_{ij} \bar{\nu}_{iL} \gamma_\mu \nu_{jL} \bar{d} \gamma^\mu (1 - \gamma_5) d,$$

with

$$\sqrt{2}G_{ij} \equiv \frac{\lambda^*_{ki1}\lambda_{kj1}}{4m^2_{\tilde{D}_k}},$$

and in the R-broken model there are also similar interactions with d_R and e. In the presence of these interactions, the ν oscillations are governed by the equation

$$i\frac{d}{dx}\begin{pmatrix}\nu_e\\ \nu_\alpha\end{pmatrix} = \begin{pmatrix}-\frac{\Delta}{4E}c2\theta + A & \frac{\Delta}{4E}s2\theta + B\\ \frac{\Delta}{4E}s2\theta + B & \frac{\Delta}{4E}c2\theta - A\end{pmatrix}\begin{pmatrix}\nu_e\\ \nu_\alpha\end{pmatrix},$$

with

$$\begin{aligned}A =& \frac{1}{\sqrt{2}}(G_F N_e - (G_{\alpha\alpha} - G_{ee})N_d)\\ B =& \sqrt{2}G_{e\alpha}N_d,\end{aligned}$$

where, for simplicity, I considered only the two-flavor case ($\alpha = \mu$ or τ). E is the neutrino energy, $\Delta \equiv m_2^2 - m_1^2$, N_e is the electron number density and N_d is the density of d-quarks, i.e. $N_d = N_p + 2N_n$ in terms of the proton and neutron densities (also, $s\theta = \sin\theta$, with θ the vacuum mixing, etc.).

I will only discuss the effects of the new non-diagonal coupling $G_{e\alpha}$, neglecting the diagonal ones G_{ee} and $G_{\alpha\alpha}$, although if these couplings are comparable to G_F (which is not excluded for $G_{\tau\tau}$ in the broken R-parity model) they may also affect the flavor conversion mechanism[5,6] allowing for a resonant behaviour also if the neutrinos are massless[7].

The important effect of the non-diagonal interactions is that they can induce flavor oscillations in matter even in the absence of vacuum mixings. In the resonant enhancement of these oscillations, the role of $s2\theta$ in the ordinary MSW effect is now played by $s2\theta + b$, with $b \simeq 2G_{e\alpha}N_d/G_F N_e$. In particular, if the strength of the new interactions is a few percent of the Fermi strength, *i.e.* $b > 10^{-2}$, the solar ν_e flux suppression as a function of Δ and $s2\theta$ is significantly affected. These values of b correspond to

$$\frac{\lambda_{k11}\lambda_{k\alpha 1}}{m^2_{\tilde{D}_k}} > \frac{10^{-3}}{(100\ \mathrm{GeV})^2}.$$

In the model *ii*, a similar condition would apply to $\lambda'\lambda'/m^2_{\tilde{e}}$ or $\lambda''\lambda''/m^2_{\tilde{d}}$.

However, the couplings inducing these interactions may also lead to processes that are known to be very suppressed, as for example rare μ ($\mu \to e\gamma$, $\mu \to 3e$) or τ ($\tau \to e\gamma$, $\tau \to \rho e$) decays. These generally[3–6] preclude the possibility of affecting sizably the $\nu_e \to \nu_\mu$

conversion, but only constrain the couplings involved in the $\nu_e \to \nu_\tau$ conversion to the level of $\lambda\lambda < 2 \times 10^{-2}(\tilde{m}/100 \text{ GeV})^2$. Hence, in these models an important window is open for this mechanism to be operative. In particular, this can help to solve the solar neutrino problem in models in which the vacuum mixings are negligible, as could for instance be the case if the couplings responsible for the ν masses conserve the individual lepton numbers, if the only significant entry of the ν mass matrix is $m_{\nu_\tau \nu_\tau}$ or even if, as usually happens in GUT theories, the lepton mixing angles are similar to the CKM quark mixings, implying $s^2 2\theta_{e\tau} < 10^{-3}$, a value that is too small to affect the $\nu_e - \nu_\tau$ oscillations in the usual MSW scenario.

From the fact that the value of the parameter b at the resonance is independent of the neutrino energy[3], one can find that the ν_e suppression as a function of E in the presence of sizable flavor changing neutrino interactions is similar to that in the ordinary MSW effect, so that for example we can expect a non-adiabatic behaviour if $b \times \Delta \simeq 10^{-7.5}$ eV^2. This would also make it hard to identify the flavor changing interactions just with solar neutrino experiments, so that to test this mechanism one should look at other induced processes, such as rare τ decays, that should be observable at a future τ factory if these interactions are relevant for the solar neutrino problem.

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