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Manifestations of neutrino magnetic moments in spin and flavor oscillations of ultrahigh-energy cosmic neutrinos

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We analyze theoretically a possible influence of neutrino magnetic moments on the propagation of ultrahigh-energy (UHE) cosmic neutrinos in the interstellar space. Using most stringent astrophysical bounds on the putative neutrino magnetic moment, probabilities of neutrino flavor and spin oscillations are calculated. Under the assumption of two-neutrino mixing, specific patterns of spin and flavor oscillations are determined for neutrino-energy values characteristic of, respectively, the cosmogenic neutrinos, the Greisen-Zatsepin-Kuz'min (GZK) cutoff, and well above the cutoff.

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1. Introduction

One of the important developments in the field of neutrino astrophysics is a search for UHE cosmic neutrinos (even above PeV–EeV energies). As is well known, the neutrino massiveness supports the assumption that neutrinos have nonzero magnetic moments [1]. This means that the propagation of the UHE cosmic neutrinos can be influenced by the presence of magnetic fields due to the effect of spin oscillations. In particular, this influence can be substantial in the interstellar space of our galaxy, where the strength of a magnetic field takes on values of the order of few μG. Therefore, it is important to analyze how spin and flavor oscillations in the interstellar magnetic field can change the propagation pattern of UHE neutrinos.

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2. Results

In our analysis we assumed the value of the putative neutrino magnetic moment to be $\mu_\nu \sim 10^{-12}\mu_B$. The flavor-change probability $P_{\nu_e^L\to\nu_\mu^L}$ for the neutrino propagating in vacuum with an energy typically anticipated for cosmogenic neutrinos, $E_\nu = 1\,\mathrm{EeV}$, is given by

$$P_{\nu_e^L\to\nu_\mu^L}(x) = \sin^2 2\theta\, \sin^2\left(\frac{\pi x}{L_{\mathrm{vac}}}\right), \tag{2.1}$$

where x is the neutrino propagation distance, and the vacuum oscillation length $L_{\mathrm{vac}} = 4\pi E_\nu/\Delta m^2 = 1.09\,\mathrm{pc}$. If the propagating neutrino interacts with an interstellar magnetic field B, the results for $P_{\nu_e^L\to\nu_\mu^L}$ are well approximated by

$$P_{\nu_e^L\to\nu_\mu^L}(x) = [1 - P_{\nu^L\to\nu^R}(x)]\sin^2 2\theta\, \sin^2\left(\frac{\pi x}{L_{\mathrm{vac}}}\right), \qquad P_{\nu^L\to\nu^R}(x) = \sin^2\left(\frac{\pi x}{L_B}\right), \tag{2.2}$$

where $L_B = \pi/\mu_\nu B \sim 1\,\mathrm{kpc}$ is the magnetic oscillation length. The simple behaviors of the neutrino flavor-change and spin-flip probabilities (2.2) owe to the fact that $L_B \gg L_{\mathrm{vac}}$. They become inapplicable when $L_B \sim L_{\mathrm{vac}}$, what can be the case for neutrino energies of the order of the GZK cutoff, such as $E_\nu = 100\,\mathrm{EeV}$ ($L_{\mathrm{vac}} = 109\,\mathrm{pc}$). The results for these energies exhibit a complex interference pattern (see details in Ref. [2]). When $E_\nu \gg 100\,\mathrm{EeV}$, the vacuum oscillation length is $L_{\mathrm{vac}} = 10.9\,\mathrm{kpc}$ ($\gg L_B$). In such a situation one can use the limit $L_{\mathrm{vac}} \to \infty$, leading to

$$P_{\nu_e^L\to\nu_\mu^L}(x) = \cos^2 2\theta\, \sin^2\left(\frac{\pi x}{L_B}\right), \qquad P_{\nu^L\to\nu^R}(x) = \frac{1}{2}(1+\sin 2\theta)\sin^2\left(\frac{2\pi x}{L_B}\right), \tag{2.3}$$

with $\cos^2 2\theta = 0.165$ and $(1+\sin 2\theta)/2 = 0.957$. The $\nu_e^L \to \nu_\mu^L$ conversion probability in this limit takes place solely through the spin-flip processes $\nu_e^L \to \nu_\mu^R \to \nu_\mu^L$ and $\nu_e^L \to \nu_e^R \to \nu_\mu^L$.

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References

[1] C. Giunti and A. Studenkin, Rev. Mod. Phys. **87** (2015) 531.

[2] P. Kurashvili, K. A. Kouzakov, L. Chotorlishvili, A. I. Studenikin, Phys. Rev. D **96** (2017) 103017.