ASYMMETRIES IN THE PROCESSES OF CREATION OF ELECTRON-POSITRON PAIRS BY NEUTRINOS (ANTINEUTRINOS) IN HOT DENSE ENVIRONMENTS IN AN EXTERNAL MAGNETIC FIELD

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The article is mainly devoted to the calculation of energy loss and resulting spin asymmetry due to the processes $\nu_i \to \nu_i e^- e^+$ when electrons are generated in the main Landau level and positrons are generated in the first Landau level in the case of longitudinal and transverse polarization. This means that the contribution of positrons created at the first Landau level and whose spins are "right" polarized to the cooling of an ordinary neutron star due to the $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$ processes is significantly greater than the contribution made by positrons created at the first Landau level and whose spins are "left" polarized.

And in the case of a magnetic environment with $B \sim 10^{14}\,Qs$ arranged magnetic fields, a sufficiently large value is obtained for the asymmetry: $A \cong 97{,}5\%$.

In this case, the magnetic environment with magnetic fields with magnetic induction $B \sim 10^{14}\,Qs$ cooling due to the $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$ processes is dominated by the contribution of positrons created in the first Landau level and with "right" polarized spins.

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Electron-positron pair emission processes by neutrino and antineutrino are, respectively, described by the reactions:

$$\nu_i \to \nu_i + e^- + e^+ \qquad (1)$$

$$\tilde{\nu}_i \to \tilde{\nu}_i + e^- + e^+ \qquad (2)$$

In reaction (1), three types of neutrinos are indicated by ν_i: electron neutrino by ν_e, muon neutrino by ν_μ and tauon neutrino by ν_τ, and in reaction (2) three types of antineutrinos are indicated by $\tilde{\nu}_i$: electron antineutrino by $\tilde{\nu}_e$, muon antineutrino by $\tilde{\nu}_\mu$ and tauon antineutrino by $\tilde{\nu}_\tau$. The processes described by reactions (1) and (2) are forbidden by the law of conservation of 4-dimensional momentum in the free state in the absence of an external field. However, in the presence of an external magnetic field, processes (1) and (2) occur. Strong and even extreme external magnetic fields are found in compact astrophysical objects (such as in magnetars and other neutron stars) and processes (such as in exploding supernovae). Thus, $B \sim 10^{13}\,Qs$ arrayed magnetic fields are found in ordinary neutron stars [Abdullayev S.G., 2012]. $B \sim 10^{15}\,Qs$ arrayed magnetic fields are found in magnetars [Gusseinov V.A., Jafarov I.G., Gasimova R.E., 2007] and $B \sim 10^{15}\,Qs - 10^{17}\,Qs$ arrayed magnetic fields are found in the initial phase of the gravitational collapse of the stellar core.The formula for the energy-momentum losses characteristic of electron-positron pair generation processes of ($\nu_i \to \nu_i e^- e^+$, $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$) by neutrinos (antineutrinos) in the external magnetic field is given. In the article, the spin asymmetries that occur in cases of transverse and longitudinal polarization of spins were considered. The article also discussed the calculation of the energy loss and resulting spin asymmetry due to the processes of $\nu_i \to \nu_i e^- e^+$ when electrons are created in the main Landau level, and positrons are created in the first Landau level, in the case of transverse polarization of the spins of electrons and positrons. In the case of transverse polarization of the spins of the generated electrons and positrons, the spin asymmetry is determined by the following formula:

$$A = \left[\left(\frac{dE}{dt}\right)_- - \left(\frac{dE}{dt}\right)_+\right] \Bigg/ \left[\left(\frac{dE}{dt}\right)_- + \left(\frac{dE}{dt}\right)_+\right] \qquad (3)$$

$$\frac{dE}{dt} = \frac{\sqrt{2}G_F^2}{24\pi^3}\frac{m_e^3}{V}\omega'^2_{\max}\left(3\omega - 2\omega'_{\max}\right) f^{3/2}\left[g_L\left(\sqrt{x}-1\right) - g_R\zeta\right]^2 e^{-x} \qquad (4)$$

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Here,

$$\left(\frac{dE}{dt}\right)_{-} = \frac{dE}{dt}(\zeta = -1), \quad \left(\frac{dE}{dt}\right)_{+} = \frac{dE}{dt}(\zeta = +1) \tag{5}$$

we obtain the following formula for spin asymmetry by performing simple calculations:

$$A = \left[2g_L g_R\left(\sqrt{x}-1\right)\right] \Big/ \left[g_R^2 + g_L^2\left(\sqrt{x}-1\right)^2\right] \tag{6}$$

The spin asymmetries in case of transverse and longitudinal polarization of the spins of electrons and positrons for supernovae are given in the table below.

Table 1.

The spin asymmetries.

$\omega \cong 75\,MeV$	$B \sim 10^{17}\ Qs$ (for supernovae)	
Processes	Asymmetries, %	
	case of transverse polarization	case of longitudinal polarization
$\nu_e \to \nu_e e^- e^+$	25%	96,8%
$\nu_\mu \to \nu_\mu e^- e^+$	–9,4%	99,6%
$\nu_\tau \to \nu_\tau e^- e^+$	–9,4%	99,6%

Formula (6) and numerical evaluations given in Table 1 show that the spin asymmetry that appears in the energy loss due to the processes of $\nu_i \to \nu_i e^- e^+$ in case of transverse polarization of the spins of electrons and positrons is sensitive to the aroma of neutrinos.

The article is mainly devoted to the calculation of energy loss and resulting spin asymmetry due to the processes $\nu_i \to \nu_i e^- e^+$ when electrons are generated in the main Landau level and positrons are generated in the first Landau level in the case of longitudinal and transverse polarization [Askerov B.M., 2005].

In the case of longitudinal polarization of the spins of the generated electrons and positrons, the spin asymmetry is determined by the following formula:

$$A = \left[\left(\frac{dE}{dt}\right)_L - \left(\frac{dE}{dt}\right)_R\right] \Big/ \left[\left(\frac{dE}{dt}\right)_L + \left(\frac{dE}{dt}\right)_R\right] \tag{7}$$

Here

$$\left(\frac{dE}{dt}\right)_L = \frac{dE}{dt}(\zeta = -1), \quad \left(\frac{dE}{dt}\right)_R = \frac{dE}{dt}(\zeta = +1).$$

by performing simple calculations, we obtain the following formula for spin asymmetry:

$$A = \left[g_R^2 - g_L^2\left(\sqrt{x}-1\right)^2\right] \Big/ \left[g_R^2 + g_L^2\left(\sqrt{x}-1\right)^2\right]. \tag{8}$$

Formula (8) and the numerical evaluations given in table 1 show that the spin asymmetry arising in the energy loss due to the processes of $\nu_i \to \nu_i e^- e^+$ in case of longitudinal polarization of spins of electrons and positrons is sensitive to the aroma of neutrinos.

Below are the formulas for calculating the energy loss and resulting spin asymmetry due to the processes of $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$ when electrons are created in the main Landau level and positrons are created in the first Landau level in the case of transverse polarization.

We determine the spin asymmetry according to the following formula:

$$A = \left[\left(\frac{dE}{dt}\right)_- - \left(\frac{dE}{dt}\right)_+\right] \Big/ \left[\left(\frac{dE}{dt}\right)_- + \left(\frac{dE}{dt}\right)_+\right] \tag{9}$$

Taking into consideration that the multiplication factor β is of the form

$$\beta = \frac{m_e}{\sqrt{m_e^2 + 2eB}} \qquad (10)$$

in the case that the positrons of the β multiplication included in the expressions of the quantities $(dE/dt)_-$ və $(dE/dt)_+$ are generated in the first Landau level, and it depends on neither ω', nor Ω' variables, we get the following simple expression for the spin asymmetry:

$$A = \beta.$$

To evaluate the spin asymmetry numerically, let's consider a strongly magnetized stellar medium. Neutron stars in the case of $(B \sim 10^{13}\, Qs)$, a value $A \cong 57{,}7\%$ is obtained for the asymmetry [Abdullayev S.G., 2012]. However, in the case of a magnetar, the asymmetry is smaller: $A \cong 7{,}1\%$. In the case of sufficiently strong magnetic fields, the spin asymmetry becomes negligibly small [Najafov I.M., 2012].

The article also considered the energy loss due to the $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$ processes and resulting spin asymmetry, in the case of longitudinal polarization, when electrons are created in the main Landau level, and positrons are created in the first Landau level.

In the case of longitudinal polarization of the spins of positrons generated due to processes of $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$, we determine the spin asymmetry that appears during energy loss according to the following formula:

$$A = \left[\left(\frac{dE}{dt}\right)_R - \left(\frac{dE}{dt}\right)_L\right] \Big/ \left[\left(\frac{dE}{dt}\right)_R + \left(\frac{dE}{dt}\right)_L\right] \qquad (11)$$

Let's see the case where the energy of the falling antineutrino is much greater than the energy of the scattered antineutrino

$$\omega >> \omega' \qquad (12)$$

We also assume that the energy of the scattered antineutrino is much smaller than the specific energy and its mass of the positron gained in the magnetic field by occupying the first Landau level, that's

$$\omega' << \sqrt{e_0 B},\ m_e \qquad (13)$$

Here, we do not consider the case where the value of the quantity $\sqrt{e_0 B}$ is much larger than m_e

$$\sqrt{e_0 B} >> m_e \qquad (14)$$

but we do this case

$$\sqrt{e_0 B} \geq m_e \qquad (15)$$

In this case, we get the following simple expression for the spin asymmetry:

$$A = \left(1 - \frac{m_e^2}{2 e_0 B}\right)^{1/2} = \left(1 - \frac{1}{2f}\right)^{1/2} \qquad (16)$$

Here $f = B/B_0$ - is a dimensionless field parameter.

To evaluate the spin asymmetry numerically, let us consider a strongly magnetized stellar medium. An ordinary neutron star in the case of $(B \sim 10^{13} Qs)$ the value of $A \cong 70{,}7\%$ is obtained for the asymmetry. This means that the contribution of positrons created at the first Landau level and whose spins are "right" polarized to the cooling of an ordinary neutron star due to the $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$ processes is significantly greater than the contribution made by positrons created at the first Landau level and whose spins are "left" polarized. And in the case of a magnetic environment with $B \sim 10^{14} Qs$ arranged magnetic fields, a sufficiently large value is obtained for the asymmetry: $A \cong 97{,}5\%$.

In this case, the magnetic environment with magnetic fields with magnetic induction $B \sim 10^{14} Qs$ cooling due to the $\tilde{\nu}_i \to \tilde{\nu}_i e^- e^+$ processes is dominated by the contribution of positrons created in the first Landau level and with "right" polarized spins.

RESULTS

1. It has been established that the heating of electron and positron gases by neutrinos occurs asymmetrically in an extreme magnetic field, and this asymmetry that appears during heating depends on the energy of electrons and positrons, the chemical potential and temperature of the medium, and is sensitive to the neutrino aroma, the spin variable of electrons and positrons in the initial state.
2. It has been shown that during the scattering of electron neutrinos from electron and positron gases in magnetars, heating asymmetry is 95 % when the spins of electrons and positrons are "left" polarized, and when the spins are "right" polarized it is 42 %. During the scattering of muon (tauon) neutrinos from electron and positron gases, heating asymmetry is 70 % when the spins of electrons and positrons are "left" polarized, and heating asymmetry is 50 % when the spins are "right" polarized.
3. In the processes of $\nu_i \to \nu_i + e^- + e^+$ in strongly magnetized stars falling neutrinos when moving in the perpendicular direction to the field, and scattered neutrinos when moving in the opposite direction to the field the energy losses that occurs during the birth of electrons at the basic Landau level and the energy that occurs during the birth of positrons at the first Landau level are sensitive to neutrino aroma and spin polarization of positrons, occurs asymmetrically.

[1] *S.G. Abdullayev*. Weak current effects in lepton-lepton and lepton-hadron interactions, 2012, Baku: AM965 LLC publishing house, 484 p.

[2] *I.M. Najafov*. Modern classical electrodynamics (textbook). Baku: "Adiloglu" publishing house, 2012, 549 p.

[3] *V.A. Gusseinov, I.G. Jafarov, R.E. Gasimova*. Neutrino-electron scattering in a magnetic field with allowance for polarizations of electrons. Physical Review D, 2007 , v. 75, № 8, p. 073021.

[4] *I.H. Jafarov, N.A. Guliyev*. Neutrino. Baku: Science, 2005, 116 p.

[5] *B.M. Askerov*. Thermodynamics and statistical physics: a textbook for higher schools. Baku: "Baku University" publishing house, 2005, 625 p.

[6] *A.I. Mukhtarov*. Quantum Mechanics: A Textbook for High Schools. Baku: "Maarif" publishing house, 1999, 608 p., with pictures.

[7] *A.A. Sokolov, I.M. Ternov, V.Ch. Zhukovsky,*

[8] *A.V. Borisov*. Quantum electrodynamics. M.: Moscow University Publishing House, 1983, 312 p.

[9] *A.I. Akhiezer, V.B. Berestetsky*. Quantum electrodynamics. Monograph. Ch. ed. physics and mathematics lit. M.: Nauka, 1969, 624 p.

[10] *J. Allen*. Neutrino. Per. from English M.: Foreign literature, 1960, 264 p.

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