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GENERAL FORMULA FOR IMPULSE LOSSES IN THE PROCESS OF EMISSION OF NEUTRINO PAIRS BY ELECTRONS IN A MAGNETIC FIELD

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ОБЩАЯ ФОРМУЛА ИМПУЛЬСНЫХ ПОТЕРЬ ПРИ ИЗЛУЧЕНИИ ПАР НЕЙТРИНО ЭЛЕКТРОНАМИ В МАГНИТНОМ ПОЛЕ

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Abstract. Considered formula pulsed radiation losses pairs neutrinos electrons in a magnetic field. Gas consisting of polarized electrons in the direction of the magnetic field and spins composed of polarized electrons in the opposite direction of the magnetic field would receive a different impulse due to the asymmetric transmission of the impulse.

Аннотация. Рассматривается формула импульсных потерь при излучении пар нейтрино электронами в магнитном поле. Газ, состоящий из поляризованных электронов в направлении магнитного поля и спинов, состоящих из поляризованных электронов в направлении, противоположном магнитному полю, получит другой импульс из-за асимметричной передачи импульса.

Keywords: magnetic field, electrons, adiation pulse losses.

Ключевые слова: магнитное поле, электроны, излучение, импульсные потери.

An impulse is transmitted to the stellar conditions by the emission of neutrino pairs by electrons in the process of neutrino synchrotron radiation of electrons in a magnetic field. Impulse transmitted to the scope of the conditions in a momentum unit (impulse losses) is generally calculated by the formula [1–5]:

$$\frac{d\vec{P}}{dt}=\frac{1}{V}\int\prod_i dn_i f_i \prod_f dn_f\left(1-f_f\right)\frac{\left|M_{if}\right|^2}{\Im}\vec{q} \tag{1}$$

Here in the dn_i and dn_f scope element of the phase, respectively, the number of initial and final cases, the distribution functions of the particles in f_i — initial state, the distribution functions of the particles in f_f — final state, the momentum unit value of the modulus of $\left|M_{if}\right|^2/\Im$ — process matrix element, $\Im$ — at the moment of the total interaction, in $\vec{q}$ — reaction it is an impulse transmitted to the conditions by a neutrino. The formulae for the impulse losses transmitted to a single scope of the stellar condition at a momentum unit due to the emission of neutrino pairs by electrons in the process of neutrino synchrotron radiation of electrons in a magnetic field are correct.

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$$\frac{d\vec{P}}{dt} = \frac{1}{V}\int dn_e f_e dn_{e'}(1 - f_{e'})dn_\nu (1 - f_\nu) dn_{\tilde{\nu}}(1 - f_{\tilde{\nu}})\frac{|M_{if}|^2}{\Im}\vec{q} \tag{2}$$

$$dn_e = \frac{L_y}{2\pi}dp_y \frac{L_z}{2\pi}dp_z \tag{3}$$

$$dn'_e = \frac{L_y}{2\pi}dp'_y \frac{L_z}{2\pi}dp'_z \tag{4}$$

$$dn_\nu = \frac{Vd\vec{k}'}{(2\pi)^3} \tag{5}$$

$$dn_{\tilde{\nu}} = \frac{Vd\vec{k}}{(2\pi)^3} \tag{6}$$

By including here, we obtain the general expression for the impulse losses transmitted to a single scope of the stellar conditions at a momentum unit by the emission of neutrino pairs by electrons in the process of neutrino synchrotron radiation of electrons in a magnetic field.

$$\frac{d\vec{P}}{dt} = \frac{G_F^2}{(2\pi)^7}\frac{L_y L_z}{\omega\omega' V}\int Q\vec{q}(1 - f_\nu)(1 - f_{\tilde{\nu}})f_e(1 - f_{e'})\delta(E' + \omega' + \omega - E)\times \tag{7}$$

$$\times\delta(p'_y + q_y - p_y)\delta(p'_z + q_z - p_z)dp_y dp_z dp'_y dp'_z d\vec{k}d\vec{k}'$$

In (7) and (1) formulae

$$f_e = f_e(E) = \frac{1}{e^{\frac{E-\mu_e}{T}} + 1} \tag{8}$$

Fermi-Dirac distribution of electrons in the initial state, Fermi-Dirac distribution of electrons in $f_{e'} = f_{e'}(E')$ final state, chemical potential of μ_e electrons, temperature of T — electron gas

$$f_\nu = f_\nu(\omega') = \frac{1}{e^{\frac{\omega'-\mu_\nu}{T_\nu}} + 1} \tag{9}$$

Fermi-Dirac distribution of neutrinos, chemical potential of μ_ν — neutrinos, — temperature of T_ν — neutrino gas:

$$f_{\tilde{\nu}} = f_{\tilde{\nu}}(\omega) = \frac{1}{e^{\frac{\omega+\mu_\nu}{T_\nu}} + 1} \tag{10}$$

are the Fermi-Dirac distribution of antineutrinos. We use it in the unit system which is $\hbar = c = k_B = 1$. Here k_B is the Bolasman constant. The Q quantity in formula (7) is determined as follows:

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$$Q = N_{\alpha\beta} J^{\alpha} J^{*\beta} \tag{11}$$

$$N_{\alpha\beta} = k_{\alpha} k'_{\beta} + k'_{\alpha} k_{\beta} - g_{\alpha\beta}(kk') + i\varepsilon_{\alpha\beta\mu\nu} k^{\mu} k'^{\nu} \tag{12}$$

Here $g_{\alpha\beta}$ is a metric tensor and $\varepsilon_{\alpha\beta\mu\nu}$ is an antisymmetric tensor. $(\alpha, \beta, \mu, \nu = 0,1,2,3)$.

The following general expression is true for the R quantity for the arbitrary kinematics of the motion of neutrinos and antineutrons:

$$\begin{aligned} Q = &\left(\omega\omega' + k_x k'_x + k_y k'_y + k_z k'_z\right)\left(J^0\right)^2 + \left(\omega\omega' + k_x k'_x - k_y k'_y - k_z k'_z\right)\left|J_1^2\right| + \left(\omega\omega' - k_x k'_x + k_y k'_y - k_z k'_z\right)\times \\ &\times\left|J^2\right|^2 + \left(\omega\omega' - k_x k'_x - k_y k'_y + k_z k'_z\right)\left(J^3\right)^2 - 2\left(\omega k'_x + k_x \omega'\right)\operatorname{Re} J^0 J^1 - 2\left(\omega k'_y + k_y \omega'\right)\operatorname{Re} J^0 J^2 - \\ &-2\left(\omega k'_z + k_z \omega'\right) J^0 J^3 + 2(k_x k'_y + k_y k'_x)\operatorname{Re} J^1 J^{2^*} + 2(k_x k'_z + k_z k'_x)\operatorname{Re} J^1 J^3 + \\ &+2(k_y k'_z + k_z k'_y)\operatorname{Re} J^2 J^3 - 2(k_y k'_z - k_z k'_y)\operatorname{Im} J^0 J^1 - 2(k_z k'_x - k_x k'_z)\operatorname{Im} J^0 J^2 + \\ &+2\left(\omega' k_z - \omega k'_z\right)\operatorname{Im} J^{1^*} J^2 - 2(\omega' k_x - \omega k'_x)\operatorname{Im} J^2 J^3 + 2(\omega' k_y - \omega k'_y)\operatorname{Im} J^1 J^3 \end{aligned} \tag{13}$$

Taking into account that p_y determines x coordinate of moving orbit of quantum number electron

$$x = x_0 = -\frac{p_y}{eH} \tag{14}$$

and this changes in this coordinate part

$$-\frac{L_x}{2} \leq x = x_0 \leq \frac{L_x}{2} \tag{15}$$

It is possible to carry out integral for dp_y in (7) expression.

$$\int dp_y = eHL_x \tag{16}$$

Integrals for dp'_y and dp'_z are implemented by means of delta functions.

$$\int F(\ldots)\delta\left(p'_y + q_y - p_y\right)dp'_y = F(\ldots) \tag{17}$$

$$\int F(\ldots)\delta\left(p'_z + q_z - p_z\right)dp'_z = F(\ldots) \tag{18}$$

Indicating the polar angle of antineutrinos (neutrinos) with $\vartheta(\vartheta')$ and the azimuthal angle with $\alpha(\alpha')$ in the spherical coordinate system, the components of the impulses of antineutrinos (neutrinos) can be written as follows,

$$k_x = \omega \sin\vartheta \cos\alpha, \tag{19}$$

$$k_y = \omega \sin\vartheta \sin\alpha, \tag{20}$$

$$k_z = \omega \cos\vartheta, \tag{21}$$

$$k'_x = \omega' \sin\vartheta' \cos\alpha', \tag{22}$$

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$$k'_y = \omega' \sin \vartheta' \sin \alpha', \tag{23}$$

$$k'_z = \omega' \cos \vartheta' \tag{24}$$

Here, non-dashed quantities refer to antineutrinos, and dashed quantities refer to neutrinos. Taking (19-24) expressions into account, it is possible to write (13) expression as:

$$Q = \omega \omega' Q_0 \tag{25}$$

The structure of the quantity depends on the polarization of the electrons in the initial and final cases, and we will give it later.

$$d\vec{k} = \omega^2 d\omega d\Omega \tag{26}$$

$$d\vec{k}' = \omega'^2 d\omega' d\Omega' \tag{27}$$

Considering the angle elements of the body in the formula (7), the formula is obtained for the impulse losses transmitted to a single scope of the stellar conditions simultaneously due to the emission of neutrino pairs by electrons in the process of neutrino synchrotron radiation of electrons in a magnetic field:

$$\frac{d\vec{P}}{dt} = \frac{G_F^2}{(2\pi)^7} eH \int Q_0 \omega^2 \omega'^2 \vec{q} (1 - f_\nu)(1 - f_{\tilde{\nu}}) f_e (1 - f_{e'}) \delta(E' + \omega' + \omega - E) dp_z d\omega d\omega' d\Omega d\Omega' \tag{28}$$

As we view the effects of polarization, we do not average the spins of the electrons in the initial (final) state.

It is possible to write delta function simplifying the energy conservation as:

$$\delta(E' + \omega' + \omega - E) = \sum_i \frac{E_i E'_i}{|E'_i p_{zi} - E_i p'_{zi}|} \delta(p_z - p_{zi}) \tag{29}$$

Here E_i, E'_i satisfies energy conservation while the law of conservation of the third component of the impulse is satisfied by $(p_z = p'_z + k_z + k'_z)$. In this case, the impulse losses transmitted by electrons to a unit scope of the stellar conditions simultaneously due to the emission of neutrino pairs by electrons in the process of neutrino synchrotron radiation in a magnetic field are determined by the following formula:

$$\frac{d\vec{P}}{dt} = \frac{G_F^2}{(2\pi)^7} eH \int \sum_i \frac{E_i E'_i}{|E'_i p_{zi} - E_i p'_{zi}|} Q_0 \omega^2 \omega'^2 \vec{q} (1 - f_\nu)(1 - f_{\tilde{\nu}}) f_e (1 - f_{e'}) d\omega d\omega' d\Omega d\Omega' \tag{30}$$

Conclusion

During neutrino synchrotron radiation, these gases will be stimulated by the transmission of impulses as a result of the emission of neutrino pairs. However, a gas consisting of polarized electrons in the direction of the magnetic field and spins composed of polarized electrons in the opposite direction of the magnetic field would receive a different impulse due to the asymmetric transmission of the impulse.

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