Contribution of the dipole moments of the neutrino in the stellar energy loss rates

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Abstract

Within the context of a $\mathrm{U}(1)_{B-L}$ model, we develop and present novel analytical formulas to assess the effects of the anomalous magnetic moment and electric dipole moment of the neutrino on the stellar energy loss rates through some common physical process of pair-annihilation $e^+e^- \rightarrow (\gamma, Z, Z') \rightarrow \nu\bar{\nu}$. Our results show that the stellar energy loss rates strongly depends on both momenta of the neutrino, but also on the parameters which characterize the adopted $\mathrm{U}(1)_{B-L}$ model.

Stellar energy loss rates through the process $e^+e^- \to \nu\bar{\nu}$

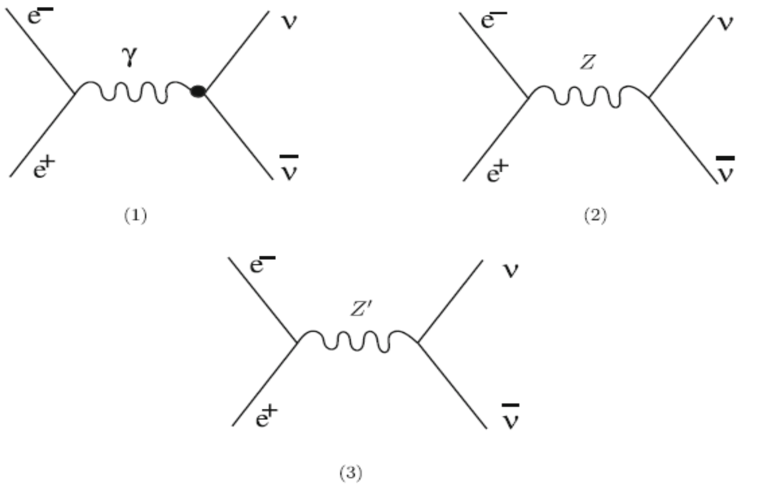

Fig. 1 The Feynman diagrams contributing to the process $e^+e^- \to (\gamma, Z, Z') \to \nu\bar{\nu}$. The dot represents an interaction arising from a effective operator

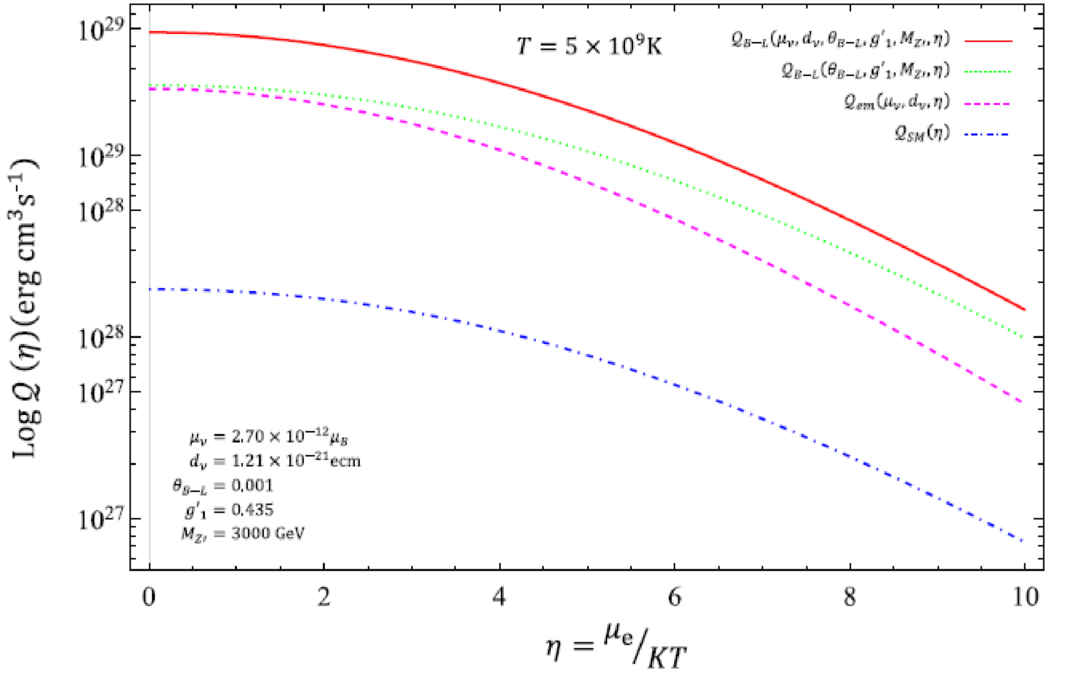

Fig. 2 The stellar energy loss rates as a function of the degeneration parameter η for stellar temperature of 5×10^8K and 5×10^9K. The solid line is for $\mathcal{Q}_{\rm B-L}(\mu_\nu, d_\nu, \theta_{\rm B-L}, g'_1, M_{Z'}, \eta)$, the tiny dashes line is for $\mathcal{Q}_{\rm B-L}(\theta_{\rm B-L}, g'_1, M_{Z'}, \eta)$, the large dashes line is for $\mathcal{Q}_{em}(\mu_\nu, d_\nu, \eta)$, and the dot-dashes line is for $\mathcal{Q}_{SM}(\eta)$

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$$
\begin{aligned}
\mathcal{Q}^{\rm B-L}_{\nu\bar{\nu}}(\mu_\nu, d_\nu, \theta_{\rm B-L}, g'_1, M_{Z'}, \eta) &= \frac{\alpha^2 m_e^9}{9\pi^3 \sin^4 2\theta_W}\left\{\frac{3\sin^4 2\theta_W}{2\pi\alpha m_e^2}\left(\mu_\nu^2 + d_\nu^2\right)\right.\\
&\times\left[2\left(G^-_{-1/2}G^+_0 + G^-_0 G^+_{-1/2}\right) + G^-_0 G^+_{1/2} + G^-_{1/2}G^+_0\right]\\
&+ 4\left(g_1^{[\rm B-L]}\right)\left[5\left(G^-_{-1/2}G^+_0 + G^-_0 G^+_{-1/2}\right) + 7\left(G^-_0 G^+_{1/2} + G^-_{1/2}G^+_0\right)\right.\\
&\left. - 2\left(G^-_1 G^+_{-1/2} + G^-_{-1/2}G^+_1\right) + 8\left(G^-_1 G^+_{1/2} + G^-_{1/2}G^+_1\right)\right]\\
&\left. + 36\left(g_2^{[\rm B-L]}\right)\left[G^-_{-1/2}G^+_0 + G^-_0 G^+_{-1/2} + G^-_0 G^+_{1/2} + G^-_{1/2}G^+_0\right]\right\}.
\end{aligned}
$$

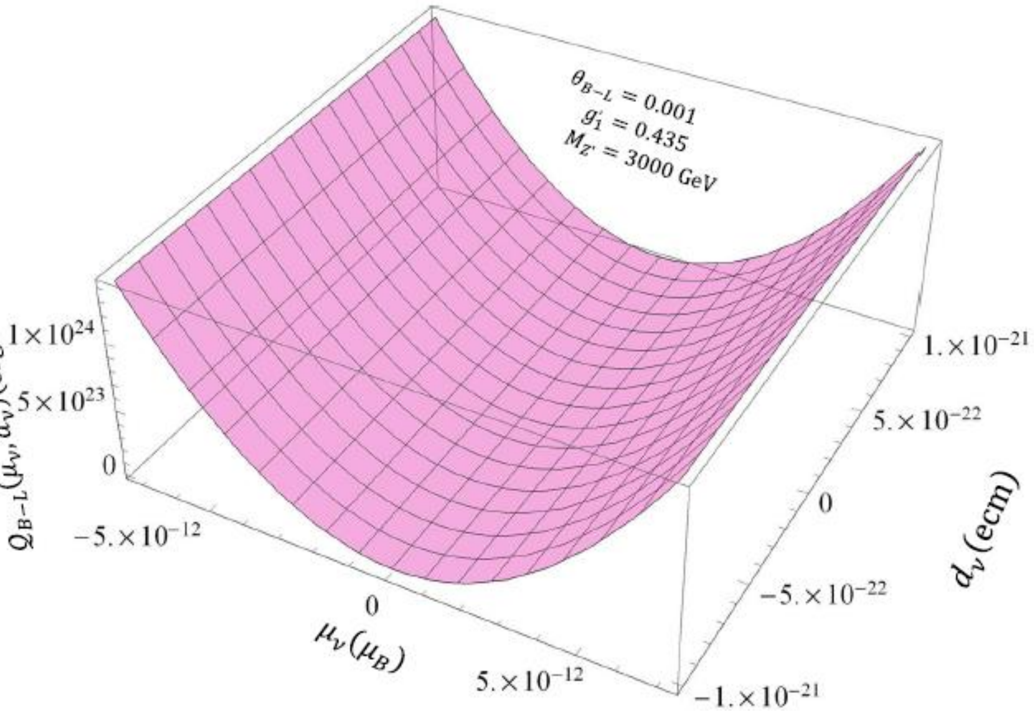


Fig. 3 The stellar energy loss rates as a function of the AMM and the EDM (μ_ν, d_ν) for $\eta = 2$

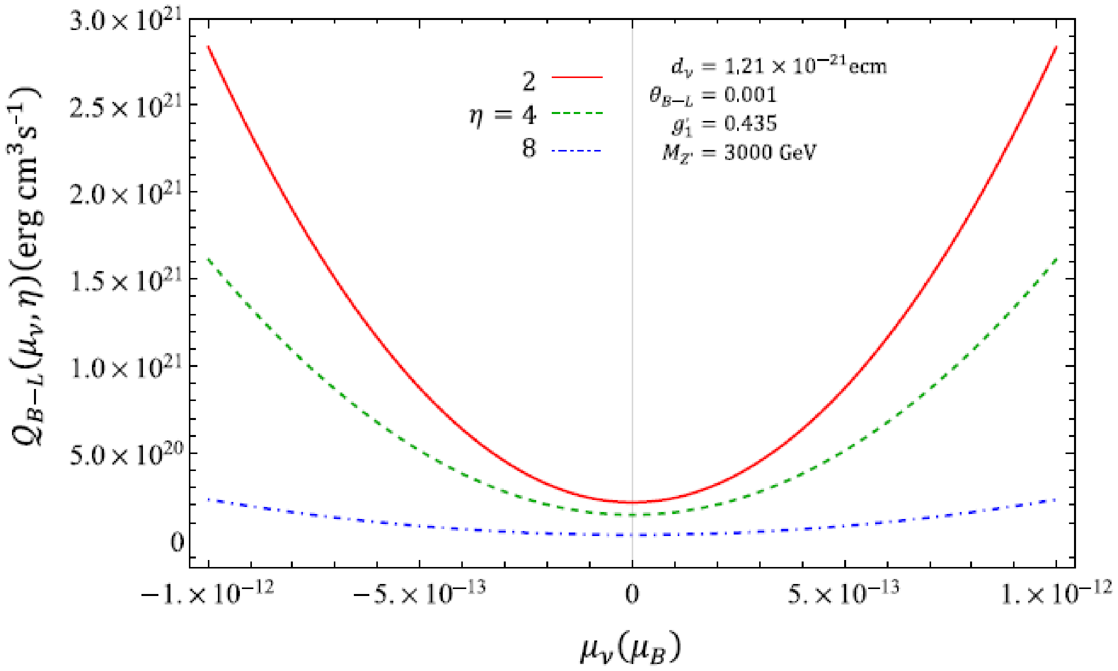


Fig. 4 The stellar energy loss rate as a function of the AMM of the neutrino. The solid line is for $\eta = 2$, the dashes line is for $\eta = 4$, and the dot-dashes line is for $\eta = 8$

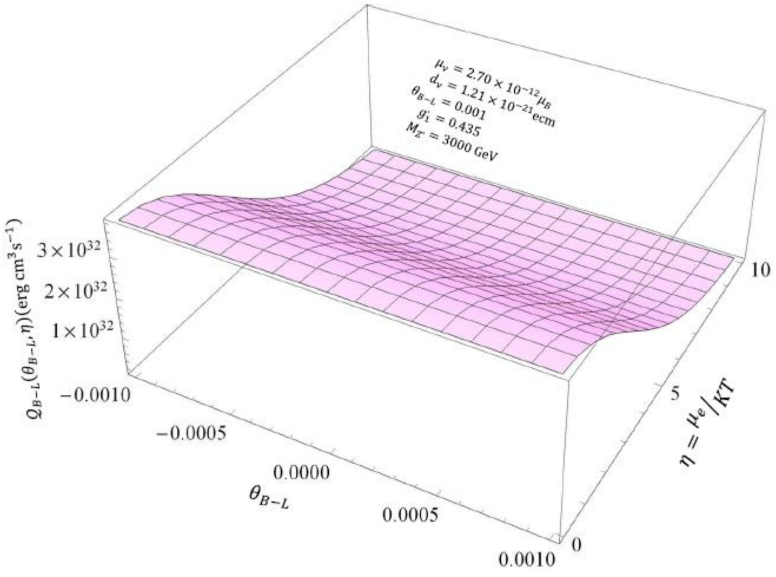
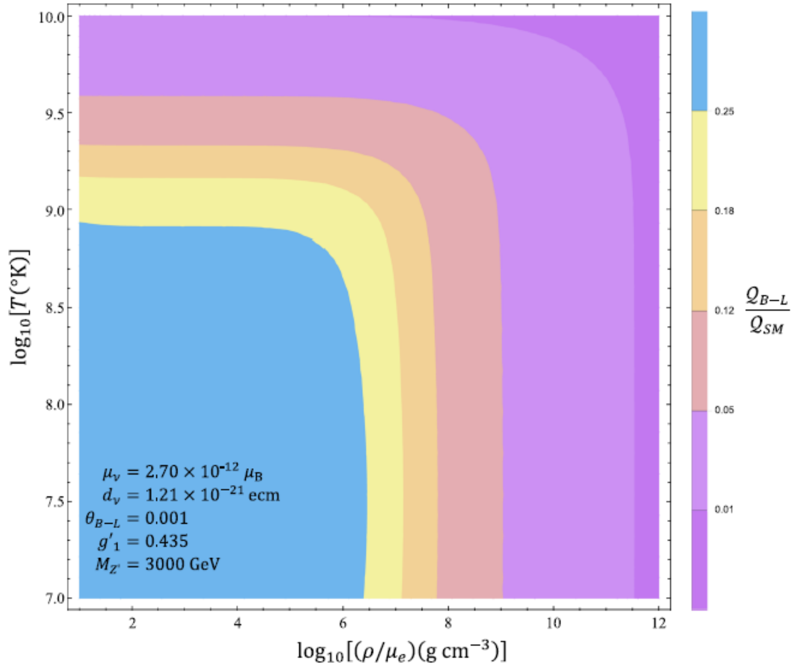


Fig. 5 The stellar energy loss rates as a function of degeneration parameter and the mixing angle $(\eta, \theta_{\mathrm{B-L}})$



Contour plot of the ratio $\frac{Q_{\mathrm{B-L}}(\mu_\nu, d_\nu, \theta_{\mathrm{B-L}}, g_1', M_{Z'})}{Q_{SM}}$ as a function of temperature (T) and matter density (ρ)

Conclusions

With our results, the process of pair-annihilation $e^+e^- \to (\gamma, Z, Z') \to \nu\bar{\nu}$ opens a number of opportunities to further study the stellar energy loss rates combining both the effects of the AMM and the EDM of the neutrino and the $U(1)_{\mathrm{B-L}}$ parameters, with the inclusion of other potentially important channels such as $\gamma + e^\pm \to e^\pm\nu\bar{\nu}$ (ν- photoproduction), $\gamma^* \to \nu\bar{\nu}$ (plasmon decay) and $e^\pm + Z \to e^\pm + Z\nu\bar{\nu}$ (bremsstrahlung on nuclei). These processes are the dominant cause of the stellar energy loss rates in different regions present within the density–temperature plane. These new calculations could contribute to a better understanding of the neutrino physics, and of new physics BSM [52].