

# $\bar{\nu}\nu$ -pair and axion productions in strong magnetic field in relativistic quantum approach and cooling of magnetars

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Magnetic fields in neutron stars play an important role in the interpretation of many observed phenomena. Magnetar, which is associated with a super strong magnetic field, show properties different than normal neutron stars. Particularly large luminosity of photon and neutrino emission attract attention from many researchers.

In this work we study new cooling processes of magnetars,  $\{\nu\bar{\nu}\}$ -pair and axion productions from the transition between the different Landau levels for electron and proton, which occur only under the strong magnetic field. In the strong magnetic field the quantum calculation is necessary because production ratios are often much larger than those in the semi-classical and/or perturbative calculations [1].

We have found that the temperature dependences in the  $\{\nu\bar{\nu}\}$ -pair and axion production processes are much weaker than those of the usual processes such as the modified Urca (MU) and direct Urca (DU), and that the emission ratio becomes much larger than those with the MU and DU processes in the low temperature region below 1keV.

[1] T.Maruyama et al., Phys. Rev. D91, 123007 (2015);  
Phys.Lett.B757, 125 (2016).

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