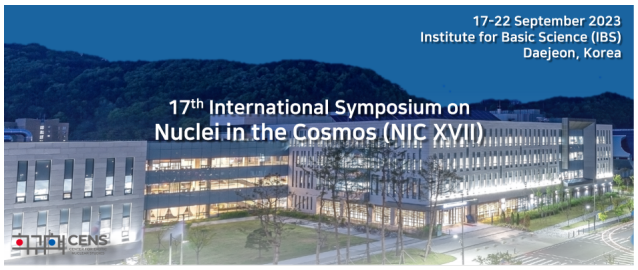

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Neutrino and Anti-neutrino Emission from Neutron-Star Matter with Strong Magnetic Field in a Relativistic Quantum Approaches

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Neutrino and antineutrino emissions are dominant for the cooling process of neutron-stars (NSs). Since neutrino emission rates depend on physical circumstances inside NSs, the study of NS cooling through neutrino emission gives important information for constraining internal NS structures. On the other hand, magnetic fields in NSs play important roles in the interpretation of many observed phenomena. In particular, magnetars, which are associated with super strong magnetic fields, have properties different from normal neutron stars (NSs). Thus, phenomena related magnetars can provide a lot of information about the physics of the strong magnetic field.
There are several kinds of the cooling processes such as the direct Urca (DU) process, the modified Urca process and the neutrino and anti-neutrino pair emission process through the Bremsstrahlung in NN scattering (NN-pair). In these processes the neutrino emission rates must be affected by the magnetic-field because these processes are restricted by the energy-momentum conservation, and a magnetic field provides additional momentum to the particles.
In this work, we study the NN-pair emission [1] and direct Urca [2] process under strong magnetic field in a relativistic quantum approach. We solve exact wave functions for protons and electrons in the states described with Landau levels and calculate neutrino (anti- neutrino) emissions from the transition between two different Landau levels, so that the NN-pair emission can be treated by one-body process.
Then we obtain the following results.
In 10^{15} G of the magnetic field, the energy loss of the NN-pair process is much larger than that of the modified Urca process. In addition, the neutrino emission increases as the magnetic field is weaker around $10^{14} - 10^{15}$ G. Therefore, the neutrino emissivity of the NN pair process must be very effective in relatively low density region. Even the direct Urca process can satisfy the kinematic constraints even in the density regions where this process could not normally occur in the absence of a magnetic field.
Thus, the strong magnetic field plays a very important role to increase the neutrino emissivity in NSs with strong magnetic fields.

[1] T.Maruyama et al., Phys. Lett. B 805, 135413 (2020)
[2] T.Maruyama et al., Phys. Lett. B 824, 136813 (2022)

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