Neutrino Opacities in Kaon Condensates and Evolution of Neutron Stars

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As a new hadronic phase, kaon condensation in neutron star matter has been widely studied in connection with astrophysical phenomena. Recently, a delayed collapse of protoneutron stars has been discussed associated with softening of the equation of state (EOS) due to kaon condensation [1,2]. In such an early stage of neutron stars, neutrino opacity (inverse of the mean free path) plays an important role on dynamical and/or thermal evolution of neutron stars. In a kaon condensate, the neutrino absorption process (KA), $\nu_e N\langle K^-\rangle \rightarrow e^- N$ $(N = p, n)$ with $\langle K^-\rangle$ being the classical kaon field, becomes possible as a unique process for kaon condensation. Here we obtain the neutrino mean free path λ(KA) for KA in both nondegenerate and degenerate neutrino cases based on the EOS with kaon condensation at finite temperatures [2]. We also compare λ(KA) with other relevant mean free paths such as the neutrino scattering processes (S), $\nu_e N \rightarrow \nu_e N$. The relevant matrix elements are obtained from the chirally-transformed effective weak Hamiltonian $\widetilde{H}_{\rm W} = \dfrac{G_F}{\sqrt{2}}\widetilde{J}_h^{\mu} l_\mu + {\rm h.c.}$, where the effective hadronic current $\widetilde{J}_h$ is given in a model-independent way within current algebra.

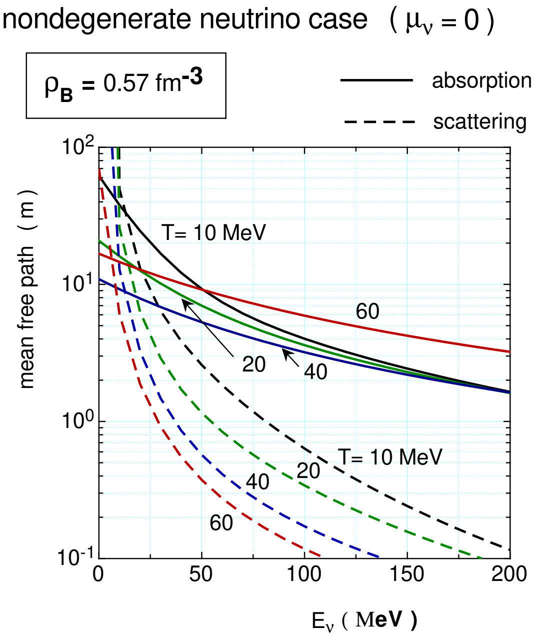

FIG. 1.

In Fig. 1, the dependences of λ(KA) on the neutrino energy E_ν are shown for the baryon number density $\rho_{\rm B}$=0.57 fm^{-3} and several temperatures T (solid lines). For comparison, those for the scattering processes (λ(S)) are also shown (dashed lines). For $E_\nu \gtrsim 20$ MeV, λ(KA) is longer than λ(S), although λ(KA) is shorter than that for the ordinary two-nucleon processes, $\nu_e nN \rightarrow e^- pN$ by a several orders of magnitude when the temperature T is not very high. We estimate a cooling time scale driven by neutrino diffusion taking into account both the KA and S processes, and discuss the relevance of KA to thermal and dynamical evolution of protoneutron stars.

References

[1] J. A. Pons et al., Astrophys.J. **553** (2001) 382.
[2] M. Yasuhira and T. Tatsumi, Nucl. Phys. **A 690** (2001) 769.