NEUTRINO-PAIR BREMSSTRAHLUNG IN DENSE STARS

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Neutrino-pair bremsstrahlung rate is calculated in the framework of the Weinberg-Salam theory for the dense matter relevant to the interior of white dwarfs and neutron stars. Ionic correlations both in the liquid state and in the bcc lattice state have been taken into account accurately. It is found that the ionic correlation in the liquid state reduces the neutrino-pair bremsstrahlung rate typically by a factor 2-20 depending on the element and temperature. It is also found that accurate inclusion of the Debye-Waller factor reduces the neutrino-pair bremsstrahlung rate in the lattice state typically by a factor 2.

Neutrino emission processes play crucial roles in the evolution of dense stars, such as cooling of white dwarfs, presupernova evolution, and cooling of neutron stars. One of the most important neutrino emission processes in dense stars is the neutrino-pair bremsstrahlung by a degenerate electron liquid interacting with the nuclear Coulomb field:

$$e^- + (Z,A) \longrightarrow e^- + (Z,A) + \nu + \bar{\nu}. \qquad (1)$$

Festa and Ruderman (1969) calculated the neutrino-pair bremsstrahlung by relativistic degenerate electrons. They also included screening of the nuclear Coulomb field and lattice effects. Their calculation, however, was based on the V-A theory of weak interaction. Dicus, Kolb, Schramm, and Tubbs (1976) were the first to calculate the neutrino-pair bremsstrahlung rate using the Weinberg-Salam theory. They calculated the neutrino energy loss rate in two cases. One is the so-called weak screening case where the Thomas-Fermi screening is taken into account for the electron-ion interaction and no correlation between the inos is assumed. The other is the so-called strong screening case where a simple model of screening based on the ion-sphere model is employed.

We have calculated the neutrino-pair bremsstrahlung rate in dense stars in the framework of the Weinberg-Salam theory by taking into account the ionic correlations and electron screening accurately.

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For the liquid case the ionic correlation is embodied through the use of the liquid structure factor of the classical one-component plasma which has been a subject of recent active studies. For the bcc lattice case the Debye-Waller factor has been accurately taken into account. Screening due to degenerate electrons is taken into account with the use of Jancovici's (1962) dielectric function.

It has been found that the ionic correlation in the liquid state reduces the neutrino-pair bremsstrahlung rate typically by a factor 2-20 depending on the element and temperature. It has been also found that the accurate inclusion of the Debye-Waller factor reduces the neutrino-pair bremsstrahlung rate in the lattice state typically by a factor 2. These findings are expected to have important consequences on the cooling of white dwarfs, presupernova evolution, and the cooling of neutron stars.

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DISCUSSION

Weidemann: White dwarf central temperatures and densities do not go up to the high values in which your mechanism is important, however, it may be in the region between white dwarf and neutron star densities ($9 < \log \rho < 14$).

Itoh: Then it refers to pre-supernova evolution.