Impact of Medium Effects on the Cooling of Non-Superfluid and Superfluid Neutron Stars

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Neutrino emission from the dense hadronic component in neutron stars is subject to strong modifications due to collective effects in the nuclear medium. We implement new estimates of the neutrino emissivities of two processes operating in the nuclear medium into numerical cooling simulations of neutron stars. The first process is the modified Urca process, for which the softening of the pion exchange mode and other polarization effects as well as the neutrino emission arising from the intermediate reaction states are taken into account. The second process concerns neutrino emission through superfluid pair breaking and formation processes. It is found that the medium effects on the emissivity of the modified Urca process result in a strong density dependence, which gives a smooth crossover from the standard to the nonstandard cooling scenario for increasing star masses. For superfluid stars, the superfluid pair breaking and formation processes accelerate mildly both the standard and the nonstandard cooling scenario. This leads to a good agreement between the theoretical cooling tracks and the rather low temperatures observed for objects like PSRs 0833-45 (Vela), 0656+14, and 0630+18 (Geminga). The robustness of our findings against variations in both the underlying equation of state of baryonic matter and the used fast cooling processes is demonstrated. Hence we conclude that the two recalculated neutrino emissivities studied here enable one to reproduce theoretically most of the observed pulsar temperatures by varying the masses of neutron star models.

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Neutron Superfluidity in Strongly Magnetic Interiors of Neutron Stars and its Effect on Thermal Evolution

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The possibility of a neutron $m = 2$–superfluid in the interior of neutron stars is investigated. This pairing state is energetically favored in strong magnetic fields ($H \sim 10^{16}$ G). Because of the node in the angular-dependent energy gap along the field direction the neutrino emissivity is only suppressed polynomially as function in T/T_c instead of exponentially, as it is obtained for a nodeless pairing state. The effect of this pairing state on the thermal evolution of neutron stars is studied, and its outcome is compared with the evolution of "normal", i.e. nodeless, superfluid and non-superfluid neutron stars, and also with observations. We find that particularly the predicted surface temperatures of the enhanced cooling scenario considerably change and come into agreement with temperatures deduced from observational data within the hydrogen atmosphere model. Furthermore the surface temperature depends on the magnetic field strength as an additional parameter aside from the neutron star mass. The latter is however only operative in the case of the intermediate cooling scenario.

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