Cooling of hyper-neutron stars

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We have studied [1] the thermal evolution of hypernuclear compact stars constructed from covariant density functional (CDF) theory of hypernuclear matter and parameterizations which produce sequences of stars containing two-solar-mass objects [2,3]. Some of the considered CDF are based on the density-dependent parametrization of nucleonic density functional (DDME2 [4] and SWL [5]) while others employ non-linear mesonic couplings (NL3 [6] and GM1A [7]). In some cases meson-hyperon coupling constants are determined on the basis of SU(6) flavor symmetry arguments, in other cases the SU(3) symmetry is used. The constraints imposed on the values of hyperonic potentials in symmetric saturated nuclear matter [8] which imply $U_{\Lambda}^{(N)} \approx -28$ MeV, $U_{\Xi}^{(N)} \approx -18$ MeV, $U_{\Sigma}^{(N)} \approx 30$ MeV have been incorporated in all these parametrizations of the CDF. We have considered $\Lambda\Lambda$ and $\Xi\Xi$ interactions in the $^1S_0$ channel according to the 2000 [9] and, and 2008 [10] versions of the Nijmegen Extended Soft Core potential, whose coordinate space expressions have been worked out in Refs. [11,12]. The fact that these two potentials are among the most attractive potentials in the literature maximizes the pairing gaps of these species and, consequently, the role of hyperonic superfluidity on the NS cooling. For the input in the simulations, we solve the BCS gap equations in the hyperonic sector and obtain the gaps in the spectra of Λ, Ξ^0 and Ξ^- hyperons. For the models with masses $M/M_{\odot} \geq 1.5$ the neutrino cooling is dominated by hyperonic direct Urca processes in general. In the low-mass stars the (Λp) plus leptons channel is the dominant direct Urca process, whereas for more massive stars the purely hyperonic channels $(\Sigma^-\Lambda)$ and $(\Xi^-\Lambda)$ are dominant. Hyperonic pairing strongly suppresses the processes on Ξ^-s and to a lesser degree on Λs. We find that intermediate-mass $1.5 \leq M/M_{\odot} \leq 1.8$ models have surface temperatures which lie within the range inferred from thermally emitting neutron stars [13], if the hyperonic pairing is taken into account. Most massive models with $M/M_{\odot} \simeq 2$ may cool very fast via the direct Urca process through the (Λp) channel because they develop inner cores where the S-wave pairing of Λs and proton is absent.

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