Towards model-independent analysis of cooling neutron stars

D. D. Ofengeim[1]*, D. G. Yakovlev[1]

[1]Ioffe Institute, 26 Politekhnicheskaya Str., St. Petersburg, 194021, Russia

We have elaborated a method for analysing cooling neutron stars with nucleon cores. The method is almost independent of a model equation of state in neutron star cores. It is based on nearly universal approximations of the neutrino luminosity L_ν and the heat capacity C of the star (e.g., [1]) by analytic functions of stellar mass M, radius R and redshifted internal temperature, for some selected basic cooling scenarios.

This allows us to analyse neutron stars at the neutrino cooling stage (ages $t \lesssim 10^5$ yr) which is governed by the L_ν/C ratio. In particular, we have considered the neutron star XMMU J173203.3–34418 in the HESS J1731–347 supernova remnant [2] and the Vela pulsar (whose spectral analysis was kindly provided by D. Zyuzin). For both stars, we calculate/constrain the neutrino cooling factor $f_\ell = (L_\nu/C)/(L_{\nu\,\mathrm{SC}}/C_{\mathrm{SC}})$, as a function of M, R and the composition of the heat blanketing envelope. Here, the subscript 'SC' refers to the standard neutrino candle [3] — a non-superfluid model of the same star which cools via the modified Urca process.

For neutron stars of ages $\sim 10^5 - 10^6$ yr which transit from the neutrino to the photon cooling stage, we find a simple temperature — age relation valid for both, the neutrino and photon cooling stages. Using these results, we analyze the cooling neutron star RX J1856.5–3754 [4]. We show that the influence of baryon superfluidity on its cooling should be described by two factors, f_ℓ and $f_C = C/C_{\mathrm{SC}}$, which we constrain.

This model-independent analysis allows one to investigate the properties of neutron and proton superfluidities in neutron stars cores. Its perspectives are described.

References

[1] D. D. Ofengeim, M. Fortin, P. Haensel, D. G. Yakovlev, J. L. Zdunik, *ArXiv:* 1612.04672 (2016)

[2] D. D. Ofengeim, A. D. Kaminker, D. Klochkov, V. Suleimanov, D. G. Yakovlev, *MNRAS*, 454, 2668 (2015)

[3] D. G. Yakovlev, W. C. G. Ho, P. S. Shternin, C. O. Heinke, A. Y. Potekhin, *MNRAS*, 411, 1977 (2011)

[4] D. D Ofengeim, D. G. Yakovlev, *MNRAS*, 467, 3598 (2017)

*E-mail: ddofengeim@gmail.com