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Effects of density-dependent lepton fraction on the properties of protoneutron stars

A. Sulaksono and L. Satiawati

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ABSTRACT

The density-dependent lepton fractions approach that is used to describe the properties of matter with neutrino trapping is systematically studied. It is found that two sets of the ratio of trapped neutrinos to leptons parameters—i.e., one for a relativistic mean field parameter set with stiff equation of state and one for a parameter set with soft equation of state—yield particle composition profiles at high densities similar to those predicted by the standard fixed lepton fraction approach. However, these sets of parameters produce significantly different behavior at low densities compared to those of standard approach. The consequences of applying the density-dependent lepton fractions approach to some properties of PNS, such as the particle composition, equation of state, the onset of low-density instability, the mass-radius relation, and the mean free path of electron neutrino, are investigated. By comparing the results with those of the standard approach, we obtain the result that the PNS equation of state is not significantly influenced by the low-density behavior difference between the two approaches. However, the density-dependent lepton fractions approach yields a smaller onset of low-density instability matter and core-crust transition density but a slightly larger maximum mass as well as a larger radius of canonical mass than those predicted by the standard approach. The estimated minimum PNS mass and its radius are apparently also sensitive to the parameter used for the ratio of trapped neutrinos to leptons. For electron neutrino transport in PNSs, matter with density-dependent lepton fractions is more transparent than matter with fixed lepton fractions.

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AUTHORS & AFFILIATIONS

A. Sulaksono[1] and L. Satiawati[2]

- [1]Departmen Fisika, FMIPA, Universitas Indonesia, Depok 16424, Indonesia
- [2]Program studi Fisika, FTS, Universitas Nasional, Jakarta 12520, Indonesia