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Regulator-independent equations of state for neutron stars generated from first principles

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Abstract

We study the equation of state (EoS) of a neutron star (NS) accounting for new advances. In the low energy density, n ≤ 0.1ns, with ns the saturation density, we use a new pure neutron matter EoS that is regulator independent and expressed directly in terms of experimental nucleon-nucleon scattering data. In the highest-density domain our EoS's are matched with pQCD to O(αs^3). First principles of causality, thermodynamic consistency and stability are invoked to transit between these two extreme density regimes. The EoS's are further constrained by the new measurements from PREX-II and CREX on the symmetry energy (S0) and its slope (L).

In addition, we also take into consideration the recent experimental measurements of masses and radii of different NSs and tidal deformabilities. A band of allowed EoS's is then obtained. Interestingly, the resulting values within the band for S0 and L are restricted with remarkably narrower intervals than the input values, with 32.9 ≤ S0 ≤ 39.5 MeV and 37.3 ≤ L ≤ 69.0 MeV at the 68% CL. The band of EoS's constructed also allows possible phase transitions (PTs) for NS masses above 2.1 Mα at 68% CL for n > 2.5ns. We find both long and short coexistence regions during the PT, corresponding to first and second order PTs, respectively.

We also generate the band of EoS's when excluding the astrophysical observables. This is of interest to test General Relativity and modified theories of gravity. Our band of EoS's for NSs can be also used to study other NS properties and dark matter capture in NS.

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