Neutron stars as dense liquid drop at equilibrium within the effective surface approximation

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The macroscopic model is formulated for a neutron star (NS) as a perfect liquid drop at the equilibrium [1]. We use the leptodermic approximation $a/R \ll 1$, where a is the crust thickness of the effective surface (ES) of NS, and R is the mean radius of the ES curvature. Within the approximate Schwarzschild metric solution to the general relativity theory equations for the spherically symmetric systems, the macroscopic gravitation is taken into account in terms of the total separation particle energy and incompressibility. Density distribution ρ across the ES in the normal direction to the ES was obtained analytically for a general form of the energy density $\mathcal{E}(\rho)$. For the typical crust thickness, and effective radius, one finds the leading expression for the density ρ. NS masses are analytically calculated as a sum of the volume and surface terms, taking into account the radial curvature of the metric space, in reasonable agreement with the recently measured masses for several NSs. We derive the simple macroscopic equation of state (EoS) with the surface correction. The analytical and numerical solutions to Tolman–Oppenheimer–Volkoff equations for the pressure are in good agreement with the volume part of our EoS.

As perspectives, one can generalize our analytical approach to take into account the gradient terms in the TOV equations, also to many-component and rotating systems. It is especially interesting to extend this approach to take into account the symmetry energy of the isotopically asymmetric finite systems. As this approach was formulated in the local nonlinear system of coordinates ξ, η, φ for deformed and superdeformed shapes of the effective surface, one can apply our method to the NS rotating pulsars at large angular momenta.

[1] A.G. Magner, S.P. Maydanyuk, A. Bonasera, H. Zheng, A.I. Levon, T.M. Depastas, U.V. Grygoriev, Int. J. Mod. Phys. E **33**(11), 2450043 (2024).