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Extension of the Relativistic Thomas-Fermi model using the three-dimensional basis of the oscillator in oblate and prolate spheroidal coordinates

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The crust of neutron stars has been the subject of intense study due to its possible inhomogeneous structures, which arise from the complex interplay between strong nuclear forces and the Coulomb interaction among particles. These structures can significantly influence various star properties, such as thermal and electrical conductivity, shear viscosity, moment of inertia, and so forth, consequently impacting the star's magneto-thermal evolution, pulsar glitches, and gravitational waves.
One of the most successful models for characterizing these peculiar structures, known as the nuclear pasta phase, is the Thomas-Fermi model. In most applications, calculations are simplified to involve only one degree of freedom. This research project aims to address this limitation by exploring the implications of an innovative modeling approach for a well-established problem.
The study will focus on neutron star phenomenology, particularly their crust and inhomogeneous structures. It will include a comprehensive literature review of the relativistic hadronic model of stellar matter based on the nonlinear Walecka model, followed by the relativistic Thomas-Fermi approximation for characterizing the pasta phase. Our main objective is to analytically extend the Thomas-Fermi model to the three-dimensional harmonic oscillator basis in oblate and prolate spheroidal coordinates.
Additionally, we intend to implement the obtained results into a custom algorithm, enabling us to analyze the implications of this new structural modeling approach using numerical computation methods. It is believed that this innovative approach may reveal new energetically favorable inhomogeneous structural formations not yet simulated. In other words, we aim to elucidate how these structures manifest in the universe with greater precision.
This research project is a crucial step toward a deeper understanding of neutron stars, illuminating the mysteries of their formations and characteristics. By exploring this new structural modeling tool, we open doors to a better comprehension of the intriguing effects of nuclear pasta in the stellar crust. Each discovery brings us closer to a clearer and more comprehensive understanding of these stars, transforming current astronomical data into richer and more meaningful narratives.

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