6 March 2025 · CC-BY 4.0 Qeios

Peer Review

Review of: "General Features of the Stellar Matter Equation of State From Microscopic Theory, New Maximum-Mass Constraints, and Causality"

Andrea Sabatucci[1]

1. INFN Sezione di Pisa, Pisa, Italy

In this paper, the authors discuss different Equations of State (EOSs) for neutron star matter and use them to compute both static properties such as the mass and radius, and cooling properties of NSs, comparing their predictions with currently available NS data. The EOSs are constructed by combining a low-density component, derived from microscopic calculations within the well-established framework of Chiral Effective Field Theory (ChEFT), with a phenomenological high-density component. Specifically, for the low-density regime, the authors consider two different chiral Hamiltonians: one including terms up to next-to-next-to-leading order (N2LO) and the other up to next-to-next-to-next-to-leading order (N3LO). For the high-density regime, they explore different parameterizations, including a piecewise polytrope, a formulation based on the speed of sound, and a combination of both.

The manuscript is well-structured and clearly written. The authors emphasize the importance of an accurate microscopic description of the physics at saturation density in shaping the EOS at higher densities relevant for neutron star matter. While the methodologies and concepts employed are not particularly novel, the study is nevertheless valuable in reinforcing the crucial role of microscopic nuclear physics in determining the EOS of dense matter. The work also highlights the need for systematic studies employing fully consistent microscopic nuclear Hamiltonians.

In particular, I personally appreciated the critical discussion about the regime of applicability and reliability of the ChEFT, and about the consistency of two- (NN) and three-nucleon (NNN) forces at

 doi.org/10.32388/YPoOT3

N2LO and N3LO. However, I have a few minor comments that, if addressed, would further improve the quality of the manuscript:

1) In Eq. (5), the authors should explicitly define the parameter 'w'.

2) In Section III, when discussing the combined parametrization, the authors should provide a more detailed justification for the choice of the second threshold density. In particular, why is an interval of two ρ_0 from the previous threshold considered a suitable choice?

3) In Section IV, the authors should expand the discussion about the formalism of cooling processes. A brief discussion of this point would enhance the reader's understanding.

Additionally, the authors should mention the many-body method employed in the derivation of the microscopic equation of state (EOS), as it is a crucial aspect of any microscopic calculation. The degeneracy in the EOS of neutron matter introduced by the choice of both the Hamiltonian and the many-body technique has been recently explored in [1,2].

Conclusion

While the study does not introduce fundamentally new methodologies, it provides a clear and well-motivated analysis that contributes to our understanding of neutron star matter. By addressing the aforementioned points, the manuscript's clarity and overall impact will be further improved.

As a final remark, some works suggest that the presence of relativistic corrections could play a role in the determination of the interaction potentials. In particular, an interplay between relativistic corrections and NNN forces has been addressed both in the context of Chiral Hamiltonians [3] and Phenomenological ones [4]. Recently, the softening of the NNN repulsion of the phenomenological Urbana IX NNN potential, induced by the presence of boost corrections to the Argonne v18 (AV18) NN potential, and its impact on the EOS of dense matter and NS properties have been discussed in Ref. [5]. Maybe the authors could find it worth exploring such a possibility in future developments.

References

[1] M. Piarulli, I. Bombaci, D. Logoteta, A. Lovato, and R. B. Wiringa. Benchmark calculations of pure neutron matter with realistic nucleon-nucleon interactions. Phys. Rev. C, 101:045801, Apr 2020

[2] A. Lovato, I. Bombaci, D. Logoteta, M. Piarulli, and R. B. Wiringa. Benchmark calculations of infinite neutron matter with realistic two- and three-nucleon potentials. Phys. Rev. C, 105:055808, May 2022

[3] Y. L. Yang and P. W. Zhao. A consistent description of the relativistic effects and three-body interactions in atomic nuclei. Phys. Lett. B, 835:137587, 2022.

[4] J. L. Forest, V. R. Pandharipande, and A. Arriaga, "Quantum monte carlo studies of relativistic effects in light nuclei," Phys. Rev. C 60 (Jun, 1999) 014002

[5] Andrea Sabatucci, Omar Benhar, and Alessandro Lovato. Relativistic corrections to the correlated basis function effective nuclear hamiltonian. Phys. Rev. C, 110:055801, Nov 2024

Declarations

Potential competing interests: No potential competing interests to declare.