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Temperature Effects on the Equation of State and Symmetry Energy: A Critique

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Abstract

The investigation of strongly interacting systems ranges from matter inside atomic nuclei to matter under extreme conditions in astrophysics. These systems require the introduction of nuclear forces and a systematic many-body approach to solve the strong interaction particles. Understanding the behavior of infinite nuclear matter provides a path to predict the properties of neutron stars and gives insights to astrophysical phenomena. Three-nucleon forces have to be considered when studying nuclear systems, because their impact is necessary to reproduce properties of nuclei and to correctly obtain the neutron drip line. Moreover, they are needed to predict the empirical saturation properties of infinite nuclear matter. The self-consistent Green's Function approach paves the way for an improved *Ab initio* analysis of nuclear matter, thereby providing the basis for the equation of state of neutron stars and supernova explosions.

Keywords

Nuclear Matter, Equation of State, Neutron Matter

Criticism

The Brueckner-Hartree-Fock (BHF) approach was used in the study of hot nuclear systems. The BHF approximation takes into account particle-particle correlations by solving the Bethe-Goldstone equation. On the other hand, a minimal consistent treatment of correlations in nuclear systems requires the addition not only of particle-particle intermediate states, but also of the hole-hole ones. One important feature of the self-consistent Green function (SCGF) approximation is that particles and holes are treated on equal footing. The effect of the hole-hole term is small at low densities and becomes larger at higher densities. In a recent work [1], the author studied the microscopic and thermal properties of hot symmetric nuclear matter and pure neutron matter. Special emphasis was made to study the equation of state at high-density and low-temperature which is critical to determine the properties of neutron stars, and the mass-radius relationship and the neutron star maximum mass. For that reason, the author made use of the microscopic approaches exact-BHF and the self consistent green's function SCGF using CD-BONN potential. Two criticisms are in order:

1) The free energy which was calculated according to Equation (13) is correct because it contains two variables m* and T. But, the author used it with wrong method. m* was taken as constant values where it is in fact a function of density. So the figures (1 - 10) are drawn with wrong method. Also, the effect of temperature is not being real with this method [2] [3]. The calculation of the symmetry energy according to equation 19 is not good especially at high densities [4] contrary to the claim of the whole work where special care of the author was given to the low and high density regions. This is simply because of the use of an incorrect density independent Skyrme potential.

2) It is noted that the author has added a wrong correction to the three-body force. The author claims in the abstract, text and conclusion that he used 3-body corrections in order to get an agreement with the experimental data besides his BHF calculation. In Equations 8 - 10, he gave the name of a potential v_i on the LHS where such terms are in fact the contribution to the energy per particle $(E/A)_i$ from Skyrme potentials v_i which are not written in the paper. The potentials used to get such results are, respectively, a zero range two-body Skyrme potential which is density independent. The second term is a zero range two-body Skyrme interaction which is density dependent. For the last one, this is equivalent to the inclusion of a three-body force. Therefore, the first term should be excluded from the calculation as this contradicts his assumptions of using 3-body forces. Hence, any further calculation in the paper using such potentials where one of them is density independent is wrong and should be repeated in a correct manner. It is noted that Mansour's three-body potential given in reference [5] is a resilient and very useful in reproducing all the physical quantities related to nuclear and neutron matter over a wide density range [5].

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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