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The transport properties of neutron matter in the *LOCV* channel dependent effective two-body interactions framework

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Abstract

The channel dependent effective two-body interactions (*CDEI*) which are generated through the lowest order constrained variational (*LOCV*) method for pure neutron matter (*PNM*) are used to calculate the in-medium neutron–neutron (*nn*) cross-sections and transport properties of *PNM* within the Landau–Abrikosov–Khalatnikov (*LAK*) formalism. Similar to our previous work, the *Reid*68, Δ-*Reid*68, and Av_{18} interactions as well as the V_6' potential are considered as the input bare nucleon–nucleon phenomenological potentials. In present work, we improve our previous results by calculating the shear viscosity and thermal conductivity of *PNM* in the framework of *LOCV CDEI* and the comparisons are made with those coming from the channel independent calculations, i.e. the averaged effective interactions (*AEI*) results. It is shown that our new results are in a good agreement with the other approaches. It is also demonstrated that, the choice of in-medium effective interaction has a crucial role in the resulting *nn* cross-section as well as the transport properties of *PNM*.

Keywords: *LOCV* method; Shear viscosity; Thermal conductivity; Pure neutron matter

1. Introduction

In our recent publication [1], the averaged effective two-body interactions (*AEI*) [2], were generated through the lowest order constrained variational (*LOCV*) [3,4] method, and they were

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used to calculate the neutron–neutron (*nn*) cross-sections as well as the transport properties of pure neutron matter (*PNM*), within the Landau–Abrikosov–Khalatnikov (*LAK*) formalism [5–7] (see Appendix A). The results were qualitatively encouraging. But it was not clear how large would be the effect of implication of *AEI*, instead of the channel dependent effective two-body interactions (*CDEI*) [2]. Our previous works are shown that in the case of nuclear matter saturation properties calculations, this approximation should not have a drastic effect [8]. So it is worth to reformulate the formalism of our recent work [1], for the channel dependent effective two-body interactions.

The transport properties of dense stellar matter, and in particular, its shear viscosity and thermal conductivity play a crucial role in the understanding of stellar structure and stellar evolutions. They are the key factors for the gravitational wave instabilities in the rapidly rotating neutron stars, and thereby the maximum rates of their rotation [9], and the main factors to explore the information about the neutron star cooling [10].

The transport properties of pure neutron and neutron star matter have been calculated by the several groups [11–18]. In the 70s, Flowers and Itoh, calculated the shear viscosity and thermal conductivity of neutron star matter by using the available bare experimental nucleon–nucleon (*NN*) phase shifts [11,12]. They neglected the many body effects of the medium from their calculations.

In the recent years, the inclusion of in medium effects in the *nn* cross-section and the transport coefficients of *PNM* have been performed by using the correlated basis function (*CBF*), *G*-matrix, Bruckner–Hartree–Fock (*BHF*) and *T*-matrix approaches [13–18], within the *LAK* formalism [5–7] (see Appendix A). In these works, the reduced versions of Av_{18}, i.e. V_8' and V_6' [13–15], and *Bonn-B* [16] potentials as well as the *nn*-phase shift [17,18] have been used. In most of these calculations it has been shown that, the inclusion of in medium modification leads to a noticeable decrease of the *NN* cross-section and as its consequence, a large increase in the shear viscosity and thermal conductivity.

As it was mentioned above, in our previous work [1], we have obtained the in-medium cross-section and the transport coefficients of pure neutron matter, by using the *LOCV* averaged effective two-body interactions, which are generated through the lowest order constrained variational calculations for neutron matter with the *operator* (Av_{18} and V_8') and *Reid* (*Reid*68 and Δ-*Reid*68) types potentials. But the results were not very satisfactory. There were the noticeable differences between our results and the other approaches.

In this paper, we intend to improve our formalism to calculate the *nn* cross-section and transport properties of *PNM*. We will use, the channel and density dependent effective two-body interactions, which are generated through our *LOCV* calculation for neutron matter, with the Av_{18}, V_6', *Reid*68 and Δ-*Reid*68 potentials. Note that in order to compare our results with other methods [15], in this work, we use V_6' potential instead of V_8' interaction.

The *LOCV* channel and density dependent effective two-body interactions, have been tested by calculating the properties of the light and heavy closed shell nuclei [2,19,20]. The *LOCV* formalism as well as its applications to nuclear matter and finite nuclei have been fully discussed in the works of Owen et al. [3,4] and Modarres et al. [2,8,19–25] (and the references therein).

So the paper is organized as follows: A very short description of the *LOCV* formalism and calculation of the channel dependent effective two-body interactions are given in Section 2. The calculation of the in-medium *nn* cross-section by using the *LOCV CDEI* are discussed in Section 3. A short presentation of the transport coefficients in the Landau–Abrikosov–Khalatnikov (*LAK*) framework is given in Appendix A. Finally, results, discussions and conclusions are presented in Section 4.