Available online at www.sciencedirect.com

SciVerse ScienceDirect

Nuclear Physics A 903 (2013) 40–53

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

The in-medium *nn* cross section and the transport properties of neutron matter using the *LOCV* effective two-body interaction

M. Modarres *, M. Rahmat

Physics Department, University of Tehran, 1439955961, Tehran, Iran

Received 17 November 2012; received in revised form 23 February 2013; accepted 25 February 2013

Available online 6 March 2013

Abstract

In order to calculate the in-medium neutron–neutron (*nn*) differential cross section and the transport properties of the pure neutron matter, the lowest order constrained variational (*LOCV*) method is applied to obtain the effective nucleon–nucleon (*NN*) interactions from the various *bare* realistic phenomenological *NN* interaction. The wide range of potentials, such as the *Reid*68, the Δ-*Reid*68, the V_8' and the Av_{18} are used as the input phenomenological interactions. The approach, based on the effective *NN* interaction, allows for a consistent description of the neutron matter and the nucleon–nucleon scattering in the nuclear medium. In this work, by using the above *LOCV* effective *NN* interactions, beside the *nn* differential cross section, the related quantities such as the shear viscosity and the thermal conductivity of the pure neutron matter, which are the important gradient for the stellar structure, are calculated within the Landau–Abrikosov–Khalatnikov (*LAK*) formalism. It is shown that, while the density dependence of effective mass are not important, the choice of in-medium effective interaction has crucial rule on the resulting *nn* differential cross section as well as the shear viscosity and the thermal conductivity of pure neutron matter. Finally, our above *LOCV* calculations are compared with those predicted by the other theoretical methods.

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

* Corresponding author. Tel.: +98 21 61118645; fax: +98 21 88004781.
E-mail address: mmodares@ut.ac.ir (M. Modarres).

0375-9474/$ – see front matter
http://dx.doi.org/10.1016/j.nuclphysa.2013.02.119

1. Introduction

The knowledge of the transport properties of the dense stellar matter is an important factor in the understanding of the stellar structure and its evolution. In particular, the viscosity plays a crucial role in determining the stability of the rotating neutron stars, and the thermal conductivity is one of the main factors to explorer the information about the neutron star cooling [1,2].

The exact solution for the transport coefficients of the multi-component of the several interacting Fermi liquids at low temperature was developed by Abrikosov and Khalatnikov [3,4], which is based on the Landau theory of the normal Fermi liquids [5]. In the 70s, Flowers and Itoh calculated the shear viscosity and the thermal conductivity of the neutron star matter by using the available *bare* experimental nucleon–nucleon (*NN*) phase shifts [6,7].

The main difficulty in obtaining the transport coefficients within the Landau–Abrikosov–Khalatnikov (*LAK*) formalism, is the determination of the nucleon–nucleon (*NN*) collision probability in the nuclear medium. Usually, the many-body effects of the medium are neglected, and as it was pointed out above, the collision probabilities are constructed from measured free (*bare*) *NN* scattering phase shifts. Recently, Benhar et al. and Zhang et al. have obtained the probability of the neutron–neutron (nn) collisions in the nuclear medium from a realistic potential, using the correlated basis function (*CBF*), the G-matrix, the Bruckner–Hartree–Fock (*BHF*) and T-matrix approaches [9–14]. They have also calculated the shear viscosity and the thermal conductivity of the neutron star matter in the frame-work of the *LAK* approach, with inclusion of the *CBF*, the G-matrix and the *BHF* in-medium effective interactions [9–14], as the input. In these works, the reduced version of the Av_{18}, i.e., V_8' [9–11] and the *Bonn-B* [12] potentials as well as nn-phase shift [13,14] have been used.

In this article, it is intended to obtain the in-medium cross section and the transport coefficients of the pure neutron matter, by using the effective *NN* interactions which are generated through the lowest order constrained variational (*LOCV*) calculation for the neutron matter with the *operator* (Av_{18} and V_8') and the *Reid* (*Reid*68 and Δ-*Reid*68) type potentials.

The authors of Refs. [9–12] claim to have included the effect of three-body force (*TBF*) in their effective two-body interaction by using (1) the density dependent parameterized *TBF* (based on two-pion exchange interaction) which fits the triton and the empirical nuclear matter saturation density or the defect function coming from *BBG*-equation which again, it is density and model dependent. But in this work we intend only to focus on the *NN* interactions which fit the two-nucleon phase shift data and have been used in both *CBF*, $G(T)$-matrix and *BHF* approaches. However our results with the Δ-*Reid*68 potential [15,16] contain the Δ state, i.e., the most important configuration which might be the original understanding of the 3*BF* [17]. The *LOCV* calculation of Modarres and Irvine [15] with this potential predicts results close to the empirical saturation of nuclear matter similar to the other approaches, in which the *TBF* have been included.

The *LOCV* formalism is capable of producing the optimized state and the density dependent effective *NN* interaction. The validity of *LOCV* method, as well as its application to the nuclear matter and the finite nuclei have been fully discussed in the works of Owens et al. [18,19] and Modarres et al. [15,20–26] (see especially our recent works [22,26,27]). The *LOCV* effective two-body potentials have been tested by calculating the properties of the light and the heavy closed shell nuclei [23–25].

So the paper is planned as follows: In Section 2, the *LOCV* method and the calculation of the effective two-nucleon potentials are briefly introduced. Section 3 is devoted to the presentation