Symmetry Energy and its density dependence using Brueckner Hartee Fock theory

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Introduction

The study of the nuclear matter symmetry energy $E_{sym}(\rho)$ which essentially characterizes the isospin-dependent part of the equation of state (EOS) of asymmetric nuclear matter, is currently an exciting topic of research in nuclear physics. Knowledge about the symmetry energy is essential in understanding many aspects of nuclear physics and astrophysics as well as some interesting issues regarding possible new physics beyond the standard model [1]. In recent years, significant progress has been made in determining the density dependence of $E_{sym}(\rho)$ especially its value $E_{sym}(\rho_0)$ and its density slope L at saturation density ρ_0.The Neutron Matter EOS combined with that of the Symmetric Nuclear Matter provides us with the information on the Iso-Spin effects [2] in particular on the Symmetry energy. The density dependence parameter L is of fundamental importance in nuclear physics as well as in astrophysics. Many astrophysical phenomena also depend sensitively on the symmetry slope parameter L. Most notable among them are the dynamical evolution of the core collapse of a massive star and the associated explosive nucleo-synthesis [3] and the nature and stability of phases within a neutron star also seem to be strongly influenced by the symmetry energy and its density dependence. Attempts on estimates of L have been made in the last few years from analyses of diverse experimental data, however, uncertainties still linger. The density distribution studies had led to an empirical value of L= 52±20MeV [4].

The symmetry energy can be expressed in terms of the difference between the binding energy of pure neutron matter $E_A(\rho,1)$ and that of symmetric nuclear matter $E_A(\rho,0)$ i.e.,

$$E_{sym}(\rho)=E_A(\rho,1)- E_A(\rho,0)$$

A number of studies have been carried out to determine the value of the symmetry energy and its density slope L at the Nuclear Matter saturation density (ρ_0). The empirical value of the symmetry energy $E_{sym}(\rho_0)$ has been found to be 30.5±3MeV [5] and L = 52±20MeV[4].

Results and Discussion

We perform a systematic analysis of the baryonic density dependence of Nuclear Symmetry energy within the microscopic non-relativistic Brueckner Hartee Fock (BHF) approach employing various new high quality NN potentials. The potentials we employ are the recent versions of Nimagen group, Argonne V18, Urbana V14 and Reid 93. We also study the effect of the introduction of phenomenological Three Body Force (TBF) in AV18 NN interaction of Urbana type UVIX on the symmetry energy. The density dependence of E_{sym} given by the density slope parameter L is defined as [4].

$$L = 3\rho_0 \frac{dE_{sym}}{d\rho} \text{ at } \rho = \rho_0$$

From our results we conclude that the values of symmetric energy calculated using different interactions are close to each other at low densities but show significant difference at higher densities. Hence the dependence of Symmetry energy on different potentials becomes evident only at high densities.

Our results for Esym(ρ_0) are 33.2MeV for AV18, 35.39MeV for Reid93,34.32MeV for NijmII and 34.05 MeV for Urbana V14. We find that our results are quite close to the empirical value. We observe that in all cases the dependence of Symmetric energy on density is nearly linear.
Further the inclusion of three body forces increases the symmetry energy at high densities and leads therefore in astrophysical applications to a stiffer EOS. For example, at density of 0.4fm^{-3} the values of symmetry energy using AV18 NN potential is 48.2MeV and using AV18 plus UVIX three body force the value of symmetry energy is 53.2 MeV.This is in accordance with the earlier qualitative studies [6,7].These deviations at high densities are important and this is being investigated. The precise value of density slope parameter L would give us a better insight of the behavior of symmetry energy with the variation of density. Our results are; 53.34MeV for AV18, 61.31MeV for Reid93 and 64.72MeV for NijmII.Thus our results are in a very close agreement with those found by to that of Lambardo et.al [6].

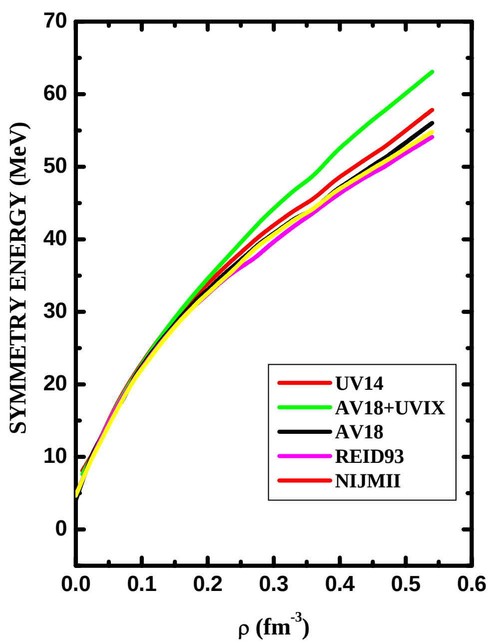

Fig. 1 Variation of Symmetry energy with the density of Nuclear Matter.

Acknowledgement

W. Haider gratefully acknowledges the financial grant from the Department of Atomic Energy (DAE), Board of Research in Nuclear Sciences (BRNS), Government of India under BRNS Project No. 2011/37P/16/BRNS.

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