EOS of Neutron Matter in Brueckner Theory

Manjari Sharma[1]*, W. Haider[1]
[1]*Department of Physics, Aligarh Muslim University, Aligarh -202002, INDIA*
* *email:manjari.1683@yahoo.co.in*

Abstract : The equation of state of pure neutron matter at zero temperature is calculated in lowest order Brueckner theory. The calculation is performed for Urbana v14 inter nucleon interaction up to Fermi momentum 4 fm^{-1}.The integral equation method of Brueckner and Gammel is used for the calculation of the reaction matrices (g-matrices).The pure neutron matter system is unbound at any density.

Introduction

The equation of state (EOS) of nuclear matter at high density is one of the relevant issue in the theory of neutron star structure. In the present work we discuss the analysis of pure neutron matter EOS,at densities up to about five times the saturation density ($\rho = 0.17 fm^{-3}$),which is more appropriate for neutron star studies. Pure neutron matter is defined as an idealized infinite, homogenous system of neutrons. At the given density the properties of such a system, treated as a gas of interacting fermions at T = 0°K, are determined by the neutron-neutron interaction. Neutron matter is not bound and therefore not stable at zero pressure with only strong interaction.

General Theory

We have followed the method of Brueckner and Gammel [1] to solve the integral equation to obtain g-matrix for all inter-nucleon states up to 1=11 using Urbana v14[2] interaction. Integral equation for the reaction matrix is defined as

$$g(w = e(j) + e(k)) = v - v\frac{Q}{e(k_1) + e(k_2) - w} g \qquad (1)$$

where the single particle energy e(k) is given by

$$e(k) = \frac{\hbar^2 k^2}{2m} + V(k) \qquad (2)$$

The nucleon-nucleus optical potential in nuclear matter is defined as (ref [3]) the antisymmetrized matrix elements of the reaction matrix g

$$V_{NM}(k, E) = \sum_{\vec{j}} n_{\langle}(j) \langle \vec{k}, \vec{j} | g(E + e(j)) | \vec{k}, \vec{j} \rangle_A \qquad (3)$$

The energy per nucleon for infinite neutron matter is given by

$$E/N = \frac{\int_0^{k_F} \left[\frac{\hbar^2 k^2}{2m} + \frac{1}{2} V(k) \right] k^2 dk}{\int_0^{k_F} k^2 dk} \qquad (4)$$

Here the Fermi momentum k_F is related to the density ρ of neutron matter

$$\rho = k_F{}^3 / 3\pi^2 \qquad (5)$$

Results

(1) Equation of state

The result of binding energy per nucleon as a function of fermi momentum for neutron matter is shown in figure1. We also compare our results with the results of ref [4], where they drive EOS of neutron matter from BBG many body theory using Argonne v14 interaction.
From figure 1 we conclude that our results are in close agreement with that of AV14. From figure 2 we see that there is no relative minimum in the energy per nucleon as a function of density, as a density increases the lack of binding energy increases. The pure neutron matter system is unbound at any density.

(2) Some Properties of neutron matter

The energy density ε (ρ) and pressure P(ρ) are obtained from the E(ρ), where E(ρ) is the energy per nucleon , p is the number density:

$$\varepsilon(\rho) = \rho (E(\rho) + M_N C^2), \qquad (6)$$

$$P(\rho) = \rho^2 \frac{\partial E(\rho)}{\partial \rho} \tag{7}$$

The cold equation of state P(ε) is obtained by eliminating ρ from (6) and (7),and sound velocity (in units of c) is given by

$$s(\varepsilon) = \sqrt{\frac{\partial P(\varepsilon)}{\partial \varepsilon}} \tag{8}$$

The energy density ε (ρ), pressure P(ρ), and sound velocity are shown in figure3. From figure 3 we see that the causality condition (eq. 9) is also fulfilled

$$C_s / c = \left(\frac{dp}{d\varepsilon}\right)^{1/2} \leq 1 \tag{9}$$

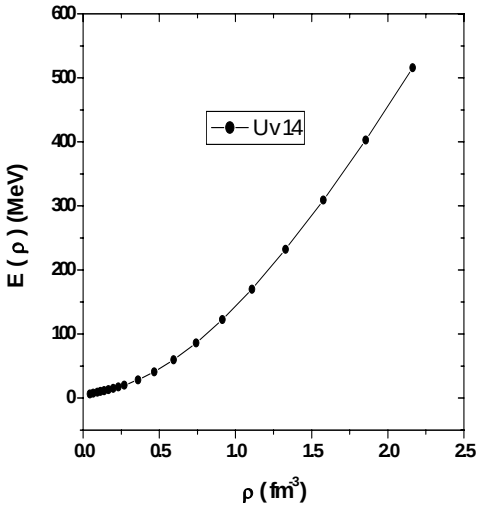

Fig2

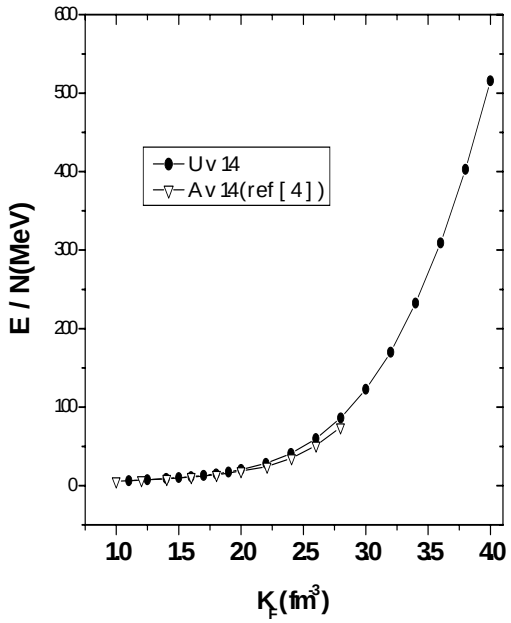

Fig. 1

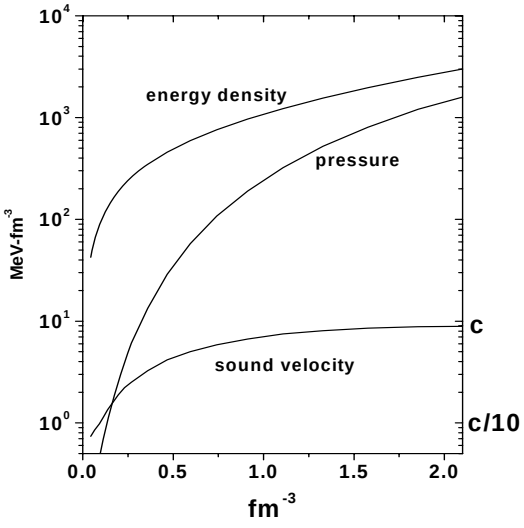

Fig. 3

References

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