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A NEW LANDAU PARAMETER SET FOR NUCLEAR MATTER USING THE SKAAN-U14 SKYRME PARAMETER SET

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Abstract. A new Landau parameter set for nuclear matter is calculated for the SKaan-U14 Skyrme interaction. The effective mass, incompressibility and symmetry energy of nuclear matter are obtained by the new Landau parameter set. The results obtained are in good agreement with those obtained by various authors with different Landau parameters.

Key words: nuclear matter, Skyrme interaction, Landau parameters.

1. INTRODUCTION

Hartree-Fock (HF) and Random Phase Approximation (RPA) approach to nuclear structure are very successful for describing ground states of spherical nuclei and their excitations, especially the giant resonances and some low-lying states. The success is partly based on the density-dependent effective interactions [1]. One of the most convenient and popular interactions is the Skyrme interaction [2, 3].

The Skyrme nucleon-nucleon interaction has been used in nuclear HF calculations since 1970s [4]. The pioneering implementation of density-dependent Skyrme type effective nucleon-nucleon (NN) interaction in HF calculations is due to Vautherin and Brink [5]. The density-dependent Skyrme type effective NN interaction is useful and successful for nuclear HF calculations. Because this model has been one of the most popular microscopic tools to describe the ground-state properties of the finite nuclei as well as that of the symmetric nuclear matter (SNM) and pure neutron matter (PNM) [6].

HF calculations are also useful for the establish the relationship between the Landau parameters and the Skyrme parameters in nuclear matter. Landau parameters have been calculated before by Gogny and Padjen [7] from the density-dependent Gogny interaction [8] for symmetric nuclear matter. Backman *et al.* [9] have also evaluated these parameters from the Skyrme interactions. The parameters of the effective interactions are chosen so as to reproduce certain specific static properties of finite and infinite nuclear systems in a microscopic approach and are then employed to calculate other physical observables [10]. Jackson *et al.* have investigated the density dependence of the Landau parameters for the Bethe-Johnson and Reid potentials [11]. Prakash and Bedell [12] studied density dependence for above two interactions along with the Skyrme interactions SIII and SKM*.

The aim of this study is to determine a new Landau parameter set which describe the properties of nuclear matter. A new Landau parameter set is obtained from SKaan-U14 Skyrme parameter set. We investigate the effective mass, incompressibility and symmetry energy of nuclear matter by using the new Landau parameter set.

2. VMC CALCULATIONS OF NUCLEAR MATTER

2.1. INTERACTION POTENTIAL

The Hamiltonian operator of a free system of N particles can be written as a two-body interaction potential V_{ij}

$$\mathbf{H} = -\frac{\hbar^2}{2m}\sum \nabla_i^2 + \sum_{i<j} V_{ij} \ . \tag{1}$$

For the correctly reproduces the saturation point of nuclear matter, ıt is necessary for any realistic two-body potential. Therefore, it is essential to have a method for reliably calculating, for an assumed two body potential, the binding energy of nuclear matter as a function of density.

In this paper we use Urbana V_{14} potential, which was proposed by Lagaris and Pandharipande. The parameters of the potential were obtained by fitting the phase-shift data from low energy NN scattering experiments and the properties of the deuteron [13]. The phase-shift data varies greatly from channel to channel and it is necessary to have operator components, and Urbana V_{14} potential contains 14 operator components.

$$\begin{aligned} V_{ij} &= V^c + V^\sigma(\sigma_i.\sigma_j) + V^\tau(\tau_i.\tau_j) + V^{\sigma\tau}(\sigma_i.\sigma_j)(\tau_i.\tau_j) + \\ &+ V^t S_{ij} + V^{t\tau} S_{ij}(\tau_i.\tau_j) + V^b(\mathbf{L.S})_{ij} + V^{b\tau}(\mathbf{L.S})_{ij}(\tau_i.\tau_j) + \\ &+ V^q L^2 + V^{q\sigma} L^2(\sigma_i.\sigma_j) + V^{q\tau} L^2(\tau_i.\tau_j) + \\ &+ V^{q\sigma\tau} L^2(\sigma_i.\sigma_j)(\tau_i.\tau_j) + V^{bb}(\mathbf{L.S})^2 + V^{bb\tau}(\mathbf{L.S})^2(\tau_i.\tau_j) \ . \end{aligned} \tag{2}$$

Due to the translational invariance of the infinite nuclear matter the terms depending on the relative angular momentum operator $\mathbf{L}$, do not considerably effect the binding energy. Furthermore, as the contributions of latter terms are much smaller than those of the first four, their effect is smaller than the statistical fluctuations inherent to the Monte Carlo technique so the inclusion of these terms was pointless. Therefore only first four terms of the Urbana potential retained in the VMC calculations. Thus, we have

$$V_{ij} = V^{c} + V^{\sigma}(\sigma_i . \sigma_j) + V^{\tau}(\tau_i . \tau_j) + V^{\sigma\tau}(\sigma_i . \sigma_j)(\tau_i . \tau_j), \tag{3}$$

for the two-body interaction. Where $V^{c}, V^{\sigma}, V^{\tau}$, and $V^{\sigma\tau}$ depend only on the distance between the nucleons *i* and *j*. In the Urbana potential each term in Eq. (2) has three parts

$$V^{i} = V_{\pi}^{i} + V_{I}^{i} + V_{S}^{i}, \tag{4}$$

representing long-range (V_{π}^{i}), intermediate-range (V_{I}^{i}), and short-range (V_{S}^{i}) interactions. The long range part of the interaction (V_{π}^{i}) is nonzero only for $i = \sigma\tau$ and is given by

$$V_{\pi}^{\sigma\tau} = 3.488 \frac{e^{-\mu r}}{\mu r}(1 - e^{-cr^{2}}), \tag{5}$$

where $\mu = 0.7$ fm^{-1} is the inverse compton wavelength for pions. The intermediate and short range parts are

$$V_{I}^{i}(r) = I^{i}\left[\left(1 + \frac{3}{\mu r} + \frac{3}{(\mu r)^{2}}\right)\frac{e^{-\mu r}}{\mu r}\left(1 - e^{-cr^{2}}\right)\right]^{2} \tag{6}$$

and

$$V_{S}^{i}(r) = \frac{S^{i}}{1 + e^{(r-R)/a}} \tag{7}$$

respectively. Values of the potential strengths I^{i} and S^{i} and the parameters *c*, *R*, *a* were given by Lagaris and Pandharipande [13].

It is well known that all two–nucleon interaction models estimate too large equilibrium densities for nuclear matter. Therefore, the three and more body interactions should be incorporated into any consistent nuclear matter calculation. In this study, we use the phenomenological approach assuming the density dependent term to be proportional to short ranged part of the Urbana potential and we assume that the total interaction, including the many body effects, is of the form

$$v_{14} + TNI = v_{\pi} + v_{I} + v_{s} + v_{s}(\alpha\rho)^{\gamma}, \tag{8}$$

where ρ is the number density of nucleons. α and γ in the above equation are free parameters and adjusted so as to obtain the correct binding energy and saturation density of SNM.

2.2. THE VARIATIONAL MONTE CARLO METHOD

We use a Monte Carlo method which is same as our previous study [6]. In the VMC calculations to obtain the properties of bulk nuclear matter we consider a cubic box of side *L* containing *N* nucleons with periodic boundary conditions. The trial wave function used in the present study is a Jastrow type wave function in the form

$$\Psi_j(\mathbf{R}) = \prod_{i\langle j} f_j(r_{ij})\Phi\,, \tag{9}$$

where Φ is the many particle wave function for the system of non-interacting particles and R is a 3*N* dimensional vector representing the coordinates of particles, while f_j is the two particle correlation function. Jastrow suggests that this correlation function in general be an operator function [14]. However in most applications f_j is assumed to depend only on the interparticle distance, $r_{ij} = |r_i - r_j|$.

One can use plane waves $\phi(\mathbf{r}) = e^{i\mathbf{k}.\mathbf{r}}$ for the single particle wave functions of the nucleons in bulk matter. We consider nucleons to be restricted to a cubic box of side *L*, so that the wave number $\mathbf{k} = 2\pi\mathbf{n}/L$ and $\mathbf{n}$ is an integer vector. In order to conserve the rotational invariance of bulk nuclear matter we perform VMC calculations only for the numbers of neutrons (*N*) and protons (*P*) corresponding to completely filled energy shells. We assume that the space and spin parts of the wavefunction is separable. Under these conditions choosing a many particle trial wave function with

$$\Phi(\mathbf{R}) = D^{P\uparrow} D^{P\downarrow} D^{N\uparrow} D^{N\downarrow} \tag{10}$$

is quite reasonable because the spin-isospin dependent parts of the interaction potential is relatively weak. Also it is well known that the expectation value of the total energy is not very sensitive to small changes in the wave function. The determinants $D^{P\uparrow}$, $D^{P\downarrow}$, $D^{N\uparrow}$ and $D^{N\downarrow}$ in Eq.(10) are the slater determinants of single particle wave functions for corresponding spin, isospin state then

$$D^s = \det(d_{ij}^s)\,, \tag{11}$$

where

$$d_{ij}^{s} = \phi_j((\mathbf{r}, s)_i)\,. \tag{12}$$

The nuclear forces are short ranged and saturates very quickly, thus the radial distribution function is not expected to have very long range correlations therefore for the two particle correlation function f_j in eq.(9) we use a function in the form

$$f_j(r) = \left[\frac{1}{1+e^{(r_0-r)/a}}\right]^t, \tag{13}$$

where t, r_0 and a are variational parameters. We define a pseudo potential $u(r)$ for practical reasons such that $f_j(r_{ij}) = \exp(-u(r_{ij}))$ then our variational wave function becomes

$$\Psi_j = \exp\left(-\sum_{i\langle j} u(r_{ij})\right) D^{P\uparrow} D^{P\downarrow} D^{N\uparrow} D^{N\downarrow}\,. \tag{14}$$

We sample the 3N dimensional space with the probability distribution

$$\frac{\left|\Psi(\mathbf{R})\right|^2}{\int \mathrm{d}\mathbf{R}\left|\Psi(\mathbf{R})\right|^2} \tag{15}$$

using a random walk created by the usual Metropolis method. The method given above is a slightly modified version of the VMC method for fermions defined by Ceperley *et al.* [15]. They have also discussed in detail the use of a trial wave function of this form.

The expectation value of any operator F is then simply the average value of the operator evaluated for the coordinates of the random walk with M moves

$$\langle \hat{F} \rangle = \frac{\int \mathrm{d}\mathbf{r}\Psi^*(\mathbf{r})F(\mathbf{r})\Psi(\mathbf{r})}{\int \mathrm{d}\mathbf{r}\left|\Psi(\mathbf{r})\right|^2} \cong \frac{1}{M}\sum_{i=1}^{M} F(\mathbf{r}_i)\,. \tag{16}$$

Thus the total energy of the system is calculated as an average over a sufficiently long random walk. The contribution of the NN interactions to total energy are calculated for interparticle separations up to a cut off distance of $L/2$. Because the NN interaction is very short ranged, the pair distribution function heals quickly and a reasonable approximation to include the contributions of the pairs farther apart is to assume that the density of particles is constant outside this interaction sphere.

For each density and asymmetry parameter the total energy corresponding to the Hamiltonian of the system is calculated for various values of the parameters in the trial wave function. Then the variational parameters r_0, a, and t are determined from these calculations so that the total energy is a minimum. Then a final Monte Carlo calculation of the system with the optimized parameter set is performed.

As we have mentioned before, one must use fully occupied closed shells of plane waves for both neutrons and protons in order to preserve the isotropy of the system. Thus the number of neutrons or protons must be chosen from the set (2, 14, 38, 54, 66, 114, ...). The isospin asymmetry parameter β is defined as $\beta = \frac{N_n - N_p}{N_n + N_p}$, where N_n and N_p are the numbers of neutrons and protons in the cubic box under consideration.

3. SKYRME-LANDAU PARAMETERIZATION OF EFFECTIVE INTERACTION

3.1. SKYRME INTERACTION

In this study we use the Skyrme type effective NN interaction [5, 16]:

$$\begin{aligned} V_{12} &= t_0(1+x_0P_{12}^{\sigma})\delta(\mathbf{r}_1-\mathbf{r}_2)+\frac{1}{2}t_1(1+x_1P_{12}^{\sigma})\left[\overleftarrow{\mathbf{k}}_{12}^{2}\delta(\mathbf{r}_1-\mathbf{r}_2)+\delta(\mathbf{r}_1-\mathbf{r}_2)\overrightarrow{\mathbf{k}}_{12}^{2}\right] \\ &+t_2(1+x_2P_{12}^{\sigma})\overleftarrow{\mathbf{k}}_{12}\delta(\mathbf{r}_1-\mathbf{r}_2)\overrightarrow{\mathbf{k}}_{12}+\frac{1}{6}t_3(1+x_3P_{12}^{\sigma})\rho^{\alpha}\left(\frac{\mathbf{r}_1+\mathbf{r}_2}{2}\right)\delta(\mathbf{r}_1-\mathbf{r}_2) \quad (17) \\ &+iW_0\overleftarrow{\mathbf{k}}_{12}\delta(\mathbf{r}_1-\mathbf{r}_2)(\boldsymbol{\sigma}_1+\boldsymbol{\sigma}_2)\times\overrightarrow{\mathbf{k}}_{12}\,, \end{aligned}$$

where t_i, x_i, α and W_0 are the parameters of the interaction and P_{12}^{σ} is the spin-exchange operator, $\boldsymbol{\sigma}_i$ is the Pauli spin operator, $\overrightarrow{\mathbf{k}}_{12} = -i(\overrightarrow{\nabla}_1 - \overrightarrow{\nabla}_2)/2$, and $\overleftarrow{\mathbf{k}}_{12} = -i(\overleftarrow{\nabla}_1 - \overleftarrow{\nabla}_2)/2$. Here, the right and left arrows indicate that the momentum operators act on the right and on the left, respectively.

The total energy E of the system is given by

$$E = \int \mathrm{H}(r)\,\mathrm{d}^3(r), \quad (18)$$

where $\mathrm{H}(r)$ is the Skyrme energy-density functional corresponding to Eq. (17) which under the time-reversal invariance is given by [2, 5, 16, 17],

$$\mathrm{H}_0 = \mathrm{K} + \mathrm{H}_0 + \mathrm{H}_3 + \mathrm{H}_{eff} + \mathrm{H}_{fin} + \mathrm{H}_{so} + \mathrm{H}_{sg} + \mathrm{H}_{coul}, \quad (19)$$

$$\mathrm{H}_0=\frac{1}{4}t_0\left[(2+x_0)\rho^2-(2x_0+1)(\rho_p^2+\rho_n^2)\right], \tag{20}$$

$$\mathrm{H}_3=\frac{1}{24}t_3\rho^\alpha\left[(2+x_3)\rho^2-(2x_3+1)(\rho_p^2+\rho_n^2)\right], \tag{21}$$

$$\begin{aligned}\mathrm{H}_{\mathrm{eff}} &=\frac{1}{8}\left[t_1(2+x_1)+t_2(2+x_2)\right]\tau\rho+\\ &+\frac{1}{8}\left[t_2(2x_2+1)-t_1(2x_1+1)\right](\rho_p\tau_p+\tau_n\rho_n),\end{aligned} \tag{22}$$

$$\begin{aligned}\mathrm{H}_{\mathrm{fin}} &=\frac{1}{32}\left[3t_1(2+x_1)-t_2(2+x_2)\right](\nabla\rho)^2-\\ &-\frac{1}{32}\left[3t_1(2x_1+1)+t_2(2x_2+1)\right]\left[(\nabla\rho_p)^2+(\nabla\rho_n)^2\right],\end{aligned} \tag{23}$$

$$\mathrm{H}_{\mathrm{so}}=\frac{1}{2}W_0\left[\mathbf{J}.\nabla\rho+\mathbf{J}_p.\nabla\rho_p+\mathbf{J}_n.\nabla\rho_n\right], \tag{24}$$

$$\mathrm{H}_{\mathrm{sg}}=-\frac{1}{16}(t_1x_1+t_2x_2)\mathbf{J}^2+\frac{1}{16}(t_1-t_2)\left[\vec{\mathbf{J}}_p^2+\vec{\mathbf{J}}_n^2\right], \tag{25}$$

$$\mathrm{H}_{\mathrm{coul}}(\mathrm{r})=\frac{1}{2}e^2\rho_p(r)\int\frac{\rho_p(r')d^3r'}{|\mathbf{r}-\mathbf{r}'|}-\frac{3}{4}e^2\rho_p(r)\left(\frac{3\rho_p(r)}{\pi}\right)^{1/3}. \tag{26}$$

Here, total densities are defined $\rho=\rho_n+\rho_p$, $\tau=\tau_n+\tau_p$, and $\mathbf{J}=\mathbf{J}_n+\mathbf{J}_p$. Proton and neutron matter, kinetic energy and spin, densities are,

$$\rho_q(\mathbf{r})=\sum_{i,s}\left|\phi_i^q(\mathbf{r},s)\right|^2 n_i^q, \tag{27}$$

$$\tau_q(\mathbf{r})=\sum_{i,s}\left|\nabla\phi_i^q(\mathbf{r},s)\right|^2 n_i^q, \tag{28}$$

$$J_q(\mathbf{r})=\sum_{i,s}\phi_i^{q*}(\mathbf{r},s)\nabla\phi_i^q(\mathbf{r},s)\times\langle s'|\sigma|s\rangle n_i^q, \tag{29}$$

where $\phi_i^q(\mathbf{r},s)$ is the single-particle wave function with orbital, spin, isospin quantum numbers *i*, *s*, and *q*, respectively; and n^q is the occupation numbers pairing probability.

The density functional Skyrme energy can be written for ASNM from Eqs. (17) and (19) as

$$\begin{aligned}\frac{E}{A}(\rho_n,\rho_p) &= \frac{\hbar^2}{2m}(\tau_n+\tau_p)+\frac{1}{4}t_0(1-x_0)\frac{(\rho_n^2+\rho_p^2)}{\rho}+\\ &+t_0\left(1+\frac{1}{2}x_0\right)\frac{\rho_n\rho_p}{\rho}+\frac{1}{12}t_3\left(1+\frac{1}{2}x_3\right)\rho^{\alpha+1}-\\ &-\frac{1}{12}t_3\left(\frac{1}{2}+x_3\right)\rho^{\alpha-1}(\rho_n^2+\rho_p^2)+\\ &+\frac{1}{8}\left[t_1(1-x_1)+3t_2(1+x_2)\right]\frac{(\rho_n\tau_n+\rho_p\tau_p)}{\rho}.\end{aligned} \qquad (30)$$

The SKaan-U14 Skyrme parameter set is generated by fitting of the energy results per nucleon, which contains 140 energy values obtained from VMC simulations, to the Skyrme energy density functional. This set obtained is $t_0 = -424.75$ MeV·fm^3, $t_1 = -1333.36$ MeV·fm^5, $t_2 = -232.82$ MeV·fm^5, $t_3 = 47807.61$ MeV·fm^6, $x_0 = 0.96$, $x_1 = 0$, $x_2 = 0$, $x_3 = -0.51$ and $\alpha = 1.5$. Saturation energy of symmetric nuclear matter obtained $E_0 = 15.80$ MeV at $\rho_0 = 0.156$ fm^{-3} ($k_F = 1.32$ fm^{-1}) by using these parameters. These values are in good agreement with our expectations from semi-empirical mass formulas of known nuclei.

3.2. SYKRME-LANDAU PARAMETERIZATION

The physics of 'normal' Fermi liquids at low temperatures is governed by the properties and interactions of quasiparticles, as emphasized by Landau in the early 1960's. Since quasiparticles are well-defined only near the Fermi surface where they are long-lived, Landau's theory is valid only for low-energy excitations about the interacting ground state [18].

The Migdal theory of nuclei based on the Landau theory of normal Fermi-liquids [19]. The interaction between the quasiparticles is parametrized in terms of Landau Fermi-liquid parameters in Migdal's theory of nuclei. Migdal has argued that the tensor part of the quasiparticle interaction is unimportant [20]. However, Backman *et al.* [21] indicates that this might not be the case.

It is useful to consider the Skyrme interaction in nuclear matter within the framework of the Landau theory of normal Fermi liquids [9, 19, 20].

The Landau parameters can be obtained by functional differentiation of the energy density. In symmetric nuclear matter, the $l = 0$ and $l = 1$ parameters are given by the following expressions [22]:

$$F_0 = N_0 \left\{ \begin{array}{l} \frac{3}{4} t_0 + \frac{1}{16} t_3 \rho^{\alpha} (\alpha+1)(\alpha+2) \\ + \frac{1}{8} k_F^2 [3t_1 + (5+4x_2) t_2 \end{array} \right\}, \tag{31}$$

$$F_0^{'} = -N_0 \left\{ \begin{array}{l} \frac{1}{4} t_0 (1+2x_0) + \frac{1}{24} t_3 \rho^{\alpha} (1+2x_3) \\ + \frac{1}{8} k_F^2 [t_1 (1+2x_1) - t_2 (1+2x_2) \end{array} \right\}, \tag{32}$$

$$G_0 = -N_0 \left\{ \begin{array}{l} \frac{1}{4} t_0 (1-2x_0) + \frac{1}{24} t_3 \rho^{\alpha} (1-2x_3) \\ + \frac{1}{8} k_F^2 [t_1 (1-2x_1) - t_2 (1+2x_2) \end{array} \right\}, \tag{33}$$

$$G_0^{'} = -N_0 \left\{ \frac{1}{4} t_0 + \frac{1}{24} t_3 \rho^{\alpha} + \frac{1}{8} k_F^2 [t_1 - t_2] \right\}, \tag{34}$$

$$F_1 = -N_0 \left\{ \frac{1}{8} k_F^2 (3t_1 + 5t_2 + 4t_2 x_2) \right\}, \tag{35}$$

$$F_1^{'} = -N_0 \left\{ \frac{1}{8} k_F^2 [t_2 (1+2x_2) - t_1 (1+2x_1)] \right\}, \tag{36}$$

$$G_1 = -N_0 \left\{ \frac{1}{8} k_F^2 [t_2 (1+2x_2) - t_1 (1+2x_1)] \right\}, \tag{37}$$

$$G_1^{'} = -N_0 \left\{ \frac{1}{8} k_F^2 [t_2 (1+2x_2) - t_1 (1+2x_1)] \right\}. \tag{38}$$

Using the SKaan-U14 Skyrme parameter set, E/A = 15.80 and k_F = 1.32fm^{-1} we find a new Landau parameter set for nuclear matter. The new set obtained is F_0 = –0.103, $F_0^{'}$ = 0.355, F_1 = –0.726, $F_1^{'}$ = 0.154, G_0 = 0.067, $G_0^{'}$ = –0.144, G_1 = = 0.154 and $G_1^{'}$ = 0.154. The obtained new Landau parameters from SKaan-U14 are given in Table 1 together with those obtained from the other Skyrme interactions [1].

Table 1

Landau parameters for different Skyrme parameter sets

	SI	SII	SIII	SGI	SGII	BLV1	SL1	SKaan-U14
F_0	0.558	–0.058	0.30	–0.246	–0.225	0.423	–0.393	–0.103
F_1	–0.266	–1.261	–0.711	–1.184	–0.645	–0.608	–1.335	–0.726
F_0'	1.213	0.695	0.868	0.436	0.726	0.944	0.435	0.355
F_1'	0.43	0.477	0.490	0.174	0.520	0.546	–0.603	0.154
G_0	–2.268	–0.769	–1.576	0.069	0.011	–1.913	–0.211	0.067
G_1	0.430	0.477	0.490	1.052	0.611	0.546	1.109	0.154
G_0'	–0.527	–0.037	–0.354	0.498	0.503	–0.484	0.240	–0.144
G_1'	0.430	0.477	0.490	0.367	0.431	0.546	0.336	0.154

SI, SII and SIII are from refs. [5, 16], BLV1 is from ref. [23], SL1 is from ref. [1] and SKaan-U14 is from [6].

Some of the Landau parameters are directly related to physical quantities [1]: F_1 is related to the effective mass m^* by

$$\frac{m^*}{m} = 1 + \frac{1}{3} F_1 , \tag{39}$$

F_0 is related to the incompressibility K in the nuclear matter by

$$K = 6 \frac{\hbar^2}{2m^*} k_F^2 (1 + F_0) , \tag{40}$$

and F_0' is related to the asymmetry energy A_s

$$A_s = \frac{1}{3} \frac{\hbar^2}{2m^*} k_F^2 (1 + F_0') . \tag{41}$$

Using the obtained new Landau parameters from SKaan-U14 in Eq. (39), (40) and (41) we found the effective mass m^*= 0.75 m, the incompressibility K = 259 MeV and the asymmetry energy A_s = 21.75 MeV. These values are given comparatively along with the values obtained from other Landau parameterizations which from other Skyrme parameterizations in Table 2.

Table 2

Comparison of the calculations of values of effective mass m^*/m, incompressibility K_∞ and asymmetry energy A_s of nuclear matter for Landau parameters from obtained SKaan-U14 and the other Skyrme interactions

Skyrme	m^*/m	K_∞ (MeV)	A_s (MeV)	$k_F\,(fm^{-1})$	*E/A* (MeV)
SI	0.91	370	29.38	1.32	–16.00
SII	0.58	342	34.10	1.30	–16.00
SIII	0.76	356	28.16	1.29	–15.87
SGI	0.61	269	28.5	1.32	–15.89
SGII	0.79	215	26.8	1.33	–15.59
BLV1	0.80	378	30.00	1.30	–16.00
SL1	0.55	230	30.20	1.30	–15.75
SKaan-U14	0.75	259	21.75	1.32	–15.80

It can be seen from Table 2 this effective mass value is very close to the results obtained from Skyrme parameterization SIII in the literature. We can see clearly that our incompressibility value is quite close to the values in the literature. Because, the incompressibility, appears in some sophisticated mass formulas, however it cannot be precisely determined from these formulas and quoted values in the literature have a wide range from 240 to 300 MeV with error estimates of $\pm$ 50 MeV [24]. For the new Landau parameters we have obtained the symmetry energy of nuclear matter as 21.75, this value is somewhat different then the experimentally quoted value of 30 ± 4 but considering the error bars in the quoted experimental values it might be acceptable [25].

4. CONCLUSION

Many calculations have been performed using different methods to describe bulk properties of nuclear matter. The Skyrme potential and other phenomenological potential models are very convenient and useful in the calculations of bulk properties of nuclear matter. However, before using such potentials the reliability of the potential model should be established. We have observed that the results of VMC simulations of the nuclear matter obtained in our previous studies [6, 24, 26–29] reasonably agree with the experimental and theoretical studies. In this study, the results obtained from Monte Carlo simulation are used to determine a new Landau parameter set. The results obtained with the new Landau parameter set for nuclear matter are compared with other selected Landau parameter sets found in the literature, and it was observed that the results obtained in this study agree reasonably well with the results found in the literature.

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