Nuclear matter properties at finite temperature within Extended relativistic mean field model

Gulshan Mahajan[a,b] and Shashi K. Dhiman[a,c]
[a] *Department of Physics, Himachal Pradesh University, Shimla - 171005, India.*
[b] *Department of Physics, R.G.M. Government College Joginder Nagar - 175015, India.*
[c] *University Institute of Natural Sciences and Interface Technologies,*
Himachal Pradesh Technical University,
Post Box 12, Hamirpur, Pin 177001, India.

I. INTRODUCTION

The properties of cold nuclear matter can be studied by imposing the constraints of bulk nuclear matter properties at the saturation density, $\rho_0 = 0.16 fm^{-3}$; recent experimental limits establish the following values: symmetry energy $E_{sym} = 30 \pm 5 MeV$ [1], slope of symmetry energy $L = 88 \pm 25 MeV$ [2], and incompressibility coefficient $K = 240 \pm 20 MeV$ [3]. It is considered theoretically that the density dependence of symmetry energy can be represented by $E_{sym}(\rho_0) = 31.6(\rho/\rho_0)^\gamma$ with γ=0.69-1.05 at subnormal density [2], which led to the extraction of a value for the slope of the nuclear symmetry energy of $L = 88 \pm 25 MeV$. This symmetry energy value is also in harmony with the symmetry energy obtained from the isoscaling analysis of the isotope ratio in intermediate energy heavy-ion collisions [4]. The Lagrangian density for the extended relativistic mean field (ERMF) model can be written as $\mathcal{L} = \mathcal{L_{BM}} + \mathcal{L}_\sigma + \mathcal{L}_\omega + \mathcal{L}_\rho + \mathcal{L}_{\sigma\omega\rho}$ [5]. The Lagrangian terms and the Euler-Lagrangian equations for ground state expectation values of the meson fields are same as in [5]. At finite temperatures the baryon vector density ρ_B, scalar density ρ_{sB} and charge density ρ_p are, $\rho_B = \frac{\gamma}{(2\pi)^3}\int_0^{k_B} d^3k(n_i - \overline{n_i}), \rho_{sB} = \frac{\gamma}{(2\pi)^3}\int_0^{k_B} d^3k \frac{M_B^*}{\sqrt{k^2+M_B^{*2}}}(n_i + \overline{n_i}), \rho_p = \left\langle \overline{\Psi}_B \gamma^0 \frac{1+\tau_{3B}}{2}\Psi_B \right\rangle (n_i + \overline{n_i})$. Where, γ is the spin-isospin degeneracy. The $M_B^* = M_B - g_{\sigma B}\sigma - g_{\sigma^* B}\sigma^*$ is the baryon effective mass , k_B is its Fermi momentum and τ_{3B} denotes the isospin projections of baryon B. The thermal distribution function in these expression are defined by $n_i = \frac{1}{e^{\beta(\epsilon_i^* - \mu^*)}+1}, \overline{n_i} = \frac{1}{e^{\beta(\epsilon_i^* + \mu^*)}+1}$ where $\epsilon_i^* = \sqrt{k^2 + M_B^{*2}}$ and $\mu^* = \mu - g_{\omega N}\omega$. The symmetry energy E_{sym}, the slope L, and incompressibility K can be evaluated as $E_{sym}(\rho) = \frac{1}{2}\frac{d^2E(\rho,\delta)}{d\delta^2}\Big|_{\delta=0}, L = 3\rho_0 \frac{dE_{sym}(\rho)}{d\rho}\Big|_{\delta=\rho_0}$, and $K = 9\rho_0^2 \frac{d^2E_0(\rho)}{d\rho^2}\Big|_{\rho=\rho_0}$, where ρ_0 is the saturation density, $E(\rho.\delta)$ is the energy per nucleons at a given density ρ and asymmetry parameter $\delta = (\frac{\rho_n - \rho_p}{\rho_n + \rho_p})$ and $E_0(\rho) = E(\rho, \delta = 0)$ is the energy per nucleon for symmetric matter.

II. RESULT AND DISCUSSIONS

We study the properties of symmetric and asymmetric nuclear matter for BSR1-BSR21 parametrizations of the ERMF model at temperatures of 0 and 30 MeV [5, 6]. The nuclear symmetry energy is a fundamental input to understand the exotic nuclei, heavy-ion collision data and many other astrophysical phenomena. Therefore, recently many efforts have been made to extract the information on the magnitude and density dependence of symmetry energy of nuclear matter. In Fig. 1 we present the values of $E_{sym}(\rho_0)$ at saturation density as a function of Δr the neutron skin thickness in the ^{208}Pb nucleus for various model parametrizations. The squares represent the parametrizations BSR1-BSR7 having ω-meson self coupling parameter $\zeta = 0.00$, the triangles represent the parametrizations BSR8-BSR14 having $\zeta = 0.03$, and the circles represent the parametrizations BSR15-BSR21 having $\zeta = 0.06$. The values of Δr varies from

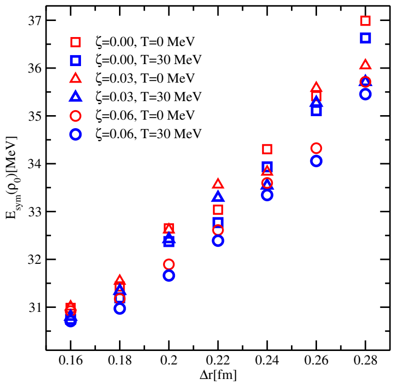

FIG. 1: (Color online) The symmetry energy $E_{sym}(\rho_0)$ plotted as a function of the neutron skin thickness Δr in the ^{208}Pb nucleus for 21 different parameterization of the ERMF model.The squares, triangles and circles represent results for parameterization BSR1-BSR7, BSR8-BSR14 and BSR15-BSR21 respectively . The red symbol represent the results at T = 0 MeV and the blue symbols represent the results at T = 30 MeV.

0.16 to 0.28 fm in steps of 0.02 fm. It is observed that at saturation density symmetry energy changed beyond T $\geq$ 20 MeV by a very small amount with respect to T = 0 MeV for the all parametrizations of the ERMF model. In Fig. 2, in the lower panel we present the slope of symmetry energy and in the upper panel we present the incompressibility coefficient for nuclear matter as a function of Δr. The incompressibility coefficient for symmetric nuclear matter decreases upto a maximum of 12.5% at temperature T= 30 MeV with respect to T = 0 MeV for the BSR1 parametrization, which provides stiffest EOS with neutron star gravitational mass M = $2.5M_{\odot}$ [5]. The variation in the values of K is a minimum of 7% for the BSR21 parametrization, which provides the softest EOS with neutron star gravitational mass M = $1.74M_{\odot}$ [5]. It is found that variation in the values of symmetry energy becomes reasonably large as the value of neutron skin thickness increases, where as the value for the slope of symmetry energy remains unaffected at temperature T = 0 and 30 MeV. The value of incompressibility coeffi-

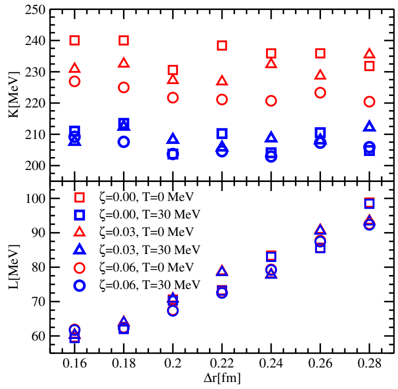

FIG. 2: (Color online) Same as Fig.1,but for the slope of the symmetry energy (L) and incompressibility coefficient (K) of nuclear matter

cient is sensitive to ζ and indicates the change at T = 30 MeV.

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