The role of isoscalar-isovector coupling in symmetric energy of Infinite nuclear matter

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The best possible and well defined theoretical laboratory to study for many body system is infinite nuclear matter at certain conditions. To review the status of microscopic studies of nuclear matter and neutron-rich matter, which already reached to the destination by mean-field models (relativistic and non-relativistic) and although by some non-microscopic methods such as Brueckner-Hartree-Fock and Dirac-Brueckner-Hartree-Fock (DBHF). The obstacle for the softening in equation of state (EOS) of nuclear matter likely lead to an exciting problem in astronuclear physics. Recently, the isospin and density dependence of the nuclear symmetry energy E_{sym}, is the current interest for its implications not only in the above problem as well as in astrophysics. Mean while the novel phenomena like formation of superheavy nuclei in astrophysical system also improved by using a proper value E_{sym}, which also front learning about the island of stability at superheavy regions.

Here, we introduce a new term in the Lagragian, which is the combined effect of isoscalar-vector and isovector-vector field with coupling constant (Λ_v). The effect of newly added term to the E_{sym}, K_0 and all other co-efficient are studied. The quest mention above i.e. the stiffness of the E_{sym} with respect to baryonic density may solve by introducing the above defined coupling constant Λ_v without affection all other observables quantitatively in the infinite nuclear matter and finite nuclei. It is worthy to mention that, without this additional constant, one cannot overcome the hindrance. As a results the modified Lagrangian with the new coupling term used here for the study of nuclear matter properties [1,2]. From the Lagrangian, we derived the energy and pressure density along with all meson field equations. All the equations are solved self-consistent by numerical methods.

Our aim in this work to study the effect of the new coupling constant to to symmetric energy, so special attention needed to this observable because of its isospin dependent, which play an important role in both infinite nuclear matter and finite nuclei. The expression of symmetric energy E_{sym}, is defined as

$$E_{sym}(\rho) = \frac{k_F^2}{6E_F^*} + \frac{g_\rho^2}{12\pi^2}\frac{k_F^3}{m_\rho^{*2}}, \qquad (1)$$

where the effective energy $E_F^* = \sqrt{(k_F^2 + m^{*2})}$, k_F is the Fermi momentum and the effective mass $m^* = m - g_S\phi_0$. The effective mass of the ρ-meson modified because of nonlinear coupling ($\rho - \omega$) interaction and is given by

$$m_\rho^{*2} = m_\rho^2 + 2g_\rho^2(\Lambda_v g_v^2 \omega_0^2), \qquad (2)$$

where m_ρ is the mass of the ρ-meson. It is noted that the non-linear isoscalar-isovector coupling (Λ_v) modified the density dependent of E_{sym} without affecting the saturation properties of the NM.

In nuclear matter NM, it is necessary to define such observables which are related to symmetric energy and its derivatives at saturation

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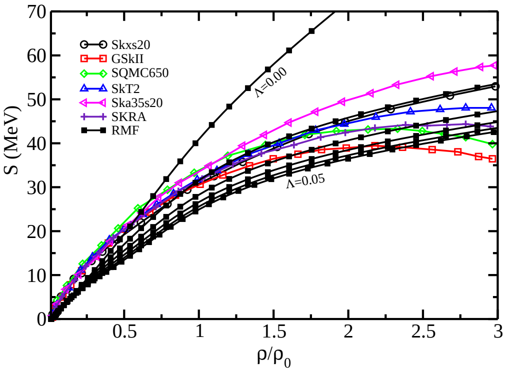

FIG. 1: The reslts of symmetric energy E_{sym} is a function of density ρ/ρ_0 from RMF for different values of Λ_v compare with others predictions.

density. The quantities are follow,

$$L_{coeff} = 3\rho_0 \left(\frac{\partial E_{sym}}{\partial \rho}\right)_{\rho=\rho_0}, \tag{3}$$

$$K_{sym} = 9\rho_0^2 \left(\frac{\partial^2 E_{sym}}{\partial \rho^2}\right)_{\rho=\rho_0}, \tag{4}$$

and

$$Q_{sym} = 27\rho_0^3 \left(\frac{\partial^3 E_{sym}}{\partial \rho^3}\right)_{\rho=\rho_0}. \tag{5}$$

Here L_{coeff} is called the slope parameter, which is nothing but the slope of E_{sym}. In other word, the rate of change in symmetric energy with respect to baryonic density is L_{coeff}. The quantity K_{sym} is the curvature co-efficient. In SNM, the value of K_{sym} at saturation density entitled by K_0 and called as symmetry incompressibility. Finally, Q_{sym} is the third derivative of the symmetric energy, which called as skewness coefficient. Now we can expand/redefined the density dependence of the E_{sym} with the help these 3-co-efficients as a function of $\mathcal{Y} = (\rho - \rho_0)/3\rho_0$ as follow,

$$\mathcal{S}(\rho) = E_{sym}(\rho_0) + L_{coeff}\mathcal{Y} + \frac{1}{2}K_{sym}\mathcal{Y}^2 + \frac{1}{6}Q_{sym}\mathcal{Y}^3 + O(\mathcal{Y}^4). \tag{6}$$

The calculation of the $\mathcal{S}$ obtained for the RMF (FSU-GOLD) for different value of Λ_v compare with other theoretical predictions are displayed in Fig. 1. At saturation density, the magnitude of $\mathcal{S} \sim 37$ MeV with a stiffer curve with respect to baryonic density distribution for $\Lambda_v \sim 0.00$. By varying the value of Λ_v from $0.00 - 0.05$, the magnitude of $\mathcal{S}$ reduced to ~ 27 MeV at saturation density and a result of softer distribution of symmetric energy. The other observables related to the E_{sym} like slope parameter L_{coeff}, the curvature K_{sym} and the skewness co-efficient Q_{sym} are also studied systematically.

In conclusion, the role of isoscalar-vector and isovector-vector coupling constant plays an important role to softening the equation of state as well as E_{sym} of the infinite nuclear matter without affecting other observables of nuclear matter and finite nuclei. This work under progress and complete soon.

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