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Screening functions of hot dense asymmetric nuclear matter

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Abstract

Screening functions of hot asymmetric nuclear matter at different densities using Skyrme effective forces are investigated for the four channels of the particle-hole interaction. They are inversely proportional to the static polarizability of nuclear matter being a measure of the response of the system to external perturbations. At zero temperature and at saturation density ρ_0 of symmetric nuclear matter this function in the isovector channel is explicitly proportional to the nuclear matter symmetry energy coefficient (a_τ). This is also true for the spin or spin-isospin channels (in the case of spin perturbations in nuclear matter). The dependence of the screening functions on the density (from .5 up to 2 ρ_0), temperature and n-p asymmetry are investigated and in the isovector channel they are compared to results obtained for the symmetry energy coefficient (a_τ) of other works. It is argued that the screening function is a more suitable parameter than a_τ in several cases. For instance the restoring force of the dipole (isovector or spin) modes as well as the energy cost to make nuclear environment still more asymmetric may depend also on the n-p asymmetry of the nuclear medium. In the scalar channel a dipolar compressibility is defined and studied. Extended stability conditions (with higher order corrections to the usual Fermi-liquid conditions) for the hot (a)symmetric dense nuclear matter are established. The relevance of this subject to the supernovae mechanism is discussed.

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1 Introduction

The proton-neutron symmetry energy coefficient of nuclear matter (a_τ) represents the tendency of nuclear forces to have greater binding energies for a symmetric system (no difference between proton and neutron numbers). It is an important piece of the mass formulae for macroscopic drop models contributing as a coefficient for the squared asymmetry: $E/A = H_0(A) + a_\tau(N-Z)^2/A$, where Z, N and A are respectively the proton, neutron and mass numbers. This form is exact in the frame of the Fermi gas model [1] but it is well known that there are important corrections due to nucleon interactions and correlations. This coefficient corresponds to the cost in energy to increase a neutron (or proton) excess in the nuclear potential, together, for exemple, with the Coulomb term it makes the mean field for neutrons to be different from that of protons. The quadratic form contribution to the binding energy of $(N-Z)$ was initially phenomenologically considered for the fit of the binding energy of many nuclei along and out of the drip line but it was also obtained in microscopic calculations of [2]. Higher orders effects of the asymmetry (proportional to $(N-Z)^n$ for $n \neq 2$, n=1, 3 respectively for the breaking of isospin symmetry term and higher orders of the symmetry energy, [3]) are expected to be much less important also for the equation of state of nuclear matter [4, 5]. Whenever the energy needed to separate protons from neutrons (or to increase the n-p asymmetry) in a nuclear environment is required the symmetry energy coefficient is needed. However, in this article, it is argued that a_τ in certain circumstances is not the appropriate variable to be used, but the screening function (or conversely the inverse of static polarizability) for nuclei/nuclear matter as derived in the following. In this work the Coulomb interaction among protons is not considered.

The parameter which measures the response of the system to a perturbation which tends to separate protons from neutron is rather given by the static polarizability of the system (the isospin/spin screening functions) which yields the definition of the symmetry energy coefficient at zero temperature symmetric nuclear matter at the saturation density. Consequently this energy cost may depend on the asymmetry of the medium. This is reasonable since the nuclear mean field is to be considered self consistent. Thus the "energy needed to separate neutrons from protons" (i.e. the restoring force in dipole- isovector collective modes) may depend on the p-n asymmetry in a nuclear environment. This can be expected after calculations which explore the n-p asymmetry dependence of the isovector collective modes of nuclear matter/finite nuclei (the higher the asymmetry the more repulsive the interaction) [6, 7, 8].

Other symmetry coefficients are also defined in nuclear matter, in particular the spin and spin-isovector ones. The former corresponds to the energy difference between the unpolarized and polarized nuclear matter while the second to the completely symmetric unpolarized and asymmetric polarized neutron matter.

In general the nuclear stability is checked via the Landau Fermi-liquid theory for $l = 0$ component. In the present work, this analysis is extended to take into account higher orders contributions of the Landau Fermi-liquid parameters. In the scalar channel of the particle hole interaction, a scalar coefficient (related to the nuclear matter compressibility) will be associated to the static polarizability being related to the stability of nuclear matter with respect to scalar density fluctuations.

The n-p symmetry energy coefficient (and its density dependence) is of great importance for the determination of the structure and reaction properties of exotic nuclear systems through radioactive ion beams experiments [10, 11]. Another fields in which the symmetry coefficients are known to be specially relevants are the giant resonances (in each one of four particle-hole channels) and nuclear Ion Collisions [12].

In proto-neutron and neutron stars it is important to extract the dependence of the symmetry coefficients at different temperatures and densities. The higher the n-p symmetry energy coefficient the smaller is the deleptonization in the quasi-static phase of the supernovae mechanism favoring a larger final proton fraction and faster cooling (via neutrino emission). This picture yields a stronger shock wave since the energy loss is smaller. The compressibility coefficient also changes with the value of the n-p asymmetry and for an asymmetric nuclear matter the compressibility acquires lower values [2], i.e., for high enough asymmetries the compressibility disappears since there is no more minimum for the EOS. This dependence is also of great relevance for the shock wave formation. In this paper we suggest that the nuclear matter screening functions are more suitable than, for exemple, a_τ and K for this kind of process.

The other channels of the p-h interaction are also very important. The stability of neutron stars with respect to spin fluctuations was investigated in [13] for localized and unlocalized protons. In the second case there is a threshold of spin interaction above which there is a spontaneous polarization for the nuclear matter in which case it could be a direct origin for the strong magnetic field observed in these stars [9]. However the experimental values of the attractive interaction does not seem to reach such values. Indeed the spin part of the nuclear interactions is not very well known. Similar arguments can be given for the spin-isospin channel, which has, at not high densities, very repulsive interaction being expected that at high energies it becomes attractive giving place to a pion condensation phase transition.

Back to the isovector channel, non relativistic calculations for the a_τ were performed via Hartree-Fock or Thomas Fermi approaches [14] yielding values of the order of 27 to 38 MeV. The values obtained in relativistic calculations (in the frame of Quantum Hadro Dynamics- QHD) are in the range of 35 to 40 MeV. Variational estimates yield values close to 30 MeV. Experimentaly the symmetry energy coefficient at the saturation density can be extracted from a systematic study of the nuclear masses based on macroscopic-microscopic model or liquid drop model [15, 5]. It is accepted a value of 30 ± 4 MeV for zero temperature and at the saturation density. But this is valid only for densities near the saturation one and a small value of the asymmetry $\alpha = (N - Z)/A$. For the effective interactions of the Skyrme type used in the present article, realistic values for a_τ were considered in the fit of the force parameters.

The dependence of a_τ with temperature and density has been studied with several approaches. Here we acknowledge two different approaches in which the temperature dependence was investigated. In [16], a strong temperature dependence was found (for T from 0 to 2 MeV): an increase of nearly 2.5 MeV to a_τ) due to the quadrupole mode coupling (via a frequency dependent effective mass) whose strength diminishes significantly with temperature. However, this result has not been confirmed by lattice calculation [17] which did not find a systematic and relevant behaviour of such parameter with T. These different predictions provide different scenarios for the the Supernovae picture, for exemple, where the symmetry energy coefficient determines the beta equilibrium and consequently influentiates neutrino interaction with nuclei and nuclear matter and the SN energy loss by the variation of the proton fraction (in deleptonization).

Concerning density dependent studies, more results are available for comparison. In reference [18] the relevance of a_τ for the dense neutron stars was studied with an effective form for the nuclear interaction. In that work the following parametrization was obtained:

$$a_\tau(\rho) = S(\rho) = (2^{\frac{2}{3}} - 1)\frac{3}{5}E_F^0(u^{\frac{2}{3}} - F(u)) + S_0 F(u), \tag{1}$$

where $u = \rho/\rho_0$ (ρ_0 is the saturation density of nuclear matter), E_F^0 is the Fermi energy of the system, S_0 may be taken as 30 MeV and F(u) is a function which satisfies the condition $F(1) = 1$. Three forms were considered for this last arbitrary function:

$$F(u) = u, \quad F(u) = 2u^2/(1+u), \quad F(u) = \sqrt{u}. \tag{2}$$

In [2], also with a microscopic non relativistic (Brueckner-Bethe-Goldstone) approach, a_τ is found to vary linearly with the density until $\rho \simeq 2.5\rho_0$ and for higher densities it remains nearly constant. An Extended-Dirac-Brueckner calculation from an One Bosom Exchange Bonn potential performed in [4] results in a value $a_\tau = 31$ MeV. The density dependence is nearly the same as obtained with expression (1) taking $F(u) = u$. As a matter of fact (sofisticated) non-relativistic calculations discussed in [19] (with a non-relativisitic Brueckner-Hartree-Fock approach using realistic NN potentials, e.g. Nijmegen, Reid93, Argonne V18, CD-Bonn) yield different behaviours, depending on the used potential. For exemple the Argonne V14 produces an increasing value for a_τ up to $\rho \simeq 2\rho_0$, and then a constant value. Other potentials yield values proportional to ρ. Variational calculations with Argonne A14 of [20] result nearly the same behaviour. Relativistic (mean field) calculations [19, 21] yield an increasing behaviour with density.

Another very important parameter for the SN mechanism is the compressibility which is also strongly density and temperature dependent as well as dependent on the p-n asymmetry [22]. In this last article the authors found the following relevant dependence of the compressibility on the p-n asymmetry $\alpha = (N - Z)/A$ from the equation of state of nuclear matter:

$$K(\alpha) = K_0(\alpha = .5)(1 - a\alpha^2),$$

with a, for several Skyrme interactions, of the order of 1.28 up to 1.99 (at zero temperature).

2 Screening Functions and Static Polarizabilities

The nuclear matter screening functions are investigated in the following. However before it is interesting to review a qualitative argument for exploring them from reference [23]. Firstly it is assumed the introduction of a small isovector perturbation $\epsilon\tau_3$ in nuclear matter which separates neutrons from protons[1] causing a fluctuation $\delta\rho = \rho_n - \rho_p$. The energy of the system can be writen as:

$$H = H_0 + a_\tau \frac{\delta\rho^2}{\rho} + \epsilon\delta\rho. \tag{3}$$

In the equilibrium: $\delta H/\delta\rho = 0$, which results the static polarizability as the proportionality function which measure the response of the medium to the external perturbation ($\epsilon\tau_3$, where τ_3 is the third

[1]This argument is valid for the four channels, it is enough to consider other external perturbations: σ_3, $\sigma_3\tau_3$ and **1** for the spin, spin-isospin and scalar channels respectively.

component of the isospin matrix). The resulting polarizability (now generalizing for any channel as done in [7, 24] with (s,t) for spin,isospin numbers) is given by:

$$\frac{\delta\rho_{s,t}}{\epsilon_{s,t}} = \frac{\rho_0}{2A_{s,t}}. \tag{4}$$

This expression corresponds to the static limit of the response function of symmetric nuclear matter at zero temperature and saturation density. When considering asymmetric hot nuclear matter at variable densities the symmetry energy gives place to a more general parameter, just called as the isospin/spin screening functions of nuclear matter, extending the concept of the symmetry energy coefficient to dense, asymmetric hot nuclear matter being inversely proportional to the polarizability. The same reasoning is valid for the other three channels. A nearly exact expression for the dynamical polarizability of an asymmetric hot dense nuclear matter was derived for Skyrme interactions in [6, 7] and in the present work the static limits are studied.

The static limit of the dynamical polarizability of an asymmetric hot nuclear matter for Skyrme interactions may be writen as:

$$\Pi^{s,t}(\omega \to 0, q \to 0, T, b) = \frac{\rho_0}{2A_{s,t}(T, b, \rho)}, \tag{5}$$

As stated before, the functions $A_{s,t}$ can be called isospin/spin (dielectric) screening functions of nuclear matter. At zero temperature in the symmetric nuclear matter limit these screening functions reduce to the symmetry energy coefficients as usually defined: $a_\tau = A_{0,1}(T \to 0, b \to 0)$, the p-n symmetry energy coefficient; $a_\sigma = A_{1,0}(T \to 0, b \to 0)$ the spin symmetry energy coefficient, $a_{\sigma\tau} = A_{1,1}(T \to 0, b \to 0)$ the spin-isospin symmetry energy coefficient, $K_D = A_{0,0}(T \to 0, b \to 0)$, a "dipolar compressibility" of nuclear matter [7].

The "generalized" symmetry energy coefficients $A_{s,t}$ are writen as:

$$\begin{aligned} A_{s,t} = \frac{\rho}{N} \Big\{ & 1 + 2\bar{V_0}^{s,t} L_c^N + 6V_1^{s,t} M_p^* (L_c^\rho + L_d^\rho) + 12 M_p^* V_1^{s,t} \bar{V_0}^{s,t} \left(L_c^N L_d^\rho - L_c^\rho L_d^N \right) + \\ & (V_1^{s,t})^2 \left(36 (M_p^*)_p^2 L_c^\rho L_d^\rho - 16 M_p^* L_c^M L_d^N \right) \Big\}, \end{aligned} \tag{6}$$

In the above expression:

$$L_v^S = v L_n^S + (1 - v) L_p^S,$$

where the densities L_q^S are ρ_q, M_q or N_q (q stands for protons or neutrons) given by:

$$(N_q, \rho_q, M_q) = \frac{2M_p^*}{\pi^2} \int df_q(k)(k, k^3, k^5),$$

In these expressions $f_q(k)$ is the fermion occupation number, V_0 and V_1 are functions of the Skyrme forces parameters (see in [7]) and $M_p^* = m_p^*/(1+a/2)$ is an effective mass for the proton. Besides that four asymmetry coefficients v have been used:

$$a = \frac{m_p^*}{m_n^*} - 1, \qquad b = \frac{\rho_{0n}}{\rho_{0p}} - 1, \qquad c = \frac{1+b}{2+b}, \qquad d = \frac{1}{1+(1+b)^{\frac{2}{3}}}. \tag{7}$$

(The coefficient b is related to another frequently used asymmetry coefficient: $\alpha = 2\rho_{0n} - \rho_0$, by: $b = 2\alpha/(1-\alpha)$.)

As discussed in other works [7, 25] the parameters V_0 and V_1 (functions of the Skyrme forces) are directly related to the Landau parameters of the Fermi liquid theory. As far as the general form of the response function of [6, 7] is concerned, it is possible to write down a generalization for the usual Landau condition for the stability of a Fermi liquid in asymmetric dense nuclear matter. The usual stability condition in each channel of the interaction is given by $J_0 > -1$, where J_0 stands for F_0, F_0', G_0, G_0' respectively for the scalar, isovector, spin and spin-isovector channels [26]. These conditions are just the denominators of the response function of symmetric nuclear matter at zero temperature and at saturation density. However this will not be the case for asymmetric nuclear matter at different densities: the $V_1^{s,t}$ term may become important and change the results. The expression for asymmetric nuclear matter is much more complicated and can be extracted from expression (6) just by substituting V_0 and V_1 by the Landau parameters. This is interesting since the contribution of $l > 0$ terms of the Fermi liquid parameter interactions may be more important for states of asymmetric nuclear matter at higher or lower densities, as could be seen in reference [7] for the case of Skyrme interactions.

The symmetric nuclear matter limit yields, as discussed in [6, 7], the symmetry energy coefficients of nuclear matter at finite T:

$$2A_{s,t} = \frac{\rho}{N}\left\{1 + (J_0^{s,t} + J_1^{s,t})N + 3\frac{J_1^{s,t}2^{1/3}}{(3\pi^2\rho)^{2/3}}m^*\rho - \frac{(J_1^{s,t})^2 2^{4/3}}{(3\pi^2\rho)^{4/3}}\left(m^*NM - \frac{9}{4}(m^*)^2\rho^2\right)\right\}. \tag{8}$$

Therefore we obtain extended condition for nuclear matter stability with relation to several perturbations:

$$A_{s,t} \geq 0. \tag{9}$$

At zero temperature and saturation density the last term, proportional to V_1^2, disappears and $A_{s,t}$ reduces to the usual definitions of the energy symmetry coefficients in the isovector (a_τ), spin (a_σ) and spin-isovector ($a_{\sigma\tau}$) channels in terms of the skyrme parameters as stated above. In the scalar channel a dipolar compressibility can be defined being related to the usual compressibility of nuclear matter (K_D and K_∞) [7]. In particular, in terms of the Landau Fermi liquid parameters:

$$
\begin{aligned}
2a_\tau &= \frac{\rho_0}{N_0}(1+F_0'), \qquad 2a_\sigma = \frac{\rho_0}{N_0}(1+G_0),, \\
2a_{\tau\sigma} &= \frac{\rho_0}{N_0}(1+G_0'), \qquad 2K_\infty = \frac{9\rho_0}{N_0}(1+F_0).
\end{aligned} \tag{10}
$$

At different densities, temperatures and n-p asymmetries the static polarizabilities have different values.

3 Results and discussion

In figure 1 we see the isospin screening function $A_{0,1}$ taking (and not taking) into account the corrections from terms of the order of V_1^2 in expression 6 (those which disappear when b=0 at ρ_0 and T=0) as a function of the density for Skyrme interactions SGII [27] and SLyb [28]. The former force was adjusted in order to obtain realistic properties of collective modes at symmetric nuclei at zero temperature. The second one (SLy) was fitted in order to reproduce the features of a realistic microscopic calculations for the Equation of State of neutron stars from [20]. Since Skyrme forces are not expected to describe physics at very high densities we decided to investigate the dependence of the polarizabilities up to 2 ρ_0, even because at higher densities they exhibit superluminal behaviour. They all reach a maximum value when $\rho_0 < \rho < 1.5\rho_0$ and then decrease. This last behaviour, as discussed in the introduction, is typical from non relativistic calculations. These parameters are compared to the parametrizations of expression (1) which was taken from [18]. Although the Skyrme forces (mainly SGII) are not well suited at high densities there is a trend to a decrease of this screening function (symmetry energy coefficient) until a phase transition in a dense nuclear system. In figure 2 the same parameter $A_{0,1}$ is presented but for non zero p-n asymmetries, i.e., for b=.25 and b=.54, this last corresponding to the asymmetry of the nucleus of ^{208}Pb. The values increase with relation to the symmetric nuclear matter but the tendency of decreasing for higher (and lower) densities still holds. The behaviour for increasing p-n asymmetry b is shown in figure 3. It is interesting to note that only for high density ($2\rho_0$) the force SLyb tends to reach a maximum value, all the other cases $A_{0,1}$ increases indefinitely. The dependence of the isospin screening function on the density at ρ_0 can be fitted with the following polynomial expression:

$$A_{0,1} = A + Bu + Cu^2 + Du^3, \tag{11}$$

where $u = \rho/\rho_0$. For the SGII and SLy interactions one obtains respectively:

$$A \simeq 6.9 \quad B \simeq 39.7 \quad C \simeq -23.5 \quad D \simeq 4.0,$$

and

$$A \simeq 17.9 \quad B \simeq 31.3 \quad C \simeq -21.6 \quad D \simeq 4.4.$$

The spin screening function is analysed in figures 4 to 7. For increasing densities $A_{1,0}$ may decrease until a minimum and then increase for $\rho/\rho_0 > 1.3$ or 1.7 (SLyb) or decrease almost continuously (force SGII) eventually reaching negative values for higher densities, which would make the matter undergoes a phase transition to a polarized state, see figure 4. For non zero asymmetry parameters (b=.25 and .54) in figure 5 the general tendency of the symmetric case is still present. The dependence of $A_{1,0}$ with the asymmetry is emphasized in figure 6: a continuous increasing is found for almost all cases, except for the dense ($2\rho_0$) matter with SGII.

The spin-isovector channel for symmetric matter with increasing density is shown in figure 7: while the force SGII causes a kind of oscillation the SLyb force rather presents $A_{1,1}$ and $a_{\sigma\tau}$ decreasing and becoming negative at $\rho \simeq 1.8$ or 2.1, exhibiting in these points phase transition which is expected to be associated with pion condensation. In figure 8 the same analysis holds for asymmetric matter (also b=.25 and .54). However the increasing asymmetry makes the phase transition to occur at higher densities. This feature can be stressed by observing figure 9.

For the scalar channel figures 10 and 11 show that the two used interactions are attractive for lower densities, becoming more and more repulsive for higher densities. The increase of the asymmetry may either stregthen the repulsion (at higher densities) or make the interaction continuoulsy attractive (for lower denstiies) as seem in figure 12. In this figure the parametrization for the n-p asymmetry dependence of the compressibility of nuclear matter of reference [22] (not the compressibility K_∞ itself, but its asymmetry dependence) is compared with our results for the "dipolar compressibility K_D". This is just to compare the qualitative behaviours as a function of the p-n asymmetry because otherwise we would be comparing different parameters. Their parametrization (using the n-p asymmetry parameter of our work) is given by: $K(b) = K_0(b=0)(1-2(b/(b+2))^2)$ while our curve (for $\rho = \rho_0$) is well fitted (for b up to 8) by: $K_D = 17.4 - 4.3b - 1.6b^2 + .07b^3$. It is senn in figure 12 that these two cases (from [22]) present nearly the same behaviour (dependence on the n-p asymmetry b with $\rho = \rho_0$) as our calculation, a remarkable feature.

The dependence of the screening functions on the temperature was verified for densities which does not depend on the temperature. The variation is very small: there is an increase of the order of $\Delta A_{s,t} \simeq 0.1$ to 1 MeV when T increases from 0 up to 6 MeV for almost all the channels for force SGII (for this force a decreasing behaviour is found for the spin channel at density $\rho = 2\rho_0$). For the interaction SLy $A_{s,t}$ exhibit decreasing values in the spin-isovector channel at the saturation density and for all the channels at density $\rho = 2\rho_0$.

Summarizing, the screening functions of hot asymmetric (non relativistic) nuclear matter at variable densities was investigated. Their density, temperature and n-p asymmetry dependences were analysed for two different Skyrme forces which may yield very different behaviours including the possibility (or not) of nuclear matter to undergo phase transitions to spin/isospin polarized states. In the isovector channel the symmetry energy coefficient is found to receive important contribution not only from variable densities (as expected) but also from the n-p asymmetry. This kind of behaviour is relevant to many nuclear processes among which those present in the Supernovae mechanism [16, 17]. In particular the increase of symmetry energy coefficient (or rather the isospin screening function), in principle, helps a successful explosion of the (contracting) star. Relevant onsequences are also found for the spin dependent channels (formation of spin-polarized matter) as well as for the scalar compressibility. Nevertheless, it is important to stress that different Skyrme forces provide very different results for the present calculations which, in most part, are difficult to test due to the difficulties of extracting experimental data at different densities and n-p asymmetries.

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References

[1] A. deShalit and H. Feshbach, *Theoritical Nuclear Physics*, Vol.1, John Wiley and Sons, Inc., Toronto, 1974; A. Bohr and B.R. Mottelson, *Nuclear Structure*, Vol. 1, W.A. Benjamin, New York, 1969.

[2] I. Bombaci and U. Lombardo, Phys. Rev. **C 44**, 1892 (1991).

[3] J. Jänecke and E. Comay, Nucl. Phys. **A 436** 108 (1985).

[4] C-H. Lee *et al*, Phys. Rev. **C 57**, 3488 (1998).

[5] P.Möller and J.R. Nix, Nucl. Phys. **A 361**, 117 (1981); P. Möller *et al*, At. Data Nucl. Tables **39** 225 (1988).

[6] F.L. Braghin, Phys. Lett. **B 446**, 1 (1999).

[7] F.L. Braghin, "Collective modes in hot asymmetric nuclear matter at variable densities", to be published in Nucl. Phys. A.

[8] N. Van Giai, Ch. Stoyanov and V.V. Voronov, Phys. Rev. **C 57**, 1204 (1998).

[9] M. Kutschera, Phys. Lett. **B 340**, 1 (1994).

[10] I. Tanihata, Prog. Part. Nucl. Phys. **35**, 505 (1995); J. Phys. **G22**, 157 (1996).

[11] P.G. Hansen, A.S. Jensen and B. Jonson, Ann. Rev. Nucl. Part. Sci. **45**, 591 (1995).

[12] R. Pak *et al*, Phys. Rev. Lett. **78**, 1022 (1997).

[13] M. Kutschera and W. Wójcik, Phys. Lett. **B 223**, 11 (1989).

[14] M. Farine, J.M. Person, B Rouben, Nucl. Phys. **A 304**, 317 (1978); J.M. Person *et al*, Nucl. Phys. **A 528**, 1 (1991).

[15] W.D. Myers and W.J. Swiatecki, Ann. Phys. **55**, 395 (1969); W.D. Myers, At. Data Nucl. Tables **17**, 411 (1976).

[16] P. Donati *et al*, Phys. Rev. Lett. **72**, 2835 (1994).

[17] D.J. Dean *et al*, Phys. Lett. **B 356**, 429 (1995).

[18] M. Prakash, T.L. Ainsworth and J.M. Lattimer, Phys. Rev. Lett. **61**, 2518 (1988).

[19] L. Engvik, M. Hjorth-Hensen, R. Machleidt, H. Müther, A. Polls, Nucl. Phys. **A 627** 85 (1997).

[20] R.B. Wiringa, R.A. Smith and T.L. Ainsworth, Phys. Rev. **C 29**, 1207 (1984); R.B. Wiringa, V. Fiks and A. Fabrocini, Phys. Rev. **C38**, 1010 (1988).

[21] C. Horowitz and B. Serot, Nucl. Phys. **A 464**, 613 (1987).

[22] E. Baron, J. Cooperstein and S. Kahana, Phys. Rev. Lett. **55**, 126 (1985).

[23] F.L. Braghin, D. Vautherin and A. Abada, Phys. Rev. **C 52** (1995) 2504.

[24] F. L. Braghin and D. Vautherin, Phys. Lett. **B 333**, 289 (1994).

[25] E.S. Hernández, J. Navarro, A. Polls and J. Ventura, Nucl. Phys. **A 597** 1 (1996).

[26] D. Pines and P. Nozieres, *The theory of Quantum Liquids*, W.A. Benjamin Inc., New York, 1966.

[27] N. Van Giai and H. Sagawa, Phys. Lett. **B 106**, 379 (1981).

[28] E. Chabanat *et al*, Nucl. Phys. **A 627**, 710 (1997).

Figure caption

Figure 1 Isospin screening function $A_{0,1} = \rho/(2\Pi_R^{0,1})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII (solid line) and SLy (dotted). The simplified expression, i.e. without terms of order of V_1^2, for forces SGII (dashed line) and SLy (long-dashed). Circles, squares and diamonds for expression of ref. [18] with three different functions F(u).

Figure 2 Isospin screening function $A_{0,1} = \rho/(2\Pi_R^{0,1})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII

with b=0.25 (solid line), b=.54 (dotted line) and SLy with b=.25 (dashed), b=.54 (long dashed).

Figure 3 Same of figures 1 and 2 $A_{0,1} = \rho/(2\Pi_R^{0,1})$ as function of the asymmetry coefficient b at differents densities and forces.

Figure 4 Spin screening function $A_{1,0} = \rho/(2\Pi_R^{1,0})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII (solid line) and SLy (dotted). The simplified expression, i.e. without terms of order of V_1^2, are presented for forces SGII (dashed line) and SLy (long-dashed).

Figure 5 Spin screening function $A_{1,0} = \rho/(2\Pi_R^{1,0})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII with b=0.25 (solid line), b=.54 (dotted line) and SLy with b=.25 (dashed), b=.54 (thick dashed).

Figure 6 Spin screening function $A_{1,0} = \rho/(2\Pi_R^{1,0})$ as function of the asymmetry coefficient b at differents densities and forces.

Figure 7 Spin-isospin screening function $A_{1,1} = \rho/(2\Pi_R^{1,1})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII (solid line) and SLy (dotted). The simplified expression, i.e. without terms of order of V_1^2, are presented for forces SGII (dashed line) and SLy (long-dashed).

Figure 8 Spin-isospin screening function $A_{1,1} = \rho/(2\Pi_R^{1,1})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII with b=0.25 (solid line), b=.54 (dotted line) and SLy with b=.25 (dashed), b=.54 (thick dashed).

Figure 9 Spin-isospin screening function $A_{1,1} = \rho/(2\Pi_R^{1,1})$ as function of the asymmetry coefficient b at differents densities and with forces.

Figure 10 Inverse of the static polarizability in the scalar channel $A_{0,0} = \rho/(2\Pi_R^{0,0})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII (solid line) and SLy (dotted). The simplified expression, i.e. without terms of order of V_1^2, are presented for forces SGII (dashed line) and SLy (long-dashed).

Figure 11 Inverse of the static polarizability in the scalar channel $A_{0,0} = \rho/(2\Pi_R^{0,0})$ as function of the ratio of density to density at saturation ($u = \rho/\rho_0$) for interactions SGII with b=0.25 (solid line), b=.54 (dotted line) and SLy with b=.25 (dashed), b=.54 (thick dashed).

Figure 12 Inverse of the static polarizability in the scalar channel $A_{0,0} = \rho/(2\Pi_R^{0,0})$ as function of the asymmetry coefficient b at differents densities and with forces. The n-p dependence of the compressibility K_∞ of nuclear matter of reference [22] is also displayed (short-long dashed using $K_D(b=0)$ from the SGII force and thick short-long dashed using $K_D(b=0)$ from the SLy force).

Figure 1

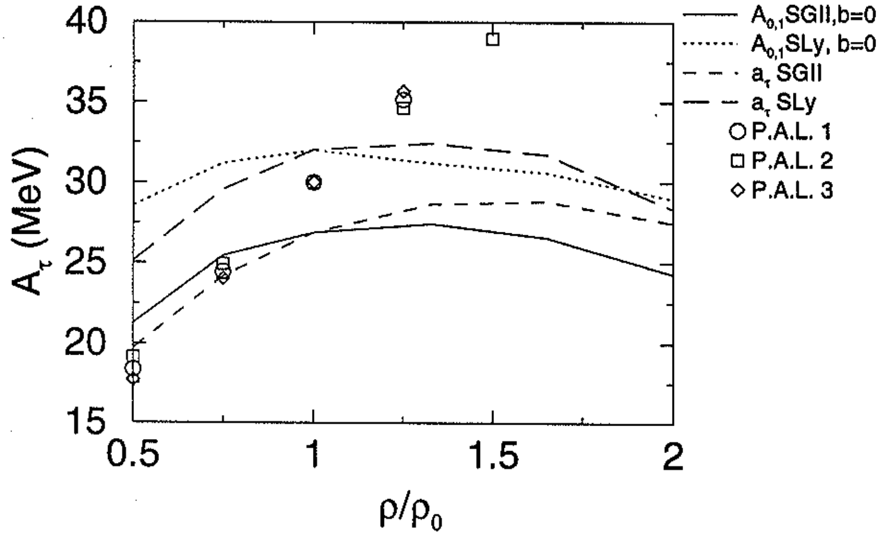


Figure 2

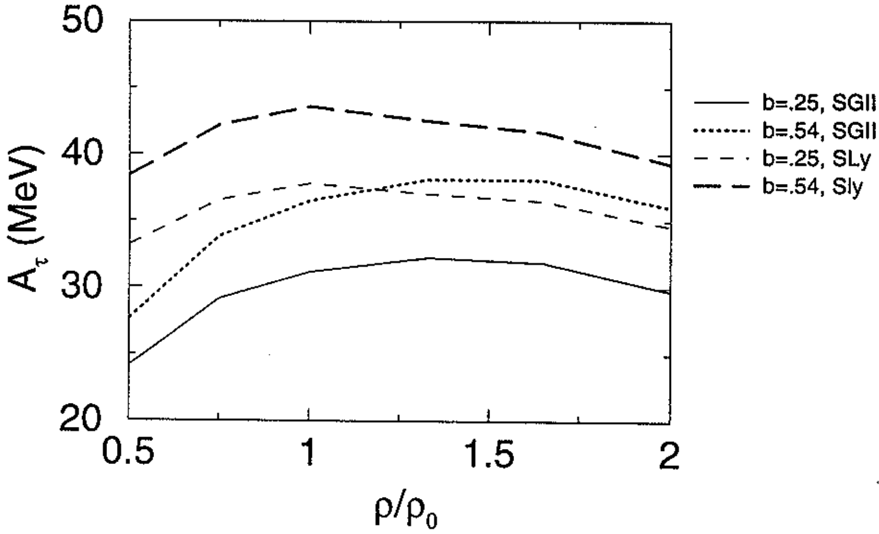
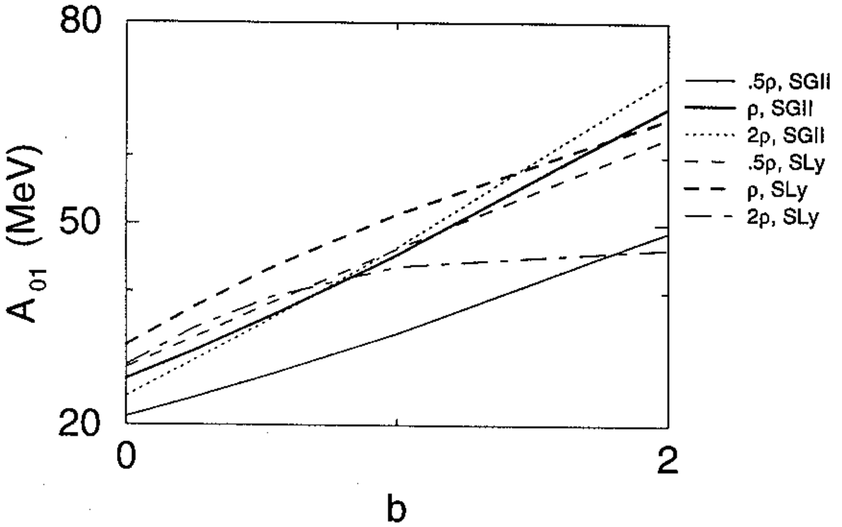


Figure 3



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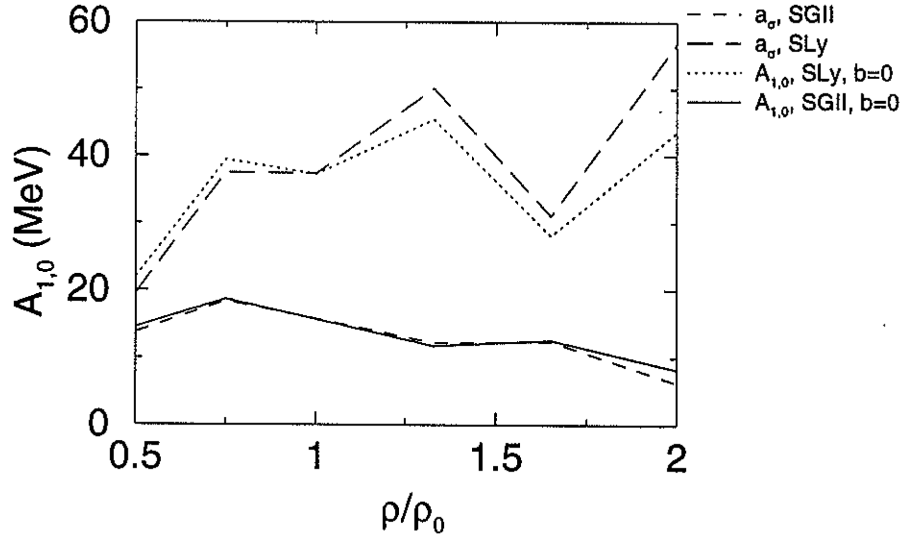

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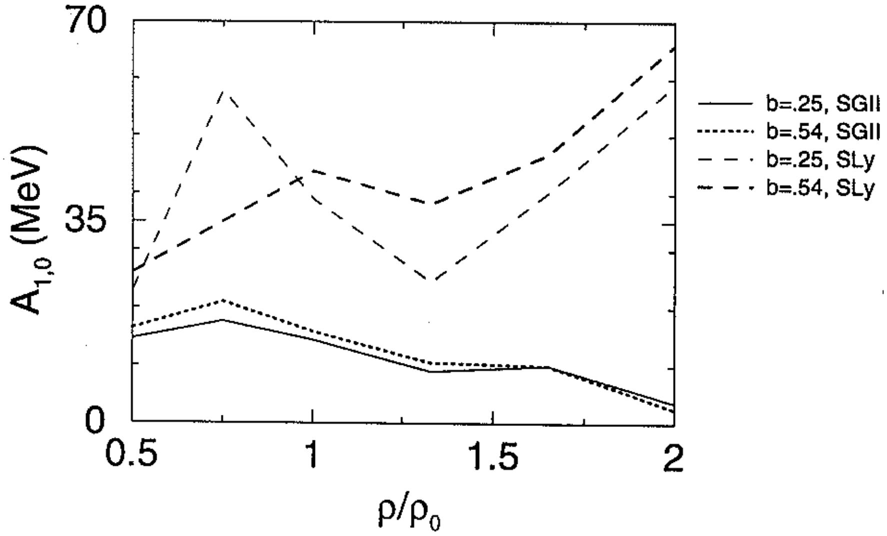

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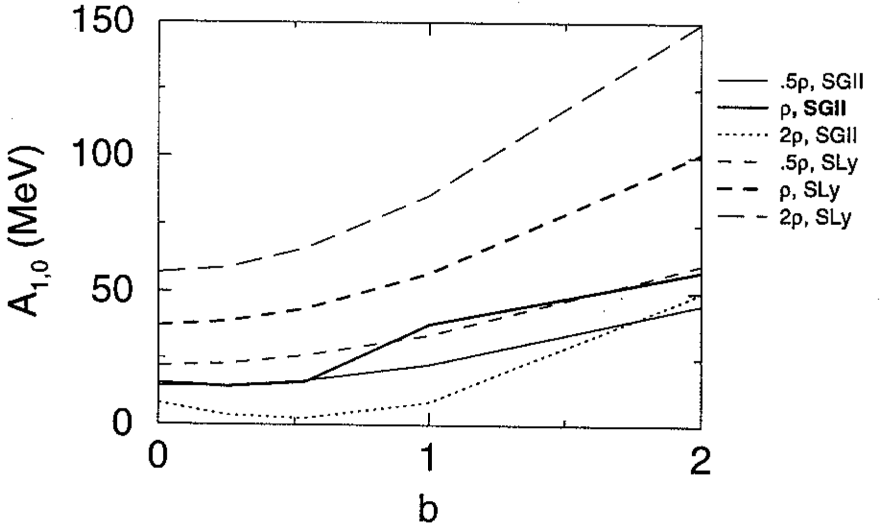

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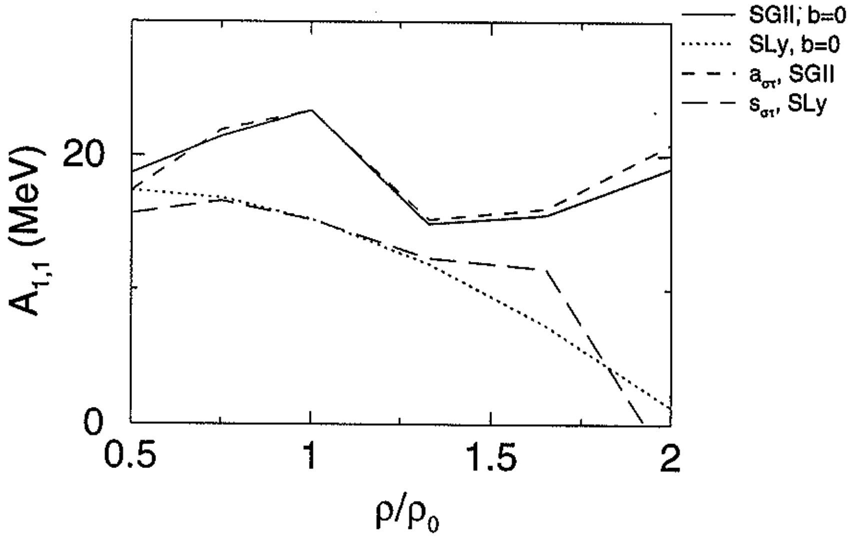

Figure 8

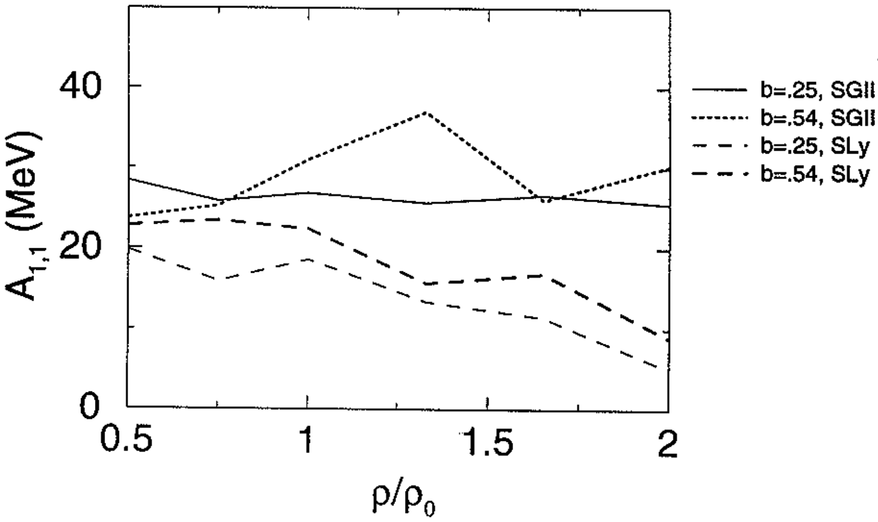

Figure 9

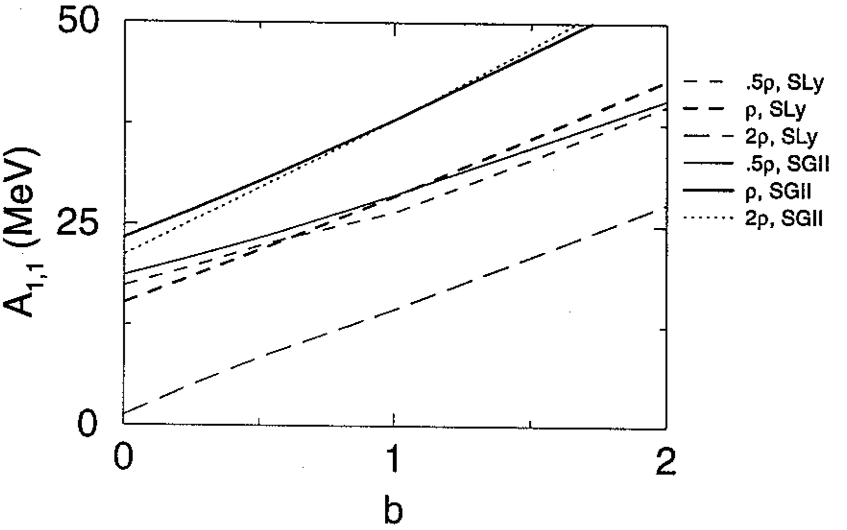

Figure 10

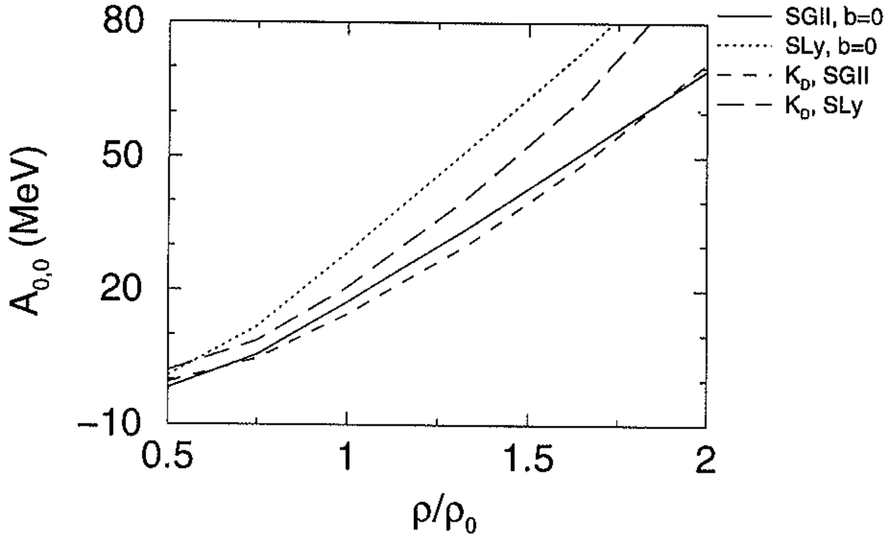

Figure 11

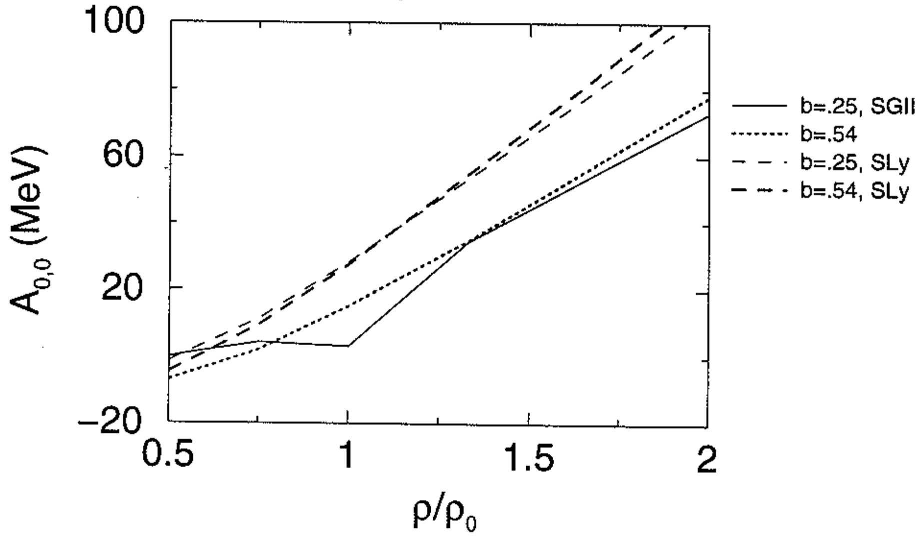

Figure 12