Linear response in infnite matter with tensor force

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Outline

1. Introduction
2. Landau
3. RPA: V_{ph}=0
4. RPA: $V_{ph} \neq 0$
5. Summary

Introduction

The tensor part is an essential part of the NN interaction.

- Early studies in mean-field framework:
  - T.H.R. Skyrme included it
  - F. Stancu, H. Flocard, D.M. Brink, PLB (1977)
  - K.F. Liu et al. NPA (1991)
- Recent attempts at adding a tensor term to mean field/density functional model:
  - Gogny: T. Otsuka et al. PRL (2005)
  - RHF: W.H. Long, N.V. Giai and J. Meng, PLB (2006)
  - Skyrme EDF:
    - B.A. Brown at al. PRC (2006)
    - T. Lesinski et al. PRC (2007)
    - M. Zalewski et al. PRC (2008)
    - J. Dobaczewski arxiv (2006)
    - ...

In the original paper of T.H.R Skyrme reads

$$\begin{aligned} V^T &= \frac{T}{2}\left\{\left[(\sigma_1\cdot\mathbf{k}')(\sigma_2\cdot\mathbf{k}') - \frac{1}{3}(\sigma_1\cdot\sigma_2)\mathbf{k}'^2\right]\delta(\mathbf{r}_1-\mathbf{r}_2)\right.\\ &+ \left.\delta(\mathbf{r}_1-\mathbf{r}_2)\left[(\sigma_1\cdot\mathbf{k})(\sigma_2\cdot\mathbf{k}) - \frac{1}{3}(\sigma_1\cdot\sigma_2)\mathbf{k}^2\right]\right\}\\ &+ \frac{U}{2}\left\{(\sigma_1\cdot\mathbf{k}')\delta(\mathbf{r}_1-\mathbf{r}_2)(\sigma_2\cdot\mathbf{k}) + (\sigma_2\cdot\mathbf{k}')\delta(\mathbf{r}_1-\mathbf{r}_2)(\sigma_1\cdot\mathbf{k})\right.\\ &- \left.\frac{2}{3}\left[(\sigma_1\cdot\sigma_2)\mathbf{k}'\cdot\delta(\mathbf{r}-\mathbf{r}')\mathbf{k}\right]\right\} \end{aligned}$$

or in moder Functional language

$$\begin{aligned} \mathcal{H}^{\text{tensor}} &= B_t^T\left(\mathbf{s}_t\mathbf{T}_t - \sum_{\mu,\nu=x}^{z} J_{t,\mu\nu}J_{t,\mu\nu}\right) + B_t^{\nabla s}(\nabla\cdot\mathbf{s}_t)^2 + B_t^{\Delta s}\mathbf{s}_t\Delta\mathbf{s}_t\\ &+B_t^F\left[\mathbf{s}_t\mathbf{F}_t - \frac{1}{2}\left(\sum_{\mu=x}^{z} J_{t\mu\mu}\right)^2 - \frac{1}{2}\sum_{\mu,\nu=x}^{z} J_{t,\mu\nu}J_{t,\nu\mu}\right] \end{aligned}$$

[E . Perlinska et al. Phys. Rev C 69, 014316 (2004))]
[D . Davesne et. al Phys. Rev C (2009)]

Fitting the parameters of the functional

EDF fitting...

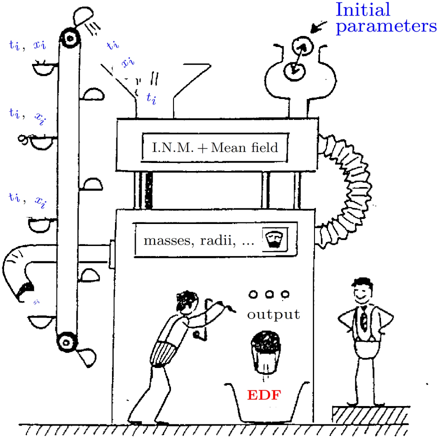
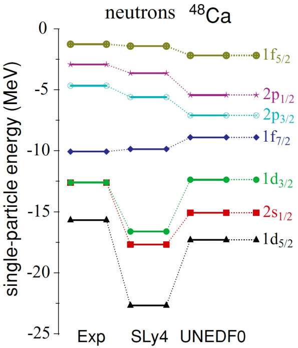
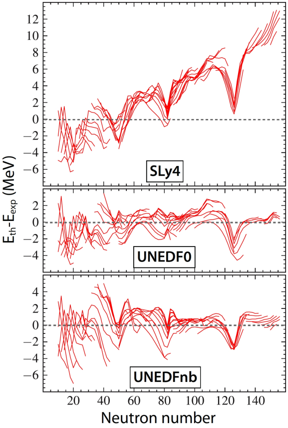


Figure: Picture by J. Dechargé, from "Approches de champ moyen et au-delà", J.-F. Berger, École Joliot-Curie: "Les noyaux en pleine forme", 1991.

Obtaining a good set of (stable) parameters is not an easy task

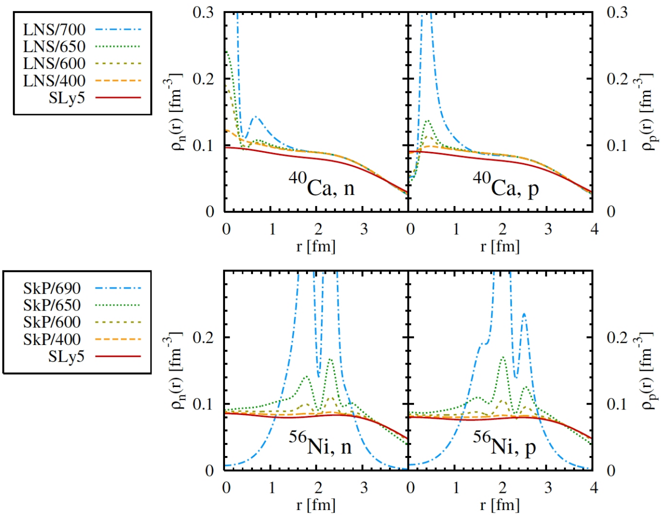




[M . Kortelainen et al. Phys. Rev C 82, 024313 (2010)]

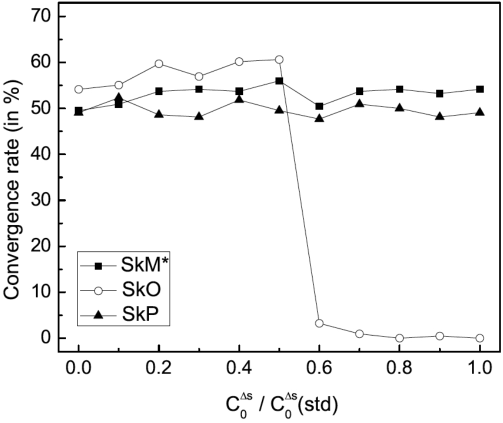
Instabilities

Instabilities can occur with the Skyrme functional, but not easy to detect!



Instabilities

... especially in odd systems



[N. Schunck et al. Phys. Rev C (2010)]

Outline

Landau parameters to detect instabilities

As a first approximation we can derive the Landau parameters from a Skyrme force [L.G. Cao et al. Phys. Rev C 81, 044302 (2010)]

$$V_{ph}^{\text{Landau}}(\mathbf{q},\mathbf{q}_1,\mathbf{q}_2) = \lim_{\mathbf{q}\longrightarrow 0,\mathbf{q}_{1,2}\longrightarrow k_F} V_{ph}(\mathbf{q},\mathbf{q}_1,\mathbf{q}_2)$$

According to Liu [K.-F. Liu et al. Nucl. Phys. A534 (1991) 1-24]

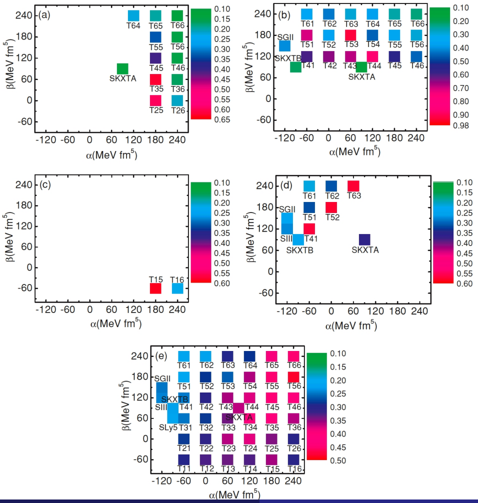
$$\begin{aligned} V_{ph} &= \delta_{\mathbf{r}_2,\mathbf{r}_1} N_0^{-1} \sum_{l=0}^{1} \Big[F_l + F_l' \hat{\tau}_a \circ \hat{\tau}_b + G_l \boldsymbol{\sigma}_a \cdot \boldsymbol{\sigma}_b + G_l' \hat{\tau}_a \circ \hat{\tau}_b \boldsymbol{\sigma}_a \cdot \boldsymbol{\sigma}_b \\ &+ \frac{k_{12}^2}{k_F^2} H_l S_{ab} + \frac{k_{12}^2}{k_F^2} H_l S_{ab} \hat{\tau}_a \circ \hat{\tau}_b \Big] P_l(\cos\theta) \end{aligned}$$

For a Skyrme force we have

$$\begin{aligned} H_0 &= N_0 \frac{k_F^2}{24}(T+3U) = N_0 \frac{k_F^2}{5}(\alpha_T + \beta_T) \\ H_0' &= N_0 \frac{k_F^2}{24}(-T+U) = N_0 \frac{k_F^2}{5}(\alpha_T + \beta_T) \end{aligned}$$

[T. Lesinski et al. Phys. Rev. C 76, 014312 (2007)]

Landau approximation: stability condition



$$a) J = 0^- : \quad 1 + \frac{1}{3}G_1 - \frac{10}{3}H_0 > 0$$

$$b) \left(1 + \frac{G_0}{2}\right) \pm \frac{1}{2}\sqrt{G_0^2 + 8H_0^2} > 0$$

$$c) J = 0^- : \quad 1 + \frac{1}{3}G_1' - \frac{10}{3}H_0' > 0$$

$$d) J = 1^- : \quad 1 + \frac{1}{3}G_1' + \frac{5}{3}H_0' > 0$$

$$e) \left(1 + \frac{G_0'}{2}\right) \pm \frac{1}{2}\sqrt{G_0'^2 + 8H_0'^2} > 0$$

[L.G. Cao et al. Phys. Rev C 81, 044302 (2010)]

[T. Lesinski et al. Phys. Rev C 76, 014312 (2007)]

Landau parameters from a generic functional

$$
\begin{cases}
N_0^{-1}F_0 = 2C_0^{\rho 0} + (2+\gamma)(1+\gamma)C_0^{\rho\gamma}\rho_0^\gamma + 2k_F^2 C_0^\tau \\
N_0^{-1}F_1 = -2k_F^2 C_0^\tau \\
N_0^{-1}F'_0 = 2C_1^{\rho 0} + 2C_1^{\rho,\gamma}\rho_0^\gamma + 2k_F^2 C_1^\tau \\
N_0^{-1}F'_1 = -2k_F^2 C_1^\tau \\
N_0^{-1}G_0 = 2C_0^{s,0} + 2C_0^{s\gamma}\rho_0^\gamma + 2k_F^2 C_0^T + \frac{2k_F^2}{3} C_0^F \\
N_0^{-1}G'_0 = 2C_1^{s,0} + 2C_1^{s\gamma}\rho_0^\gamma + 2k_F^2 C_1^T + \frac{2k_F^2}{3} C_1^F \\
N_0^{-1}G_1 = -2k_F^2 C_0^T - \frac{2k_F^2}{3} C_0^F \\
N_0^{-1}G'_1 = -2k_F^2 C_1^T - \frac{2k_F^2}{3} C_1^F \\
N_0^{-1}H_0 = \frac{k_F^2}{3} C_0^F \\
N_0^{-1}H'_0 = \frac{k_F^2}{3} C_1^F
\end{cases}
$$

Only in the case of a Skyrme force the tensor coupling constant enter only in H_0, H'_0

Which Sum Rule you have to use with the tensor?

An equivalent form of the sum rules,

$$S_1 = \sum_l \left[\frac{F_l}{1+F_l/(2l+1)} + \sum_J \frac{2J+1}{2l+1} \mathcal{A}_{ll}^{JT=1} \right] = 0 ,$$

$$S_2 = \sum_l \left[\frac{2}{3} \frac{F_l}{1+F_l/(2l+1)} + \frac{F_l'}{1+F_l'/(2l+1)} + \frac{1}{3} \sum_J \frac{2J+1}{2l+1} \mathcal{A}_{ll}^{JT=0} \right] = 0 , \qquad (16)$$

is obtained by eliminating first C_l and then C_l' in eq. (15). Here we have also used eqs. (5) and (12). If the tensor part of the quasiparticle interaction is neglected, eq. (16) reduces to

$$S_1' = \sum_l \left[\frac{F_l}{1+F_l/(2l+1)} + 3 \frac{G_l'}{1+G_l'/(2l+1)} \right] = 0 ,$$

$$S_2' = \sum_l \left[\frac{2}{3} \frac{F_l}{1+F_l/(2l+1)} + \frac{F_l'}{1+F_l'/(2l+1)} + \frac{G_l}{1+G_l/(2l+1)} \right] = 0 , \qquad (17)$$

which when all Landau parameters are small further reduces to

$$\sum_l (F_l + 3G_l') = 0 , \quad \sum_l (\tfrac{2}{3} F_l + F_l' + G_l) = 0 . \qquad (18)$$

These relations have been written down, in truncated form, by Bauer et al. [7] and Backman et al. [8, eq. (5)]. However, these "sum rules" do not apply to nuclear matter since the Landau parameters are not small. There fore, the full sum rules, S_1 and S_2, must be satisfied.

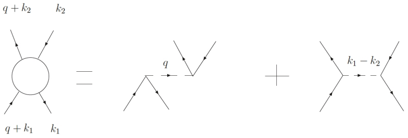
[B.L. Friman, Phys. Lett. 85b, 1979]

Outline

RPA formalism

We consider an in infinite medium in the Hartree-Fock formalism (T=0). We act with an external field

$$\sum_j \exp^{i\mathbf{q}\mathbf{r}} \Theta_\alpha^j \quad \Theta_\alpha^j = 1, \sigma^j, \tau^j, \sigma^j \tau^j$$



Within the Green function formalism we have for non interacting system

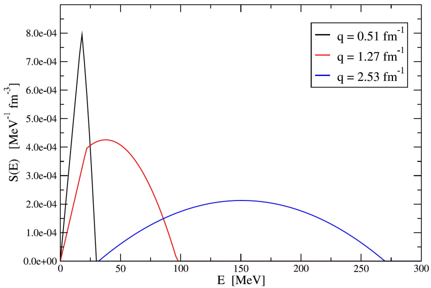
$$G_{HF}(q,\omega,\mathbf{k}_1) = \frac{\theta(k_F - k_1) - \theta(k_F - |\mathbf{k}_1 + \mathbf{q}|)}{\omega + \varepsilon(\mathbf{k}_1) - \varepsilon(|\mathbf{k}_1 + \mathbf{q}|) + i\eta\omega}$$

Response function: non-interacting system

$$\chi_0(q,\omega) = g\int \frac{d^3k_1}{(2\pi)^3} G^{\alpha}_{HF}(q,\omega,\mathbf{k}_1)$$

$$S^{\alpha}(q,\omega) = -\frac{1}{\pi}\mathrm{Im}\chi^{\alpha}_{RPA}(q,\omega)$$

The Lindhardt function can be written explicitly [C . Garcia-Recio , Ann. Phys. 214, 293-340, 1992]



$$\chi_0 = -\frac{m^* k_F}{4\pi^2}[1 + A_+(\nu,k) + A_-(\nu,k)]$$

$$A_{\pm}(\nu,k) = \frac{1}{4k}[1-(k\pm\nu)^2]$$

$$\times\left(\ln\left(\frac{k\pm\nu+1}{k\pm\nu-1}\right) \mp sign(\nu)\theta(1-(k\pm\nu)^2)\right)$$

[F . Raimondi, Ms. Thesis, 2007)]

Outline

Residual interaction

Second functional derivative of the Skyrme functional [E . Perlinska et al. Phys. Rev C 69, 014316 (2004))]

$$
\begin{aligned}
V_{ph} \quad &= \quad \frac{1}{4}W_1^{00} + \frac{1}{4}W_1^{01}\hat{\tau}_a \circ \hat{\tau}_b + \frac{1}{4}W_1^{10}\boldsymbol{\sigma}_a \cdot \boldsymbol{\sigma}_b + \frac{1}{4}W_1^{11}\boldsymbol{\sigma}_a \cdot \boldsymbol{\sigma}_b \hat{\tau}_a \circ \hat{\tau}_b \\
&+ \quad \frac{1}{4}\left(W_2^{00} + W_2^{01}\hat{\tau}_a \circ \hat{\tau}_b + W_2^{10}\boldsymbol{\sigma}_a \cdot \boldsymbol{\sigma}_b + W_2^{11}\boldsymbol{\sigma}_a \cdot \boldsymbol{\sigma}_b \hat{\tau}_a \circ \hat{\tau}_b\right) \\
&\times \quad \left[q_1^2 + q_2^2 - \frac{8\pi}{3}q_1 q_2 \sum_{\mu=-1,0,1} Y_\mu^{(1)*}(\hat{q}_1) Y_\mu^{(1)}(\hat{q}_2)\right] \\
&+ \quad \left[+2\vec{\rho}C_1^{\rho,\gamma}\gamma\rho_0^{\gamma-1} \circ (\hat{\tau}_a + \hat{\tau}_b) + 2\gamma C_0^{s\gamma}\rho_0^{\gamma-1}\mathbf{s}_0 \cdot (\boldsymbol{\sigma}_a + \boldsymbol{\sigma}_b) + 2\gamma C_1^{s\gamma}\rho_0^{\gamma-1}\vec{\mathbf{s}} \cdot (\boldsymbol{\sigma}_a \circ \hat{\tau}_a + \boldsymbol{\sigma}_b \circ \hat{\tau}_b)\right] \\
&+ \quad 2\left(C_0^{\nabla s} + C_1^{\nabla s}\hat{\tau}_a \circ \hat{\tau}_b\right)\mathbf{q}\cdot\boldsymbol{\sigma}_a \mathbf{q}\cdot\boldsymbol{\sigma}_b + \left(C_0^F + C_1^F\hat{\tau}_a \circ \hat{\tau}_b\right)\left\{\mathbf{k}_{12}\cdot\boldsymbol{\sigma}_a \mathbf{k}_{12}\cdot\boldsymbol{\sigma}_b - \frac{1}{2}\mathbf{q}\cdot\boldsymbol{\sigma}_a \mathbf{q}\cdot\boldsymbol{\sigma}_b\right\} \\
&- \quad i\left(C_0^{\nabla J} + C_1^{\nabla J}\hat{\tau}_a \circ \hat{\tau}_b\right)(\boldsymbol{\sigma}_a + \boldsymbol{\sigma}_b)\cdot[\mathbf{q}\times\mathbf{q}_1 - \mathbf{q}\times\mathbf{q}_2]
\end{aligned}
$$

$$
\frac{1}{4}W_1^{00} = 2C_0^{\rho 0} + (2+\gamma)(1+\gamma)C_0^{\rho\gamma}\rho_0^{\gamma} + \gamma(\gamma-1)C_1^{\rho,\gamma}\rho_0^{\gamma-2}\vec{\rho}^2 + \gamma(\gamma-1)C_0^{s\gamma}\rho_0^{\gamma-2}\mathbf{s}_0^2
$$

$$
+\gamma(\gamma-1)C_1^{s\gamma}\rho_0^{\gamma-2}\vec{\mathbf{s}}^2 - \left[2C_0^{\Delta\rho} + \frac{1}{2}C_0^{\tau}\right]q^2
$$

$$
\frac{1}{4}W_1^{01} = 2C_1^{\rho 0} + 2C_1^{\rho,\gamma}\rho_0^{\gamma} - \left[2C_1^{\Delta\rho} + \frac{1}{2}C_1^{\tau}\right]q^2 \quad \frac{1}{4}W_1^{10} = 2C_0^{s,0} + 2C_0^{s\gamma}\rho_0^{\gamma} - \left[2C_0^{\Delta s} + \frac{1}{2}C_0^{T}\right]q^2
$$

$$
\frac{1}{4}W_1^{11} = 2C_1^{s,0} + 2C_1^{s\gamma}\rho_0^{\gamma} - \left[2C_1^{\Delta s} + \frac{1}{2}C_1^{T}\right]q^2
$$

$$
\frac{1}{4}W_2^{00} = C_0^{\tau} \quad \frac{1}{4}W_2^{01} = C_1^{\tau} \quad \frac{1}{4}W_2^{10} = C_0^{T} \quad \frac{1}{4}W_2^{11} = C_1^{T}
$$

Matrix elements of the tensor part [S=S'=1]

The residual interaction is

$$V_{ph}^{\alpha\alpha'}(q,\mathbf{k}_1,\mathbf{k}_2) = \langle \mathbf{q}+\mathbf{k}_1, \mathbf{k}_1^{-1}, (\alpha)|V|\mathbf{q}+\mathbf{k}_2, \mathbf{k}_2^{-1}, (\alpha')\rangle$$

M	$M'=1$	$M'=0$	$M'=-1$
1	$(-2B_t^T - 8B_t^{\Delta s})q^2$ $4B_t^T(k_{12})_0(k_{12})_0$ $(-8B_t^T - 4B_t^F)(k_{12})_1(k_{12})_{-1}$	$-4B_t^F(k_{12})_{-1}(k_{12})_0$	$-4B_t^F(k_{12})_{-1}(k_{12})_{-1}$
0	$4B_t^F(k_{12})_0(k_{12})_1$	$(-2B_t^T + 8B_t^{\nabla s} - 8B_t^{\Delta s} - 2B_t^F)q^2$ $(4B_t^T + 4B_t^F)(k_{12})_0(k_{12})_0$ $-8B_t^T(k_{12})_1(k_{12})_{-1}$	$4B_t^F(k_{12})_{-1}(k_{12})_0$
-1	$-4B_t^F(k_{12})_1(k_{12})_1$	$-4B_t^F(k_{12})_1(k_{12})_0$	$(-2B_t^T - 8B_t^{\Delta s})q^2$ $4B_t^T(k_{12})_0(k_{12})_0$ $(-8B_t^T - 4B_t^F)(k_{12})_1(k_{12})$

[D. Davesne et al. Phys. Rev. C]

Response function: interacting system

The RPA correlated Green function is the solution of Bethe-Salpeter equation

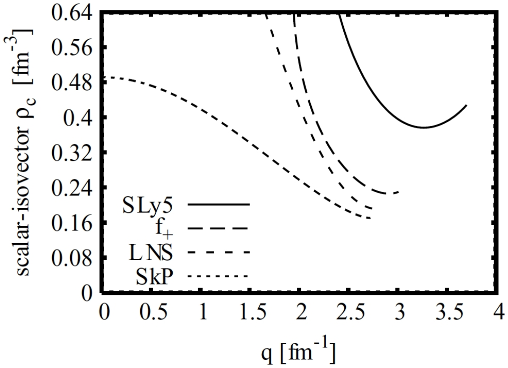
$$
\begin{aligned}
G^{\alpha}_{RPA}(q,\omega,\mathbf{k}_1) &= G_{HF}(q,\omega,\mathbf{k}_1) \\
&+ G_{HF}(q,\omega,\mathbf{k}_1)\sum_{\alpha'}\int\frac{d^3k_2}{(2\pi)^3}V^{\alpha\alpha'}_{ph}(q,\mathbf{k}_1,\mathbf{k}_2)G^{\alpha'}_{RPA}(q,\omega,\mathbf{k}_2)
\end{aligned}
$$

The response function is now defined as

$$
\begin{aligned}
\chi^{\alpha}_{RPA}(q,\omega) &= g\int\frac{d^3k_1}{(2\pi)^3}G^{\alpha}_{RPA}(q,\omega,\mathbf{k}_1) \\
S^{\alpha}(q,\omega) &= -\frac{1}{\pi}\mathrm{Im}\chi^{\alpha}_{RPA}(q,\omega)
\end{aligned}
$$

Instabilities

We look for the poles of $\chi(\omega = 0, q)$, zero energy modes.



Symmetric nuclear matter (SNM)

The response function is a combination of generalized Lindhardt functions

$$\chi_{2i}(\mathbf{q}) = \int \frac{d_3^q}{(2\pi)^4} G_0(q_3, q) \frac{1}{2} \left[\left(\frac{q_3^2}{k_F^2} \right)^i \left(\frac{(\mathbf{q}+\mathbf{q}_3)^2}{k_F^2} \right)^i \right]$$

[C . Garcia-Recio , Ann. Phys. 214, 293-340, 1992]

$$\begin{aligned}
\frac{\chi_{HF}}{\chi_{RPA}^{(1I0)}} &= \left[1 + 2B_I^F \frac{m^* k_F^3}{3\pi^2} \right]^2 - \tilde{\tilde{W}}_1^{(1I0)} \chi_0 \\
&+ W_2^{(1I)} \left\{ \frac{q^2}{2} \chi_0 \left[1 + 4B_I^F \frac{m^* k_F^3}{3\pi^2} \right] - 2k_F^2 \chi_2 + 4B_I^F \frac{m^* k_F^5}{3\pi^2} (\chi_0 - \chi_2) \right\} \\
&+ [W_2^{(1,I)}]^2 k_F^4 \left[\chi_2^2 - \chi_0 \chi_4 + \left(\frac{m^* \omega}{k_F^2} \right)^2 \chi_0^2 - \frac{m^*}{6\pi^2 k_F} q^2 \chi_0 \right] \\
&+ 2\chi_0 \left(\frac{m^* \omega}{q} \right)^2 \frac{W_2^{(1,I)} [1 + \frac{m^* k_F^3}{3\pi^2} X^{(1I0)}]}{1 - \frac{m^* k_F^3}{3\pi^2} \left[W_2^{(1,I)} - X^{(1I0)} \right]}
\end{aligned}$$

Symmetric nuclear matter (SNM)

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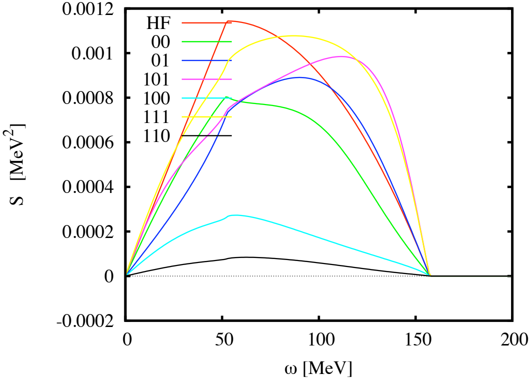
[C . Garcia-Recio , Ann. Phys. 214, 293-340, 1992]

$$\begin{aligned}
\frac{\chi_{HF}}{\chi_{RPA}^{(1I0)}} &= \left[1 + 2B_I^F \frac{m^* k_F^3}{3\pi^2}\right]^2 - \tilde{\tilde{W}}_1{}^{(1I0)} \chi_0 \\
&+ W_2{}^{(1I)} \left\{ \frac{q^2}{2}\chi_0 \left[1 + 4B_I^F \frac{m^* k_F^3}{3\pi^2}\right] - 2k_F^2 \chi_2 + 4B_I^F \frac{m^* k_F^5}{3\pi^2}(\chi_0 - \chi_2) \right\} \\
&+ [W_2{}^{(1,I)}]^2 k_F^4 \left[\chi_2^2 - \chi_0\chi_4 + \left(\frac{m^*\omega}{k_F^2}\right)^2 \chi_0^2 - \frac{m^*}{6\pi^2 k_F} q^2 \chi_0 \right] \\
&+ 2\chi_0 \left(\frac{m^*\omega}{q}\right)^2 \frac{W_2^{(1,I)}[1 + \frac{m^* k_F^3}{3\pi^2} X^{(1I0)}]}{1 - \frac{m^* k_F^3}{3\pi^2}\left[W_2^{(1,I)} - X^{(1I0)}\right]}
\end{aligned}$$

Linear response for T22 [Lesinski et al.]

For $k = k_F$ at ρ_0 we compare different response functions in different channels S,I,M



Sum Rules

To calculate the results we check the odd-power sum rules

$$M_p^{(\alpha)}(\mathbf{q})/N = -\frac{1}{\pi\rho}\int_0^{+\infty} d\omega\omega^p Im\chi^\alpha(\omega,\mathbf{q})$$

$$\chi^{(\alpha)}(\omega,\mathbf{q}) \approx 2\rho\sum_{p=0}^{+\infty}(\omega)^{-(2p+2)}M_{2p+1}(\mathbf{q})/N$$

$$\chi^{(\alpha)}(\omega,\mathbf{q}) \approx -2\rho\sum_{p=0}^{+\infty}(\omega)^{2p}M_{-(2p+1)}(\mathbf{q})/N$$

$$M_1 = \frac{1}{2}\langle 0|\left[F,\left[H,F\right]\right]|0\rangle$$

$$M_3 = \frac{1}{2}\langle 0|\left[F,H\right],\left[H,\left[H,F\right]\right]|0\rangle$$

Sum Rules: M_1

The analytical expression of M_1 reads

$$M_1/N = \frac{q^2}{2m^*}\left(1 - W_2^{(SI)}\frac{m^*\rho}{2}\right)$$

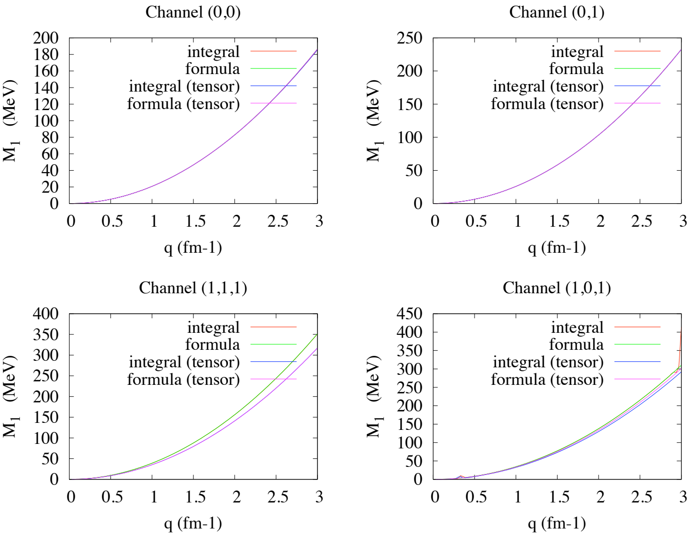
Where

$$\frac{1}{4}W_2^{00} = C_0^{\tau} \quad \frac{1}{4}W_2^{01} = C_1^{\tau}$$
$$\frac{1}{4}W_2^{10} = C_0^{T} \quad \frac{1}{4}W_2^{11} = C_1^{T}$$

The tensor affects the coupling costant

$$C_I^T = A_I^T + B_I^T$$

Sum Rules: M_1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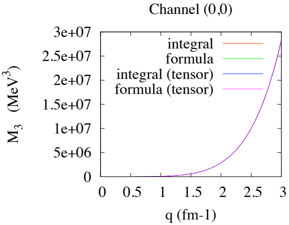
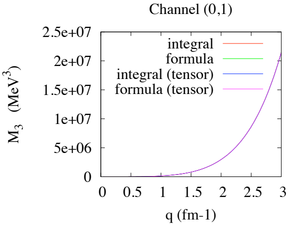
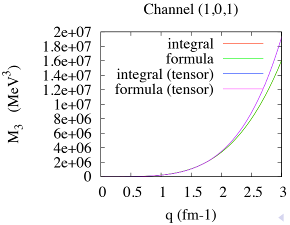
Channel (0,1)
Channel (1,1,1)
Channel (1,0,1)
integral
formula
integral (tensor)
formula (tensor)
M1 (MeV)
q (fm-1)
0
0.5
1
1.5
2
2.5
3
0
20
40
60
80
100
120
140
160
180
200
50
150
250
300
350
400
450

Sum Rulse: M_3

The sume rules M_3 involve a more complicated combination of coupling constants. It mainly depends on $W_2^{(ST)}$ and B_I^F

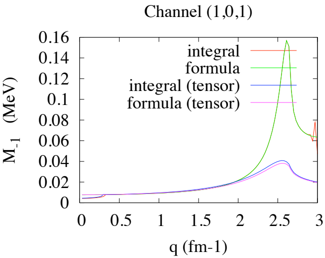


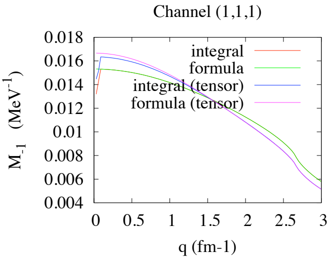




Sum Rule: M_{-1}

Used to test the low energy part of the response.





It is a combination of $W_2^{(ST)}$ and B_I^F parameters.

Sum Rules: applications

The sum rules are not simply a numerical test for the accuracy of the calculation. We can define

$$E_3 = \sqrt{M_3/M_1} \quad E_1 = \sqrt{M_1/M_{-1}}$$

A general theorem shows

$$E_1 \leq E_{av} = M_1/M_0 \leq E_3$$

Possibility to understand the position of the giant resonances?

[E. Lipparini and S. Stringari, Phys. Rep. 175, 103-261, (1989)]

Outline

Summary and Perspective

Status of the work...

- Derivation of the response function for Symmetric Nuclear Matter for a given Skyrme functional
- Derivation of the response function for Pure Neutron Matter for a given Skyrme functional
- Derivation of the Sum Rules M_1, M_3, M_{-1}

... and future development

- Derive the response function for asymmetric nuclear matter
- Inclusion of the temperature
- To use the code in the fitting method for new functionals
- Extensive comparison among finite nuclei and infinite matter.

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.... thank you!!!