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CONTINUUM FLUID DYNAMICS AND RPA FOR GIANT RESONANCES

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Résumé - On inclut le continu à une dynamique de fluide nucléaire irrotationnel. Des forces de transition des résonances géantes isovectorielles sont calculées dans ce modèle et comparées aux résultats de la R.P.A.

Abstract - Irrotational nuclear fluid dynamics is extended to include the continuum. Isovector giant resonance strengths are calculated in this model and are compared with RPA results.

Under the restriction of irrotational flow the macroscopic fluid-dynamical (FD) theory of giant resonances based on the generalized scaling approach can be used to calculate excitations in the continuum. It is essential to employ a selfconsistent description of the ground-state ensuring the correct asymptotic properties of the single particle wave functions for large radii \( r \). The irrotational (IFD) fluid-dynamical equation of motion then shows an excitation spectrum with the correct onset of the continuum at the particle emission threshold \( \hbar \omega = \hbar \omega_p \) (Fermi energy), just as in the selfconsistent RPA. For the comparison of RPA and IFD results the same simple density-dependent force has been used, corresponding to the energy functional

\[
E[\tau, p_\pm] = \int d^3r \left\{ \tau \left( \frac{1}{2} + \frac{1}{6} \frac{1}{t_0 + \frac{1}{6} t_3 \rho^{\alpha}} \right) \rho^2 - \frac{1}{4} \left( t_0 (\frac{1}{2} + x_0) + \frac{1}{6} t_3 (\frac{1}{2} + x_3) \rho^{\alpha} \right) \rho^2 \right. \\
+ a_+ (\nabla \rho)^2 + a_- (\nabla \rho)^2 \right\}
\]

containing six parameters \( t_0, t_3, x_0, x_3, \alpha, a_+ (a_-=0) \). This is simple enough for performing RPA calculations within reasonable computer time; although the Coulomb, spin-orbit and effective mass contributions to \( E[\tau, p_\pm] \) have been neglected reasonable groundstate distributions can be obtained.

The HF-IFD formalism represents a certain "average" description of the RPA. This is most clearly seen if the IFD equation of motion is formulated in terms of the Hartree-Fock single particle wave func-

\( ) \)A detailed and extensive presentation of the subject including more references will appear in Nucl. Phys. A642 (1984) (ref.1)
tions $\psi_j$ and energies $\varepsilon_j$ ($H_0 \psi_j = \varepsilon_j \psi_j$). We find

$$\sum_i \psi_i^* \left[ (\hbar \omega)^2 - (H_0 - \varepsilon_i)^2 \right] \hat{D} \psi_i - (H_0 - \varepsilon_i) \left( \frac{\delta U}{\delta \rho} \delta \rho_{FD} \right) \psi_i = 0$$

(2)

$$\hat{D} \psi_i = -\frac{\alpha_2}{R^2} (H_0 - \varepsilon_i) \psi_i \phi = \frac{1}{2} \left( \nabla \cdot \nabla \phi + \nabla \phi \cdot \nabla \right) \psi_i$$

(3)

$$\delta \rho_{FD} = \nabla \cdot \rho \cdot \nabla \phi = 2 \sum_i \psi_i^* \hat{D} \psi_i$$

(4)

$\frac{\delta U}{\delta \rho}$ being the residual interaction, $\hat{D}$ the generalized scaling operator and $\delta \rho_{FD}$ the fluid-dynamical transition density. The RPA equations may be formulated in terms of the first order change $\delta \psi_i$ of the real part of the TDHF single-particle wave functions$^2$)

$$\left[ (\hbar \omega)^2 - (H_0 - \varepsilon_i)^2 \right] \delta \psi_i - (H_0 - \varepsilon_i) \left( \frac{\delta U}{\delta \rho} \delta \rho_{RPA} \right) \psi_i = 0$$

(5)

$$\delta \rho_{RPA} = 2 \sum_i \psi_i^* \delta \psi_i$$

(6)

By comparing (2) with (5) and (4) with (6) it is seen that in IFD $\delta \psi_i$ is replaced by $\hat{D} \psi_i$ , and the summation $\sum_i \psi_i^* \psi_i$ yields one sixth order differential equation for the displacement potential out of the complicated set of coupled equations (5). A careful analysis of the asymptotic IFD equation of motion (2) shows that this model takes properly into account centrifugal barriers for the "escaping" particle, as well as energy conservation which allows only occupied states $j$ with $\varepsilon_j + \hbar \omega > 0$ to participate in the escaping mechanism. Furthermore the energy- and cubic energy-weighted sum rules $m_1$ and $m_3$ are identical in the RPA and HF-IFD models.

Strength functions, velocity fields and transition densities obtained from RPA and IFD are systematically compared. It is demonstrated that the simple irrotational fluid-dynamical model yields satisfactory results in cases where the single-particle structure plays no important role and the fragmentation of the strength is not significant. As an example we show in figs. 1 and 2 the isovector monopole and quadrupole strength distributions (excitation operators $\sum_i \gamma_i^1 \gamma_i \tau_j^{(1)}$ and $\sum_i \gamma_i^3 \gamma_i \tau_j^{(3)}$, respectively) in two systems with mass numbers $A=212$ and $A=80$.

The simple IFD is certainly very limited, because, by construction, this model rules out excitations with transverse flow. In this connection we have studied the significance of transverse components of the scaling field within the framework of the "rotational" fluid-dynamical model (RFD) which has been used previously for the description of bound states$^3$). For this purpose we have calculated static polarizabilities (inverse energy-weighted sum rule $m_{-1}$) resulting
from the HF-IFD, HF-RFD and RPA descriptions. It has been shown from this study that the HF-RFD model finds the same "correct" irrotational isoscalar quadrupole state as the IFD in model systems having no col-
lective low-lying quadrupole states. In systems where such states are present, the RFD model tries to simulate the strongly enhanced quadrupole polarizability by making the best use of the transverse component. This is, however, far from being sufficient, demonstrating the limitation of the generalized scaling approach. In contrast to this the transverse component has been found to play a really significant role in the isovector dipole polarizability: It now serves to bring $m_{-1}(RFD)$ in excellent agreement with $m_{-1}(RPA)$ for all examined model systems with mass numbers ranging from 16 to $\infty$.

References
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