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► **To cite this version:**

C. Fiolhais, L. De Brito. FRAGMENTATION OF HIGH MULTIPOLAR VIBRATIONAL STRENGTH IN A SEMICLASSICAL APPROACH. *Journal de Physique Colloques*, 1987, 48 (C2), pp.C2-51-C2-54. <10.1051/jphyscol:1987207>. <jpa-00226472>

HAL Id: jpa-00226472

<https://hal.archives-ouvertes.fr/jpa-00226472>

Submitted on 1 Jan 1987

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FRAGMENTATION OF HIGH MULTIPOLAR VIBRATIONAL STRENGTH IN A SEMICLASSICAL APPROACH

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Résumé - Une nouvelle approche variationnelle de l'équation de Vlasov peut décrire la fragmentation d'intensité correspondante aux résonances nucléaires géantes ($\ell = 2 - 4$), comme un résultat de l'existence de flux rotationnel. Cette fragmentation doit se comprendre comme la manifestation, dans un système fini, du phénomène de l'amortissement de Landau, qui est bien connu, par exemple, pour le gaz d'électrons. Dans ce travail, nous étendons des études antérieures pour analyser la fragmentation des hautes multipolarités ($\ell = 5 - 7$). On observe une augmentation progressive de la fragmentation, de telle façon que l'on peut dire qu'il n'y a plus de modes collectifs bien définis pour $\ell \geq 6$. Cette conclusion est en accord avec des calculs RPA, mais la perte de cohérence des modes de haute multipolarité n'est pas si développée dans le cadre de l'approximation semiclassique que dans le cas quantique.

Abstract- A recent variational approach to the Vlasov equation has shown its ability to describe some splitting of the strength corresponding to nuclear giant resonances ($\ell = 2 - 4$), as a consequence of the allowance for rotation flow. This fragmentation of strength should be understood as a manifestation in a finite system of the phenomenon of Landau damping, which is well-known, for instance, in the electron gas. In this work we extend previous studies, in order to discuss the fragmentation of strength with higher multipolarity ($\ell = 5 - 7$). We observe a progressive increase of the fragmentation, so that there are no well-defined collective modes for $\ell \geq 6$. This conclusion is in agreement with RPA studies, although the loss of coherence for high multipolar modes is not so pronounced in the semiclassical approach as in the quantal case.

One of the present authors (in collaboration with C. da Providência) has developed a variational method to obtain approximate solutions of the Vlasov equation [1,2] :

$$\frac{\partial f}{\partial t} + \{h, f\} = 0, \tag{1}$$

with $f = f(\vec{r}, \vec{p}, t)$ a distribution function and $h = h[f]$ a self-consistent single-particle hamiltonian. We choose the following Skyrme-like hamiltonian :

$$H = \sum_k \frac{p_k^2}{2m} + \frac{1}{2} a \sum_{kl} \delta(\vec{r}_k - \vec{r}_l) + \frac{1}{6} b \sum_{jkl} \delta(\vec{r}_j - \vec{r}_k) \delta(\vec{r}_l - \vec{r}_k). \tag{2}$$

The force parameters a and b are adjusted in order to reproduce static nuclear properties ($k_F = 1.26 \text{ fm}^{-1}$ and $\frac{E}{A} = -13.8 \text{ MeV}$ yield $a = -799.13 \text{ MeV fm}^3$, $b = 6711.23 \text{ MeV fm}^6$). Since this force is zero-range, it is convenient to include the following phenomenological surface energy:

$$E_s = \sigma \oint ds, \tag{3}$$

where $\sigma = 1.017 \text{ MeV fm}^{-2}$ is the surface tension coefficient.

The method of solving eq. (1) relies on a variational principle, i.e. an appropriate lagrangian $L[f]$ is chosen so that (1) arises when general variations are performed [3]. We are interested in the case of small oscillations around equilibrium, so that a truncation of L is made in order to obtain the linearized version of eq.(1). A family of distribution functions is obtained from the equilibrium one, f_0 , by means of a canonical transformation. This transformation is parametrized by two pairs of a scalar and a tensorial field. The first pair, $w(\vec{r}, t)$ and $\chi_{\alpha\beta}(\vec{r}, t)$, with $\alpha, \beta = 1, 2, 3$, describes static local distortions of the Fermi sphere. The second one, $\phi(\vec{r}, t)$ and $\phi_{\alpha\beta}(\vec{r}, t)$, with $\alpha, \beta = 1, 2, 3$, allows for dynamic deformations of the Fermi sphere as a whole, including the possibility of rotational flow.

The trial distribution function may be written as

$$f = f_0 + \{f_0, Q + P\} + \frac{1}{2} \{\{f_0, Q + P\}, Q + P\} + \dots, \quad (4)$$

where P is such that

$$f_0 + \{f_0, P\} + \frac{1}{2} \{\{f_0, P\}, P\} + \dots = \theta(\lambda - h_0(\vec{r}, \vec{p}) - w(\vec{r}, t) - \sum_{\alpha\beta} \frac{p_\alpha p_\beta}{2m} \chi_{\alpha\beta}(\vec{r}, t)), \quad (5)$$

with $h_0 = h[f_0]$ and $Q = \phi(\vec{r}, t) + \frac{1}{2} \sum_{\alpha\beta} p_\alpha p_\beta \phi_{\alpha\beta}(\vec{r}, t)$.

The variation of the lagrangian leads to the equations of motion and the corresponding boundary conditions. We refer to [1,2,4] for further details. In those references energies and fractions of the EWSR corresponding to excitation operators $r^\ell Y_{\ell 0}$ have been presented for modes with $\ell = 2, 3$ and 4 in the case of ^{208}Pb .

We have now extended the calculations to the higher multiplicities $\ell = 5, 6$ and 7 to confirm whether the model is able to describe the increase of strength fragmentation with the multipolarity, as suggested by the previous results. In particular, we wish to find out the upper multipolarity, within the semiclassical approach, for which the concept of giant resonances is still meaningful.

The fragmentation of strength at a 1p-1h level (RPA or linearized Vlasov description) is a manifestation in a bound system of the process known as Landau damping in infinite systems, as helium-3 or the electron gas [5,6]. Landau damping consists in the decay of a phonon into its p-h components. In both helium-3 and the electron gas at zero temperature there is a very effective Landau damping of respectively the zero-sound phonon and the plasmon with high wavevectors, due to their position over the band of single-particle excitations. The description of the damping by a time-reversible equation is usually explained invoking the role of particular initial conditions. Nevertheless, some authors prefer to reserve the word "damping" for decay processes due to collisions.

The results are shown in Fig. 1. We remark that it is essential, in order to obtain any fragmentation at all, the inclusion of the field $\phi_{\alpha\beta}(\vec{r}, t)$, which allows for the existence of transverse flow. If the generator Q is restricted to $\phi(\vec{r}, t)$ irrotational flow results, so that all the strength is concentrated in a single high-lying mode. On the other hand, if Q is allowed to depend on all powers of p_α , a continuous distribution of strength would appear.

From the numerical results, the following main conclusions may be drawn:

1) There is a progressive increase of fragmentation of the high-lying strength. It is therefore possible to describe Landau damping of a bound system in a semiclassical framework. Landau damping is irrelevant for the lowest multiplicities.

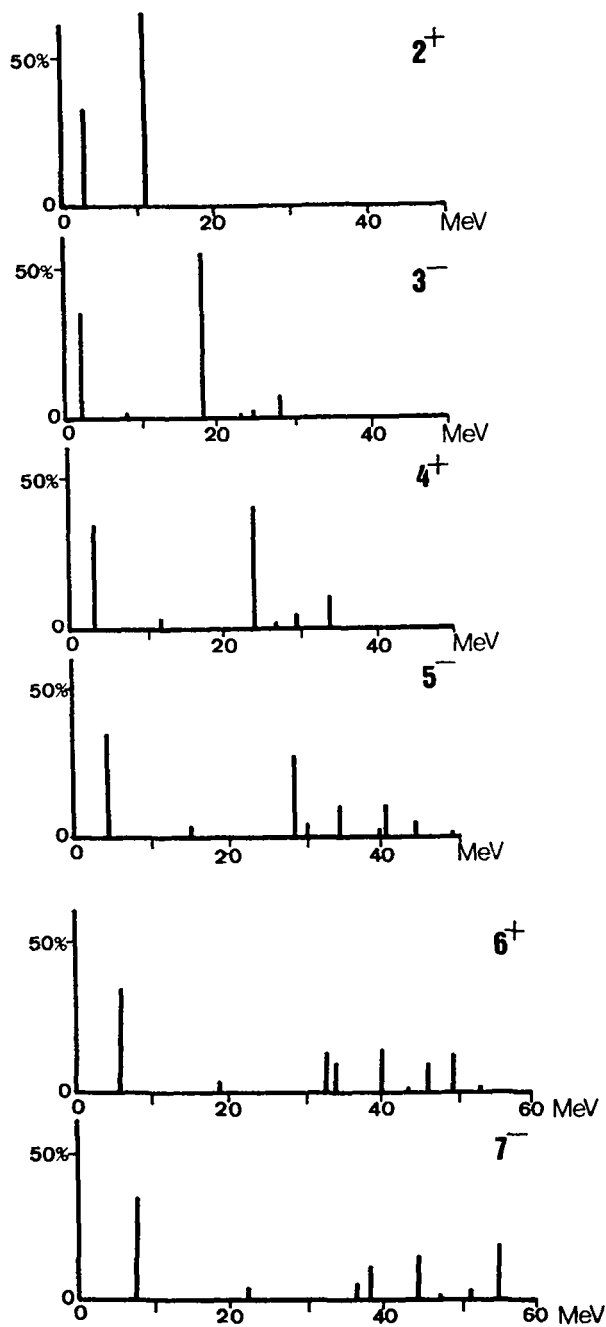


Fig. 1 - The fraction of the EWSR as a function of the energy, corresponding to the isoscalar strength with multipolarities $\ell = 2-7$ in ^{208}Pb .

2) We may say that for $\ell \geq 6$, there is no more a clear-cut concentration of strength in a single peak, so that this is the multipolar limit of giant resonances. This conclusion agrees with findings of Van Giai and Casas and Martorell, based on RPA sum-rules [7,8].

In fact, the fragmentation of strength is amplified, when going from the 1p-1h to the 2p-2h level (in the latter case, "collision damping" is possible), so that the spreading of high-lying strength becomes important before $\ell = 6$. This statement seems to be confirmed by experimental observations [9]. An attempt to include anharmonic terms in the present model and its application to an infinite system has been undertaken by J. da Providência ("Damping of the giant resonances in a fluid-dynamical model", preprint, Coimbra, 1986).

3) From the comparison of our Vlasov results with those arising in the RPA [10] we conclude that the semiclassical fragmentation is less extended than the quantal one. This feature is easy to understand, since semi-classical methods provide a smoothing of shell effects.

4) The low-lying modes are not fragmented at all in the present model, as it occurs in reality, due to their superposition, at high multipolarities, with the first bunch of single-particle energy levels. The gap to the $1\hbar\omega$ excitation is $\approx 7\text{ MeV}$ in ^{208}Pb in the schematic harmonic shell model and is $3.5 - 4\text{ MeV}$ as extracted from the experimental spectrum. The fraction of the sum-rule exhausted in the low-lying region of the spectrum remains approximately the same (around 34%), being the strength concentrated in a single peak, whose energy increases smoothly with ℓ . This energy depends on the surface tension. The lack of any fragmentation of low-lying strength is clearly a deficiency of the model, which is not able to account for fine shell effects.

5) If we redistribute all the high-lying strength in a single peak we find that its position agrees very accurately with the irrotational macroscopic formula proposed by Bertsch [11]. A phenomenological model for one-body damping is given by the modified wall formula of Sierk, Koonin and Nix [12]. Their model provides an increase of the one-body width with the multipolarity, but its magnitude is larger than the range in energy of the fragmentation obtained in the present semi-classical approach.

We are indebted to Prof. J. da Providência for useful discussions. This work has been supported by the Instituto Nacional de Investigação Científica, Lisboa. One of us (C.F.) is grateful to the C. Gulbenkian Foundation for providing a travel grant to Aussois.

REFERENCES

- [1] L. P. Brito and C. da Providência, Phys. Rev. **C32** (1985) 2049
- [2] L. P. Brito, Phys. Lett. **177B** (1986) 251
- [3] J. da Providência and C. Fiolhais, J. Phys. **20A** (1987), in press
- [4] L. P. Brito, Ph.D. Thesis, Coimbra, 1986
- [5] C. Fiolhais, Ann. Phys. **171** (1986), 186
- [6] C. Fiolhais, in "Phase Approach to Nuclear Dynamics", Ed. M. di Toro *et al*, World Scientific, Singapore, 1986, 356
- [7] N. van Giai, Phys. Lett. **105B** (1981) 11
- [8] M. Casas and J. Martorell, Anales de Física (Madrid) **A81** (1985) 150
- [9] B. Bonin *et al*, Nucl. Phys. **A430** (1984) 349
- [10] R. de Haro, S. Krewald and J. Speth, Nucl. Phys. **A388** (1982) 265
- [11] G. Bertsch, Ann. Phys. **86** (1974) 138; Nucl. Phys. **A249** (1975) 253
- [12] A. Sierk, S. Koonin and J. Nix, Phys. Rev. **C17** (1978) 846.