DISSIPATIVE PROPERTIES OF ISOSCALAR COLLECTIVE EXCITATIONS IN HEAVY NUCLEI

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The dissipative properties of isoscalar collective motion in heavy nuclei are studied within a kinetic model of collective excitations in finite Fermi systems with a free moving surface. The model includes both the one-body damping produced by the interaction of nucleons with the dynamic surface of nucleus and the Landau damping mechanism. In this paper, we study the damping and dissipative properties of the isoscalar dipole collective modes and the isoscalar vortex octupole mode, which are formed due to dynamic effects of the nuclear surface [1, 2].

In order to study the damping of the isoscalar collective modes under consideration, we use the multipole strength function in different approximations. The isoscalar octrupole strength function is shown in Figs. 1(a) and 1(b). It can be seen that the resonance structure around the energy of 12.5 MeV (the vortex octupole mode) is formed in the moving-surface model (the solid curves), thus its width is due to the one-body damping mechanism. When the residual interaction is taking into account (the parameter κ_L determines the strength of the isoscalar residual interaction of multipolarity L), the resonance centroid shifts slightly, while the resonance width is decreased, compare the solid and dashed curves in Fig. 1(b). The isoscalar dipole strength function (see Figs. 1(c) and 1(d)) shows similar properties for the isoscalar dipole resonances in the energy region 10-30 MeV.

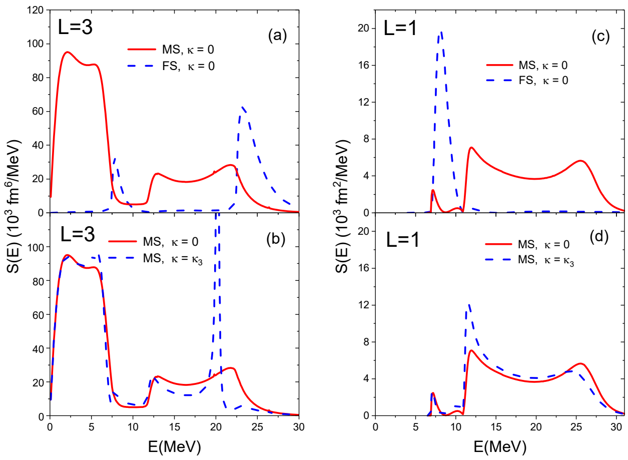

Fig.1. Isoscalar octrupole (L=3) and dipole (L=1) strength functions in different approximations. In Figs. 1(a) and 1(c), the strength functions are shown in moving- (solid curves) and fixed-surface models (dashed curves), the strength parameter $\kappa = 0$. In Figs. 1(b) and 1(d), the moving-surface strength function is given for the strength parameters: $\kappa = 0$ (solid curves), and $\kappa = \kappa_L$ (dashed curves). The parameters κ_L are chosen as $\kappa_3 = -2 \cdot 10^{-5}$ MeV/fm^6 in Fig. 1(b), and $\kappa_1 = -7.5 \cdot 10^{-3}$ MeV/fm^2 in Fig. 1(d). The system contains A=208 nucleons.

To consider the dissipative properties of the isoscalar collective modes under consideration, we evaluate the dissipation coefficient for collective variable $\delta R_{L0}(t)$ that describes axially-symmetric multipole surface vibrations of spherical nucleus of radius R in our kinetic model. We assume that isoscalar multipole modes are excited by a weak harmonic external field with the frequency ω, which acts only on the system surface, and find the surface multipole response function. Using this response function, we obtain an expression for the rate of energy dissipation, which is transferred from the external field to our system, and determine the dissipation coefficient at a finite frequency $\gamma_L(\omega)$ as

$$\gamma_L(\omega) = \frac{1}{\omega} Im\, \chi_L(\omega) \,. \qquad (1)$$

Here the function $\chi_L(\omega)$ (see eq. (80) in [3]) determines how a gas of nucleons confined to a spherical cavity responds to harmonic multipole vibrations of the surface with the frequency ω. The one-body dissipation coefficient (1) is shown in Fig. 2 in the energy region of the isoscalar collective modes under consideration (solid curves). The dashed line in Fig. 2 indicates the dissipation coefficient, which is determined by the rate of energy dissipation in a gas of nucleons confined to a spherical cavity with a slowly moving surface (the wall formula friction coefficient). The wall formula friction coefficient for a spherical system of radius R is given by [4] $\gamma_{wf} = \frac{3}{4}\rho_0 p_F R^4$, where ρ_0 is the nuclear equilibrium density, and p_F is the Fermi momentum.

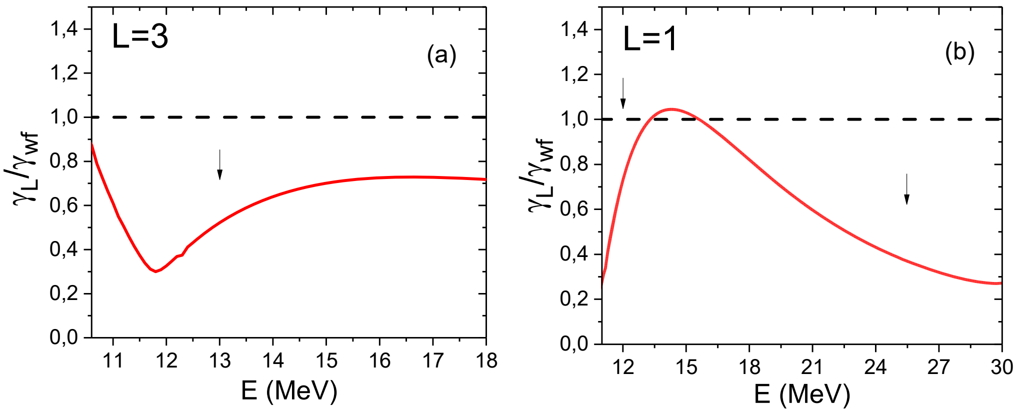

Fig. 2. The octupole and dipole dissipation coefficients $\gamma_L(\omega)$ are shown in units of the wall formula friction coefficient γ_{wf} as a function of the excitation energy $E = \hbar\omega$. Fig. 2(a) shows the octupole dissipation coefficient in the energy region of the isoscalar vortex octupole mode, while Fig. 2(b) is for the dipole dissipation coefficient in the energy region of isoscalar dipole collective modes. The theoretical centroid energies of the isoscalar vortex octupole mode and the low- and high-energy isoscalar dipole collective modes (see Fig. 1) are indicated by arrows.

It can be seen from Fig. 2 that both the octupole dissipation coefficient in the energy region of the vortex octupole resonance with a centroid energy of 13 MeV (see Fig. 2(a)) and the dipole dissipation coefficient in the energy region of low- and high-energy dipole resonances with centroid energies of 12 MeV and 25.5 MeV, respectively, (see Fig. 2(b)) are less than the wall formula friction coefficient.

This paper shows that the main contribution to the collisionless width of the vortex octupole mode and isoscalar dipole modes in heavy nuclei is due to the one-body damping mechanism. It is found that in a self-consistent model, the coupling between the one-body damping mechanism and the Landau damping mechanism leads to a decrease in the width of isoscalar collective excitations under consideration. The one-body dissipation coefficient at a finite frequency is evaluated and it is shown that its value for both the isoscalar vortex octupole mode and the isoscalar dipole modes, which are formed due to dynamic effects of the nuclear surface, does not exceed the wall formula friction coefficient. This result confirms our understanding of the wall formula friction coefficient as a macroscopic limit of the one-body nuclear dissipation.

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