DISSIPATION MECHANISM IN NUCLEAR COLLECTIVE MOTION

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The dissipation mechanism in the nuclear collective motion is studied in the frame of the extendent mean-field theory (EMFT)[1]. In the EMFT the residual interactions (two-body collisions) act as an agent to randomize the single-particle momentum distributions and consequently the system evolves towards the thermal equilibrium. However, with its fully microscopic description of the EMFT, it is difficult to understand the dissipation and fluctuation mechanism of the collective motion. It seems that, in spite of loosing the detailed microscopic description, the collective motion should be explicitly treated. In this case one finds that in addition to the mean field a fluctuating force is acting on the collective motion. The fluctuating force (mean-field fluctuations) is a consequence of the random two-body collisions, however it is not apparent in the microscopic equation of motion of the EMFT. In the present work, within the semi-classical approximation the collective variables are identified with the help of the cranking single-particle representation and the rate of change of the collective kinetic energy $p^2/2M(q)$ is calculated using the extendent mean-field equations[1]. As a result we find that the rate of energy dissipation is described by

$$\frac{d}{dt}\,[p^2/2M(q)] = -\,\dot{q}\,\sum_{\alpha}\frac{\partial}{\partial q}\,\varepsilon_{\alpha}(q)\;\rho_{\alpha}(t) - \dot{Q}(t) \tag{1}$$

with

$$\dot{Q}(t) = \dot{q}^2 \sum_{\alpha\beta} \left|\langle\alpha(q)\right|\,\frac{\partial v}{\partial q}\,(q)\left|\beta(q)\rangle\right|^2 \frac{\partial}{\partial w_{\alpha\beta}}\;\left(\frac{2\,\Gamma_{\alpha\beta}}{w_{\alpha\beta}^2 + \Gamma_{\alpha\beta}^2}\right)\,\rho_{\alpha}(t) \tag{2}$$

where $w_{\alpha\beta}(q) = \varepsilon_{\alpha}(q) - \varepsilon_{\beta}(q)$ and $\Gamma_{\alpha\beta} = \Gamma_{\alpha} + \Gamma_{\beta}$ are the energy difference and the sum of the widths of the quasi-static single-particle states which are determined by $\mathcal{H}(q)\,|\alpha(q)\rangle = \varepsilon_{\alpha}(q)\,|\alpha(q)\rangle$ with $\mathcal{H}(q) = -\nabla^2/2m + v(\vec{r},q)$. The dissipation rate is coupled to the two-body collisions via the width Γ_{α} of the single-particle states and via the occupation probabilities $\rho_{\alpha}(t)$ which are determined by a master equation. According to (1) the damping of the collective kinetic energy is simultaneously governed by two different mechanisms; (i) the dissipation of the dynamical potential energy by redistributions of the occupation probabilities via two-body collisions[2] and (ii) the $\dot{Q}$ dissipation due to the random collisions of the particles with the mean field. The latter process is closely related to the one-body dissipation mechanism[3] and it comes about here as a direct consequence of the mean-field fluctuations. In contrast to $\dot{Q}$, the potential dissipation in the low energy nuclear reactions has a strong memory effect as a result of the large value of the local equilibration times and it appears as a non-local friction force acting on the collective motion[2].

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2) W. Nörenberg and C. Riedel, Z. Phys. A290 (1979) 385
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3) S.E. Koonin, R.L. Hatch and J. Randrup, Nucl. Phys. A283 (1977) 87