On the Nature of Nuclear Dissipation, as a Hallmark for Collective Dynamics at Finite Excitation ◇

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We study slow collective motion of isoscalar type at finite excitation. The collective variable is parameterized as a shape degree of freedom and the mean field is approximated by a deformed shell model potential. We concentrate on situations of slow motion, as guaranteed, for instance, by the presence of a strong friction force, which allows us to apply linear response theory. The prediction for nuclear dissipation of some models of internal motion are contrasted. They encompass such opposing cases as that of pure independent particle motion and the one of "collisional dominance". For the former the wall formula appears as the macroscopic limit, which is here simulated through Strutinsky smoothing procedures. It is argued that this limit hardly applies to the actual nuclear situation. The reason is found in large collisional damping present for nucleonic dynamics at finite temperature T. The level structure of the mean field as well as the T-dependence of collisional damping determine the T-dependence of friction. Two contributions are isolated, one coming from real transitions, the other being associated to what for infinite matter is called the "heat pole". The importance of the latter depends strongly on the level spectrum of internal motion, and thus is very different for "adiabatic" and "diabatic" situations, both belonging to different degrees of "ergodicity".

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A Quantal Transport Theory for Nuclear Collective Motion: The Merits of a Locally Harmonic Approximation

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A transport theory is developed for collective motion of systems such as an atomic nucleus, which may be considered as a typical representative of a self-bound microsystem. Albeit for pragmatic reasons, collective variables are introduced as shape parameters, self-consistency with respect to the nucleonic degrees of freedom has been implemented at various important stages. This feature leads to subsidiary conditions which are obeyed locally for both the average motion as well as for the quantized Hamiltonian constructed through a Bohm-Pines procedure. Furthermore, self-consistency governs the definition of the transport coefficients appearing in the equations for collective motion. The latter is associated to the time evolution of the density in collective phase space, for which the concept of the Wigner function is employed. Global motion is described by propagating the system in successive time laps which are macroscopically small, but microscopically large. This enables one to exploit linearization procedures and to take advantage of the benefits of linear response theory. A microscopic damping mechanism is introduced by dressing the energies of the independent particle model by complex self-energies, the parameters of which are determined from optical model considerations. Numerical evaluations of transport coefficients are described and tested for the case of fission in the light of recent experimental findings. The theory allows one to extend both Kramers' picture of this process as well as his equation for the density distribution into the quantum regime. These quantum effects are seen to show up at smaller excitations, say below $T \approx 1 - 1.5\ MeV$ in case that the concept of temperature may be used. This extension is possible down to a critical temperature T_c below which for unstable modes as encountered for motion in barrier regions, diffusion coefficients can no longer be defined. For large damping the T_c is only slightly greater than the so called "cross over temperature" known from conventional treatments of dissipative tunneling, but the T_c is small on the nuclear scale. Last but not least, relations are established to other approaches, such as "Dissipative Diabatic Dynamics", or ones based on Random Matrix Models as well as those employing wall friction and two body viscosity.

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