Stability and instability of a hot and dilute nuclear droplet: adiabatic isoscalar modes

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The diabatic approach to dissipative large-amplitude collective motion [1] is reformulated in a local energy-density approximation. We consider a general displacement field, which is defined by an expansion of the displacement potential in terms of multipoles, and include Coulomb interactions. This expansion allows the analytical evaluation of collective mass and stiffness tensors within a consistent harmonic approximation. The set of eigenvalue equations couple modes with different number of nodes in the radial function of the displacement field. The orthogonal eigenmodes of the droplet are determined as function of the relaxation time τ for the decay of deformations of the local Fermi sphere, *i.e.* continuously from the adiabatic to the diabatic limit. Furthermore we consider also pure surface modes and compare the instability properties for soft and stiff equations of state.

In a first application the adiabatic ($\tau = 0$) isoscalar modes are studied and results for the eigenvalues of compressional (bulk) and pure surface modes are presented as function of density and temperature inside the droplet, as well as for different mass numbers and for soft and stiff equations of state [2]. We have studied these adiabatic isoscalar modes in detail, because they are related to thermodynamics and to many studies performed in the past.

The results on adiabatic isoscalar bulk instabilities are summarized as follows.

– As compared to infinite nuclear matter the spinodal region for compressional (bulk) instabilities shrinks to smaller densities and temperatures with $T_{\rm crit} = 6$ MeV (8 MeV) for a soft (stiff) EOS. The observed fragmentation temperatures of about 5 MeV are consistent with spinodal decomposition after expansion. Typical values for the growth rates are $\gamma \approx 5$ MeV (10 MeV for a stiff EOS) corresponding to growth times $\hbar/\gamma \approx 40$ fm/c (20 fm/c).

– Effects from Coulomb interactions on the bulk instabilities are negligible.

– With decreasing density and temperature the modes with the lowest multipolarities and no radial node become unstable first.

– At densities below $0.3\varrho_0$ (with $\varrho_0 = 0.16$ fm^{-3}) the instability growth rates for different multipolarities ($l = 2, 3, 4, 5$) and number of nodes ($n = 0, 1, 2, 3$) are practically equal. This property can yield a power-law behavior $A^{-\sigma}$ with $\sigma \approx 2.0$ of the fragment-mass distribution in agreement with experimental observations and is not related to the critical point.

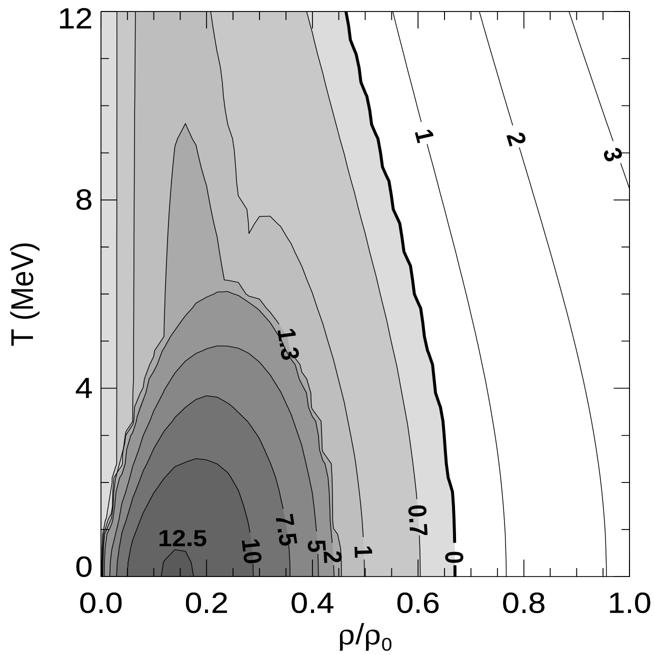

Figure 1: Combined bulk (below $T_{crit} = 6$ MeV) and surface instabilities for a gold-like droplet and a soft EOS. Shown are the largest growth rates (shaded areas) and the lowest vibrational energies (surface modes).

For finite nuclear droplets surface modes are important in addition to the compressional modes. Indeed, pure surface modes show some interesting features.

– The instability region of pure surface modes extends to larger densities up to about the spinodal line of infinite nuclear matter and to large temperatures.

– In general the growth times are smaller by half an order of magnitude as compared to the typical values for bulk instabilities.

– In the stable region surface modes are slow, such that deformations initiated in the excitation process will persist during expansion and clustering.

– The surface instability is dominated by quadrupole deformation.

References

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