3E04 Quadrupole oscillations and Coulomb- stability of highly charged liquid droplets

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The break-up of charged microdroplets is an important process for the charge separation in electrified clouds as well as in various technical applications like electrospray ionization, fuel injection or ink jet printing. The stability of charged droplets has been studied theoretically as early as 1882 by Lord Rayleigh [1]. He concluded that in an incompressible charged liquid droplet the quadrupole oscillation becomes unstable as soon as the disruptive Coulomb force is equal to the attractive cohesive force or, in terms of energies, when the Coulomb energy E_C corresponds to twice the surface energy E_S.

Metal clusters can be viewed as quantum liquid drops [4]. The onset of instabilities of charged metal clusters has been studied by many groups both experimentally[5-11] and theoretically [6, 12-14] and the Rayleigh model has proven to be powerful. Most often the fission of charged metal clusters has been observed and studied for X<1 as a thermally activated process. Recently an experimental method has allowed to systematically approach the Rayleigh limit up to the value of 0.85 and confirmed its validity [11]. Several modern experiments addressed Rayleigh's original subject, the stability of liquid macroscopic droplets. In all cases, a droplet break-up below the Rayleigh limit was found [15-19]. As thermally activated fission is not effective for macroscopic droplets, it remained up to now unclear whether in macroscopic droplets an alternative pathway to fission exists, which is more effective then the instability of the quadrupole oscillation.

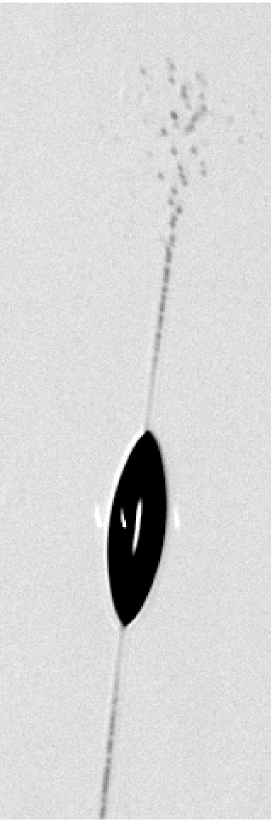

Fig. 1: Microphotograph of the two jets emitted from a microdroplet charged to the Rayleigh limit

We report here direct experimental observations of the breakup of charged evaporating microdroplets held in an electrodynamic levitator. The amplitude and phase of forced quadrupole shape oscillations of the droplets are taken as probe for their fissility. We observe that fission occurs coincident with the divergence of the quadrupole oscillation amplitude and can therefore confirm for the first time directly the limit of coulomb stability at X = 1 for charged microdroplets. When a droplet reaches the stability limit we observe a strong ellipsoidal deformation of the whole droplet, just as predicted by Rayleighs analysis. When the aspect ratio of the ellipsoid reaches about 3.5, sharp tips form at the poles of the ellipsoid from which subsequently fine liquid jets are emitted which carry a large fraction of the droplet charge but only a tiny fraction of the droplet mass (c.f. Fig. 1). These jets which occur just at the limit of stability were predicted by Lord Rayleigh for much higher charge states. In our contribution we will quantify the fission behaviour as a function of the size and viscosity of the parent droplet.

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