Dipolar Quantum Droplets

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Attractively interacting Bose-Einstein condensates (BECs) are known to be unstable and collapse [1]. It was proposed that in certain conditions where two types of interactions compete, beyond mean-field effects originating from quantum fluctuations can actually prevent the collapse [2]. This results in a dilute self-bound liquid state living at the equilibrium between mean-field attraction and beyond mean-field repulsion.

In a strongly dipolar BEC of dysprosium atoms where both the contact and dipole-dipole interaction are at play and sizeable, these conditions are fulfilled. Owing to the long-range and anisotropic character of the dipole-dipole interaction, a strongly dipolar BEC in a harmonic trap with tunable interactions is described by a rich phase diagram with either a finite-wavelength instability reminiscent of the Rosensweig instability of ferrofluids, or a crossover to a single quantum droplet. The self-bound liquid state can be obtained in the absence of any trap, but only above a critical atom number, below which the natural quantum-mechanical dispersion prevents self-binding.

We will present our recent experiments on Dy BECs. First we have observed the Rosensweig instability in a flat BEC, thus creating droplet ensembles [3], with which we have confirmed the nature of the stabilization mechanism [4,5]. Then we have measured the critical point beyond which a crossover is observed, which has allowed us to create single self-bound dipolar quantum droplets. We observed the self-bound character over several tens of milliseconds, and we finally measured the lower critical atom number and its variation with the interaction strength [6].