Quantum droplets in attractive Bose-Bose mixtures

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Dilute quantum droplets are liquid-like clusters of ultra-cold atoms self-trapped by attractive mean-field forces, and stabilized against collapse by repulsive beyond mean-field many-body effects. Originally predicted for mixtures of Bose-Einstein condensates with attractive interactions [1], these systems have been recently realized in dipolar quantum gases [2–5]. We exploit a mixture of two $^{39}$K Bose-Einstein condensates with attractive inter-state and repulsive intra-state interactions to experimentally explore the physics of quantum droplets in two different geometries.

For a gas confined only along the vertical direction, we observe droplets self-bound along the radial direction, which evaporate into an expanding gas below a critical atom number due to the quantum pressure of their constituents. We experimentally map out the liquid-to-gas transition as a function of atom number and interaction strength, and compare it to a simple theoretical model.

For a gas confined in a quasi-one dimensional geometry, two types of self-bound states exist: solitons, stabilized by quantum pressure, and droplets, stabilized by quantum fluctuations. Depending on the atom number and interaction strength, they are separated either by an abrupt transition or by a smooth crossover, a situation that we explore experimentally.