Quantum liquid droplets in a mixture of Bose-Einstein condensates

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Self-bound states appear in contexts as diverse as solitary waves in channels, optical solitons in non-linear media and liquid droplets. Their binding results from a balance between attractive forces, which tend to make the system collapse, and repulsive ones, which stabilize it to a finite size. This talk will present our recent experiments on dilute quantum liquid droplets: macroscopic clusters of ultra-cold atoms that are eight orders of magnitude more dilute than liquid Helium, but have similar liquid-like properties. In particular, they remain self-trapped in the absence of external confinement due to the compensation of attractive mean-field forces and an effective repulsion stemming from quantum fluctuations [D. S. Petrov, Phys. Rev. Lett. **115**, 155302 (2015)]..

We observe these self-bound droplets in a mixture of two Bose-Einstein condensates with attractive inter-state and repulsive intra-state interactions. Exploiting *in situ* imaging, we directly measure their ultra-low densities and micro-meter scaled sizes, and demonstrate the many-body origin of their stabilization mechanism. Furthermore, we observe that for small atom numbers quantum pressure is sufficient to dissociate the droplets and drive a liquid-to-gas transition, which we map out as a function of atom number and interaction strength [C. R. Cabrera *et al.*, arXiv:1708.07806]..

In a second series of experiments, we study the difference existing between these liquid droplets and more conventional bright solitons. In analogy to non-linear optics, the former can be seen as one-dimensional matter-wave solitons stabilized by dispersion, whereas the latter correspond to high-dimensional solitons stabilized by a higher order non-linearity due to quantum fluctuations. We find that depending on the system parameters, solitons and droplets can be smoothly connected or remain distinct states coexisting only in a bi-stable region, and we determine experimentally its boundary [P. Cheiney *et al.*, arXiv:1710.11079].