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Quantum droplets in Bose-Einstein condensates

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Quantum fluctuations can stabilize bosonic mixtures and Bose-Einstein condensates (BECs) with dipolar interactions against the collapse predicted by the mean-field theory. This stabilization mechanism allows for two new states of matter to arise: self-bound quantum droplets and dipolar supersolids. When dipolar interactions between the atoms are present, these droplets can self-assemble into arrays and form a supersolid, which presents both a crystalline structure and superfluid properties.

In 3D bosonic systems, the formation of droplets has been studied in non-dipolar binary mixtures within the miscible regime and in single-component dipolar gases with highly magnetic atoms, where the dipolar interactions (long-range and anisotropic) dominate over the contact interactions (short-range and isotropic). We will first focus on non-dipolar binary mixtures to explore the main ground state properties of self-bound droplets and the excitation of the monopole breathing mode.

As opposed to non-dipolar mixtures, dipolar mixtures can form droplets when the two species are immiscible since the droplets remain self-bound due to the dipole-dipole interactions between the two components. Also, a self-bound droplet may bind a second component that would be unstable by itself. In the context of dipolar binary mixtures, the orientation of the dipoles of each component plays a crucial role in the ground state physics of the system. In particular, we will study mixtures with antiparallel dipoles, which present a wider immiscibility region and a different phase separation as observed with parallel dipoles.

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