Ultradilute Quantum Droplets

Xia-Ji Liu

Centre for Quantum Technology Theory, Swinburne University of Technology, Melbourne 3122, Australia

Over the past few years, a newly discovered phase of ultracold, dilute quantum droplets has attracted increasingly attention in different fields of physics. In sharp contrast to other gas-like phases in containers, quantum droplets are self-bound, liquid-like clusters of ten to hundred thousand of atoms in free space, formed by the delicate balance between the attractive mean-field force and repulsive force from quantum fluctuations.

Here, I will give our theoretical progress on quantum droplets in two-component Bose-Bose mixtures. We revisit the Bogoliubov theory of quantum droplets proposed by Petrov [1], where the mean-field collapse is stabilized by the Lee-Huang-Yang quantum fluctuations. We show that a loophole in Petrov's theory, i.e., the ignorance of the softening complex Bogoliubov spectrum, can be naturally removed by the introduction of bosonic pairing [2]. The pairing leads to weaker mean-field attractions, and stronger Lee-Huang-Yang term in the case of unequal intraspecies interactions. As a result, the equilibrium density for the formation of self-bound droplets significantly decreases in the deep droplet regime, in agreement with a recent observation from diffusion Monte Carlo simulations. Our construction of a consistent pairing theory of ultradilute quantum droplet may also be relevant to understand the supersolid in dipolar gases. Further, by considering both attractive two-body interaction and repulsive three-body interaction, we determine a rich phase diagram for three-body interacting droplets and show the existence of a tri-critical point, where the three phase – quantum droplet, superfluid gas, and normal gas – meet together [3].

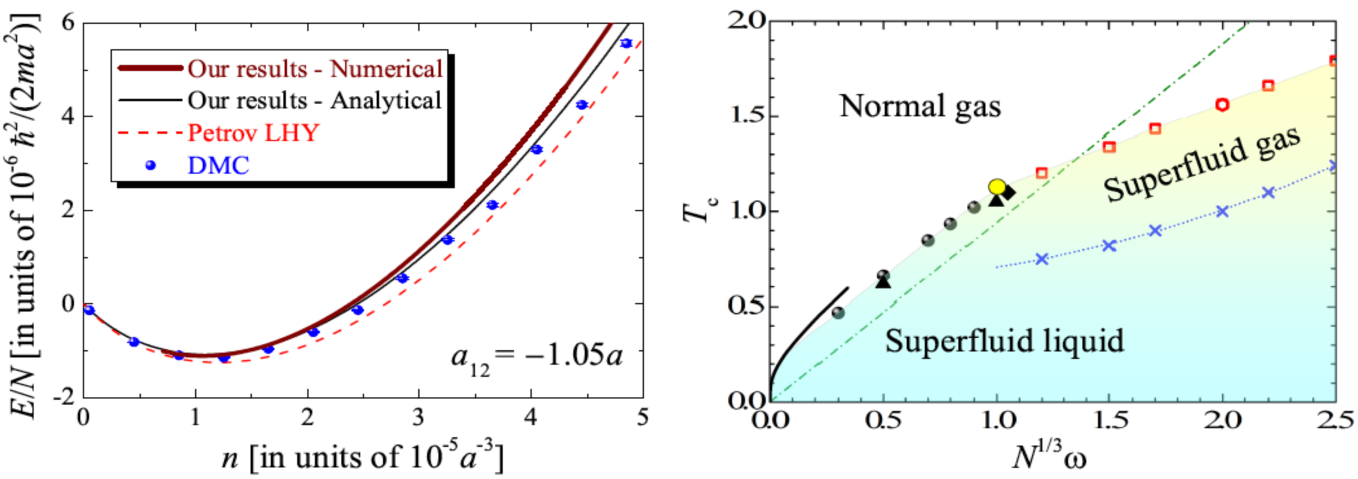

Fig.1 Left: Energy per particle as a function of density [2]. Right: Critical temperature as a function of the effective trapping frequency in quantum droplet formed by three-body interactions [3].

[1] D. S. Petrov, *Phys. Rev. Lett.* **115**, 155302 (2015).

[2] H. Hu and X. -J. Liu, *Phys. Rev. Lett.* **125**, 195302 (2020).

[3] H. Hu, Z. -Q. Yu, J. Wang, and X. -J. Liu, *Phys. Rev. A* **104**, 043301 (2021).