Contributed Talk

Supersolid Phase via Roton Softening in Spin-Orbit Coupled Quantum Droplets

Aniruddha Rana[1], Inderpreet Kaur[2], and **Priyam Das**[1]

[1]*Bankura Sammilani College, West Bengal, India*

[2]*Department of Physics, Indian Institute of Technology Hauz Khas, New Delhi, India*

Quantum fluids in ultracold atomic gases exhibit remarkable phenomena in both mean-field and beyond-mean-field regimes. We explore the dynamics of quantum liquids and droplets in a symmetric spin-orbit coupled Bose-Einstein condensates with Lee-Huang-Yang corrections, uncovering the interplay of spin-orbit coupling (SOC), mean-field, and beyond mean-field interactions. This study provides insights into stability, structure, surface tension, energy, and momentum. We predict a roton mode in the energy-momentum dispersion driven by SOC and beyond-mean-field effects, suggesting density modulations at finite momentum. The superfluid fraction's sudden rise indicates coexistence of superfluidity and spatial ordering, leading to a supersolid phase with potential applications in quantum technologies.

References

[1] D. S. Petrov. Quantum mechanical stabilization of a collapsing Bose-Bose mixture. Phys. Rev. Lett. **115,** 155302 (2015).

[2] L. Tanzi et. Al., Observation of a Dipolar Quantum Gas with Metastable Supersolid Properties, Phys. Rev. Lett. **122**, 130405 (2019).

[3] L. Chomaz, et. Al.,, Observation of Roton Mode Population in a Dipolar Quantum Gas, Nat. Phys. **14**, 442 (2018).

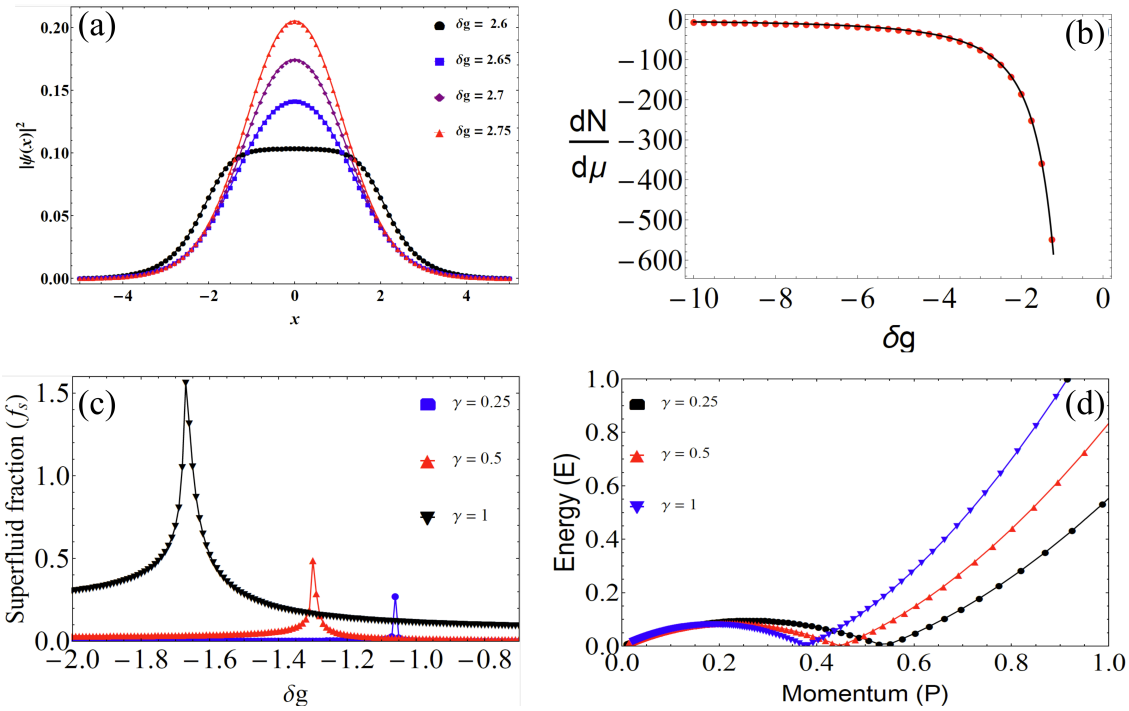

Figure 1: (a) The transition from solitons to quantum droplets is observed due to the interplay between mean-field attraction and beyond-mean-field interactions, demonstrating the formation of self-bound quantum droplets. (b) Stability diagrams illustrate the parameter regimes where quantum droplets remain stable, providing insights into the structural and energetic properties of the droplets. (c) The superfluid fraction exhibits a sudden rise as a function of interaction strength, indicating the emergence of a supersolid phase. This rise corresponds to the coexistence of superfluidity and spatial ordering, which is a hallmark of the supersolid state. The results suggest that spin-orbit coupling enhances the superfluid fraction by inducing density modulations at finite momentum. (d) The energy-momentum dispersion relation reveals the presence of a roton mode, driven by spin-orbit coupling and beyond-mean-field effects. The appearance of roton instabilities further supports the prediction of a supersolid state, characterized by simultaneous superfluidity and crystalline ordering.