Phase transitions in a spin-orbital-angular-momentum coupled Bose-Einstein condensate

With the support by the National Natural Science Foundation of China, National Key R&D Program of China, and Chinese Academy of Sciences, the research team led by Prof. Jiang KaiJun (江开军) at the State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics, Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, experimentally mapped out the ground-state phase diagram of a spin-orbital-angular-momentum coupled Bose-Einstein condensate for the first time. The relevant research results were published in *Physical Review Letters* (2019, 122: 110402).

Coupling between a particle's spin and orbital motion is ubiquitous in atoms, photons, solid materials and many other systems. It contributes to the topological properties like quantum-Hall effect in solid materials and electronic fine structure in atoms. Ultracold atoms with a high tunability provide an ideal platform to study spin-orbit (SO) coupling. Spin-linear-momentum (SLM) coupling has been observed in quantum gases and subsequently a variety of exotic quantum states have been explored during the last ten years. While the experimental study on the other kind of SO coupling, namely the spin-orbital-angular-momentum (SOAM) coupling, is still lacking.

The team at Wuhan Institute of Physics and Mathematics reported the experimental observation of the ground-state phase diagram of the SOAM coupled Bose-Einstein condensate. By inducing a Raman transition using a pair of Gaussian and Laguerre-Gaussian (LG) laser beams, they realized SOAM coupling of ultracold atoms. The phase transitions occurred when the two-photon Raman coupling strength or detuning approached the critical value. The phase transitions were classified as the first order, which featured a discontinuous jump of the angular momentum (OAM) and the spin polarization. The hysteresis loop across the first-order phase transition was demonstrated. The role of interatomic interaction in the phase transition was also elucidated. This work represented a pioneering study towards the use of SOAM coupled quantum gases to explore exotic quantum states.

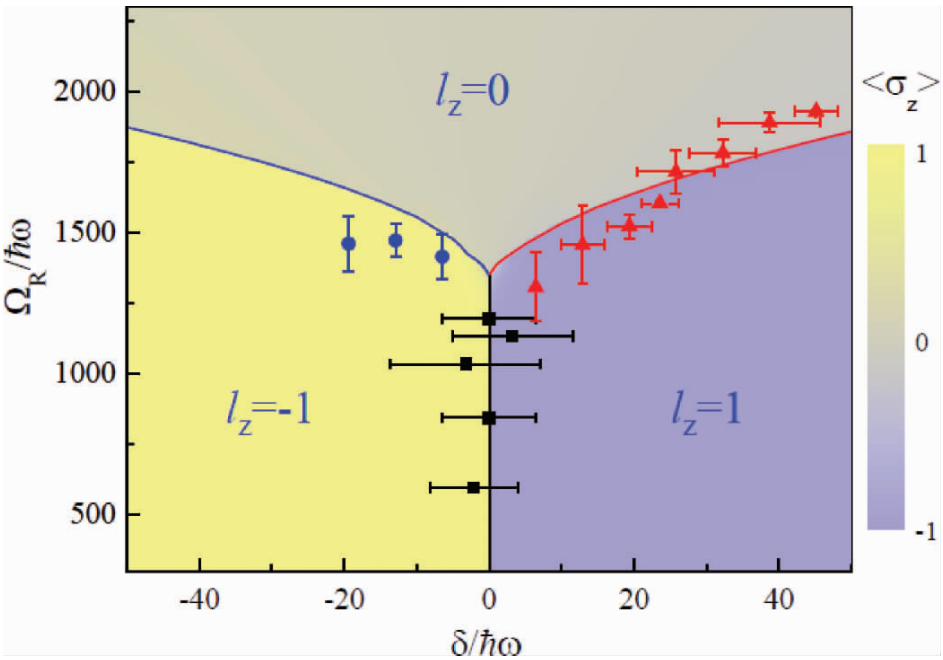

Figure Ground-state phase diagram of the SOAM coupled condensate.