Strongly Interacting Quantum Gases of Dipolar Molecules: From Bose–Einstein Condensate to Self-Bound Droplets

Haneul Kwak
Department of Physics
Columbia University

Ultracold quantum gases provide a powerful platform for exploring many-body physics with highly controllable interactions. While neutral atomic gases are dominated by short-range contact interactions, dipolar molecular gases introduce long-range and anisotropic interactions, enabling access to novel quantum phases inaccessible in conventional atomic gases. In this seminar, I will present our experimental realization of a Bose-Einstein condensate (BEC) of sodium-cesium (NaCs) molecules, the first quantum degenerate bosonic system of dipolar molecules. By dressing the molecules with microwave fields, we engineer dipolar interactions between molecules with controllable anisotropy and strength. As the interaction strength increases, the system exhibits a rich evolution of behavior. In the weakly interacting regime, the condensate undergoes electrostriction, an anisotropic deformation of its shape driven by dipolar interactions. At stronger interactions, we observe the emergence of complex density structures beyond mean-field descriptions, eventually entering the regime of self-bound droplets—a quantum liquid phase stabilized by interactions. The observed droplet densities are up to two orders of magnitude higher than those of weakly dipolar condensates, highlighting the strongly interacting nature of the system. As an outlook, I will discuss how molecular BECs can serve as a platform for quantum simulation of lattice systems and for exploring strongly correlated quantum matter.