Microscopic Signature of Quantum Depletion

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Quantum fluctuations play a fundamental role in many-body physics, determining the nature of the ground state or driving quantum phase transitions. An ensemble of bosons at zero temperature will form a Bose-Einstein condensate, but quantum fluctuations due to interactions between the particles will deplete the condensate mode while populating higher energy states [1]. The resulting many-body state exhibits strong correlations, such as pairing between particles of opposite momenta and characteristic tails in the momentum-space distribution [2]. In this talk, I will present our recent progress towards the observation of these signatures of quantum depletion. Our experiments are performed with an ultracold gas of metastable Helium-4 atoms [3] for which electronic detection of individual particles is possible, providing direct access to the three-dimensional, momentum-space distribution of the gas [4]. An optical lattice allows us to vary the interaction between the atoms by confining them in periodic wells of tunable depth. We find characteristic power-law scaling of the depletion population with momentum, the fraction of which can be controlled with the amplitude of the lattice. Importantly, our measurements are able to distinguish between quantum and thermal effects, allowing for an unambiguous identification of quantum depletion.

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[2] L. Mathey et al, PRA 79, 013609 (2009)
[3] Q. Bouton et al, PRA 91, 061402(R) (2015)
[4] F. Nogrette et al., Rev. Sci. Instrum. 86, 113105 (2015)