Thermodynamics of the unitary Bose gas from first principles

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Ultracold atomic gases offer access to a broad class of quantum systems. The strength of interatomic interactions, in particular, may be tuned across a wide range, through the Feshbach-resonance technique. We consider a gas of bosonic atoms in the unitary limit, where the scattering length is infinite. For three bosons, unitary interactions lead to the Efimov effect, consisting in an infinite sequence of scale-invariant three-body bound states. The Efimov scenario (predicted in nuclear physics in the 1970s, and first observed in 2006 with ultracold atoms) is correctly described through a model with zero-range two-body interactions and a hard-core three-body repulsion. We use this model to describe a many-body system of unitary bosons, which we study through a dedicated path-integral quantum Monte Carlo algorithm. At thermal equilibrium, the phase diagram of the system includes the normal-gas phase at high temperature and two low-temperature phases: The Efimov liquid and the Bose-Einstein condensate. We determine the critical temperature for Bose-Einstein condensation, which is found to be 10% smaller than for non-interacting bosons. We also compute the momentum distribution of the gas, and compare it with available experimental results which are part of the current effort towards the realization of a degenerate unitary Bose gas.

[1] T. Comparin, W. Krauth, Phys. Rev. Lett. **117**, 225301 (2016).