Beyond-mean field effects in Rabi-coupled two-component Bose-Einstein condensate

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Beyond-mean field effects linked to (vacuum) quantum fluctuations are among the most sticking features of quantum field theories and are playing a key role in the properties of strongly correlated material. The high degree of control of cold gases has made this systems ideal candidates to measure and understand quantum fluctuations in matter fields. Here, we work in a two-component Bose-condensed mixtures with repulsive intraspecies interaction and attractive interspecies such that global mean-field energy can be cancelled. A a consequence, beyond-mean-field effects, although small in dilute gases, can dominate the system dynamics.

More precisely, we theoretically calculate and experimentally observe the beyond-mean-field equation of state in a coherently-coupled two-component Bose-Einstein condensate in the regime where averaging of the interspecies and intraspecies coupling constants over the hyperfine composition of the single-particle dressed state predicts the exact cancellation of the two-body interaction. We show that with increasing the Rabi frequency, the beyond-mean-field energy density crosses over from the nonanalytic Lee-Huang-Yang scaling $\propto n^{5/2}$ to an expansion in integer powers of density, where, in addition to a two-body term $\propto n^2$, there is an emergent repulsive three-body contribution $\propto n^3$. We work in a Rabi-coupled two-component ^{39}K condensate which is released in a waveguide. Its expansion dynamics is governed by the beyond-mean-filed energy allowing for its quantitative measurement.

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