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Rotons and Bose condensation in Rydberg-dressed Bose gases[1]
BILAL TANATAR, Bilkent University, Ankara, Turkey, IRAN SEYDI, SAEED H. ABEDINPOUR, Institute for Advanced Studies in Basic Sciences (IASBS), Zanjan, Iran, ROBERT E. ZILLICH, Johannes Kepler University, Linz, Austria, REZA ASGARI, Institute for Research in Fundamental Sciences (IPM), Tehran, Iran — We investigate the ground-state properties and excitations of Rydberg-dressed bosons using the hypernetted-chain Euler-Lagrange approximation, which accounts for correlations and thus goes beyond the mean-field approximation. The short-range behavior of the pair distribution function signals the instability of the homogeneous system with respect to the formation of droplet crystals at strong couplings and large soft-core radius. This tendency to spatial density modulation coexists with off-diagonal long-range order. The contribution of the correlation energy to the ground-state energy is significant at large coupling strengths and intermediate values of the soft-core radius while for a larger soft-core radius the ground-state energy is dominated by the mean-field (Hartree) energy. We have also performed path integral Monte Carlo simulations at selected system parameters to verify the performance of our hypernetted-chain Euler-Lagrange results. In the homogeneous phase, the two approaches are in very good agreement. Moreover, Monte Carlo simulations predict a first-order quantum phase transition from a homogeneous superfluid phase to the quantum droplet phase with face-centered cubic symmetry for Rydberg-dressed bosons.

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