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Atom-atom correlations in time-of-flight imaging of ultra-cold bosons in optical lattices

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We propose a combined method of Bogoliubov and the quantum rotor approach to study the spatial correlations of strongly interacting bosons in a ground state, confined in two-dimensional square optical lattice. We map the Bose-Hubbard Hamiltonian of strongly interacting bosons onto U(1) phase action and calculate the atom-atom correlation decay as a function of distance. This allow us to determine quantities that are directly bound to experimental outcomes, namely time-of-flight absorption images and resulting visibility. Our results contain all the characteristic features present in experimental data (transition from Mott insulating blob to superfluid peaks, etc.), which emphasizes the usability of the proposed approach.