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Realization of Extended Hubbard Models with Tailored Orbitals in Optical Lattices[1]

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Optical lattices containing cold atoms represent nearly ideal manifestations of Hubbard models free from disorder, defects, impurities and lattice phonons. Experiments with bosonic alkali atoms confined to the lowest optical lattice band demonstrate strongly correlated phases including the superfluid and Mott insulator that arise from a real space contact interaction between atoms. Can other quantum condensed phases of matter be observed in these systems? We show that promoting bosons to higher bands effectively extends the range of the contact interaction. Quasi-localized orbitals in higher bands overlap with nearest neighbors. They can be modeled with extended Bose-Hubbard models that harbor density wave and supersolid phases. Bosons promoted to higher bands can decay but the purity of optical lattice systems limits possible decay mechanisms (e.g. phonons). We propose that long-lived metastable states of bosons promoted to higher bands of optical lattices may therefore provide a route to a novel class of extended Hubbard models.

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