Title: "The Molecular Hubbard Hamiltonian"

Ultracold polar molecules are on the edge of quantum degeneracy. A number of molecular types are being assembled and cooled at JILA, Innsbruck, Heidelberg, and elsewhere. What is the natural many-body physics of such molecules in optical lattices? We explore this question and present a general molecular Hubbard Hamiltonian (MHH), including strong external electric and magnetic fields. Effects range from long-range dipole-dipole interactions to a massive number of internal degrees of freedom. Among other practical experimental suggestions, we show that a new handle exists for these systems, the angle between electric and magnetic DC fields. We present a thorough exposition of all energy scales down to 1 Hz, which allows us to systematically truncate terms in the MHH to a consistent order of approximation. This controlled truncation is important when discussing the stability of many-body phases. We explore the behavior of the MHH in different field regimes and for different experimentally relevant species, and provide mappings to known spin models in specific cases in order to demonstrate the underlying many-body physics.

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