FRONTIERS IN OPTICAL COHERENT AND ULTRAFAST SCIENCE
A NATIONAL SCIENCE FOUNDATION PHYSICS FRONTIER CENTER AT
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A nugget from FOCUS:

Title: Effective Hamiltonian for ultracold fermionic atoms in an optical lattice across a Feshbach resonance

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We have derived the effective Hamiltonian for cold fermionic atoms in an optical lattice across a broad Feshbach resonance, taking into account both multi-band occupations and neighboring-site collisions. On different sides of a lattice resonance, the effective Hamiltonian is reduced to either a *t-J* model for the fermionic atoms or an *XXZ* model for the dressed molecules. The parameters in these models are experimentally tunable in the full range, which allows for the observation of various phase transitions.

There are many recent exciting developments in ultracold atom physics, mainly due to two experimental control techniques: one is the Feshbach resonance to control the magnitude of the interaction between the atoms, and the other is the optical lattice to introduce diverse interaction configurations. It is natural to consider a combination of these two techniques, and such a direction has recently aroused strong interest. Here, a fundamental problem is to derive an appropriate Hamiltonian for this strongly interacting system which can serve as the starting point for further investigations. This task is highly nontrivial due to the following two complications. First, one needs to consider multi-band couplings as the strong atom-molecule interaction results in population of the upper bands. Second, one also needs to consider the atom-molecule coupling from the neighboring sites.

The strong on-site interaction between the atoms makes them first form local dressed molecules. We then derive an effective single-band Hamiltonian, describing the resonant interaction between the local dressed molecules and the valence bonds (singlets) of fermions at neighboring sites. This lattice resonance model reduces to either a *t-J* model for the fermionic atoms or an *XXZ* (anisotropic Heisenberg) model for the dressed molecules under particular cases, opening up the prospect of using this system to probe some fundamental physics associated with the latter two models. The following figure illustrates the lattice resonance between dressed molecules and atom valence bonds [L.-M Duan, Phys. Rev. Lett. **95**, 243202 (2005)].