Optical Lattices with Large Scattering Length

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I will discuss a new proposal to go beyond the standard way of thinking of atoms in optical lattices by bringing in ideas from few-body physics. I will consider a setup where one atomic species is trapped in a lattice at full filling while another is untrapped (does not see the optical lattice) but has an s-wave contact interaction with the first one. If the interspecies scattering length is positive and on the order of the lattice spacing then the usual two-body bound (dimer) states overlap forming a polyatomic molecule extending over the entire lattice, which can also be viewed as a band solid for the untrapped species, where the trapped atoms play the role of ions. This setup requires large scattering lengths but minimises losses, does not need higher bands and adds new degrees of freedom which cannot easily be described in terms of lattice variables. As an example I show how to create an electron-phonon quantum simulator which exhibits renormalization of the phonon frequencies due to electron-ion interactions, Peierls instability, and where the effective phonon Hamiltonian can be mapped in some cases to a quantum transverse Ising model.

[1] Z. Lan, and C. Lobo, Phys. Rev. A **90**, 033627 (2014).