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Interplay of spin and motional dynamics in ultracold atoms and molecules

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Several recent ultracold experiments have realized many-body "spin models" – systems where interacting spins are frozen in space. One example I will discuss is polar molecules in an optical lattice. By comparing the JILA group's measurements of far-from-equilibrium molecule dynamics with theoretical predictions, we were able to characterize the spin Hamiltonian and benchmark a new numerical algorithm. Even richer possibilities exist *beyond* spin models, where both spin and motional degrees of freedom evolve dynamically. Such interplay of spin and motion underlies exotic phenomena such as high-temperature superconductivity. I will describe how the unique properties of emerging ultracold systems – *nonreactive* ultracold molecules, Rydberg atoms, and alkaline earth atoms – make possible the independent control of the spins, their motion, and the spin-motion coupling.