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Quantum simulation with cold molecules[1]

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Recent experimental developments on cooling, trapping, manipulating and loading ultra-cold ground state molecules in an optical lattice have opened the door for the exploration of quantum magnetism and the observation of complex quantum dynamics. In this talk I will discuss recent developments towards the implementation of controllable spin lattice models in polar molecules with the spin degrees of freedom encoded in rotational states. The spin-spin couplings are generated by direct dipolar interactions and can be fully controlled by dc electromagnetic fields and microwaves. The spin models realized in this way are long range, anisotropic and can even feature direction-dependent spin interactions. They can emulate Hamiltonians ranging from the Heisenberg spin model, to Hamiltonians with symmetry protected topological phases to Hamiltonians without solid state counterpart. At JILA we have been able to realize for the first time a lattice spin model with fermionic KRb molecules pinned in a 3D lattice. We observe clear manifestation of dipolar exchange interactions in Ramsey spectroscopy even at substantially less than unit lattice filling. I will describe the new theoretical methods that we developed to model the spin dynamics and show that those reproduce the experimental observations. Even though so far the spin dynamics has been restricted to pinned molecules, in part to prevent chemical reactions, I will finish by presenting theoretical calculations supported by experimental measurement at JILA that demonstrate that the continuous quantum Zeno mechanism can actually suppress loss in this highly reactive system. This finding opens the exciting possibility of observing itinerant quantum magnetism in near term experiments.

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