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Quantum matter based on ultracold molecules

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Molecules cooled to ultralow temperatures provide fundamental new insights to strongly correlated quantum systems, molecular interactions and chemistry in the quantum regime, and precision measurement. Complete control of molecular interactions by producing a molecular gas at very low entropy and near absolute zero has long been hindered by their complex energy level structure. Recently, a range of scientific tools have been developed to enable the production of molecules in the quantum regime. Here, molecular collisions follow full quantum descriptions. Chemical reaction is controlled via quantum statistics of the molecules, along with dipolar effects. Further, molecules can be confined in reduced spatial dimensions and their interactions precisely manipulated via external electromagnetic fields. For example, by encoding a spin-1/2 system in rotational states, we realize a spin lattice system where many-body spin dynamics are directly controlled by long-range and anisotropic dipolar interactions. These new capabilities promise further explorations of strongly interacting and collective quantum effects in exotic quantum matter.