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Rotational Frenkel excitons in optical lattices with polar molecules[1]

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Ultracold polar molecules trapped in an optical lattice may form crystal-like structures with unique properties. Here, I will discuss a Mott insulator phase of ultracold molecules with one molecule per lattice site under conditions that can be realized in ongoing experiments with optical lattices. I will show that dipole-dipole interactions between molecules in different lattice sites give rise to collective excitations, such as Frenkel excitons, characteristic of solid-state molecular crystals. Due to the perturbative nature of the intermolecular interactions, the collective excitations in this system can be controlled by an external electric field. This can be used to realize Frenkel excitons in the presence of dynamically tunable disorder or an ensemble of Frenkel excitons with tunable exciton - exciton interactions. An external electric field can thus be used to induce strong localization or delocalization of Frenkel excitons as well as bi-exciton annihilation. The latter can be used to produce dark exciton states and entangled exciton pairs. The complicated quantum statistics of excitons leads to kinematic interactions. Our results show that the kinematic interactions can be eliminated by varying an external electric field, effectively leading to a system of quantum quasi-particles with tunable quantum statistics.

[1] "Tunable disorder in a crystal of cold polar molecules," Felipe Herrera, Marina Litinskaya, Roman V. Krems, Phys. Rev. A **82**, 033428 (2010).

[1]in collaboration with Felipe Herrera, Ping Xiang and Roman V. Krems