Towards quantum simulations of chemical and biological processes using ultra-cold Rydberg atoms

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ABSTRACT:

In Rydberg Atoms in highly excited electronic states with n=30-100 are recent additions to the versatile toolkit of ultracold atomic physics. At rest, treated as a "frozen gas", they hold promise for applications well beyond atomic physics and serve as experimentally accessible interacting many-body systems for quantum information and in condensed matter physics. While for those applications the residual atomic motion is usually an unavoidable perturbation and source of noise, we will make use of this motion for preserving coherent electron dynamics, very much like in molecules, but for transport instead of stationary states.

In Rydberg atoms, accelerated via dipole-dipole interactions, we find an intricate link between atomic motion and the transport of electronic excitation energy. This link allows one to realize adiabatic exciton transport schemes and system potential energy landscapes that mimick those of relevance for quantum chemistry. The analogy between the chemical energy surfaces and those among Rydberg atoms will enable more detailed studies of quantum many-body dynamics on these surfaces.

On shorter time scales where atomic motion is no longer crucial, a system of a few interacting Rydberg atoms shows parallels to energy transport in photosynthetic light harvesting complexes. Consequently, it provides a transparent analog for the quantum simulation of the latter. In particular, by embedding the assembly of Rydberg atoms into a background atomic gas, crucial but complex features in light harvesting systems, such as disorder and decoherence can be introduced in a controlled manner.