Long-range interactions and spin transport with Rydberg dressed atoms

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Ultracold Rydberg atoms, with their exceptionally large dipole moments, offer the exciting prospect to create and study new types of strongly-interacting quantum systems in which the strength, anisotropy, range and character of the interaction potential can be controlled at will. In particular, state-changing interactions between Rydberg atoms are similar to those found in complex molecules, but can be orders of magnitude stronger and extend over micrometer distances, far beyond nearest neighbours. We experimentally and theoretically study the dipole-mediated transport of Rydberg impurities through a surrounding gas of atoms coupled via an electromagnetically induced transparency (EIT) resonance. This system can be mapped onto an effective spin-1/2 model for the impurity Rydberg state and the laser dressed atoms. Using the background gas as an amplifier we monitor the migration of electronic excitations with high time and spatial resolution. Through precise control of interactions and the coupling to the environment via the laser fields, we find different regimes ranging from coherent exciton motion to classical diffusive transport and a collective regime in which a new length scale emerges. Finally I will discuss the possibility to exploit the extreme properties of Rydberg-dressed atoms to create novel types of long-range interacting quantum fluids.