Rydberg-atom molecules and Rydberg-atom imaging

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Cold atomic systems have opened new frontiers at the interface of atomic and molecular physics. These include novel types of Rydberg molecules. In this talk, two types of molecules will be discussed in detail. Long-range, homonuclear Rydberg-ground molecules are formed via low-energy electron scattering of the Rydberg electron from a ground-state atom that is present within the Rydberg atom's volume. The binding mostly arises from S-wave and P-wave triplet scattering. In the presented analysis, we use a Fermi model that includes S-wave and P-wave singlet and triplet scattering, the fine structure coupling of the Rydberg atom and the hyperfine structure coupling of the $5S_{1/2}$ atom (in rubidium). A recent experiment on deeply bound Rb $24D_J$-$5S_{1/2}$ will be discussed, in which a set of 32 resonances on several adiabatic potentials for ^{85}Rb and ^{87}Rb have been analyzed. I will further ultra-long-range Rydberg-Rydberg molecules of Rb and Cs. These molecules, which have even larger bonding length than Rydberg-ground molecules, are formed via electrostatic multipole interactions. Experimental methods that allow the direct imaging and mapping of Rydberg-atom interactions and Rydberg molecules will be presented in detail.