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Observation of ultralong range Rydberg molecules[1]

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In 1934, Enrico Fermi described the scattering of a low energy electron from a neutral atom by using the ideas of scattering length and pseudopotential. Although the long range potential for an electron-atom interaction is always attractive, Fermi realized that the s-wave scattering length that characterizes the low energy collision can be either positive or negative. For a positive scattering length, the wavefunction of the electron is shifted away from the atom, the electron is repelled; whereas for a negative scattering length, the wavefunction of the electron is shifted to the atom, the electron is attracted. Based on Fermi's approach, Greene and co-workers predicted a novel molecular binding mechanism where a low energy Rydberg electron is scattered from a ground state atom in the case of negative scattering length. In this situation, the interaction between the electron and ground state atom is attractive and results in the formation of bound states of the ground state atom and the Rydberg atom. Molecules bound by electron scattering can have an internuclear separation of several thousand Bohr radii and are very different from molecules formed by 2 Rydberg atoms where the binding is the result of multipolar forces between the atoms alone. In this talk, we present experimental data on the observation of these exotic molecular states for Rb Rydberg atoms in S states for principal quantum numbers n between 34 and 40. The spectroscopic results for the vibrational ground and first excited state of the dimer Rb(5S)-Rb(nS) are presented and the s-wave scattering length for electron-Rb(5S) scattering in the low energy regime where the kinetic energy is less than 100 meV. Finally, we discuss and present data on the lifetimes and decay mechanisms of these molecules in a magnetic trap.

[1]In collaboration with Vera Bendkowsky, Björn Butscher, Johannes Nipper, Robert Löw, and Tilman Pfau, University of Stuttgart.