A Rydberg molecule as a testbed for spin-orbit-dependent electron-neutral scattering

Spin-orbit interaction is ubiquitous across various fields of research such as AMO physics, solid state physics, physical chemistry. It had been predicted to also appear in electron-neutral scattering for several decades, but the experimental observation has been elusive. A collaboration of the Institut für Quantenmaterie and groups from Hamburg and Stuttgart now shows direct evidence and resolves this open question. These results are published in Phys. Rev. Research 2, 013047 (2020).

As a model system the collaboration uses an ultralong-range Rydberg molecule which can be understood as follows. In general, a Rydberg atom is a highly excited atom where at least one electron has a very large, spatially extended wave function with many nodes. If a ground state atom is added to such a system, it can be trapped in individual potential wells which arise from the oscillating Rydberg electron wave function. If the trapping occurs far away from the Rydberg ionic core, an ultralong-range molecule is given. Since their discovery about a decade ago a variety of such molecules have been studied and their quantized motion in the potential wells has been investigated in terms of vibrational ladders. Now, in the collaborative work also substructures of vibrational states are observed, and these substructures directly reflect the effect of the described spin-orbit interaction. This observation is possible, since resonant interaction increases the level splittings of spin states, which then can be experimentally resolved.

The work of the collaboration shows that ultralong-range Rydberg molecules can serve as a microlaboratory for low-energy scattering experiments, opening up a new realm for experimental studies. For example, it is expected that this microlaboratory can be employed to study interesting wave packet dynamics in non-trivial potential landscapes.