XXIX International Conference on Photonic, Electronic, and Atomic Collisions (ICPEAC2015) IOP Publishing
Journal of Physics: Conference Series **635** (2015) 092140 doi:10.1088/1742-6596/635/9/092140

Mass scaling in photoassociation of spin-singlet atoms

Mateusz Borkowski[1], Piotr Morzyński[1], Roman Ciuryło[1], Piotr S. Żuchowski[1], Paul S. Julienne[2], Axel Görlitz[3], T. C. Killian[4], Yoshiro Takahashi[5]

[1]Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Grudziadzka 5, 87-100 Torun, Poland

[2]Joint Quantum Institute, University of Maryland and National Institute of Standards and Technology, College Park, Maryland 20742, USA

[3]Institut für Experimentalphysik, Heinrich-Heine-Universität Düsseldorf, Universitätstraße 1, 40225 Düsseldorf, Germany

[4]Rice University, Department of Physics and Astronomy, Houston, Texas, 77251, USA

[5]Department of Physics, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan

Synopsis Photoassociation spectroscopy, based on forming of molecules from colliding atoms in the presence of light, is a priceless tool for the study of atomic interactions. It enables direct measurements of bound state energies, both in excited and ground state molecules. Applications include determinations of s-wave scattering lengths, as well as atomic state lifetimes. In this work we present the results of our research on the mass-scaling behaviour of molecular bound state energies and collisional properties in spin-singlet atoms. We will concentrate on two such species: strontium and ytterbium, both of which offer several stable isotopes, enabling mass tuning of the system's properties.

Two-valence-electron atoms, particularly strontium and ytterbium, have special features that make them particularly attractive from the standpoint of ultracold physics. Their $^1S_0$ ground state makes them insensitive to external magnetic fields. Narrow intercombination lines present in these systems (7.5 kHz in Sr and 181 kHz in Yb) enable magneto-optical trapping at microkelvin temperatures. A doubly-forbidden $^1S_0 \rightarrow {}^3P_0$ line in both species is used as atomic references in optical clocks. Finally, both species have an array of stable isotopes (five bosons and two fermions in ytterbium, three bosons and a fermion in strontium), which enables mass tuning of collisional properties of cold gases of these atoms simply by switching the isotope. The increased interest in ultracold gases of divalent atoms has resulted in spectacular achievements, including degenerate quantum gases in almost all of the isotopes of both species. Photoassociation spectroscopy [1], which enables direct measurement of molecular bound state energies of molecules formed by colliding cold atoms in the presence of light, has also been extensively performed with divalent atoms. In this work we concentrate on the mass-scaling behaviour of bound state energies of molecules formed in photoassociation spectroscopy, as well as the properties of collisions of divalent atoms.

The first presented system is the case of two-color photoassociation of ytterbium with rubidium atoms [2]. This system is of particular importance as it bridges the gap between alkali and divalent species. Based on data from photoassociation spectroscopy we have fitted an *ab initio* based single-channel model of the ground state Rb-Yb interaction. Using this model we have determined the s-wave scattering lengths for all isotopologues of this system.

In the case of the RbYb system, a mass scaled model was obtained using just one potential curve. A different case is seen the Sr_2 dimer near the $^1S_0+{}^3P_1$ asymptote [3]. Here, not only the nonadiabatic mixing between two potential curves (0_u^+ and 1_u) has to be considered to even obtain a good fit to photoassociation data for one isotope, but also an additional 0_u^+ curve perturbs the mass-scaling behaviour of the bound state energies in this molecule.

The last presented system is the $^1S_0+{}^3P_1$ 0_u^+ curve in the ytterbium dimer [4], for which we have constructed a mass scaled model of the atomic interactions, again by fitting to photoassociation data. We will show that the rotational structure of photoassociation spectra near the intercombination line of ytterbium depends heavily on the properties of the ground state collision due to the emergence of shape resonances.

References

[1] K. M. Jones *et al.* 2006 *Rev. Mod. Phys.* **90** 032713

[2] M. Borkowski *et al.* 2013 *Phys. Rev. A* **78** 483

[3] M. Borkowski *et al.* 2014 *Phys. Rev. A* **88** 052708

[4] M. Borkowski *et al.* 2009 *Phys. Rev. A* **80** 012715