

Q 52: Cold Molecules II (joint session Q/MO)

Time: Thursday 14:00–15:45

Location: f442

Invited Talk

Q 52.1 Thu 14:00 f442

Long-range interactions between polar molecules and Rydberg atoms — ●MARTIN ZEPPENFELD — MPI für Quantenoptik, Hans-Kopfermann Str. 1, 85748 Garching

Due to large dipole moments in polar molecules and huge dipole moments in Rydberg atoms, strong interactions between polar molecules and Rydberg atoms persist for separations beyond $1\ \mu\text{m}$. This provides exciting opportunities in quantum science, with applications such as cooling of internal or motional molecular degrees of freedom, nondestructive molecule detection, and quantum information processing.

In my talk, I will provide an overview of these opportunities and present my work on realizing such ideas experimentally. In particular, we have investigated Förster resonant energy transfer between molecules and Rydberg atoms at room temperature in the past, observing huge interaction cross sections and electric-field-controlled collisions. Currently we are setting up a new experiment to investigate interactions between cold molecules and Rydberg atoms, providing many new opportunities.

Q 52.2 Thu 14:30 f442

Heteronuclear long-range Rydberg molecules — ●MICHAEL PEPPER¹ and JOHANNES DEIGLMAYR² — ¹Laboratory of Physical Chemistry, ETH Zürich — ²Felix-Bloch Institut, University of Leipzig

The binding of long-range Rydberg molecules is based on the low-energy scattering of an Rydberg atom's electron off a neutral ground-state atom within its orbit. Improving the quantitative understanding of this binding mechanism thus carries the potential to extract electron-atom-scattering potentials, important quantities to benchmark *ab-initio* atomic structure calculations [1], from photoassociation spectra of long-range Rydberg molecules. Current theoretical models are, however, challenged by the necessity to accurately model the scattering interaction while including all relevant spin couplings, such as the hyperfine interaction [2].

We propose to rigorously test the modelling of long-range Rydberg molecules by isoelectronic substitution, *i.e.*, by systematically varying isotopic variant and chemical species of both Rydberg and ground-state atom. To this end we have completed the construction of a dual-species ultracold atom experiment, which allows for simultaneous trapping of ultracold cesium and potassium atoms. We will present our current progress towards performing photoassociation spectroscopy of homo- and heteronuclear long-range Rydberg molecules in this setup.

[1] H. Saßmannshausen, F. Merkt, and J. Deiglmayr, PRL 114, 133201 (2015); F. Engel *et al.*, PRL 123, 073003 (2019); J.L. MacLennan, Y.-J. Chen, and G. Raithel, PRA 99, 033407 (2019) [2] C. Fey *et al.*, New J. Phys. 17, 055010 (2015)

Q 52.3 Thu 14:45 f442

Stability of quantum degenerate Fermi gases of tilted polar molecules — ●VLADIMIR VELJIĆ¹, AXEL PELSTER², and ANTUN BALAZ¹ — ¹Center for the Study of Complex Systems, Institute of Physics Belgrade, University of Belgrade, Serbia — ²Physics Department and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany

A recent experimental realization of quantum degenerate gas of $^{40}\text{K}^{87}\text{Rb}$ molecules opens up prospects of exploring strongly dipolar Fermi gases and many-body phenomena arising in that regime [1]. Here we derive a mean-field variational approach based on the Wigner function for the description of ground-state properties of such systems [2,3]. We show that the stability of dipolar fermions in a general harmonic trap is universal as it only depends on the trap aspect ratios and the dipoles orientation. We calculate the species-independent stability diagram and the deformation of the Fermi surface (FS) for polarized molecules, whose electric dipoles are oriented along a preferential direction. Compared to atomic magnetic species [2], the stability of a molecular electric system turns out to strongly depend on its geometry and the FS deformation significantly increases [3]. We also show that tuning the trap frequencies appropriately reduces the 3D system to a quasi-2D system of either a pancake- or a cigar-shaped gas cloud, which turn out to have smaller stability regions.

[1] L. De Marco *et al.*, Science **363**, 853 (2019)

[2] V. Veljić *et al.*, New J. Phys. **20**, 093016 (2018)

[3] V. Veljić *et al.*, Phys. Rev. Res. **1**, 012009 (2019)

Q 52.4 Thu 15:00 f442

Progress on Zeeman slowing of CaF — ●MARIA STEPANOVA, PAUL KAEBERT, TIMO POLL, MAURICE PETZOLD, SUPENG XU, MIRCO SIERCKE, and SILKE OSPELKAUS — Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Experiments with ultracold molecules promise to have a large impact on many fields of physics such as quantum simulations and computation, metrology and ultracold chemistry. Due to the complex energy level structure of molecules, direct laser cooling yields a relatively low number of particles that can be trapped. In this talk I will present a novel method of direct slowing of molecules, reminiscent of Zeeman slowing of atoms, which promises a significant increase in flux of slow molecules. I will show data from a proof-of-principle experiment using the D1-line of ^{39}K , demonstrating the efficiency of the method. Comparing our proof-of-principle results shows a flux and slowing efficiency comparable to traditional D2-line Zeeman slowing, and a factor of ~ 20 increase in flux below 35m/s compared to white-light slowing. I will also highlight the newest developments in our experiment such as our efforts on implementing a chemical cell for molecule production in reaction of ablated Ca and SF₆ gas. This will be followed up by our latest results in measurement of the CaF hyperfine structure as well as the Zeeman splitting in CaF energy levels at high magnetic fields.

Q 52.5 Thu 15:15 f442

Towards Direct Laser Cooling of Barium Monofluoride — ●RALF ALBRECHT, MARIAN ROCKENHÄUSER, and TIM LANGEN — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We report on the progress of our experiment for the direct laser cooling and trapping of barium monofluoride molecules. Laser cooling of molecules had long been considered impossible due to their complex vibrational and rotational level structure. However, beneficial Franck-Condon factors and selection rules allow for optical cycling in many molecular species, including barium monofluoride. Hot molecules are generated through laser ablation of a pressed pellet inside a cold cell and precooled by collisions with a cold buffer gas of helium atoms. The thermalized gas mixture exits the cell through a few-millimeter-sized aperture and enters a high vacuum region as a cold and intense beam. A careful characterization of this beam and demonstration of optical cycling is presented in [1], which paves the way for the implementation of transversal laser cooling of the beam. The current status of this effort will be presented.

[1] R. Albrecht *et al.*, arXiv: 1906.08798 (2019)

Q 52.6 Thu 15:30 f442

Manipulation of molecular hydrogen in a Rydberg-Stark state on a chip to study cold collisions — ●KATHARINA HÖVELER¹, JOHANNES DEIGLMAYR², JOSEF AGNER¹, HANSJÜRGEN SCHMUTZ¹, and FRÉDÉRIC MERKT¹ — ¹Laboratorium für Physikalische Chemie, ETH Zürich, 8093 Zurich, Switzerland — ²Felix-Bloch Institut, Universität Leipzig, Linnéstraße 5, 04103 Leipzig, Germany

The exothermic, barrierless $\text{H}_2^+ + \text{H}_2 \rightarrow \text{H}_3^+ + \text{H}$ reaction has been studied in the collision-energy range $E_{\text{coll}}/k_{\text{b}} = 0.3 - 50\text{K}$. To reach such low collision energies, we use a merged-beam approach and substitute the H_2^+ reactants by the ionic cores of H_2 molecules in high- n Rydberg-Stark states. The Rydberg electron does not influence the reaction but shields the ion from heating by space-charge effects and stray electric fields. A curved surface-electrode device is used to deflect a supersonic beam of H_2 molecules excited to high- n Rydberg-Stark states and to merge it with a supersonic beam containing ground-state H_2 molecules. The collision energy is tuned by varying the temperature of the valve generating the H_2 ground-state beam for selected velocities of the deflected H_2 beam. The reaction cross section is found to follow the classical Langevin capture model down to $E_{\text{coll}}/k_{\text{b}} = 5\text{K}$. At lower temperatures, a deviation is observed and attributed to ion-quadrupole long-range interactions. An expected different cross section for a pure para $\text{H}_2(J=0)$ neutral reactant will be tested. Investigation of the reactions $\text{H}_2^+ + \text{D}_2$ and $\text{H}_2^+ + \text{HD}$ enables us to distinguish between charge transfer, D or H atom transfer and H^+ ion transfer and to determine the ratio of the two competing reaction channels.