

## MO 15: Cold Molecules (joint session MO/A)

Time: Wednesday 14:00–16:00

Location: S HS 002 Biologie

MO 15.1 Wed 14:00 S HS 002 Biologie

**Progress towards ultracold RbSr molecules in an optical lattice** — ●VINCENT BARBÉ, LUKAS REICHSÖLLNER, SÉVERIN CHARPIGNON, KLAASJAN VAN DRUTEN, and FLORIAN SCHRECK — University van Amsterdam, Amsterdam, Netherlands

Our group recently reported on the observation of Feshbach resonances between Rb and Sr atoms in an optical dipole trap [1], and on the experimental investigation of the Rb-Sr electronic ground-state interaction potential [2]. We will present our current efforts aimed at building an optical lattice system that supports a Rb-Sr double-Mott insulator with a high filling fraction, and a high magnetic-field stabilization system for magnetoassociation.

[1] V. Barbé, A. Ciamei, B. Pasquiou, L. Reichsöllner, F. Schreck, P. Zuchowski, and J. Hutson, *Nature Physics* 14, 881-884 (2017)

[2] A. Ciamei, J. Szczepkowski, A. Bayerle, V. Barbé, L. Reichsöllner, S. M. Tzanova, C.C. Chen, B. Pasquiou, A. Grochola, P. Kowalczyk, W. Jastrzebski and F. Schreck, *Phys. Chem. Chem. Phys.*, 20, 26221-26240 (2018)

MO 15.2 Wed 14:15 S HS 002 Biologie

**Phase protection of Fano-Feshbach resonances** — ALEXANDER BLECH<sup>1</sup>, YUVAL SHAGAM<sup>2</sup>, NICOLAS J. HÖLSCH<sup>2</sup>, PRERNA PALIWAL<sup>2</sup>, WOJCIECH SKOMOROWSKI<sup>1</sup>, JOHN W. ROSENBERG<sup>2</sup>, DANIEL ZAJFMAN<sup>3</sup>, ODED HEBER<sup>3</sup>, ●DANIEL M. REICH<sup>1</sup>, EDVARDAS NAREVICIUS<sup>2</sup>, and CHRISTIANE P. KOCH<sup>1,2</sup> — <sup>1</sup>Theoretische Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany — <sup>2</sup>Department of Chemical Physics, Weizmann Institute of Science, Rehovot 76100, Israel — <sup>3</sup>Department of Particle Physics and Astrophysics, Weizmann Institute of Science, Rehovot 76100, Israel

Fano-Feshbach resonances (FFR) describe the decay of a quantum system due to coupling of quantum-mechanical bound states to a continuum of scattering states. They serve as a key mechanism to controlling interactions in ultracold atomic gases. The position of FFR was shown to follow quantum chaotic statistics. In contrast, their lifetimes have so far escaped a similarly comprehensive understanding, despite the intriguing observation of spanning many orders of magnitude. We attribute this phenomenon, which has also been observed in predissociation FFR, to phase protection: For each scattering energy, there exists a phase for which the lifetime becomes infinite. Any bound state which is resonantly coupled to the scattering state with exactly this phase is phase protected. Supported by lifetime measurements of rovibrational FFR, we demonstrate that both the reduced mass and the shape of the potential can significantly influence the occurrence of phase-protected resonances. Our results provide a blueprint for identifying naturally long-lived states in a decaying quantum system.

MO 15.3 Wed 14:30 S HS 002 Biologie

**The Dipolar Ground State of Ultracold LiK Molecules** — ●SOFIA BOTSIS<sup>1</sup>, ANBANG YANG<sup>1</sup>, SUNIL KUMAR<sup>1</sup>, and KAI DIECKMANN<sup>1,2</sup> — <sup>1</sup>Centre for Quantum Technologies, 3 Science Drive 2, 117543 Singapore — <sup>2</sup>Department of Physics, National University of Singapore, 2 Science Drive 3, 117542 Singapore

Ultracold polar molecules are an ideal tool for the quantum simulation of a large class of many-body effects, for quantum information processing, controlled ultracold chemistry, and quantum metrological applications. We report on our experiments that identified the ground state of bosonic heteronuclear dimers of <sup>6</sup>Li and <sup>40</sup>K. In the ground state these molecules possess a large permanent electric dipole moment of 3.6 Debye, which makes them a suitable candidate for a quantum gas with long-range anisotropic dipole interaction. Starting from closed channel dominated Feshbach molecules we describe a new spectroscopy route to the ground state that is different from schemes previously used for other alkali heteronuclear dimers. Only strong transitions between molecular spin singlet states are involved avoiding the need to identify suitable perturbed triplet states. We demonstrate how only a sole hyperfine component can be addressed, even if the hyperfine structure is not resolved. Effectively creating a three level system the resulting scheme is the most straight forward to date and takes full advantage of the closed molecular channel that can be discussed by means of the simple asymptotic bound state model for our case. Further, we present results from rotational spectroscopy that facilitates to exploit the high electric dipole moment for use of the molecules as a quantum bit.

MO 15.4 Wed 14:45 S HS 002 Biologie

**Ultracold <sup>23</sup>Na<sup>40</sup>K Ground-State Molecules in a 3D Optical Lattice** — ●MARCEL DUDA<sup>1</sup>, ROMAN BAUSE<sup>1</sup>, SCOTT EUSTICE<sup>1</sup>, FRAUKE SEESSELBERG<sup>1</sup>, XING-YAN CHEN<sup>1</sup>, CHRISTOPH GOHLE<sup>1</sup>, IMMANUEL BLOCH<sup>1,2</sup>, and XIN-YU LUO<sup>1</sup> — <sup>1</sup>Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — <sup>2</sup>Ludwig-Maximilians-Universität, Schellingstraße 4, 80799 München, Germany

Ultracold polar molecules represent an interesting platform to study quantum many-body physics. In contrast to atoms, molecules exhibit a rich rotational and vibrational structure. Additionally, ground-state molecules have a strong permanent electric dipole moment which allows the investigation of spin models beyond nearest-neighbor interactions. In this talk, we will report on the progress of creating a fermionic low entropy gas of <sup>23</sup>Na<sup>40</sup>K ground-state molecules in a three-dimensional optical lattice.

After loading an ultracold mixture of <sup>23</sup>Na and <sup>40</sup>K atoms into the 3D lattice, we produce NaK molecules in the rotational-vibrational ground-state by associating Feshbach molecules from atoms followed by stimulated Raman adiabatic passage. We observe a significantly extended lifetime of NaK molecules in the 3D optical lattice and anticipate an improved Feshbach molecule association efficiency.

With sufficiently high filling and lifetimes of the ground-state NaK molecules in the 3D lattice, it is possible to observe intriguing spin dynamics such as condensate of rotational excitations or anisotropic propagation of spin waves.

MO 15.5 Wed 15:00 S HS 002 Biologie

**Reaction and Spectroscopy Studies of Astrophysically Relevant Anions in Multipole Traps** — ●MARKUS NÖTZOLD, ROBERT WILD, MALCOLM SIMPSON, THOMAS ZURIN, and ROLAND WESTER — Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Austria

Multipole ion traps are versatile tools for the study of cold molecular ions. After the radioastronomical discovery of the first interstellar anions, interest has grown in understanding the formation and destruction pathways of negative ions in the interstellar medium (ISM). Our group has previously performed photodetachment studies on C<sub>n</sub>H<sup>-</sup> [1], CN<sup>-</sup> and C<sub>3</sub>N<sup>-</sup> anions [2], and recently begun to study the three-body recombination mechanism H<sub>2</sub> + H<sup>-</sup> + X ⇒ H<sub>3</sub><sup>-</sup> + X. We report on progress and the current status of these experiments. In addition to the foregoing, our group is currently developing a new multipole wire trap for our setup. We present the main features of this improvement compared to our existing 22-pole trap.

[1] T. Best, R. Otto, S. Trippel, P. Hlavenka, A. von Zastrow, S. Eisenbach, S. Jézouin, R. Wester, E. Vigrén, M. Hamberg, *Astrophys. J.* 742, (2011).

[2] S. S. Kumar, D. Hauser, R. Jindra, T. Best, Š. Roučka, W. D. Geppert, T. J. Millar, and R. Wester, *Astrophys. J.* 776, (2013).

MO 15.6 Wed 15:15 S HS 002 Biologie

**A Cold and Slow Molecular Beam of Barium Monofluoride** — ●RALF ALBRECHT, MICHAEL SCHARWAECHTER, TOBIAS SIXT, and TIM LANGEN — 5. Physikalisches Institut und Center for Integrated Quantum Science and Technology IQST, Universität Stuttgart

We report on our progress towards 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.

In our experiment, molecules are generated through laser ablation of a sintered precursor target inside a cryogenic cell. Subsequently, the initially ~ 10<sup>4</sup> K hot molecules are precooled to the few Kelvin regime by collisions with a cold buffer gas of helium atoms. The precooled molecules exit the cell through a millimeter-sized aperture and enter a room-temperature high-vacuum region, where they form a cold and intense molecular beam. We present measurements characterizing this beam using laser-induced fluorescence and outline our strategy for future laser cooling.

MO 15.7 Wed 15:30 S HS 002 Biologie

**Cold beam of water dimer** — •HELEN BIEKER<sup>1,2,4</sup>, JOLIJA ONVLEE<sup>1</sup>, MELBY JOHNY<sup>1</sup>, LANHAI HE<sup>1,5</sup>, THOMAS KIERSPEL<sup>1,2,4</sup>, BORIS SARTAKOV<sup>3</sup>, ANDREY YACHEMENEV<sup>1</sup>, SEBASTIAN TRIPPEL<sup>1,3</sup>, DANIEL A. HORKE<sup>1,2</sup>, and JOCHEN KÜPPER<sup>1,2,4</sup> — <sup>1</sup>Center for Free-Electron Laser Science, DESY — <sup>2</sup>The Hamburg Center for Ultrafast Imaging, University Hamburg — <sup>3</sup>General Physics Institute, Russian Academy of Sciences — <sup>4</sup>Department of Physics, University of Hamburg — <sup>5</sup>Institute of Atomic and Molecular Physics, Jilin University, Changchun, China

To unravel the microscopic details of intermolecular interactions in water, we prepared controlled samples of size- and isomer-selected water clusters. Inhomogeneous electric fields allowed us to create pure samples of individual structural isomers or of size-selected molecular clusters and to disperse molecules in a beam according to their quantum states [1].

Here, we aim to develop an understanding of the structures of water clusters containing a few monomer units. We present our first results on the production of size-selected samples using supersonic expansions - subsequent separation of water dimer, extending previous studies.

[1] Y.P. Chang, D. A. Horke, S. Trippel and J. Küpper, *Int. Rev. Phys Chem.* **34**, 557-590 (2015)

MO 15.8 Wed 15:45 S HS 002 Biologie

**Manipulation of molecular hydrogen on a chip to study**

**cold collisions with a merged beam apparatus** — •KATHARINA HÖVELER<sup>1</sup>, JOHANNES DEIGLMAYR<sup>2</sup>, PITT ALLMENDINGER<sup>1</sup>, JOSEF AGNER<sup>1</sup>, HANSJÜRGEN SCHMUTZ<sup>1</sup>, and FRÉDÉRIC MERKT<sup>1</sup> — <sup>1</sup>Laboratorium für Physikalische Chemie, ETH Zürich, 8093 Zurich, Switzerland — <sup>2</sup>Felix-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  $E_{\text{coll}}/k_{\text{b}} = 0.3 - 50$  K. To reach such low collision energies, we use a merged-beam approach and substitute the  $\text{H}_2^+$  reactants by the ionic cores of  $\text{H}_2$  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  $\text{H}_2$  molecules excited to high- $n$  Rydberg-Stark states and to merge it with a supersonic beam containing ground-state  $\text{H}_2$  molecules. The collision energy is tuned by varying the temperature of the valve generating the  $\text{H}_2$  ground-state beam for selected velocities of the deflected  $\text{H}_2$  beam. The reaction cross section is found to follow the classical Langevin capture model down to  $E_{\text{coll}}/k_{\text{b}} = 5$  K. At lower temperatures, a deviation is observed and attributed to ion-quadrupole long-range interactions. Investigation of the reaction  $\text{H}_2^+ + \text{D}_2$  enables us to distinguish between charge transfer, D atom transfer and  $\text{H}^+$  ion transfer and to determine the ratio of the two competing reaction channels leading to the product ions  $\text{H}_2\text{D}^+$  and  $\text{D}_2\text{H}^+$ .