MO 21: Astrophysics and Ions

Time: Friday 14:00–16:00 Location: f142

Invited Talk MO 21.1 Fri 14:00 f142

Laboratory experiments as tool to understand the infrared sky at high spectral resolution — •Guido W. Fuchs — Laborastrophysik, Physik Institut, Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

In the universe, chemistry starts when atoms are expelled from the hot inner regions of evolved stars and form molecules in the cooler outer atmospheres and stellar envelopes. Thus, at the end of their lifetime low and intermediate mass asymptotic giant branch (AGB) stars and the more massive red super giants, are building up strong stellar winds which are major sources of small to intermediate sized molecules and dust in the universe. Especially molecules composed of refractory materials like metal atoms, carbon or silicon are crucial for dust formation. To understand these formation processes these precursor molecules need to be observed and identified which can be done at infrared wavelengths using high resolution spectrographs. But in addition, high resolution gas-phase spectra of possible precursor molecules are needed to compare with those from astronomical observations. In our laboratories we study the gas-phase spectra of these kinds of molecules via high resolution infrared spectroscopy. Our experimental setups will be presented and examples of investigated molecules, like TiO, Al_2O and C_3, will be given. In addition, recent observations using the TEXES spectrograph on the infrared telescope IRTF observations will be shown. Examples are the late-type stars, Canis Majoris, o-ceti (Mira) and others. The observational and experimental results will be related and discussed.

MO 21.2 Fri 14:30 f142

Rotational state selective electron recombination of CH^+ molecules — •Daniel Paul[1], Klaus Blaum[1], Sebastian George[1,2], Jürgen Göck[1], Manfred Grieser[1], Florian Grussie[1], Robert von Hahn[1], Naman Jain[1], Ábel Kálosi[1], Claude Krantz[1], Holger Kreckel[1], Christian Meyer[1], Damian Müll[1], Oldřich Novotný[1], Felix Nuesslein[1], Sunny Saurabh[1], Daniel W. Savin[3], Viviane C. Schmidt[1], Xavier Urbain[4], Patrick Wilhelm[1], and Andreas Wolf[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]University of Greifswald, Germany — [3]Columbia University, New York, NY, USA — [4]Institute of Condensed Matter and Nanosciences, UCLouvain, Belgium

Molecular cations in the interstellar medium (ISM) are used to trace the properties of diffuse interstellar clouds, out of which stars and planets are formed. These cations can be destroyed by dissociative recombination (DR) with electrons. Laboratory studies of DR are needed to understand molecular evolution in space. Here we have studied DR of CH^+, which is of particular interest for diffuse cloud observations. In the electrostatic cryogenic storage ring CSR, CH^+ ions in lowest rovibrational states can be stored for DR studies at ISM-relevant conditions. Using merged ion and electron beams with a recently implemented electron cooler, low energy (meV) collisions can be studied. Here, we report on rotational state selective DR rate coefficient measurements of the CH^+ ion. In addition, final state branching ratios and angular fragmentation characteristics were observed.

MO 21.3 Fri 14:45 f142

Electron Recombination Studies of TiO^+ molecules — •Naman Jain[1], Klaus Blaum[1], Sebastian George[1,2], Jürgen Göck[1], Manfred Grieser[1], Florian Grussie[1], Robert von Hahn[1], Ábel Kálosi[1], Holger Kreckel[1], Damian Müll[1], Oldřich Novotný[1], Felix Nuesslein[1], Daniel Paul[1], Sunny Saurabh[1], Viviane C. Schmidt[1], Albert A. Viggiano[3], Patrick Wilhelm[1], and Andreas Wolf[1] — [1]Max Planck Institute for Nuclear Physics, Heidelberg, Germany — [2]University of Greifswald, Greifswald, Germany — [3]AFR Laboratory, New Mexico, USA

The complex chemical processes observed in the gas-phase of interstellar medium (ISM) are majorly based on ion reactions. Dissociative recombination (DR) of molecular ions is a dominant process in such environments that neutralizes the plasma and leads to the fragmentation of molecules. In the ISM, the titanium oxide (TiO^+) cation can be formed by the associative ionization process between atomic titanium and oxygen. The process has been proposed to be responsible for the production of free electrons and severe atomic depletion of Ti in gas phase ISM. The inverse process, DR, is expected to be endothermic, contrary to most other cases. Precise laboratory studies on the DR of TiO^+ are needed for a concrete proof of the reaction energetics, thus elucidating the molecular reaction dynamics. Such experiments are being conducted at the electrostatic Cryogenic Storage Ring (CSR) in similar conditions as in the cold ISM. Here, we report on our initial results of a TiO^+ DR experiment with the electron cooler at CSR.

MO 21.4 Fri 15:00 f142

Direct detection of nuclear scattering of sub-Gev dark matter using molecular excitations — •Jesús Pérez-Ríos[1], Harikrishnan Ramani[2], Oren Slone[3], and Rouven Essig[4] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Berkeley Center for Theoretical Physics, Department of Physics, University of California, Berkeley, California 94720, USA — [3]Princeton Center for Theoretical Science, Princeton University, Princeton, New Jersey 08544, USA — [4]C. N. Yang Institute for Theoretical Physics, Stony Brook University, New York 11794-384, USA

The evidence for the existence of dark matter, which makes up about 85% of the matter density in the Universe, is overwhelming. Efforts to detect galactic dark matter particles in the laboratory are crucial for developing a detailed understanding of the particle nature of dark matter. The past decades have seen tremendous progress in direct-detection searches for Weakly Interacting Massive Particles, which have masses above the proton. However, dark matter with masses below the proton is woefully underexplored, despite being theoretically well-motivated. We propose a novel direct detection concept to search for dark matter with masses in the 100 keV to 100 MeV range. Here, dark matter particles scatter off molecules in a gas and exciting a vibrational and rotational state of the molecule. The excited rovibrational mode relaxes rapidly and produces a spectacular signal consisting of multiple infrared photons, which can be observed with ultrasensitive photodetectors

MO 21.5 Fri 15:15 f142

Towards *para-ortho* conversion in ammonia — •Guang Yang[1,4], Dominic Laumer[2,4], Christoph Heyl[2], Andrey Yachmenev[1,3], Ingmar Hartl[2], and Jochen Küpper[1,3,4] — [1]Center for Free-Electron Laser Science, DESY, Hamburg — [2]DESY, Hamburg — [3]The Hamburg Center for Ultrafast Imaging, Hamburg — [4]Department of Physics, Universität of Hamburg, Hamburg

The spectrum of ammonia can be considered as the combination of the spectra of two distint molecules, *para* and *ortho*, which have different total-nuclear-spin number *I=1/2* and *I=3/2*, respectively, of the three hydrogen atoms. It is considered a good approximation that interconversions of nuclear spin isomers are forbidden. However, weak hyperfine couplings weakly allow the conversion happen.

We present a combined theoretical and experimental study of the hyperfine-resolved spectrum of ammonia. The calculations have been performed using the variational approach TROVE, a new spectroscopically determined potential energy surface, and *ab initio* quadrupole, spin-spin, and spin-rotation coupling surfaces. For the spectroscopic observation of the *para-ortho* conversion, we utilized a mid-infrared frequnecy-comb Fourier-transform spectrometer [2] to perfom first survey scans of the absorption spectrum in the 4 μm region. We investigated the self-broadening and self-shift. Currently, we are optimizing the experimental setup to improve the resolution and sensitivity and search the weak *para-ortho* conversion lines.

[1] S. N. Yurchenko, et al., *J. Mol. Spectrosc.*, **245**, 126 (2007)
[2] V. Silva de Oliveira, et al., *arXiv:1904.02611*, (2019)

MO 21.6 Fri 15:30 f142

Delayed electron detachment and fragmentation of laser-excited Al_4^- clusters — •Felix Nuesslein[1], Klaus Blaum[1], Paul Fischer[2], Sebastian George[2], Jürgen Göck[1], Manfred Grieser[1], Robert von Hahn[1], Oded Heber[3], Ábel Kálosi[1], Stav Knaffo[4], Michael Lembach[5], Yannick Mees[5], Damian Müll[1], Gereon Niedner-Schatteburg[5], Oldřich Novotný[1], Daniel Paul[1], Hilel Rubinstein[3], Sunny Saurabh[1], Viviane C. Schmidt[1], Lutz Schweikhard[2], Raj Singh[3], Yoni Toker[4], Patrick Wilhelm[1], Andreas Wolf[1], and Yitzhak Yonas[4] — [1]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — [2]Universität Greifswald, Institut für Physik, 17487 Greifswald, Ger-

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The Delayed Electron Detachment (DED) and fragmentation of Al_4^- ions were studied in the Heidelberg electrostatic Cryogenic Storage Ring (CSR) [1] by merging nanosecond OPO laser pulses with the stored Al_4^- ion beam in one of the four ∼2.6 m linear, field-free experimental sections. Up to 600 μs after a laser pulse, neutrals due to electron detachment were detected downstream with a MicroChannel Plate (MCP) detector. With a second, movable MCP detector, we observed prompt and delayed fragment events on a 300 μs timescale. To examine DED near the Adiabatic Electron Affinity (AEA∼2.2 eV) of Al_4^-, we varied the photon energy in 5 meV steps from 1.8–2.3 eV. For up to 65 s, cooling of the ions in the extremely low blackbody radiation field of CSR (T_{eff} ∼15 K [2]) was observed. The studies yield insight into the cooling and AEA of the Al_4^- clusters.

[1] von Hahn et al., Rev. Sci. Instrum. 87, 063115 (2016)
[2] Meyer et al., Phys. Rev. Lett. 119, 023202 (2017)

MO 21.7 Fri 15:45 f142

The electronic spectrum of Au_3^+ and $Au_3N_2O^+$ — •Marko Förstel[1], Karim Saroukh[1], Kai Pollow[1], Este A. Najib[1], Alice Green[2], Stuart Mackenzie[2], and Otto Dopfer[1] — [1]Institut für Optik und Atomare Physik, Technische Universität Berlin, Germany — [2]Department of Chemistry, University of Oxford, Oxford, UK

In this talk we present our latest findings on the optical spectra of Au_3^+ and $Au_3N_2O^+$ clusters. By using our recently enhanced setup we are able to record the optical spectra of very dilute targets in a quality that is sufficient to resolve vibrational progressions [1,2]. This allows comparisons to TD-DFT calculations on a hitherto unavailable precision. This is especially interesting in the case of gold, where theoretical models tend to have difficulties due to relativistic effects, spin-orbit coupling, and the participation of d electrons in bonding and charge*transfer effects. Thus our results will lead to a better understanding of electronic structure and the resulting catalytic properties of Au at a molecular level.

[1] M. Förstel et al., Rev. Sci. Instr. 88, 2017
[2] M. Förstel et al., Angew. Chem. Int. Ed. 131, 2019