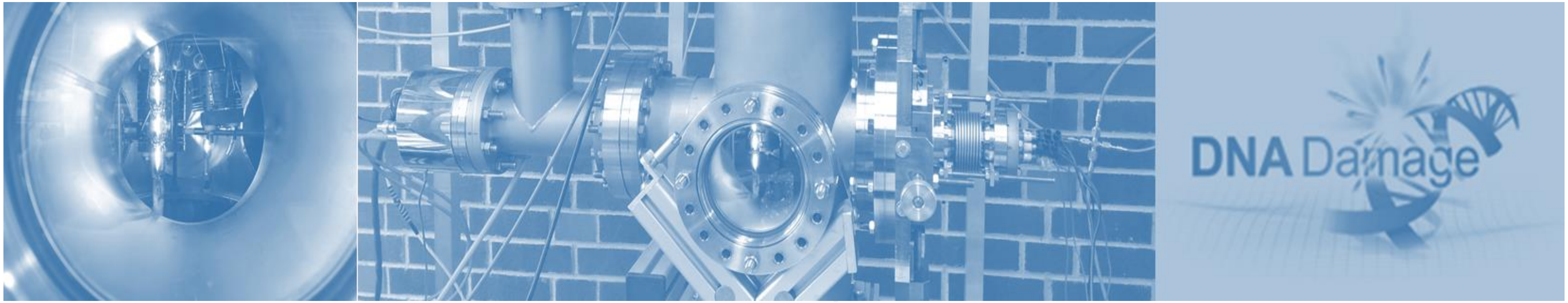
Institut für Ionenphysik und Angewandte Physik

Inelastic Electron Scattering – WG Denifl



Stephan Denifl

About the Inelastic Electron Scattering Group

The Group

- 3 PhD Students and one student coworker.

Research fields

Single molecule studies

- Low-energy electron (E_{kin}<100 eV) interaction with biomolecules, *radiosensitizers* and polymeric compounds

Clusters

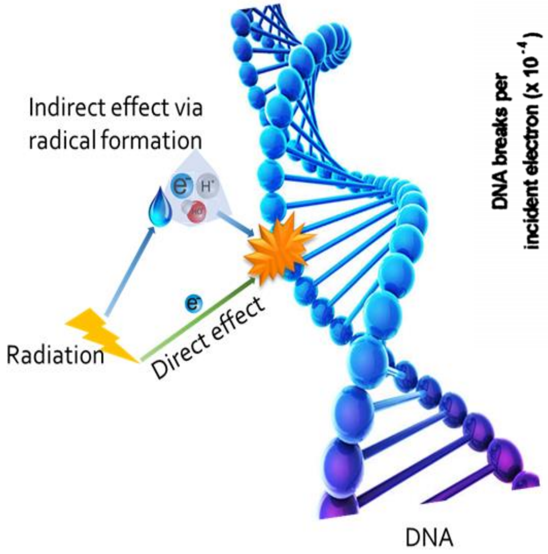
- Rare gas clusters and/or molecular clusters

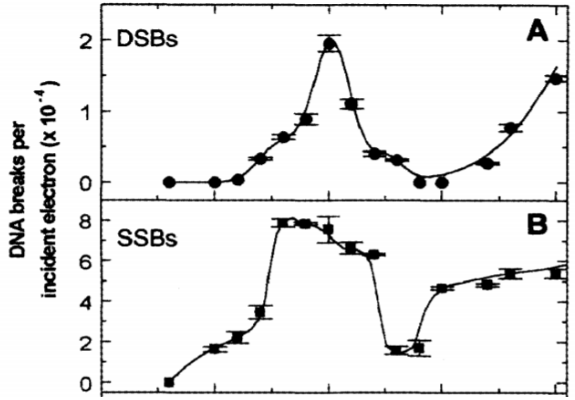
Applications

- Radiation chemistry, astrochemistry, material sciences

Motivation

Chemical effect of radiation and low-energy electrons





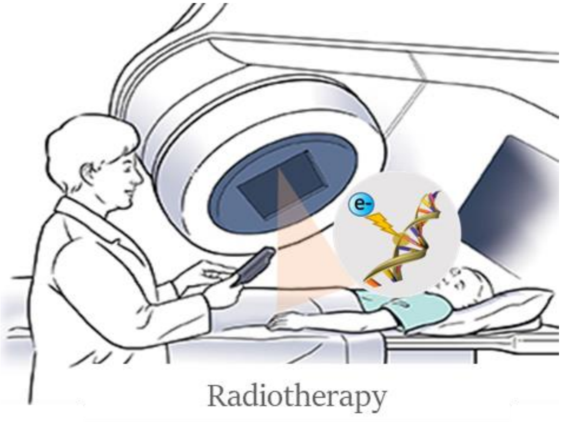
B. Boudaïffa et al., (2000).

SSB – Single Strand Break
DSB – Double Strand Break

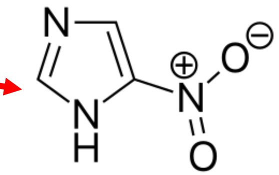
Methods of cancer treatment

Combination Therapy

Radiotherapy + chemotherapy

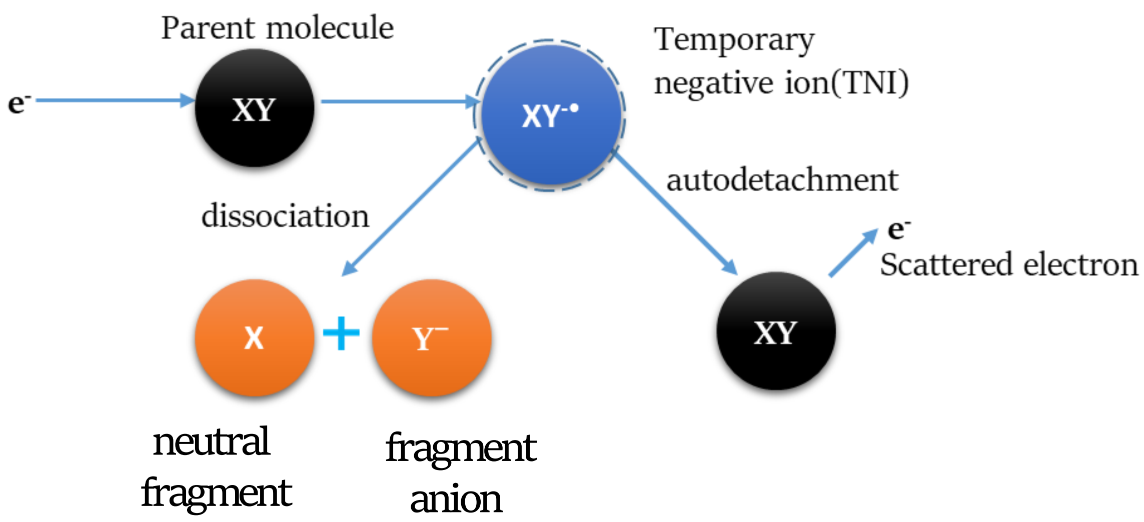


Incorporation of chemical agents



Radiosensitizers

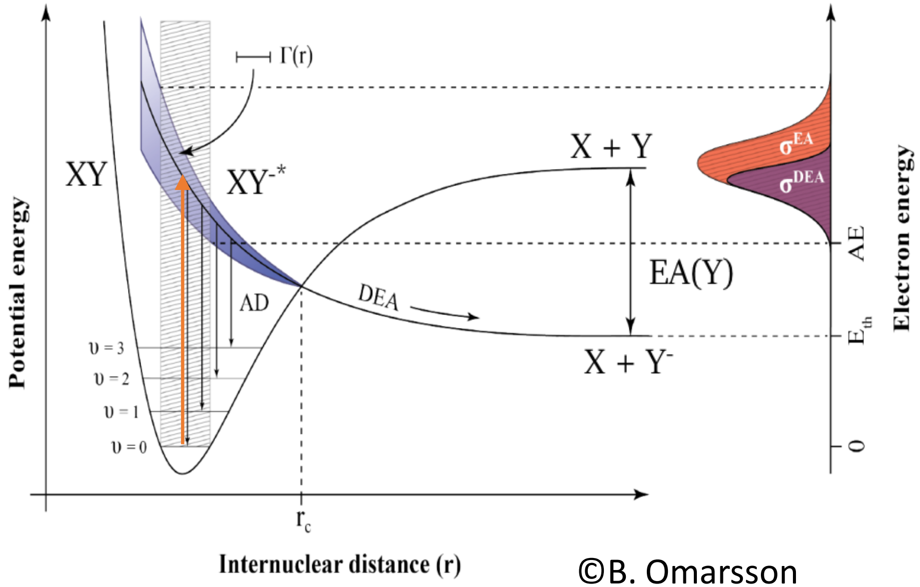
Dissociative Electron Attachment (DEA)



$$e^- + XY \rightarrow XY^{-*} \rightarrow X + Y^-$$

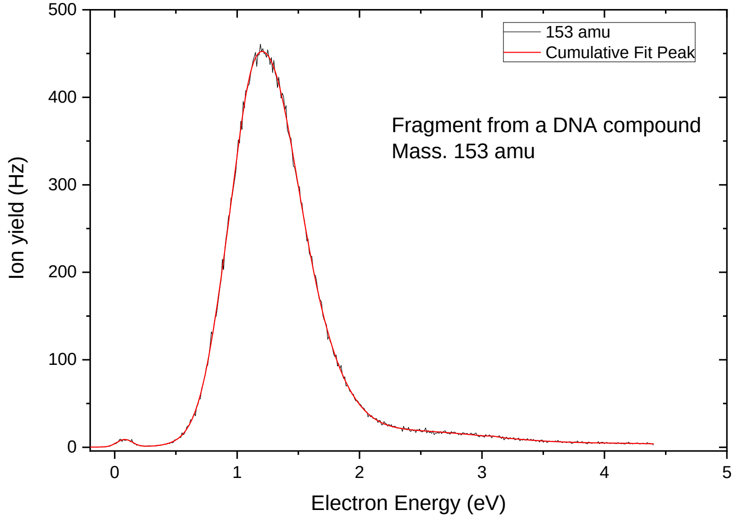
Results in bond cleavages:

Single bond, double bond or complex decompositions into multiple fragments



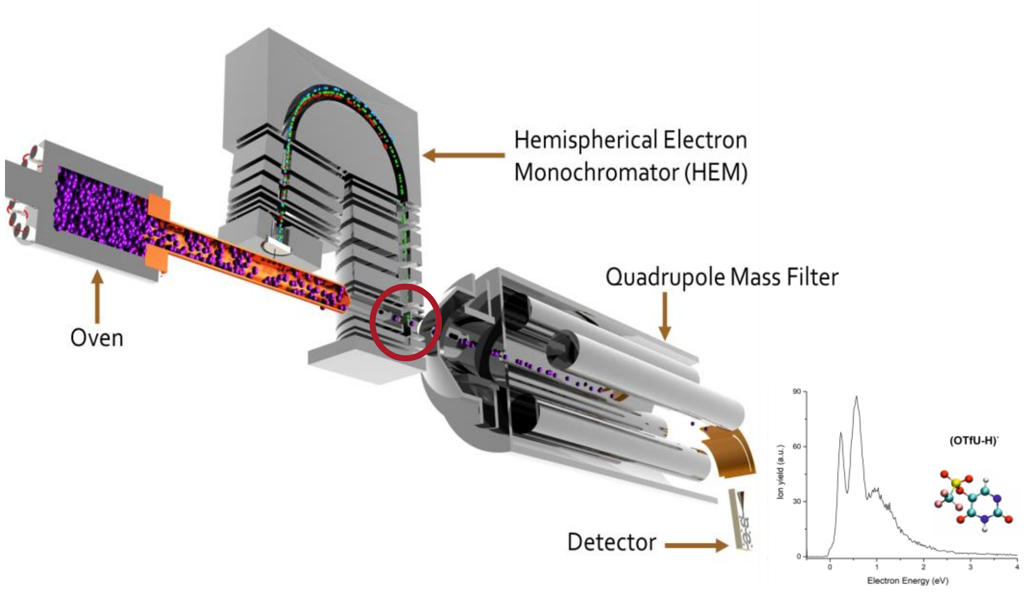
©B. Omarsson

Potential Energy Diagram illustrating electron attachment

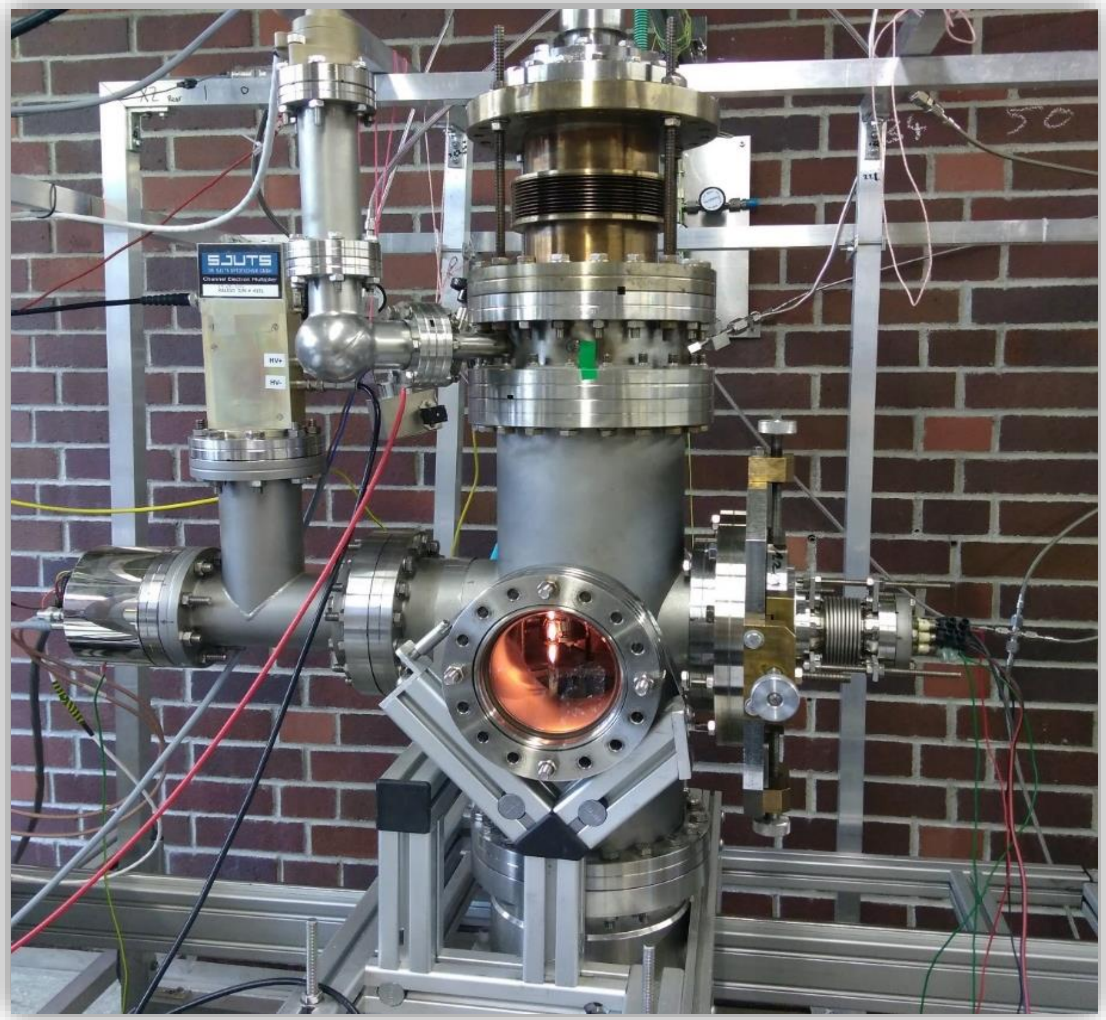


Experimental Setup

Crossed electron-molecular beam setup (WIPPI)

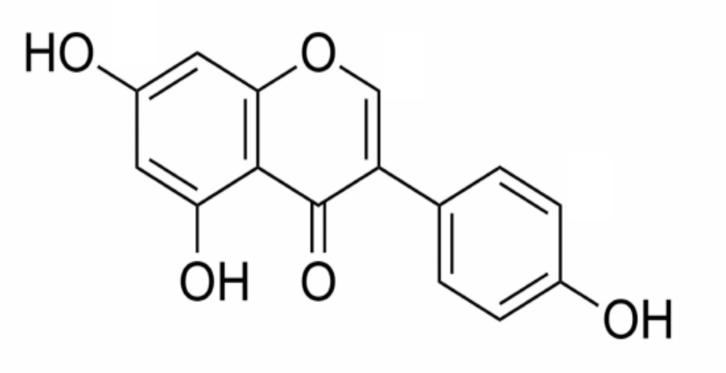


Hemispherical electron monochromator coupled to a quadrupole mass spectrometer in order to detect with high energy resolution (<100meV) the product ions upon inelastic electron interaction.



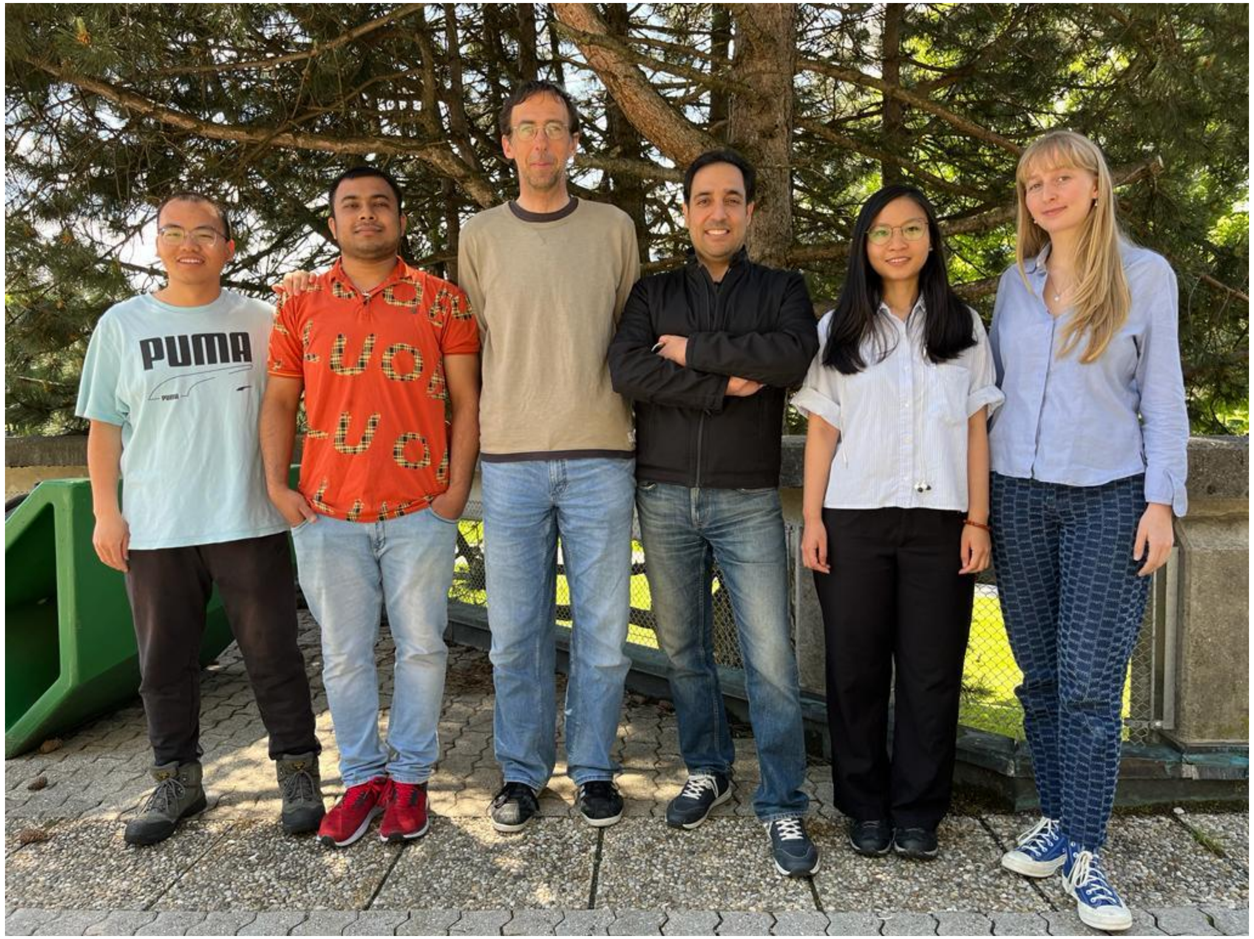
Possible topics in this year

- Experimental work: Electron attachment to a potential anti-cancer compound (genistein).



- Literature review work: Physical/chemical aspects of radiation therapy and the combination with radiosensitizers

Acknowledgement



Thank you for your attention! For further information, please contact me: Stephan.Denifl@uibk.ac.at

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Institut für Ionenphysik
und Angewandte Physik

Chemical Physics

Group of Prof. Martin Beyer

Presentation of Thesis Topics

Manuel Rainer & Sarah Madlener

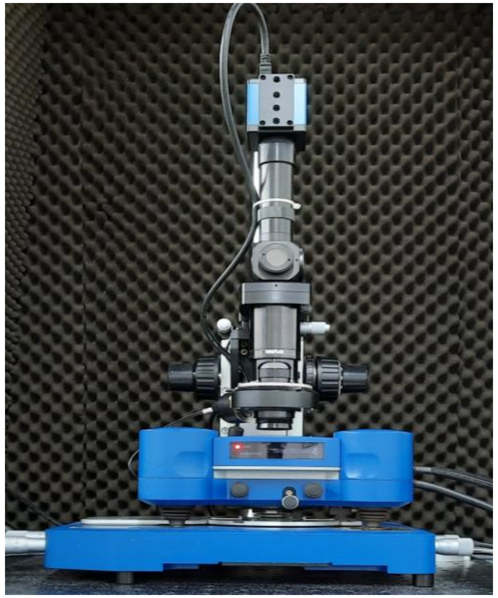
10.01.2024

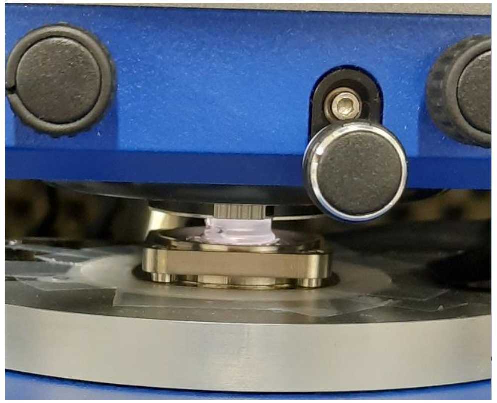
Two types of experiments

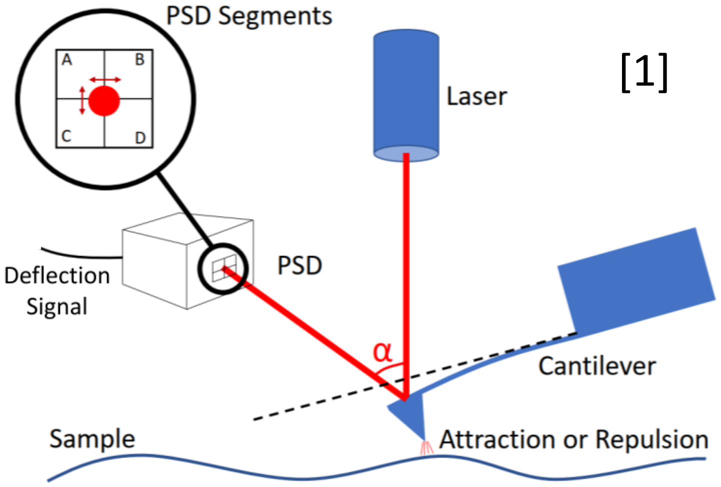
Atomic Force Microscopy (AFM)

Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS)

Atomic Force Microscopy (AFM)

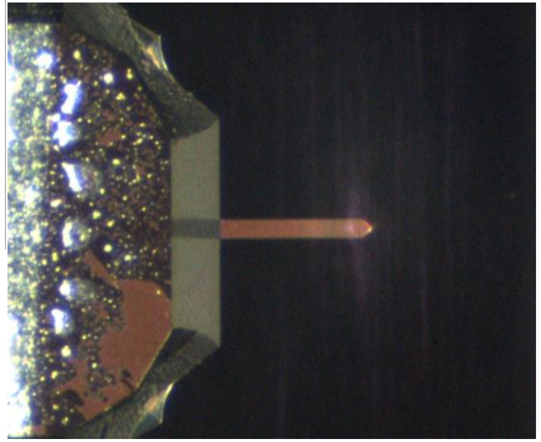


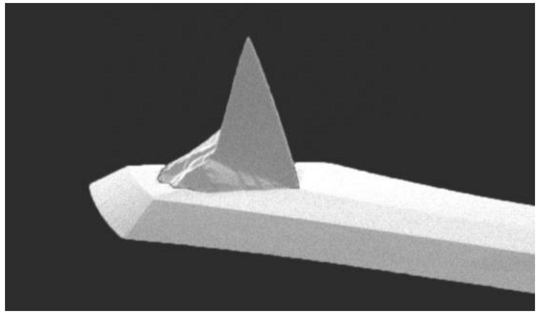




[1]

- Cantilever tip senses over Surface
- Repulsive/attractive Forces → bending of Cantilever
- Detection via deflection of laser beam

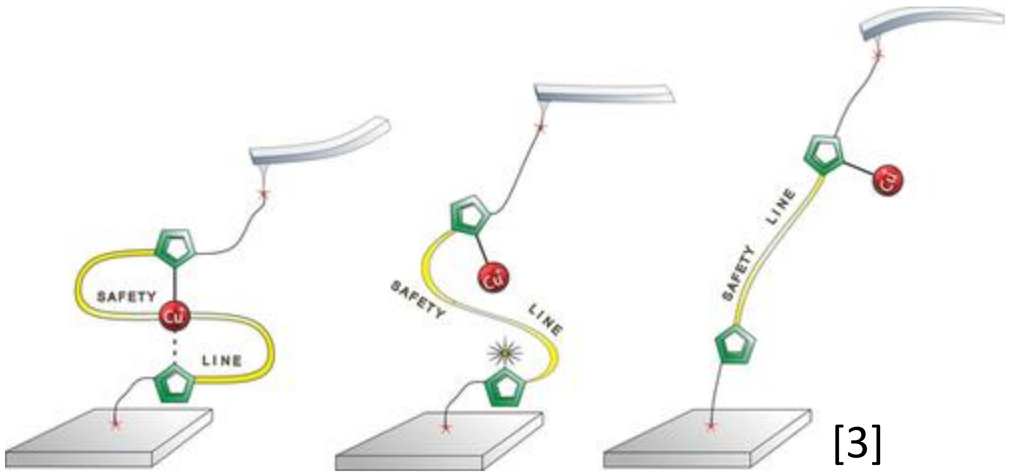


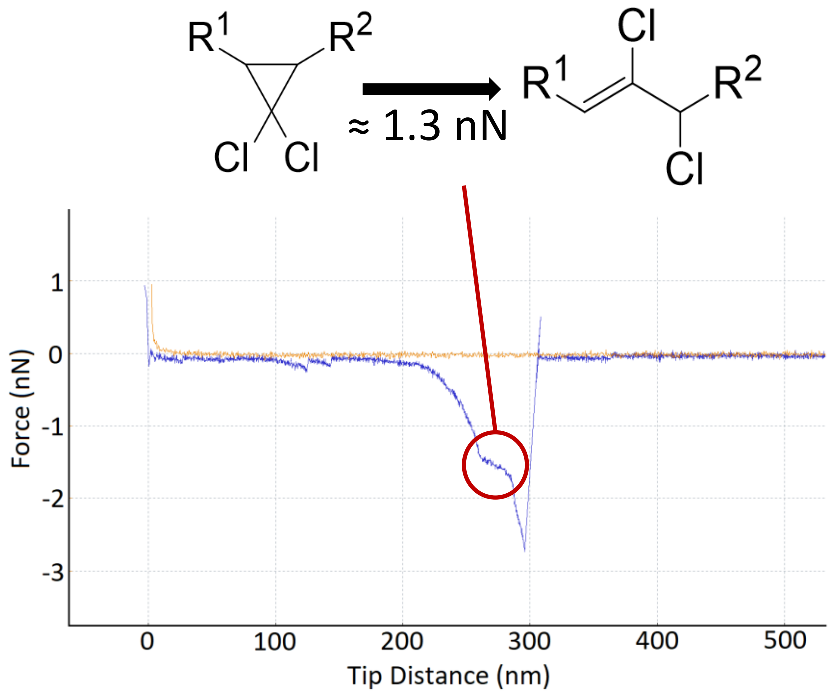


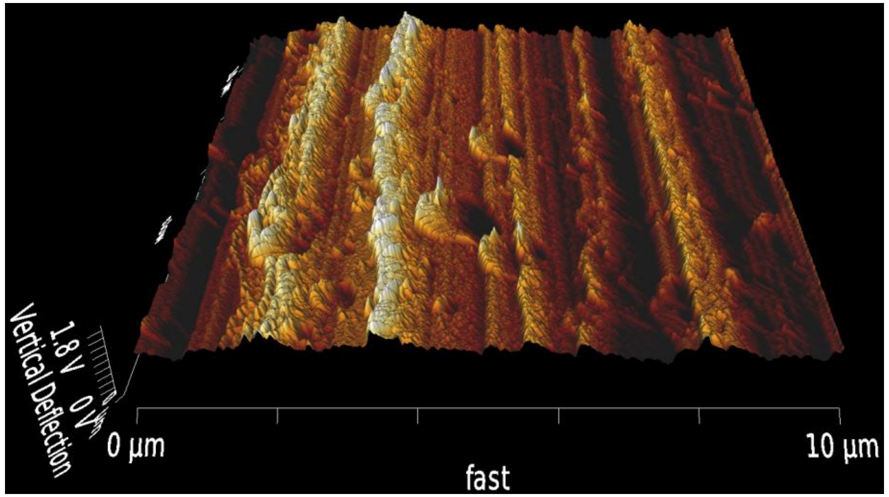
[2]

[1] adapted from JPK handbook version 2.2 https://www.nanophys.kth.se/nanolab/afm/jpk/manuf-manuals/usermanual.4.2.pdf
[2] taken from https://www.spmtips.com/afm-tip-hq-nsc14-hard-al-bs22.12.2023, 22.12.2023

What we measure…







- **S**ingle **M**olecule **F**orce **S**pectroscopy
- How strong is a Covalent Bond?
- Investigate Reaction Kinetics
- Quantum Chemical Simulations
- Make nice Pictures

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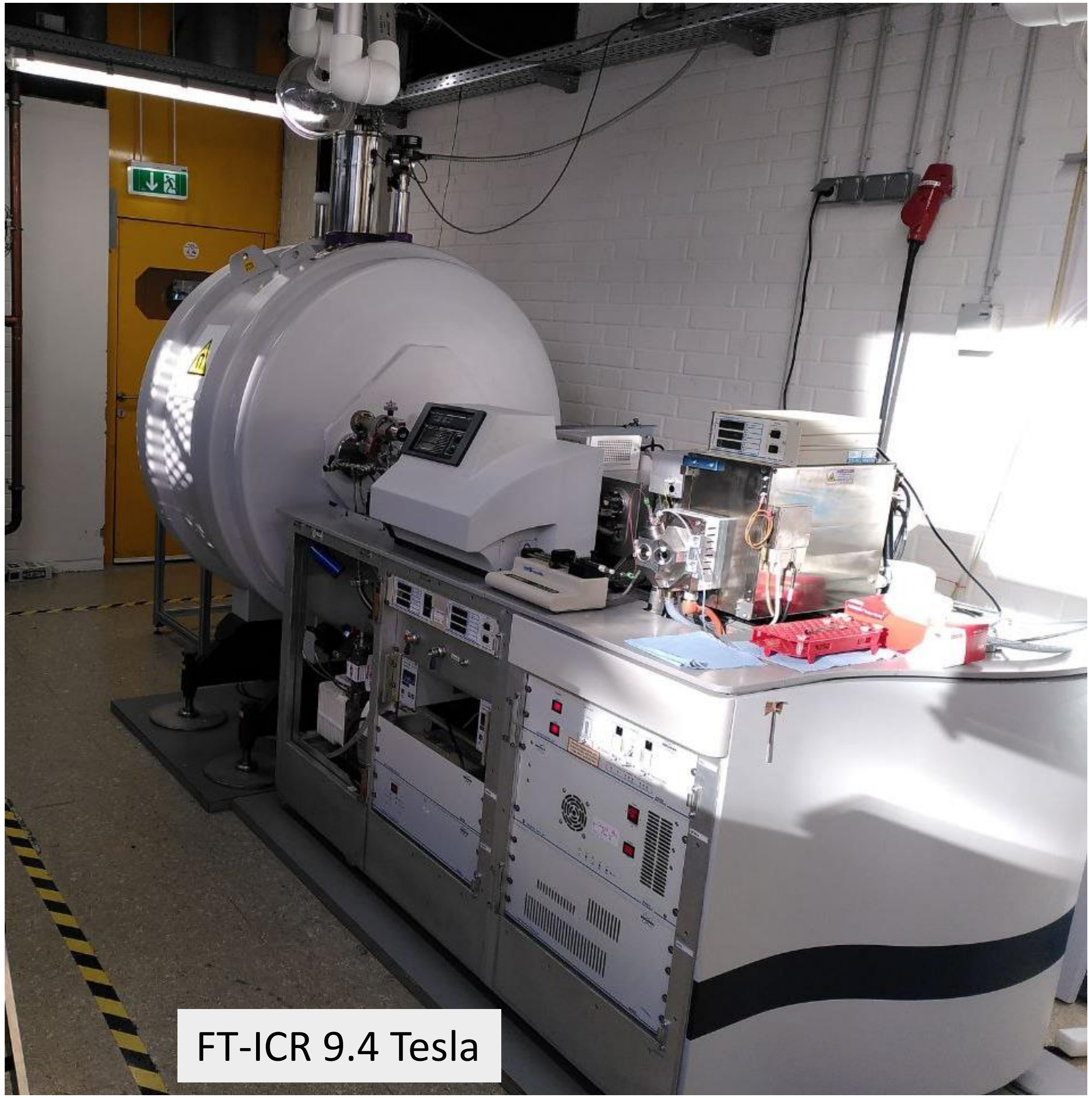
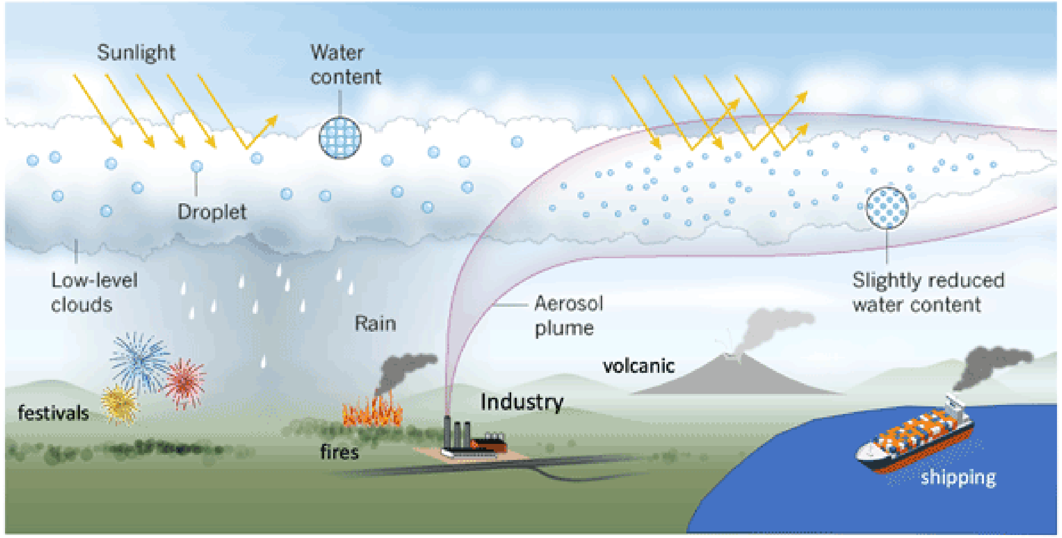
[3] M. S. Sammon, M. Biewend, P. Michael, S. Schirra, M.247Ončák, W. H. Binder, M. K. Beyer, Chem. Eur. J. 2021, 27, 8723.

Experimental setups



Motivation – Impact of Aerosols on Climate



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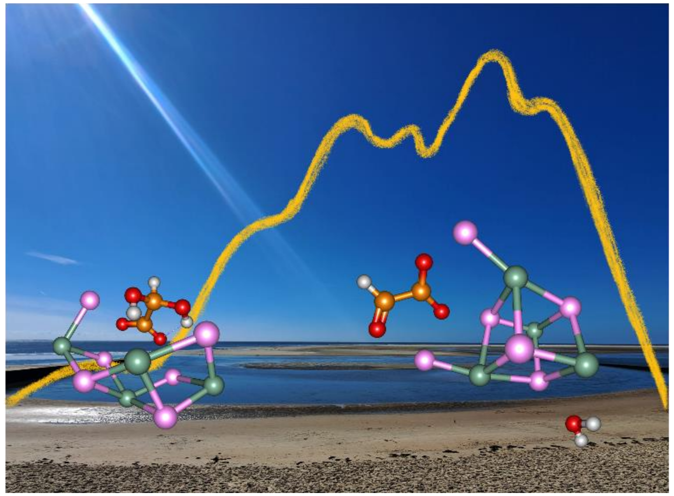
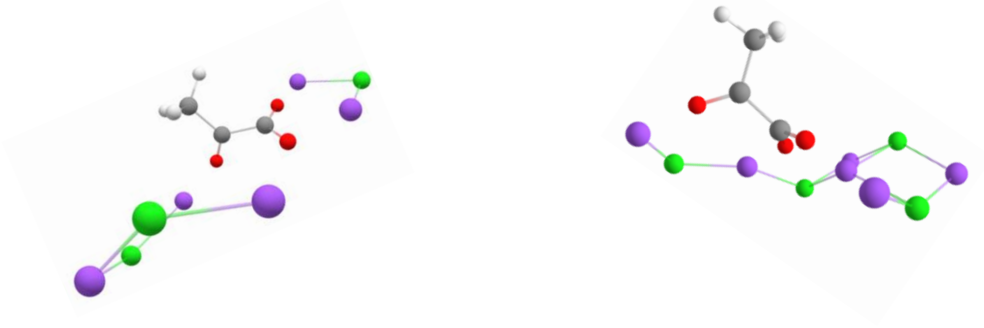
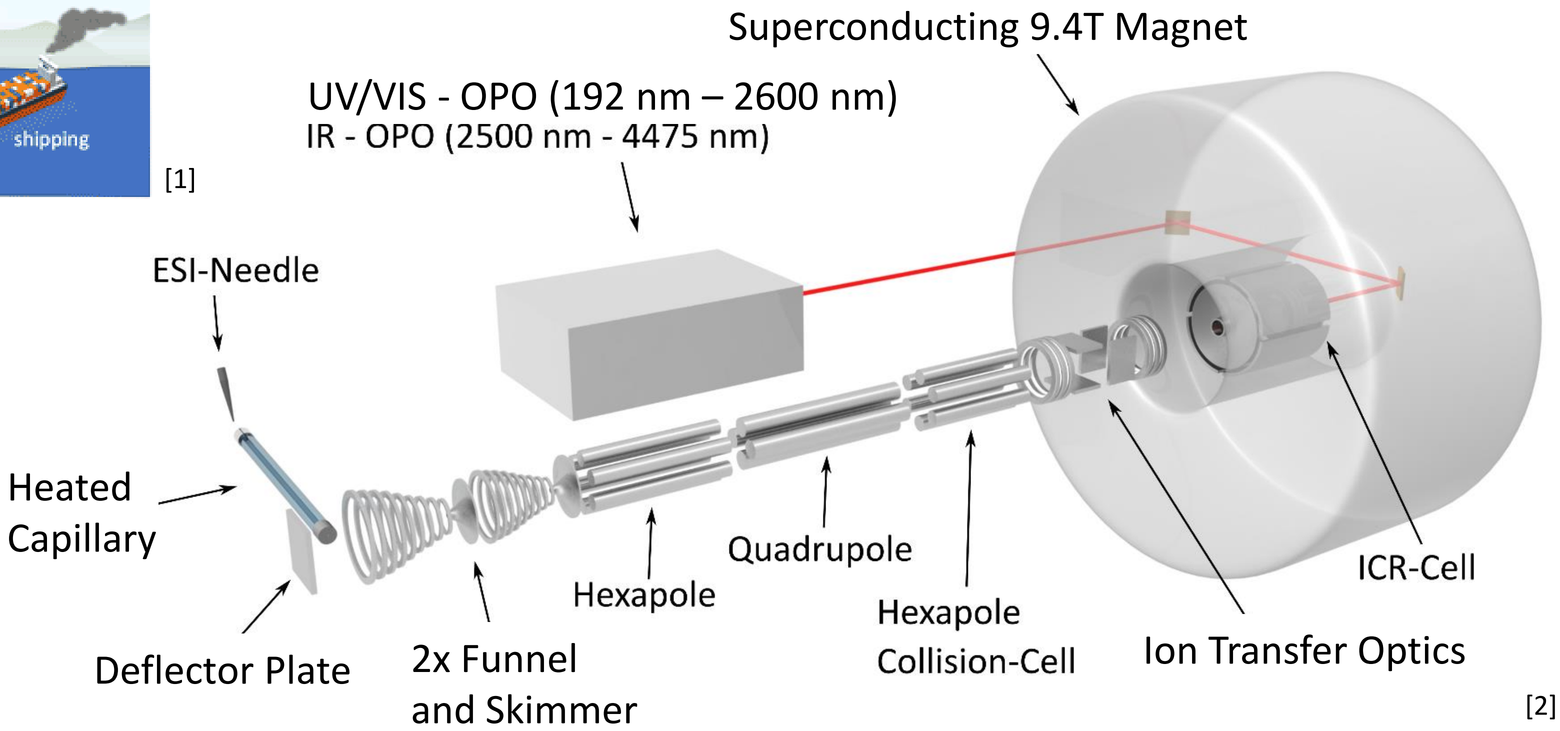


[3]



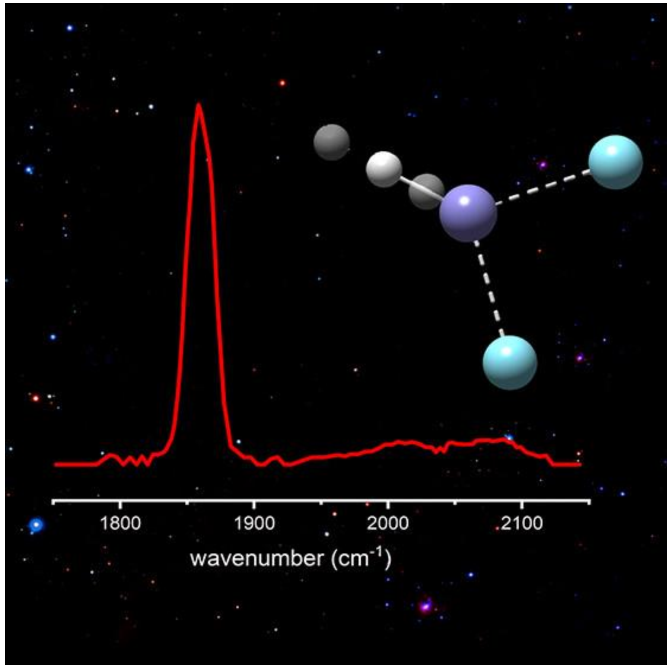


[2]

[1] M.W. Christensen, et al., *Atmos Chem Phys*, 2022, **22**(1), 641.
[2] J. Heller, *Infrared multiphoton dissociation of cesium iodide clusters doped with peptides. Master thesis*, 2017.
[3] N.K. Bersenkowitsch, et al., *Environ. Sci.: Atmos.*, 2023, **3**(10), 1396.

Motivation – Hydrated Metal Complexes

Toward Detection of FeH^+ in the Interstellar Medium



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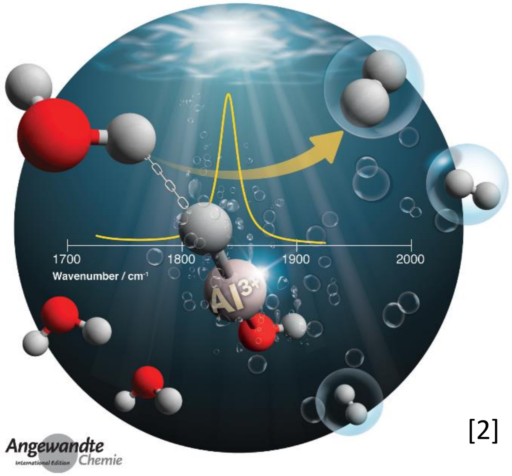
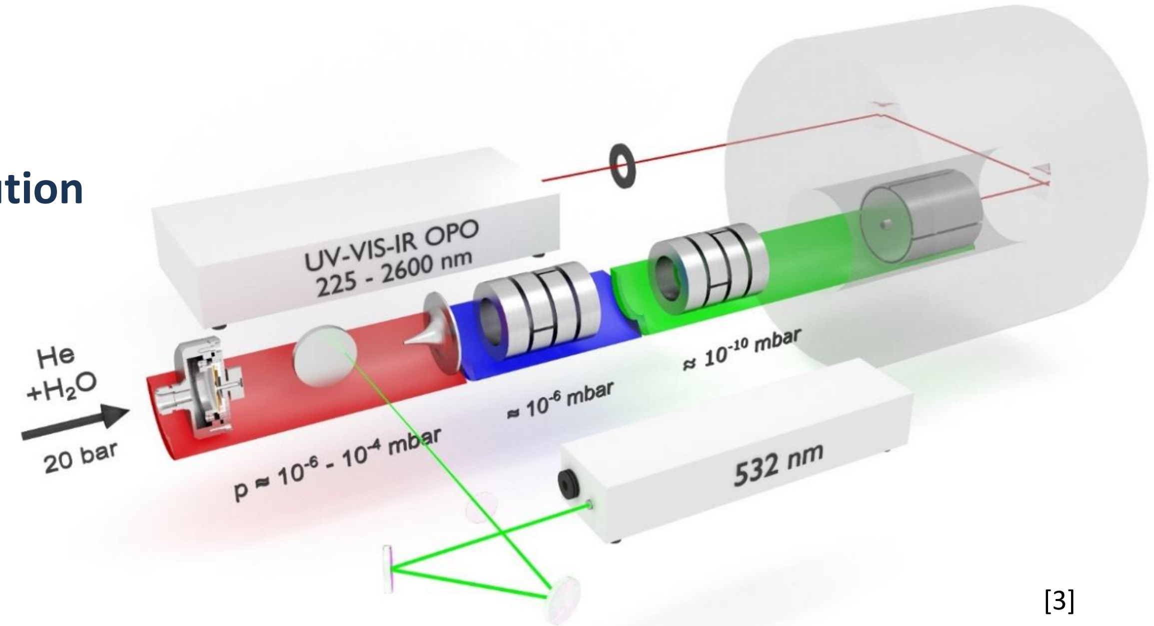


[2]

Photochemical Hydrogen Evolution at Metal Centers



[3]

[1] S. Jin, et al., *J. Phys. Chem. Lett*, 2022, **13**, 5867.
[2] J. Heller, et al., *Chem. - Eur. J.*, 2022, **27**(66), 16367.
[3] J. Heller, *Photochemistry and spectroscopy of hydrated metal ions, M+(H2O)n, M = Al and V. Dissertation*, 2021

Topics for Bachelor Students

- Force spectroscopy of rhodium – alkene bonds
- Photodissociation spectroscopy of $FeOH^+$, a molecular ion that should be present in space
- Reactions of sodium chloride clusters
- Photodissociation spectroscopy of sodium nitrate clusters

Topics for Master Students

- Force spectroscopy of metal complexes with the fly fishing technique
- Photodissociation spectroscopy and photochemistry of $Co(H_2O)_n^-$
- Reactions of hydrated sodium chloride clusters
- Photodissociation spectroscopy and photochemistry of salt clusters

Joint Group Hike with Computational Photophysics

Joint Group Hike with Computational Photophysics

Bachelorarbeit Themen **AG Hansel** **Umweltphysik**

Armin.Hansel@uibk.ac.at

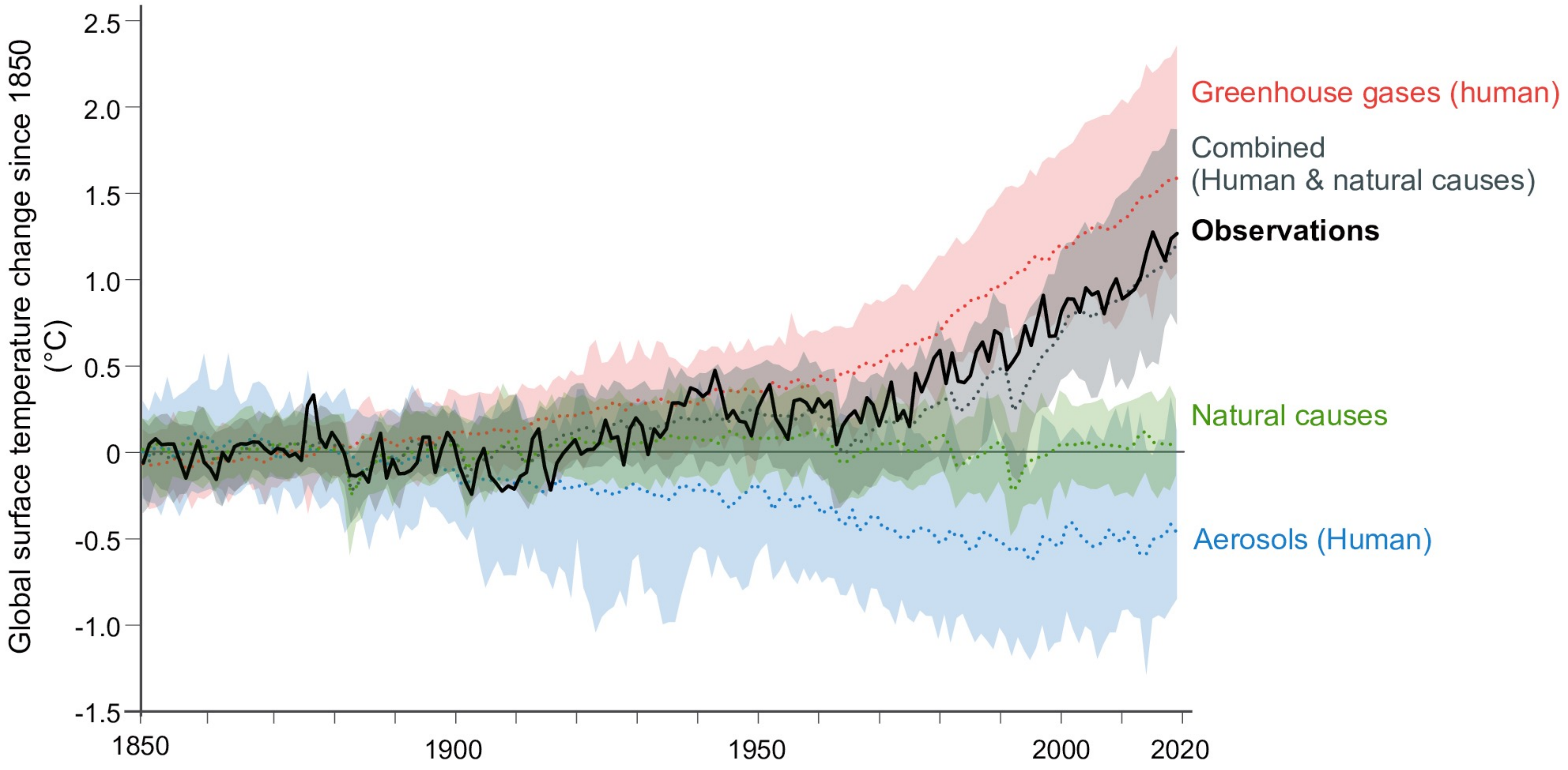
Themen im Zusammenhang mit Erderwärmung

- **Treibhausgase** (wärmender Effekt) CO_2, **CH_4, Ozon**, Lachgas,…
  Quellen – Senken
- **Aerosole** (kühlender Effekt)
  Entstehung von Wolkenkondensationskeimen

Themen im Zusammenhang mit Ultrafeinpartikel (UFP) und Gesundheit

- räumliche / zeitliche Verteilung von UFP
- Quellen / Senken von UFP

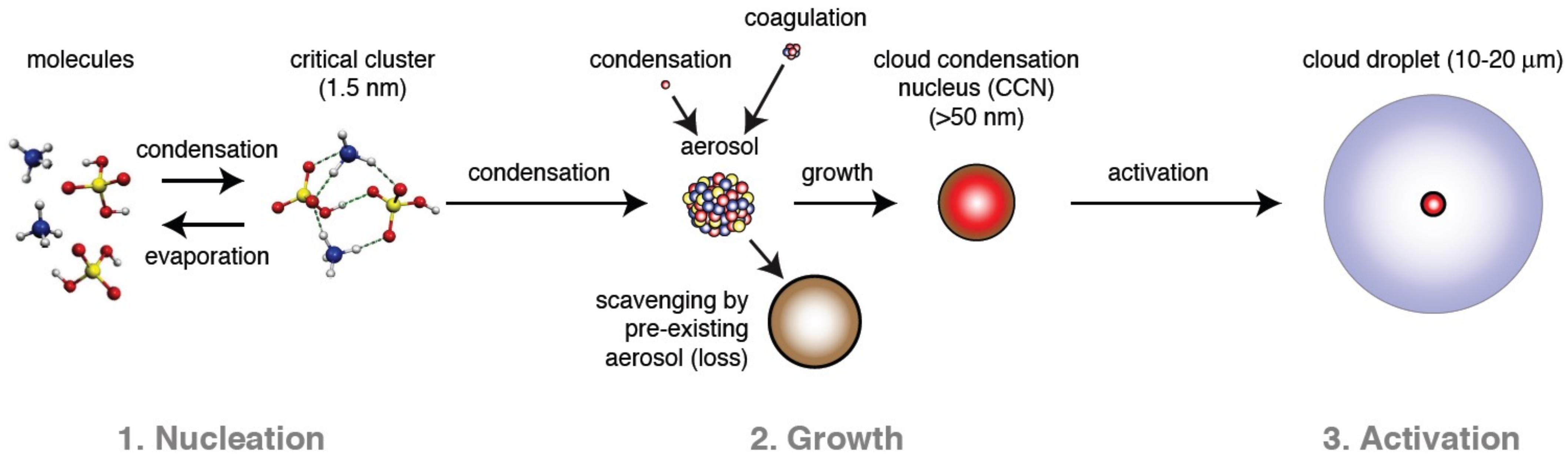
Erderwärmung seit 1850



https://www.ipcc.ch/report/ar6/wg1/

Wie beeinflusst kosmische Strahlung die Wolkenbildung?

Wie entstehen Kondensationskeime für die Bildung von Wolkentropfen?



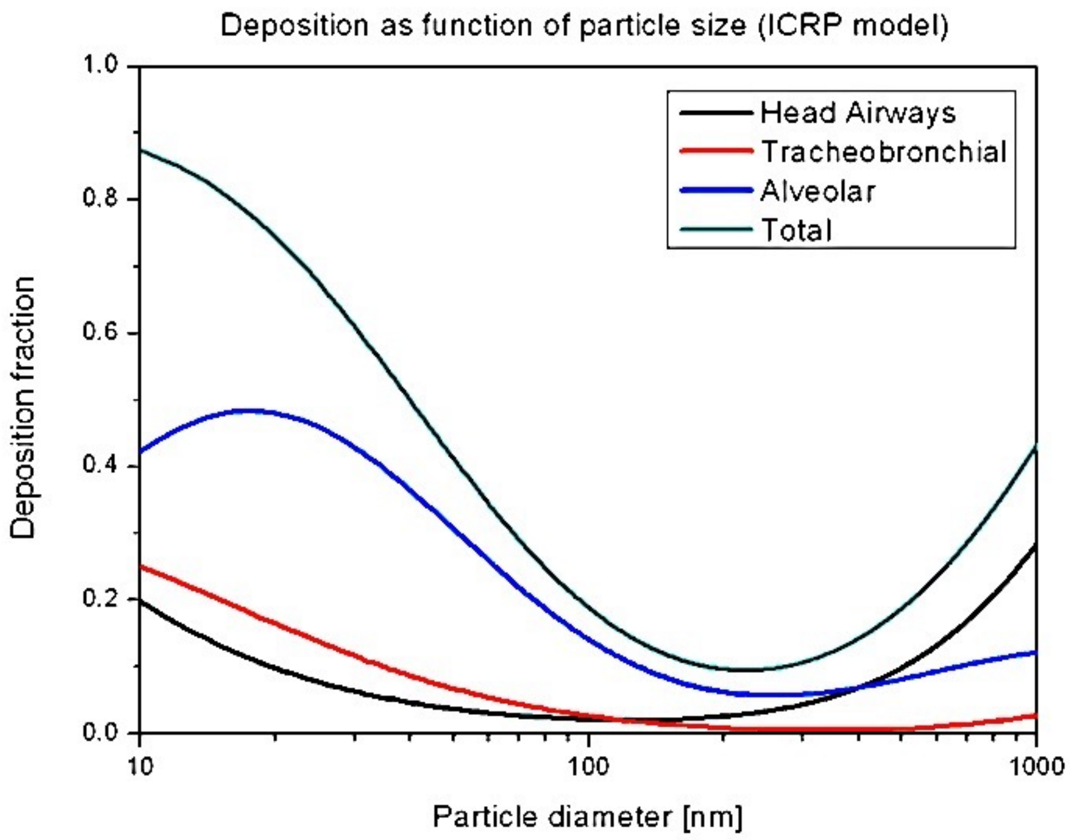
Sind dafür Ionen nötig, die durch kosmische Strahlung gebildet werden?

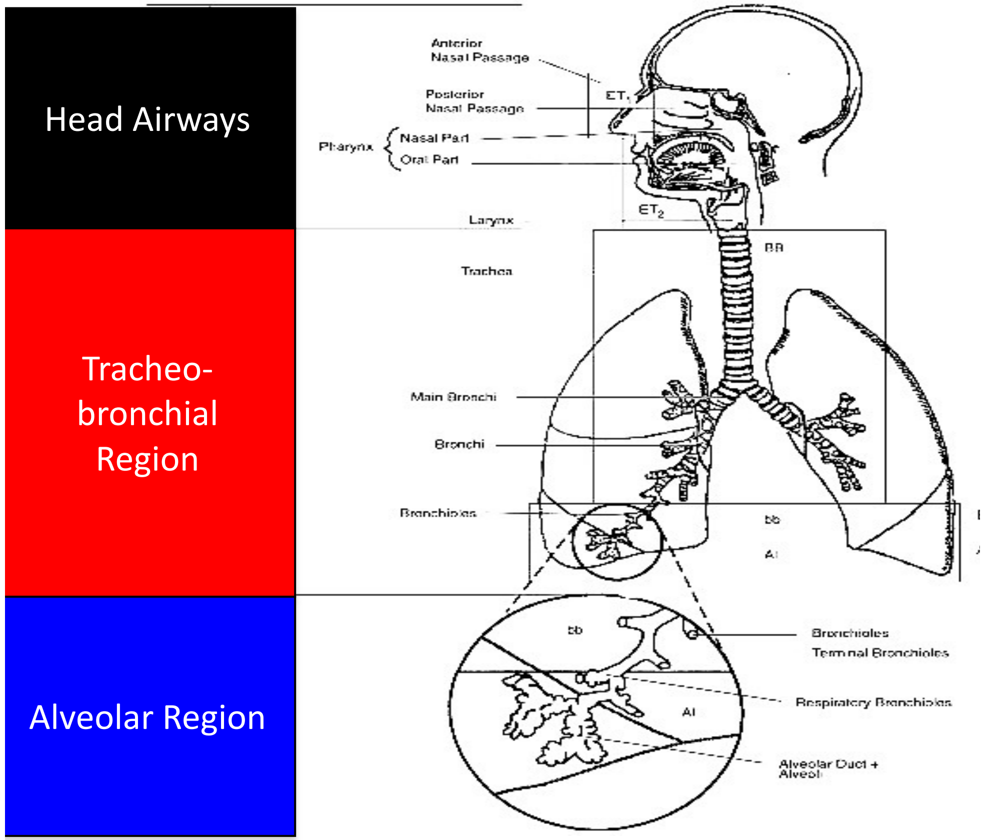
Wie entstehen Kondensationskeime für die Bildung von Wolkentropfen?

- **Beim CLOUD - Experiment am CERN wird die Keimbildung mit Ionen und ohne Ionen untersucht.**

https://home.cern/science/experiments/cloud

Aerosol Particle Deposition as a Function of Particle Size





Ultra Fine Particles < 100 nm

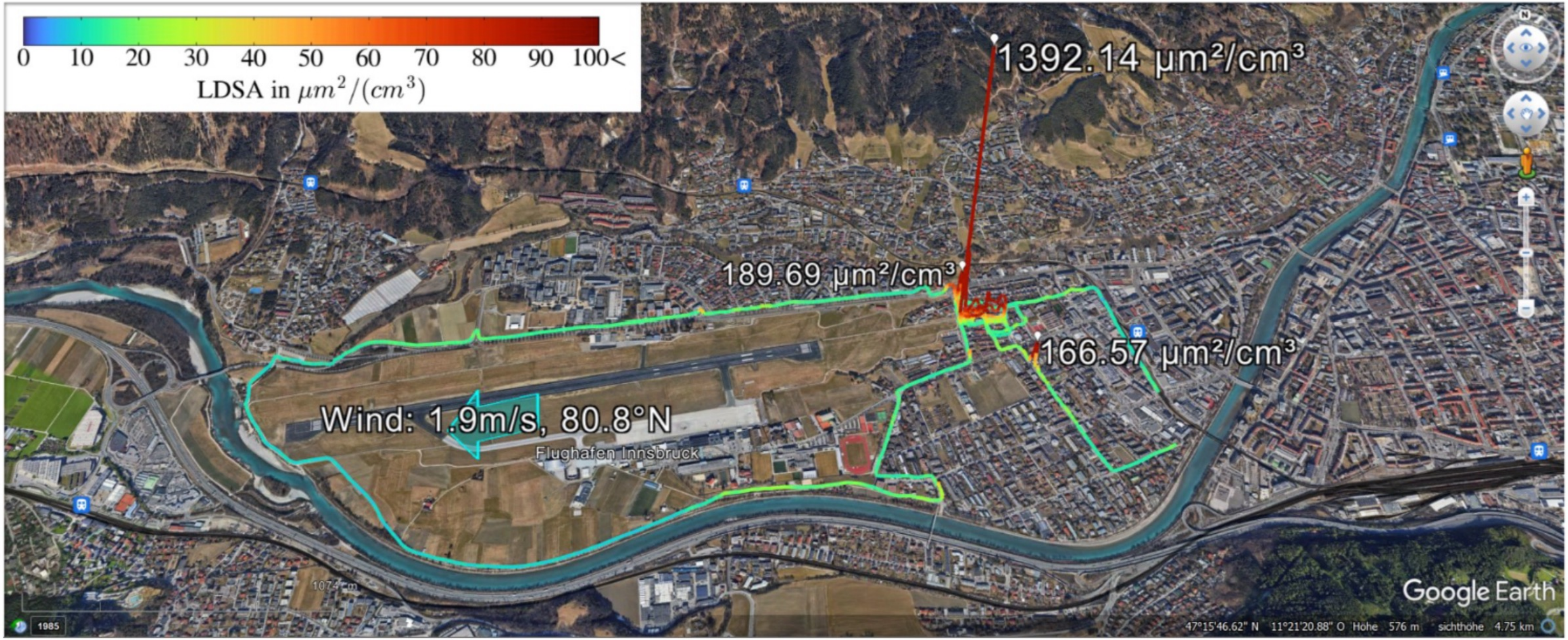
Hofmann W. Journal of Aersol Science 2011 42 p. 692 - 724

Mobile LDSA Measurements

The **Partector*** (NANEOS, Switzerland) with its high **time resolution** of **1 s** is an ideal tool to map out the **spatial distribution** of Lung deposition surface area (**LDSA**) in **Innsbruck** with a **bike** at **different weather** conditions during **Winter** and **Summer** seasons. In total more than **2000 km** were recorded.

* Fierz et al. ***Aerosol Measurement by Induced Currents***, AS&T, 2014

Ulftrafine Particle concentration at Innsbruck airport



https://www.uibk.ac.at/ionen-angewandte-physik/umwelt/sparkling-science-atemluft/index.html.de

Bachelorarbeit Jurij Hartmann

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Institut für Ionenphysik und Angewandte Physik

Computational Photophysics

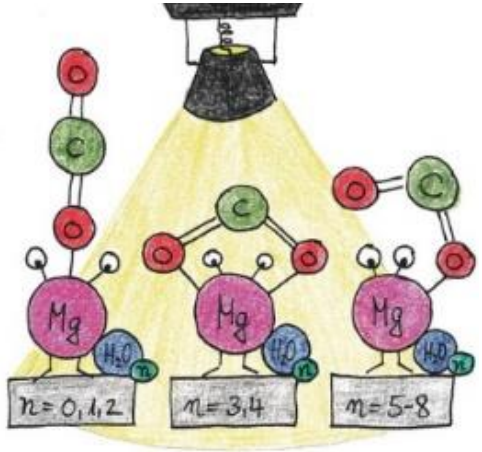
Milan Ončák

Institut für Ionenphysik und Angewandte Physik

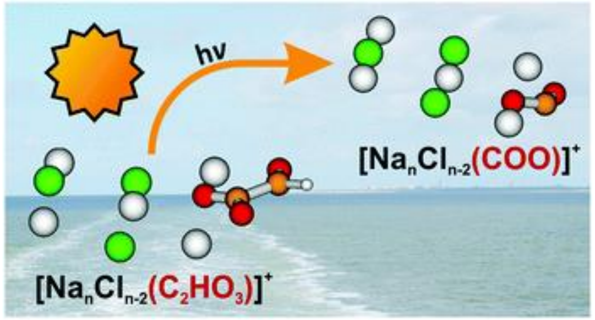
10.1.2024, Bachelorarbeit-Präsentation

Verständnis durch quantenchemische Rechnungen

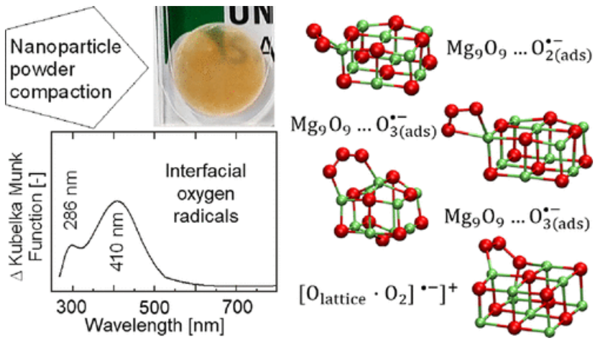
- **CO_2-Capture/Aktivierung**
- **Atmosphärische Physik**
- **Chemische Prozesse auf den Oberflächen**
- **Elektronenanlagerung**
- **Metastabile Moleküle in Helium-Tröpfchen**
- **…**



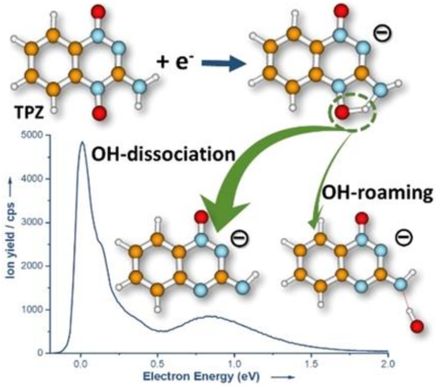
Angew. Chem. Int. Ed. 59, 7467-7471 (2020)
Chem. Eur. J., 29, e202203259 (2023)



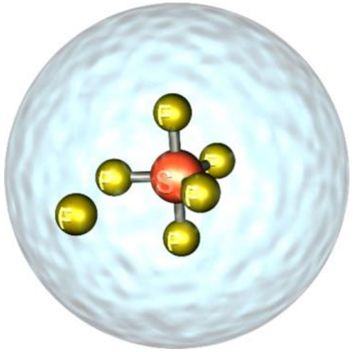
Phys. Chem. Chem. Phys. 20, 8143-8151 (2018)
Env. Science: Atmos., 3, 1396 (2023)



J. Phys. Chem. C, 48, 23332 (2023)

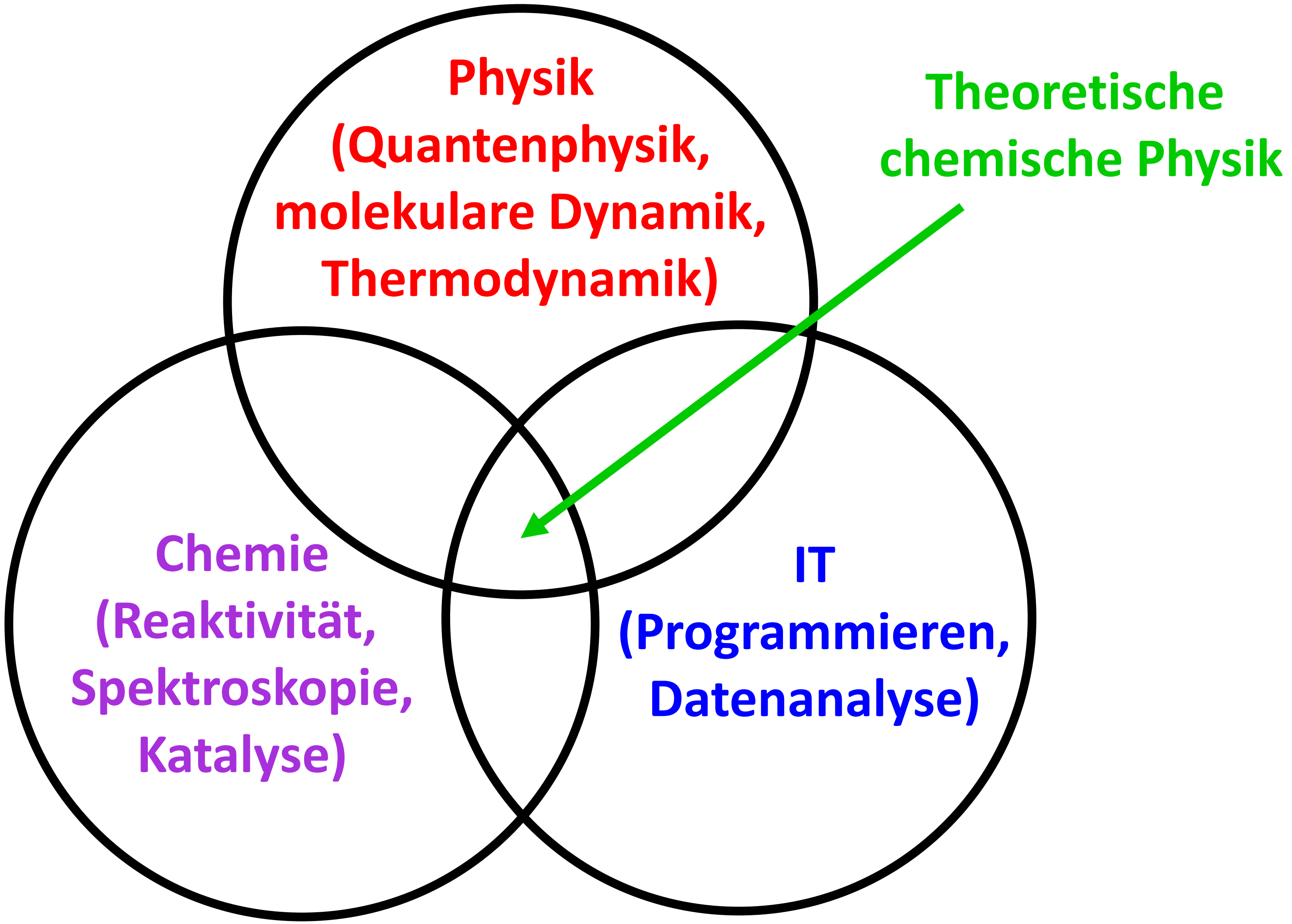


Angew. Chem. Int. Ed., 59, 17177-17182 (2020)

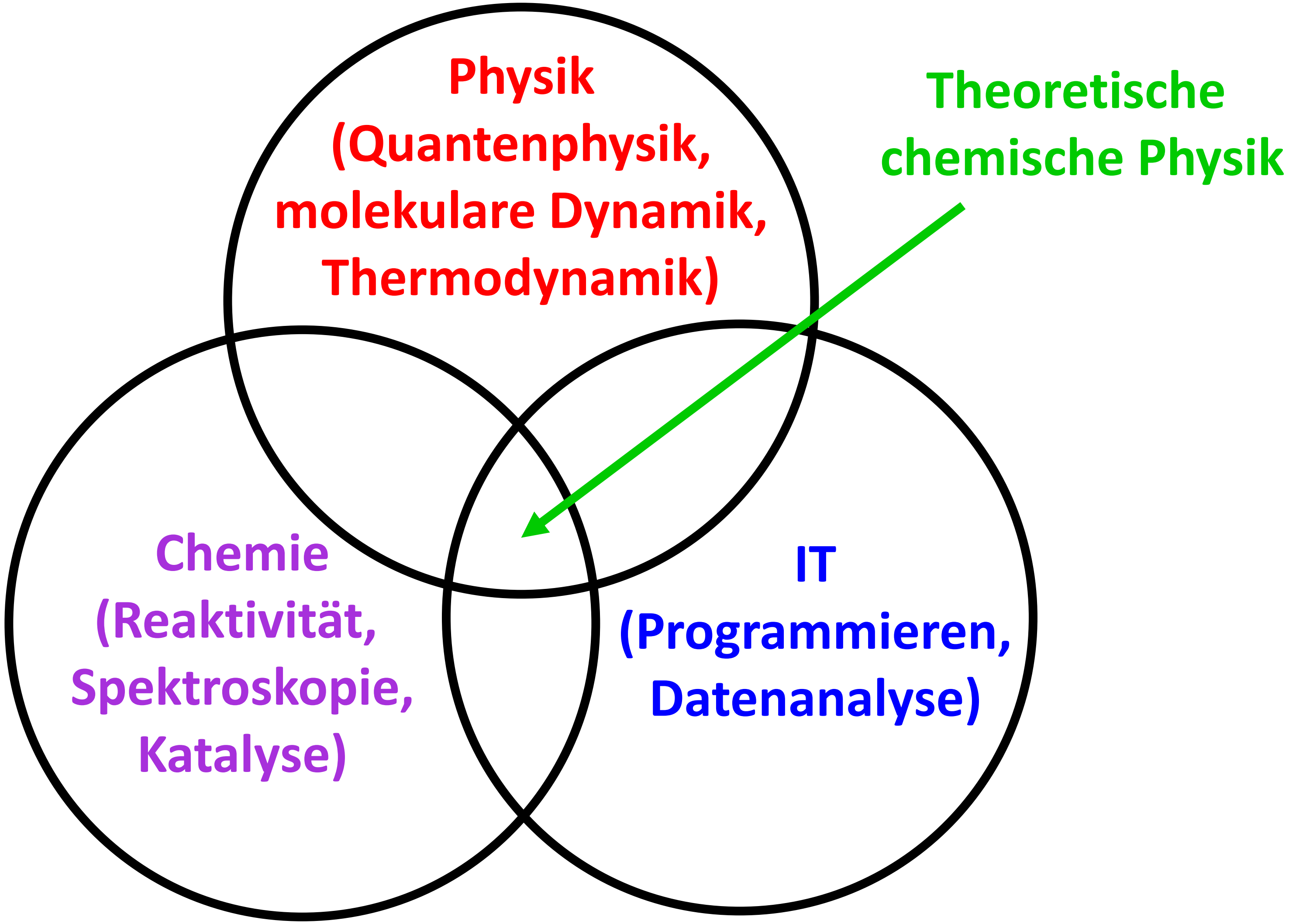


J. Phys. Chem. Lett., 12, 4112–4117 (2021)

Theoretische chemische Physik



Theoretische chemische Physik

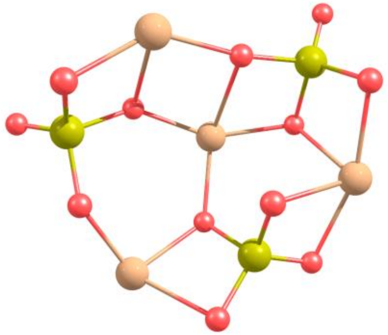



```
$ZRunGauss
%nproc=14
#BLYP/6-31g* scf=xqc DensityFit opt freq

comment

2 1
O 2.512941 -1.671005 1.332481
S 2.859590 -0.958565 0.019818
O 2.861521 0.547767 0.279037
Mg 2.205838 2.247039 -0.215428
O 0.650547 3.206772 0.664220
S -0.400592 2.272419 0.137839
O 0.376747 1.611476 -1.079963
O 4.006325 -1.425428 -0.704969
O 1.477604 -1.271636 -0.761095
Mg -0.188554 -0.339209 -1.199816
O -0.959949 -1.852424 0.176473
S -2.484257 -1.491221 -0.093930
O -3.062284 -0.768880 1.102681
O -2.204566 -0.252419 -1.073976
O -0.734226 1.110248 1.053581
O -1.727298 2.831269 -0.265149
O -3.209540 -2.592617 -0.653979
Mg -2.752237 1.109989 0.457234
Mg 0.776751 -2.430077 0.826812
```

$$\hat{H}_{\mathrm{el}}\Psi = E_{\mathrm{el}}\Psi$$



$[Mg_4(SO_4)_3]^{2+}$

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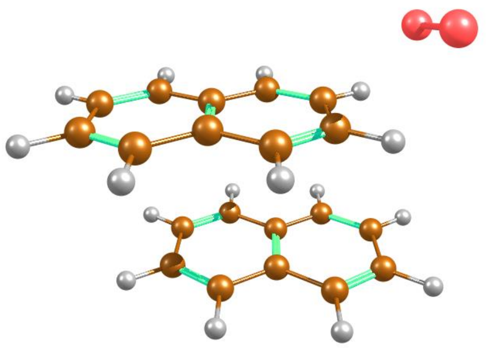
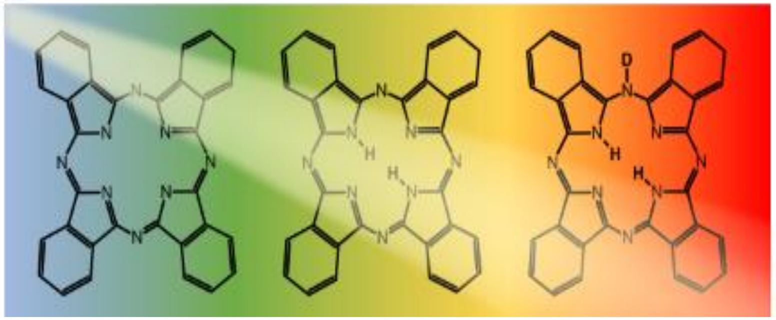
Kontakt: milan.oncak@uibk.ac.at, Raum 3/5
www.uibk.ac.at/ionen-angewandte-physik/photophys/

Angewandte Themen



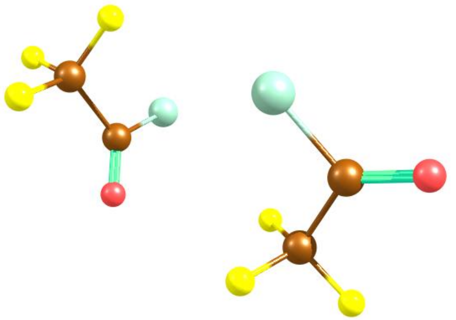
(„Wir haben experimentelle Daten, verstehen diese jedoch noch nicht“)

- **Wie schwierig ist es, ein Elektron auf unreaktiven Molekülen zu fangen?**
  Molekularstrahl-Experimente mit Naphthalin-Clustern + O_2
  (mit Dr. Michal Fárník, Prag)



- **Phtalocyanin-Moleküle: Was macht ein Metall-Atom mit der Photochemie?**
  Phtalocyanin@Fe/Mg/Ni in Helium-Tröpfchen
  (mit Dr. Elisabeth Gruber, AG Scheier, Innsbruck)

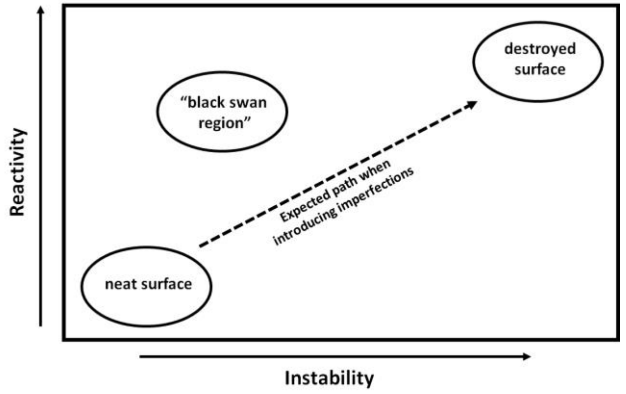
- **Reaktivität von halogenierten Molekülen unter Ionisierung und Elektronenanlagerung**
  Molekularstrahl-Experimente mit CH_3COCl, CF_3COCl, CCl_3CCOH
  (mit Dr. Michal Fárník, Prag)



Explorative Themen

(„Wir haben wenig Ahnung, was zu erwarten ist, man muss rumprobieren")

- **Vielversprechend, aber nicht verstanden: CO_2-Aktivierung auf Indium-Oxid**
  - Wie sieht der katalytische Prozess aus? Was sind die aktiven Stellen?
  - Gibt es extrem seltene, aber extrem aktive Stellen („schwarze Schwäne")?
  - Wie kann man ein besseres katalytisches Material gezielt vorbereiten?
  - (mit CHASE Competence Center, Linz)



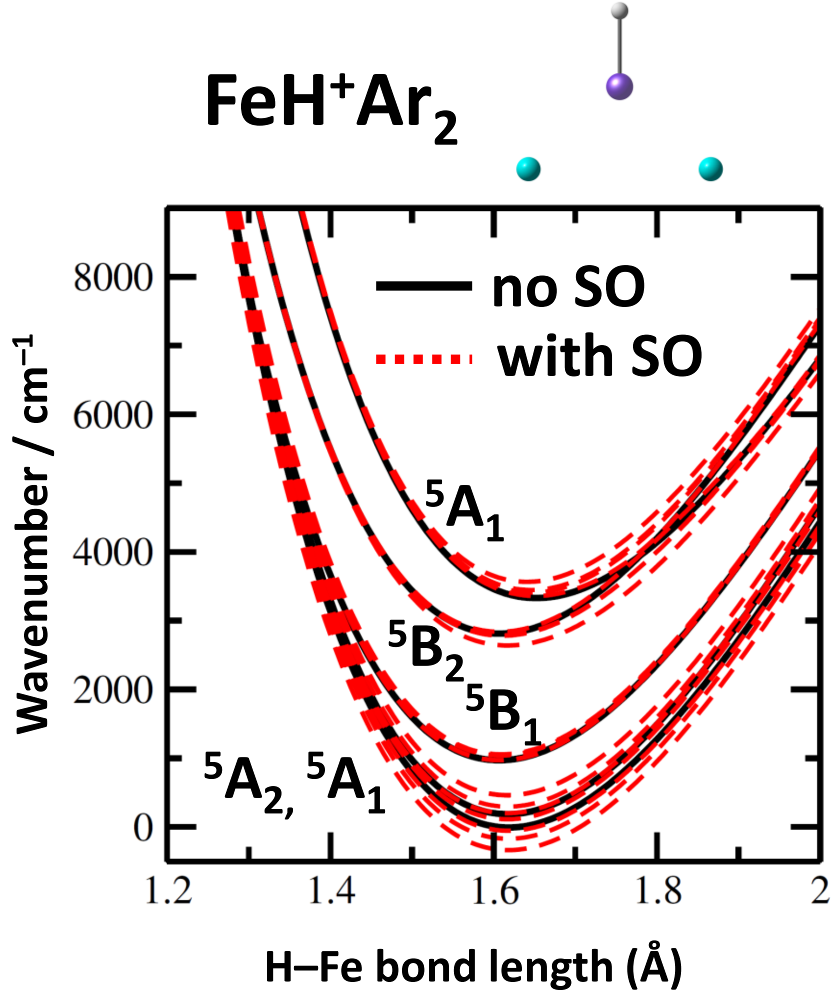
- **Iod-Uhr für Satelliten: Kann die Quantenchemie dabei helfen, diese kleiner zu machen?**
  - Wie sensitiv reagiert I_2 auf Magnetfelder?
  - Gibt es weitere Übergänge, die man für die Zeitmessung nutzen könnte?
  - (mit SpaceTech, Deutschland)

Methoden-Entwicklung

(für die, die gern programmieren und tief in Methoden einsteigen)

- Path Integral Monte Carlo: Wie beschreibt man komplizierte Komplexe mit Übergangsmetallen, die in verschieden elektronischen Zuständen koexistieren?
  (Experimente: AG Beyer, Innsbruck)

- Genetische Algorithmen: Die ultimative Optimierungslösung, um Systeme mit geeigneten Eigenschaften zu finden



Kontakt: milan.oncak@uibk.ac.at, Raum 3/5
www.uibk.ac.at/ionen-angewandte-physik/photophys/

universität innsbruck
Institut für Ionenphysik
und Angewandte Physik

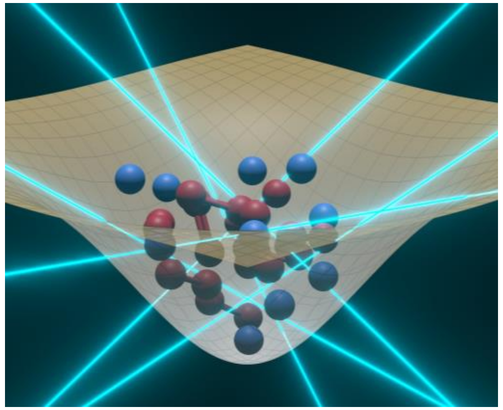
Forschungsarbeiten in der Gruppe Erath-Dulitz

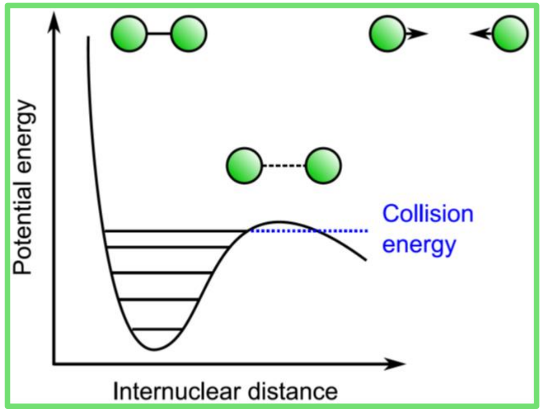
Katrin Erath-Dulitz

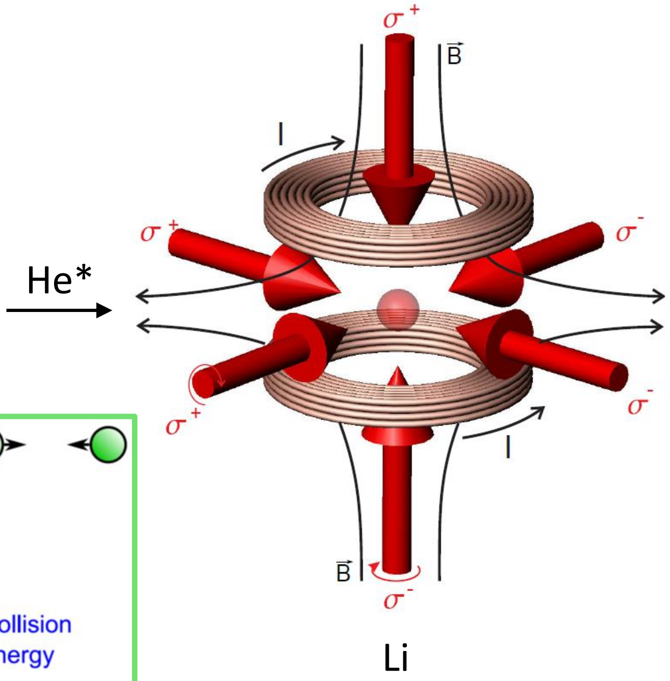
Kontakt: katrin.erath-dulitz@uibk.ac.at, Büro 3/09 (3. Stock)

Forschungsinteressen

Produktion kalter Moleküle → Chemie nahe 0 K



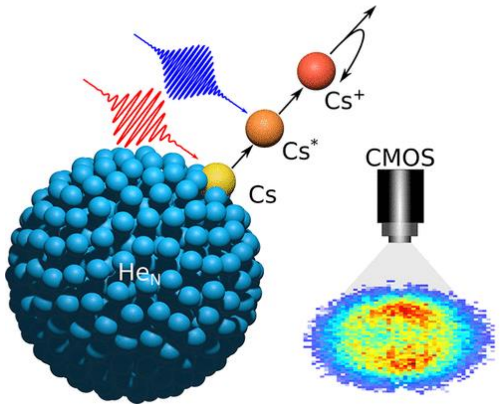


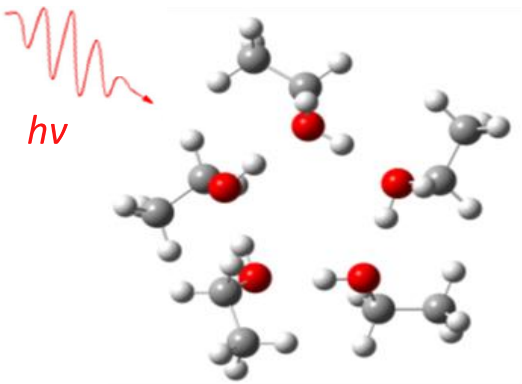


Studium ultraschneller chemischer Reaktionen in Echtzeit

ELI Beamlines, Prag

FERMI FEL, Triest





Exkursion ins Innere des Freie-Elektronen-Lasers SwissFEL (EU 744952)

02.04.-05.04.2024

[https://www.psi.ch/de/swissfel/contact]

Exkursion ins Innere des Freie-Elektronen-Lasers SwissFEL (EU 744952)

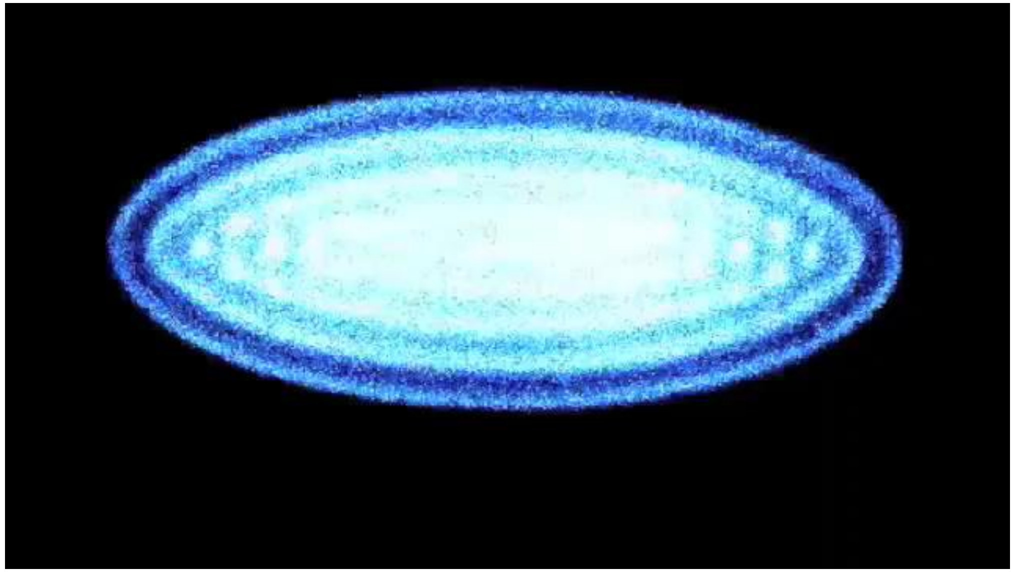
02.04.-05.04.2024

SwissFEL

Swiss Light Source

Video: https://www.youtube.com/watch?v=TcCx0i-ekNI

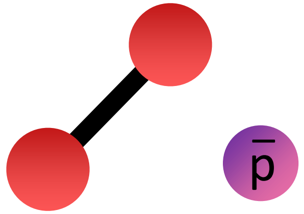
Ziel: Kristalle kalter negativ geladener Ionen (≈ 10 mK) durch Kühlung mit Laserstrahlung



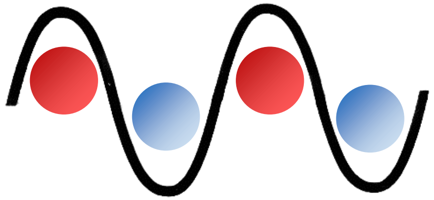
Coulomb-Kristall aus $^{40}Ca^{+}$

[Willitsch Gruppe, Basel.]

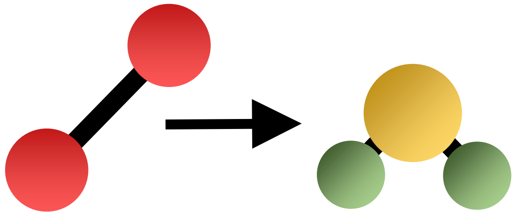
ANWENDUNGEN



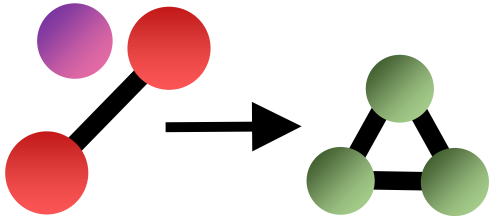
Kalter Anti-Wasserstoff



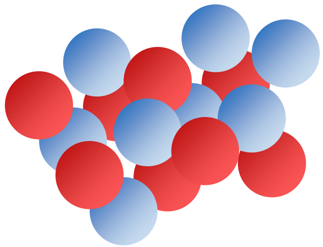
Quantencomputer



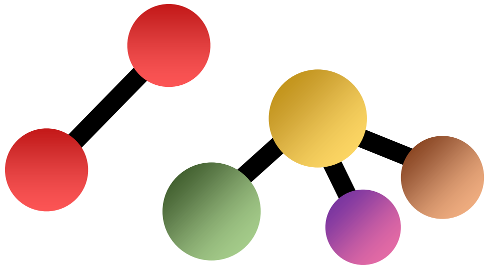
Kalte und kontrollierte Chemie



Chemie im Weltall



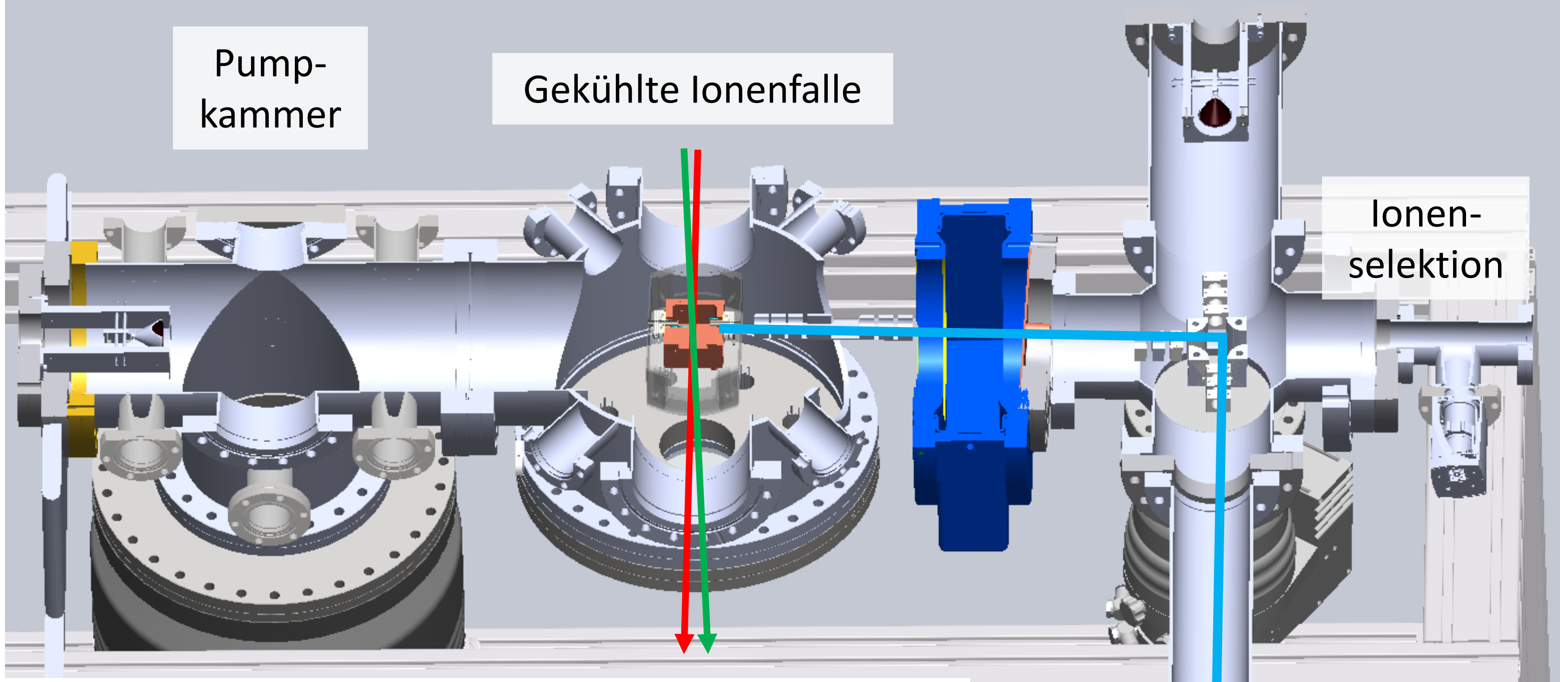
Kalte Plasmen

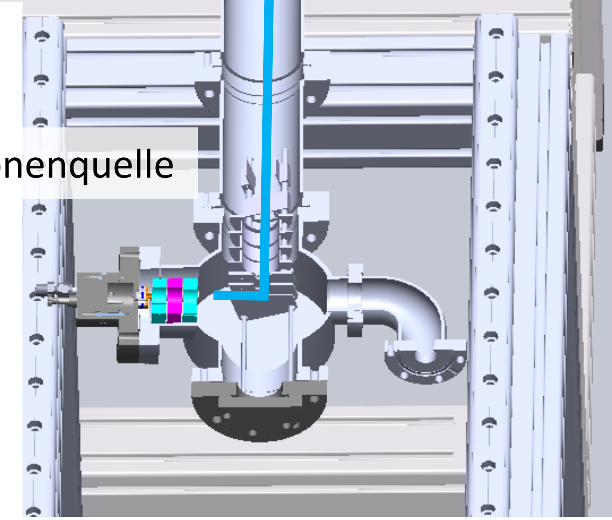


Suche nach neuer Physik

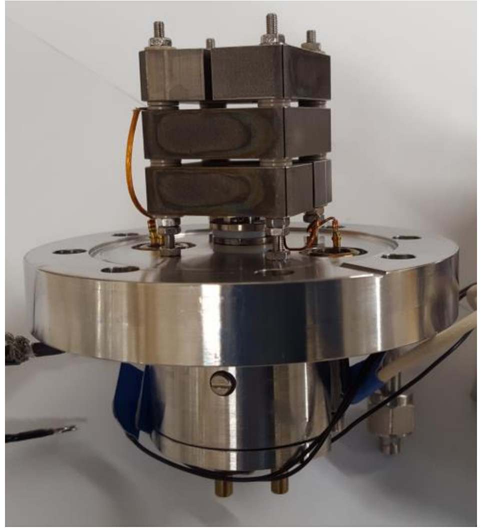
Das Labo CoMo

VERSUCHSAUFBAU

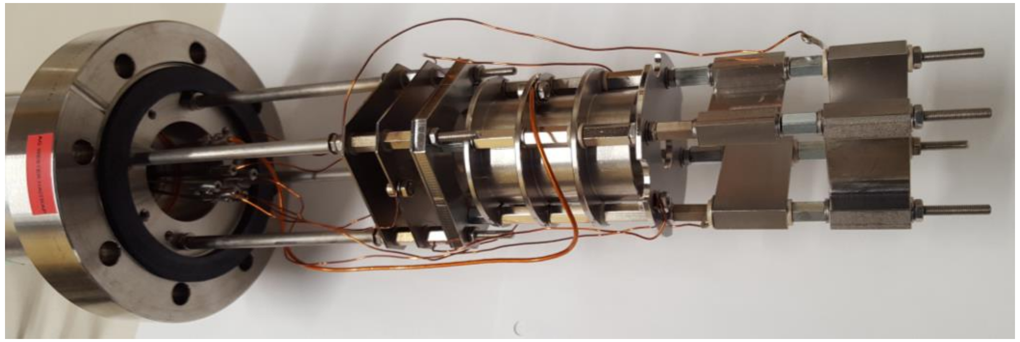




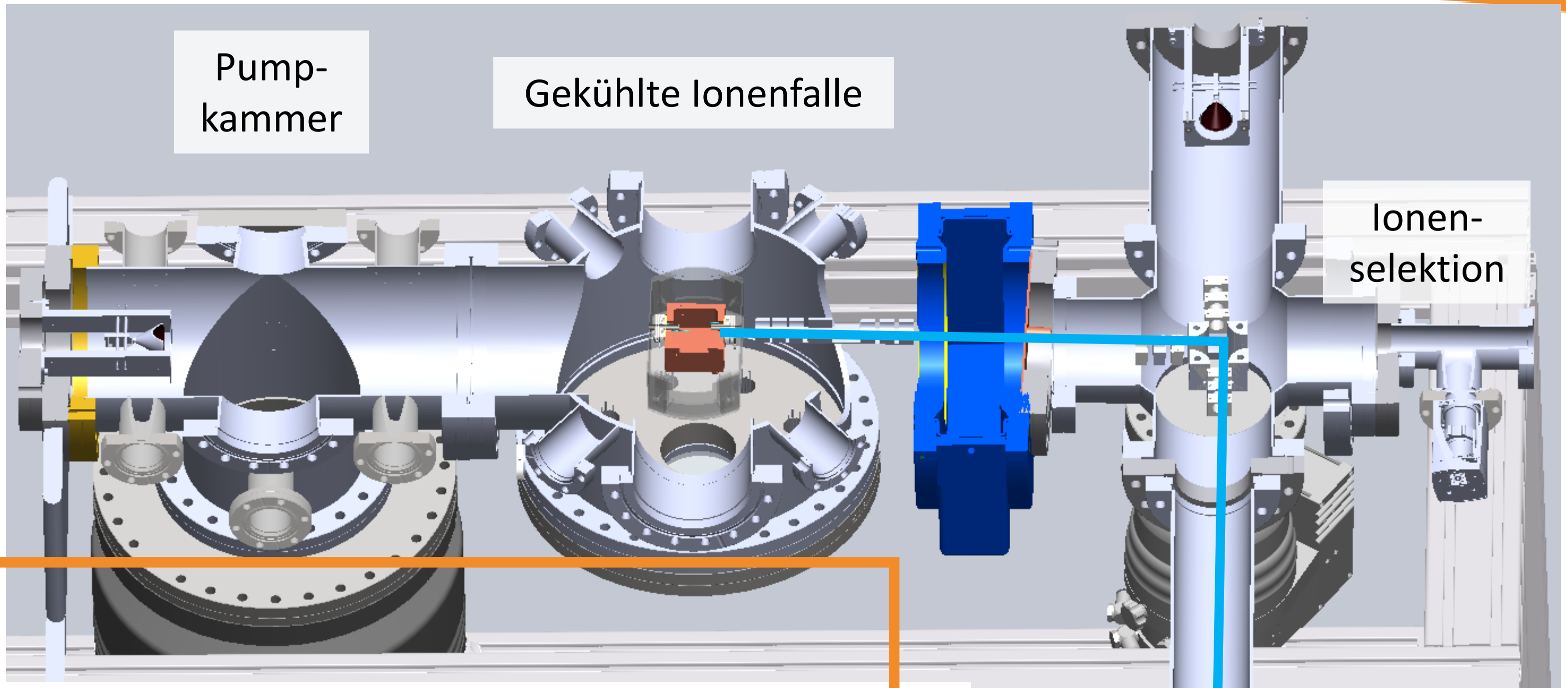
Ionenquelle

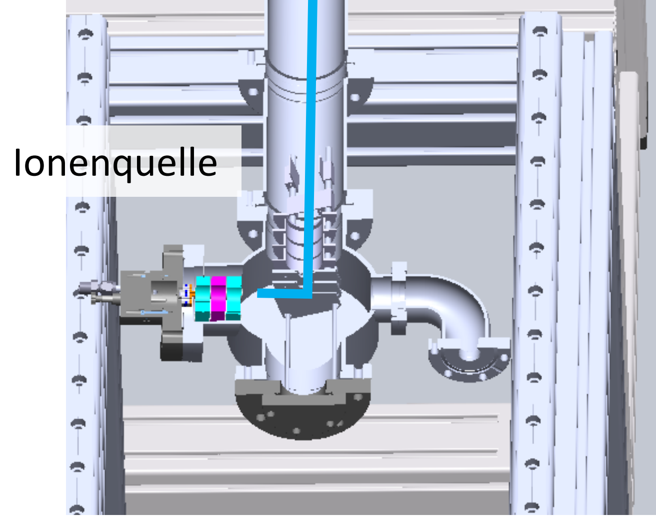


Ionenstrahlbeschleunigung



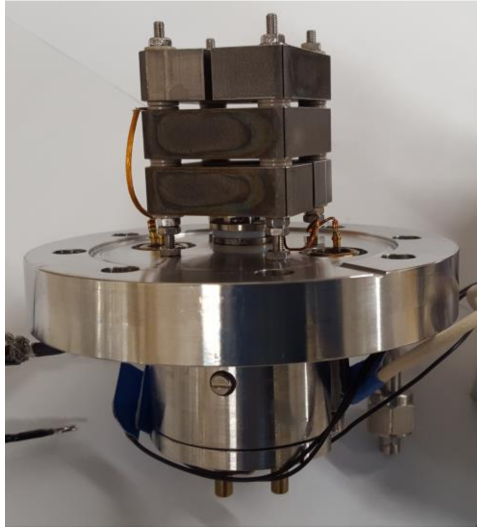
PROJEKTTHEMEN



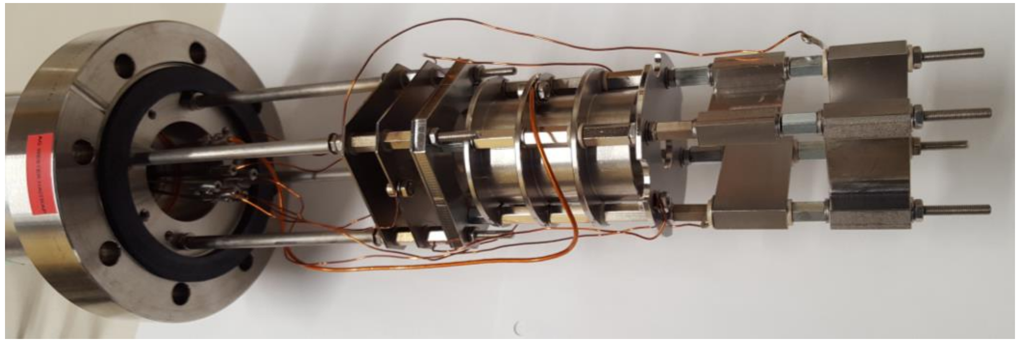


Charakterisierung der Ionenquelle

Ionenquelle

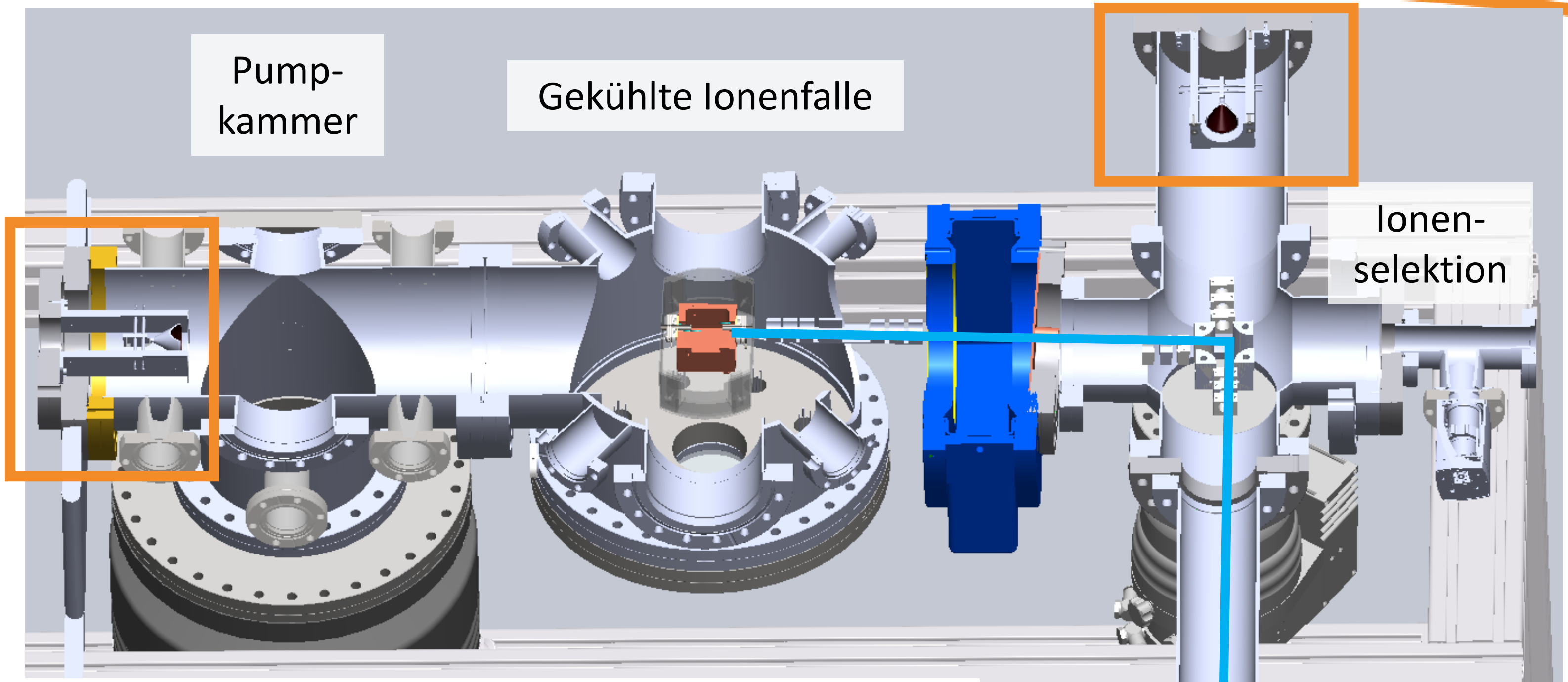


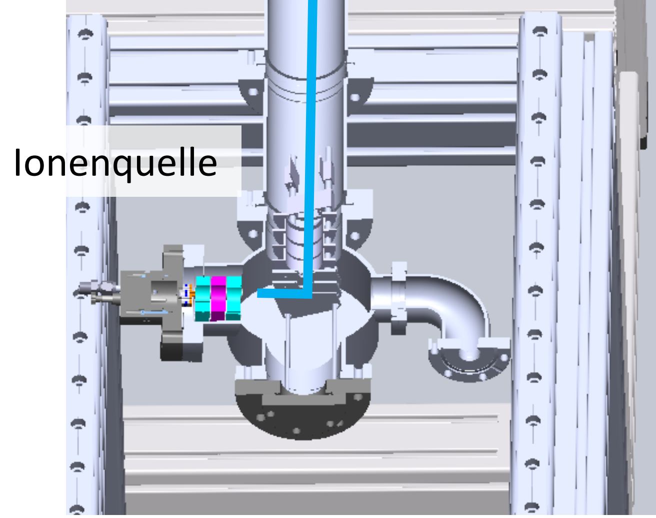
Ionenstrahlbeschleunigung



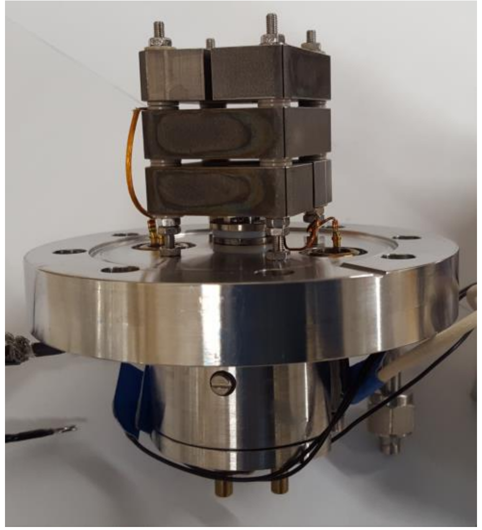
PROJEKTTHEMEN

Aufbau von Ionendetektoren





Ionenquelle



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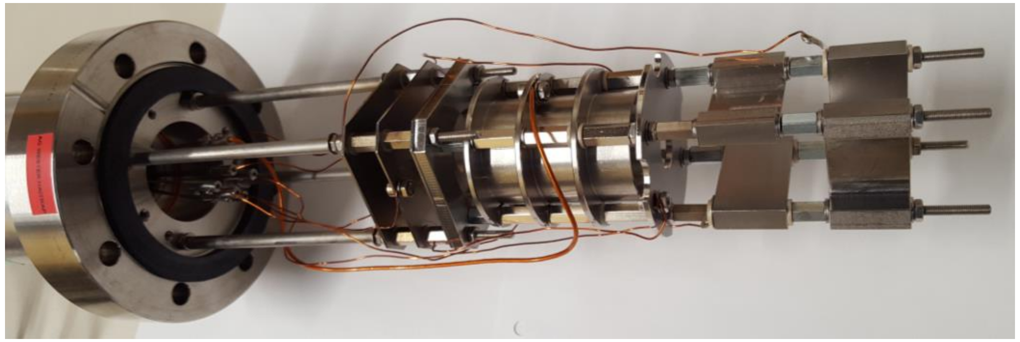
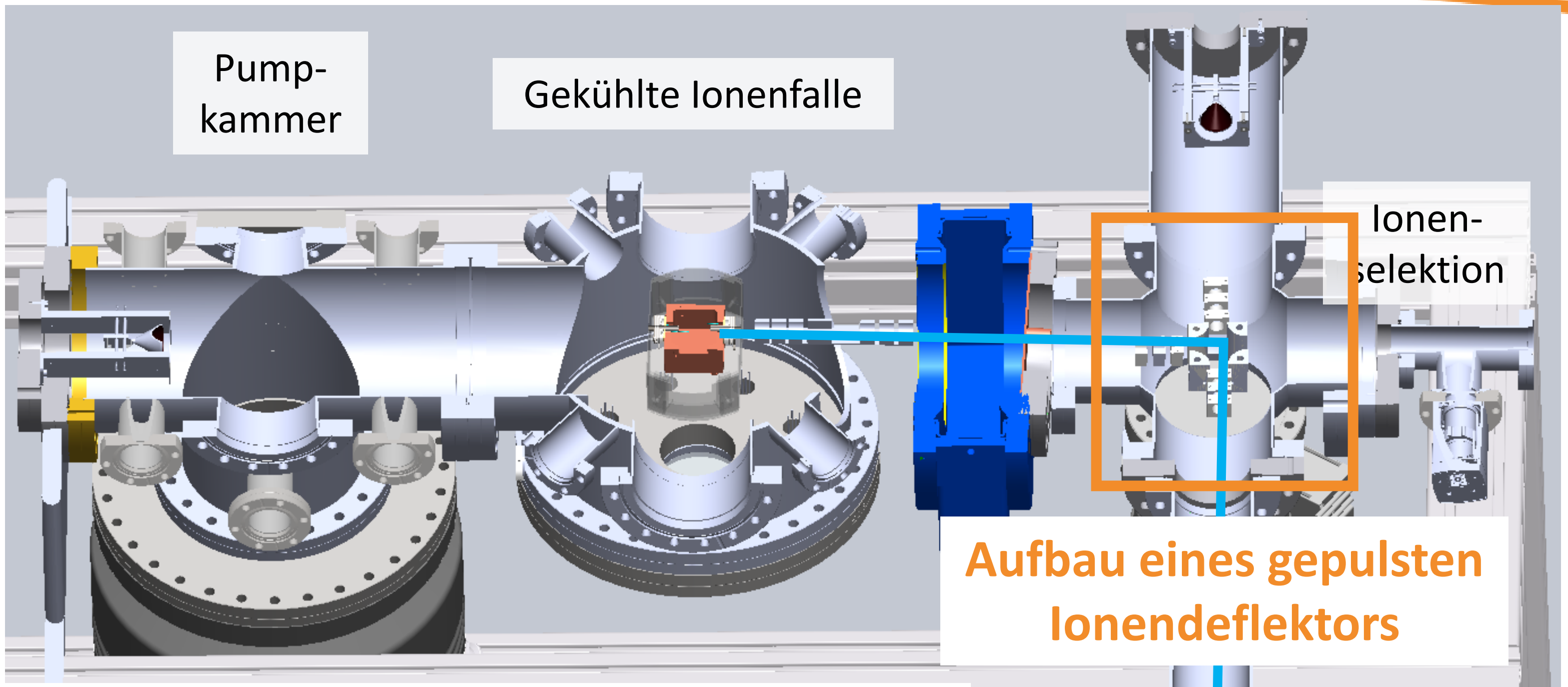
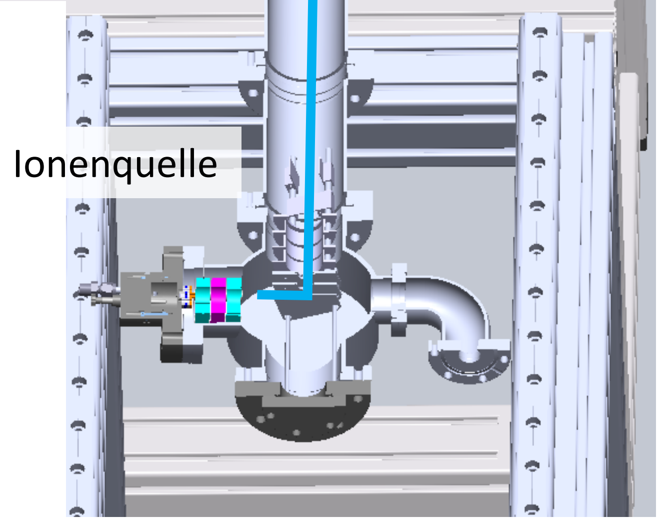
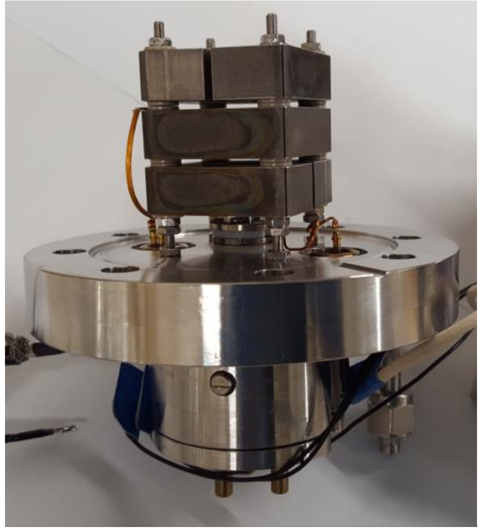


Projektthemen

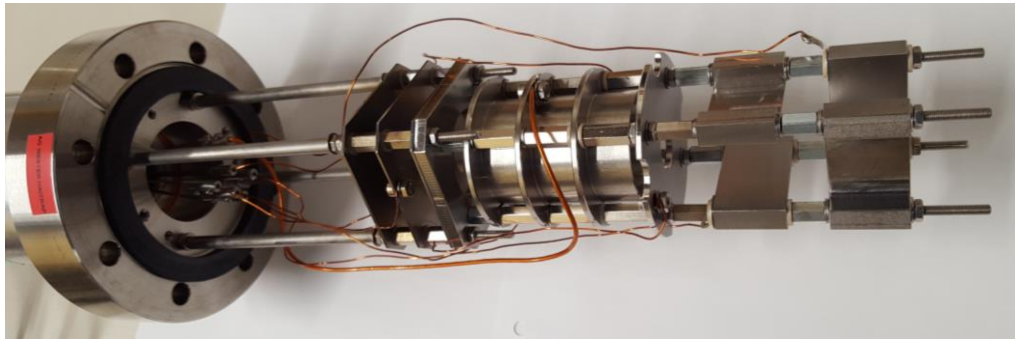




Ionenquelle



Ionenstrahlbeschleunigung

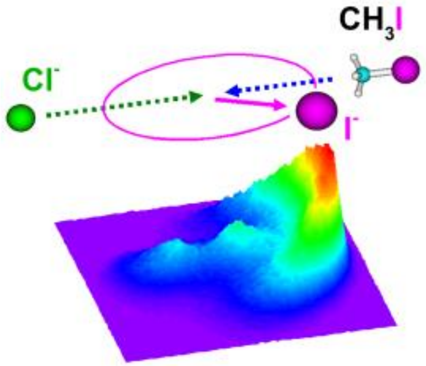


Molecular Systems group

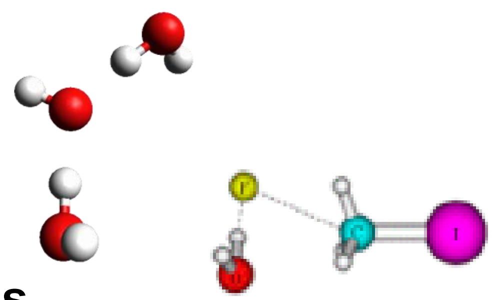
Our research focus:
Quantum effects in the structure and interaction of molecules and ions

Dynamics and Spectroscopy of Charged Molecular Systems

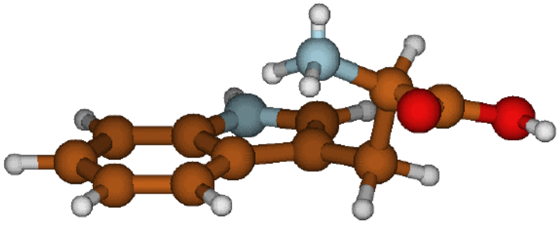
Ion-molecule reaction dynamics



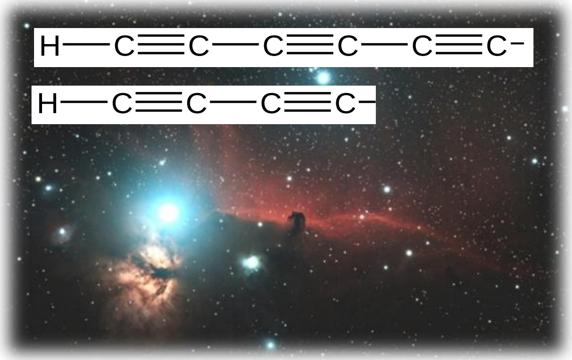
Micro-hydration effects



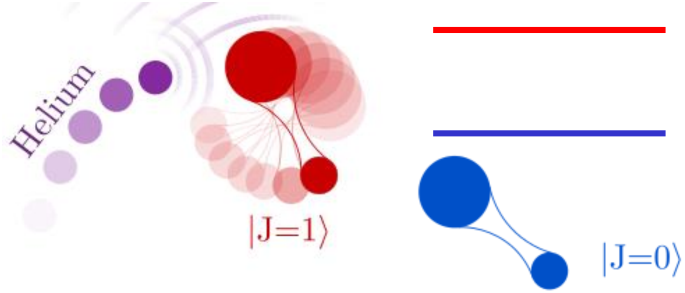
Biomolecular ions



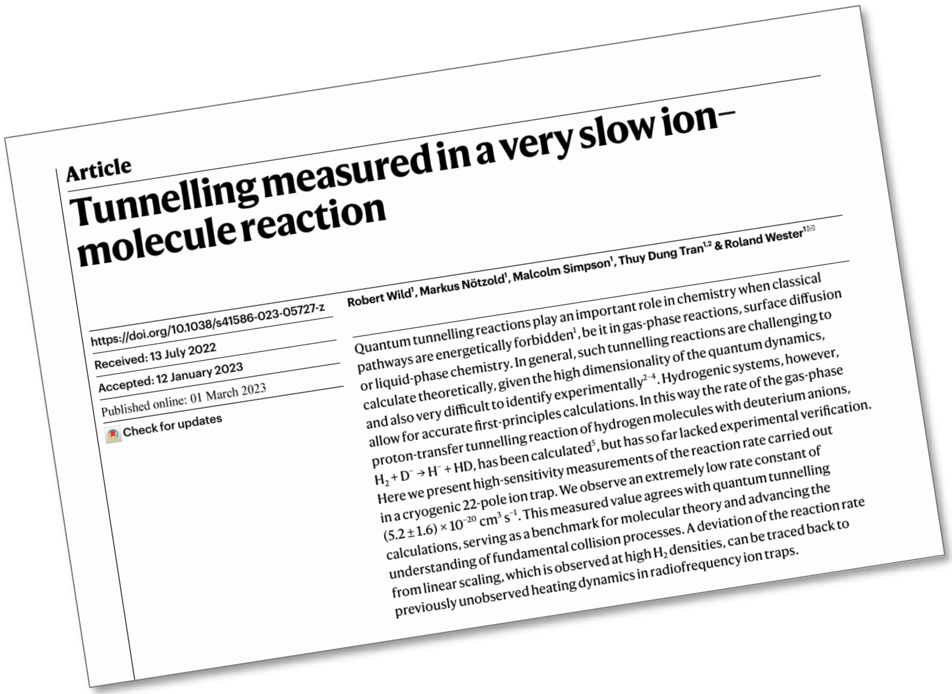
Interstellar ion formation



Cold and state-controlled ions



2023 Breakthrough: Quantum tunneling in the $D^- + H_2$ reaction


Article

Tunnelling measured in a very slow ion–molecule reaction

Robert Wild[1], Markus Nötzold[1], Malcolm Simpson[1], Thuy Dung Tran[1,2] & Roland Wester[1]✉

https://doi.org/10.1038/s41586-023-05727-z

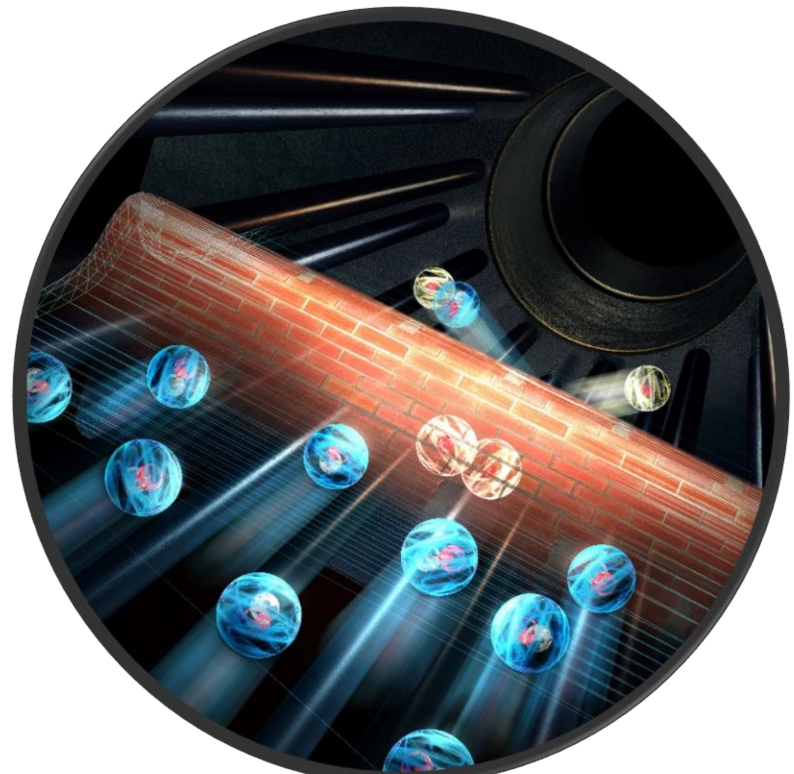
Received: 13 July 2022

Accepted: 12 January 2023

Published online: 01 March 2023

Check for updates

Quantum tunnelling reactions play an important role in chemistry when classical pathways are energetically forbidden[1], be it in gas-phase reactions, surface diffusion or liquid-phase chemistry. In general, such tunnelling reactions are challenging to calculate theoretically, given the high dimensionality of the quantum dynamics, and also very difficult to identify experimentally[2–4]. Hydrogenic systems, however, allow for accurate first-principles calculations. In this way the rate of the gas-phase proton-transfer tunnelling reaction of hydrogen molecules with deuterium anions, $H_2 + D^- \rightarrow H^- + HD$, has been calculated[5], but has so far lacked experimental verification. Here we present high-sensitivity measurements of the reaction rate carried out in a cryogenic 22-pole ion trap. We observe an extremely low rate constant of $(5.2 \pm 1.6) \times 10^{-20}$ cm^3 s^{-1}. This measured value agrees with quantum tunnelling calculations, serving as a benchmark for molecular theory and advancing the understanding of fundamental collision processes. A deviation of the reaction rate from linear scaling, which is observed at high H_2 densities, can be traced back to previously unobserved heating dynamics in radiofrequency ion traps.



R. Wild *et al.*, Nature (2023)

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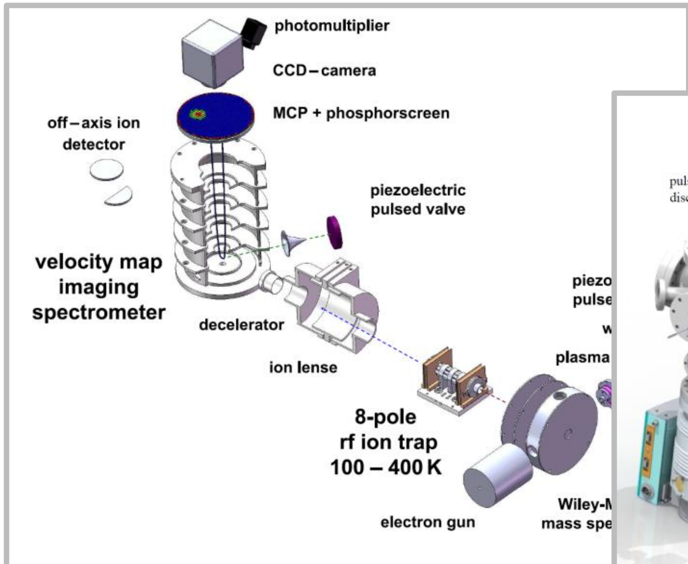
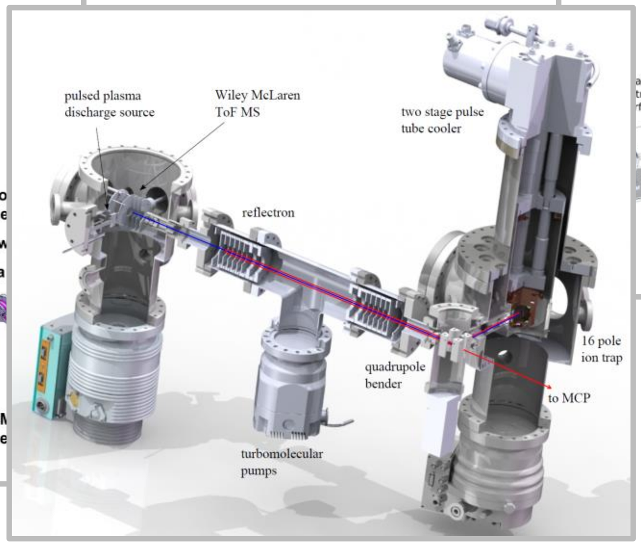
Dynamics and Spectroscopy of Charged Molecular Systems

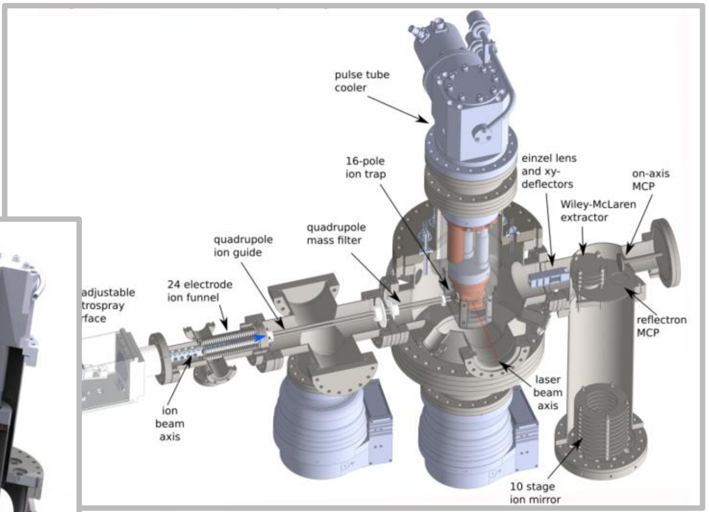
Experimentelle Aufbauten



Kreuzstrahlspektrometer für Ionen-Molekül-Reaktionsdynamik



6 Kelvin Ionenfalle für Laborastrophysik an interstellarer Ionen

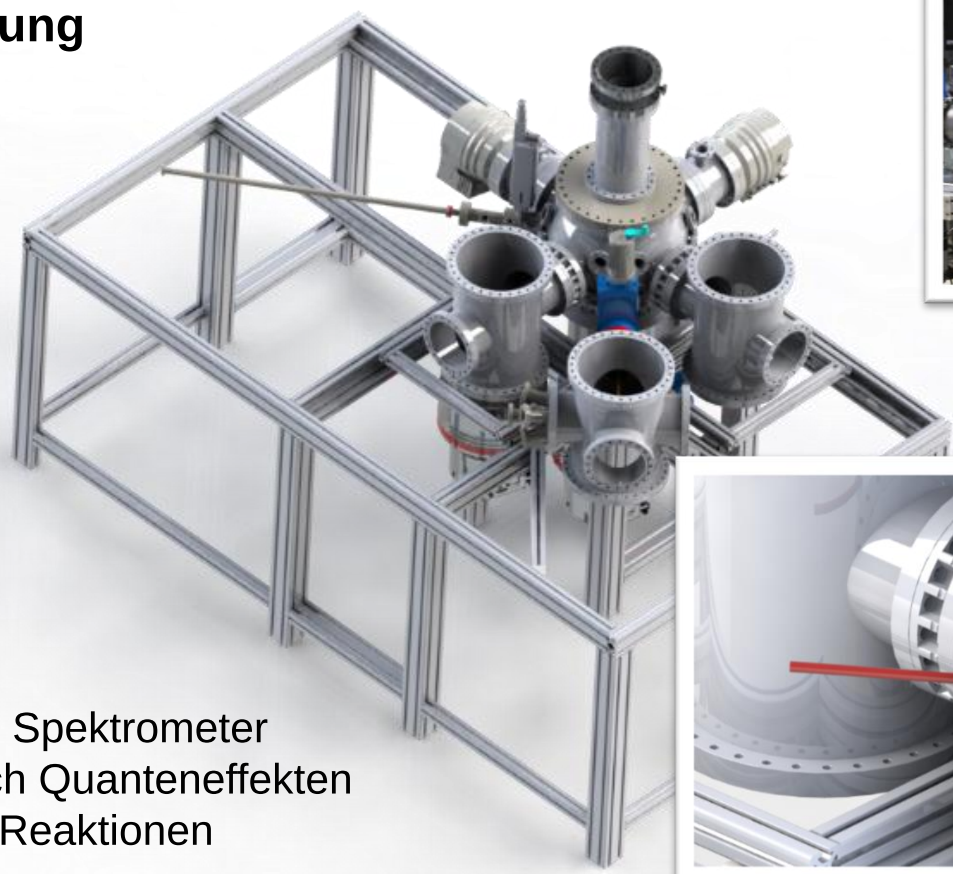


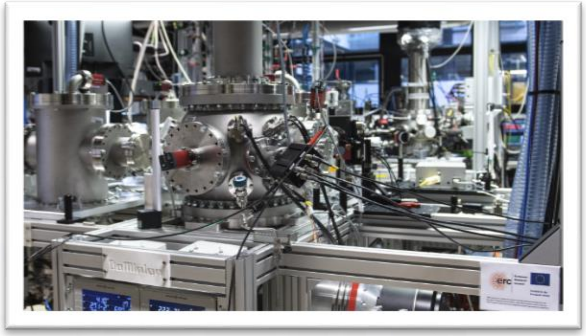
3 Kelvin Elektrospray-Ionenfalle für Spektroskopie an Biomolekülen und Clustern

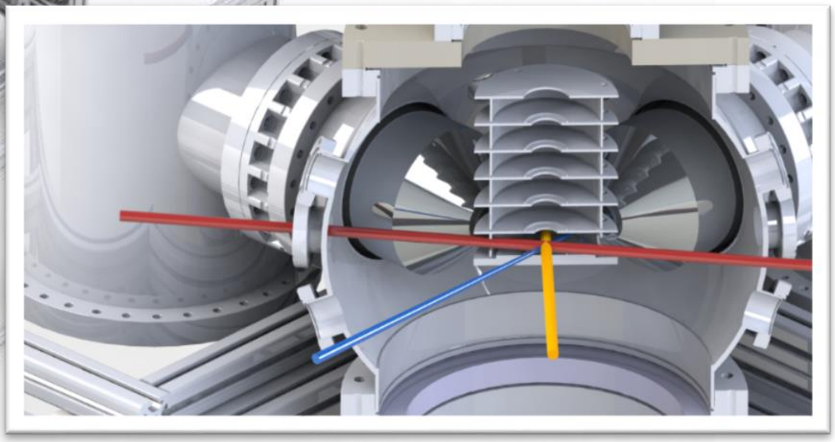
Dynamics and Spectroscopy of Charged Molecular Systems

Neue Entwicklung

DoMInIon







Hochauflösendes Spektrometer
für die Suche nach Quanteneffekten
in Ionen-Molekül-Reaktionen

universität innsbruck

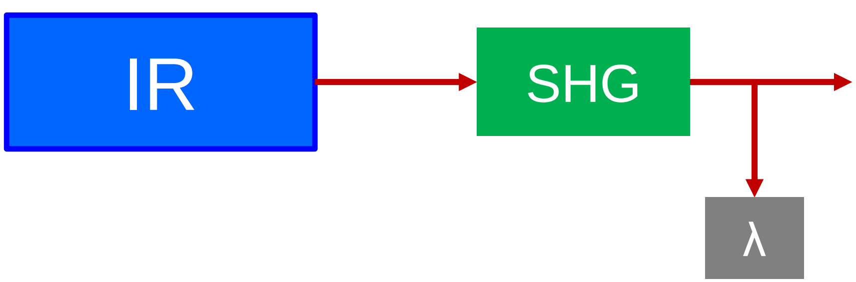
Dynamics and Spectroscopy of Charged Molecular Systems

Mögliche Themen für Bachelorarbeiten 2024

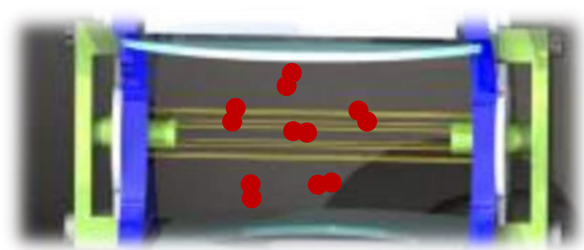
Charakterisierung von hoch-sensitiven CCD-Kameras

Massenspektrometrie von negativen Ionen für die Laserspektroskopie

Aufbau einer Laser-Frequenzverdopplung



Bestimmung von absoluten Dichten in einer Tieftemperatur-Ionenfalle



Dynamics and Spectroscopy of Charged Molecular Systems

Bei Interesse, einfach melden:

roland.wester@uibk.ac.at

Vielen Dank für die Aufmerksamkeit!

Atoms, Light, and Molecules
Innsbruck Physics Research Center

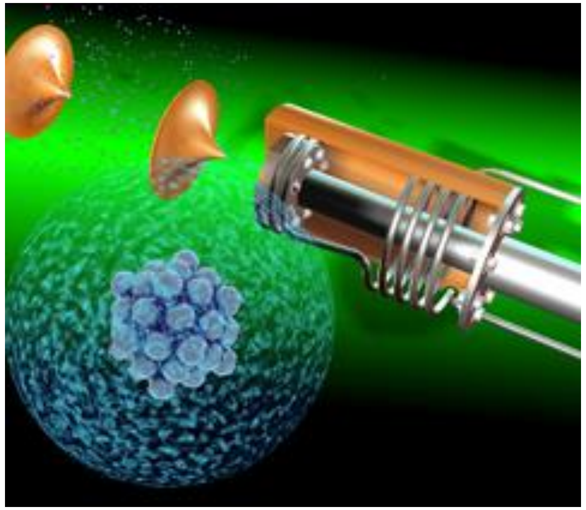
FWF

erc

Collaborations
Szeged
Heidelberg
Prag
Stockholm
Bordeaux
Orlando
Albuquerque

Nano – Bio – Physics

Physics and Chemistry in cold superfluid helium nanodroplets

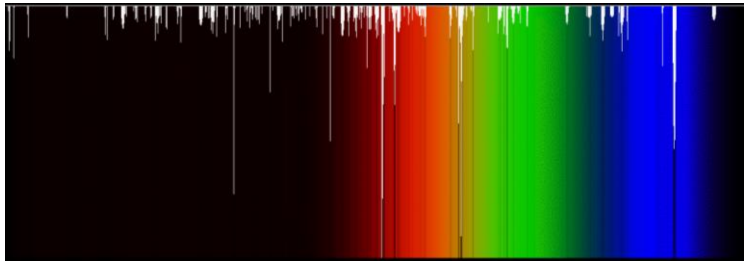


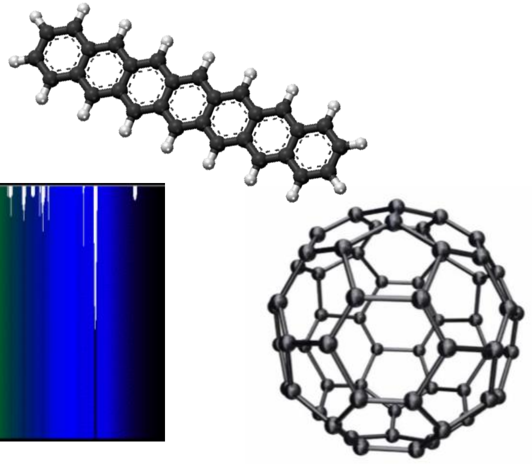
https://www.uibk.ac.at/ionen-angewandte-physik/nanobio/

Contact:
Paul.Scheier@uibk.ac.at
E.Gruber@uibk.ac.at
Olga.Lushchikova@uibk.ac.at

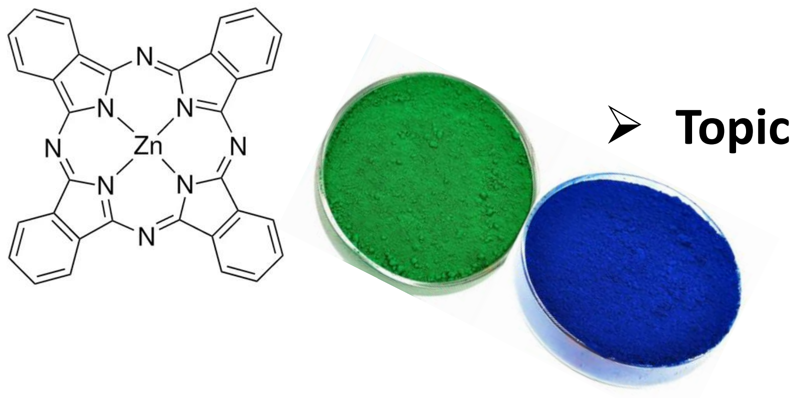
Spectroscopy of cold molecular ions

➢ **Topic 1: On the search of the carriers of the diffuse interstellar bands**

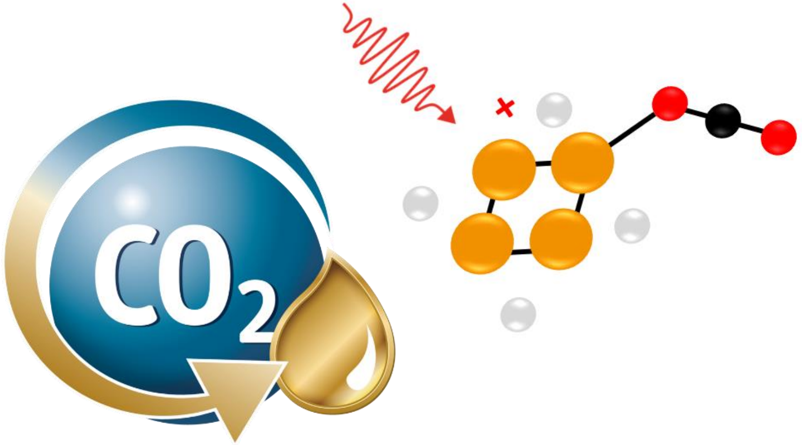




- Spectroscopy of $(C_{60}\text{-metal})^+$ complexes
- Spectroscopy of PAHs



➢ **Topic 2: Messenger spectroscopy of photoactive (metal)organic molecules**

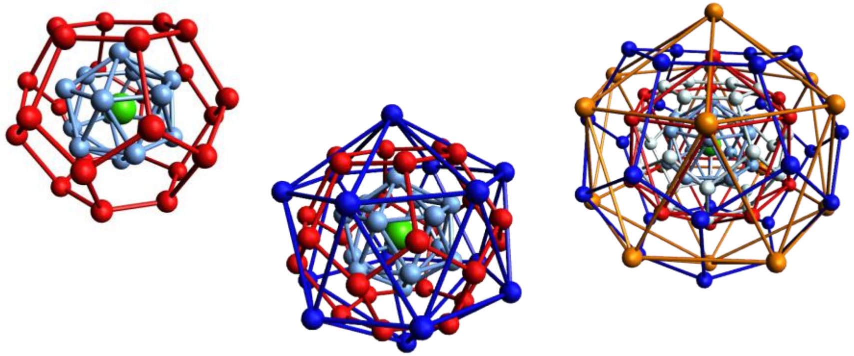


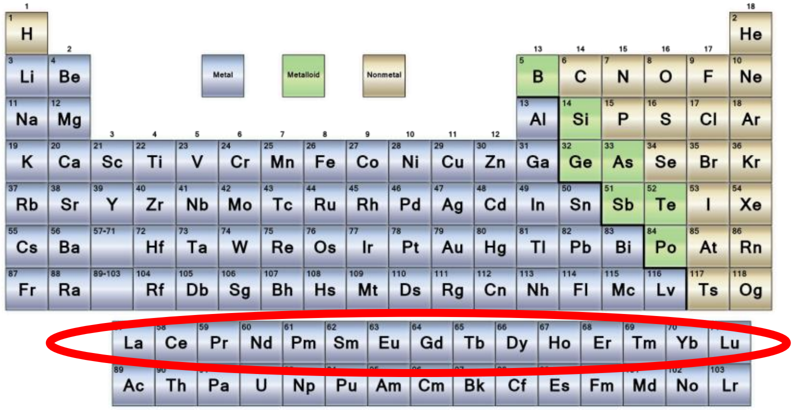
➢ **Topic 3: Investigation of catalytic CO_2 utilization by metal clusters**

- IR-spectroscopy of $(M)^{+/-}\text{-}CO_2$

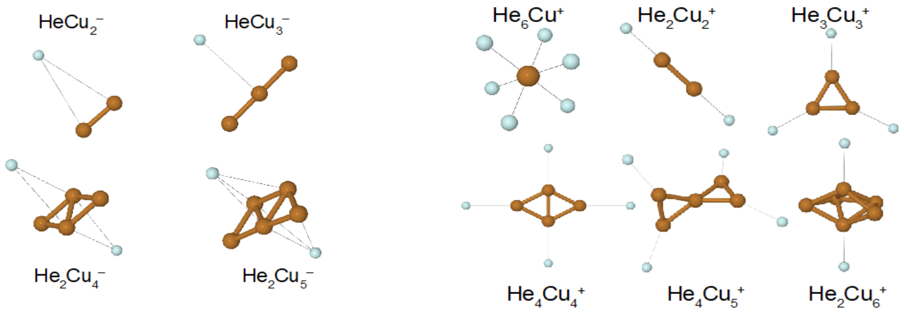
Solvation of ions in helium nanodroplets

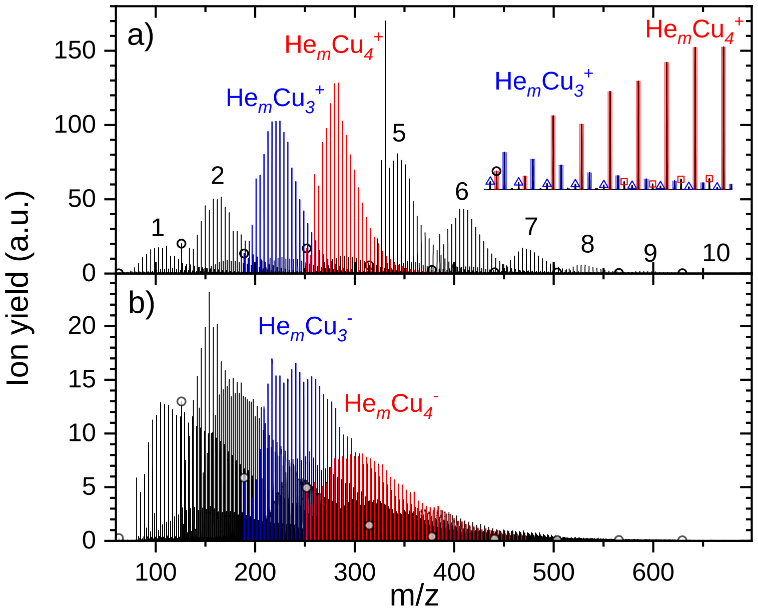
- **Topic 4: Solvation shells of multiply-charged ions**





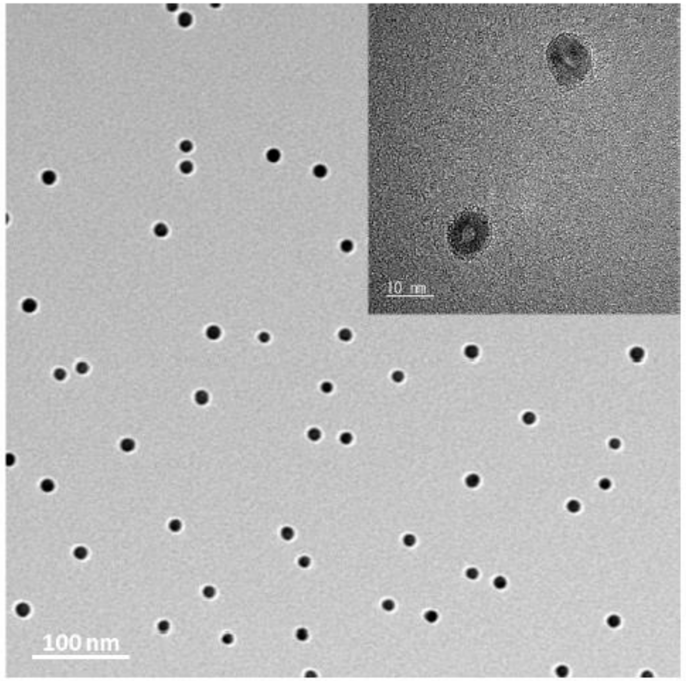
- **Topic 5: Structural characterization of metal clusters**





Deposition of nanoparticles on surfaces

- **Topic 6: Test measurements of a novel setup**



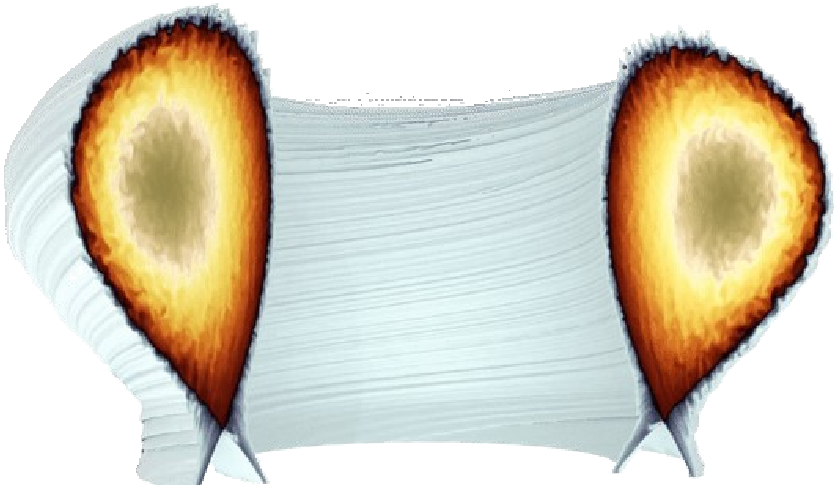
Nichtlineare Plasma-Dynamik

Univ.-Prof. Dr. Alexander Kendl

Institut für Ionenphysik und Angewandte Physik

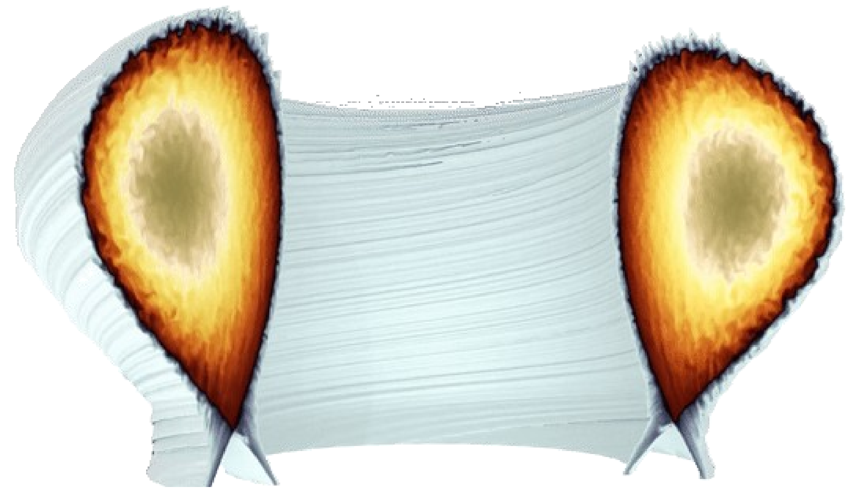
- Theorie und numerische Simulation
- nichtlineare Dynamik, Turbulenz und Strukturbildung
- komplexe Fluide und ionisierte Vielteilchen-Systeme

- Aktuelle Schwerpunkte:
  - # Turbulenz und Transport in Plasmen
  - # Magnetische Rekonnexion
  - # Fusionsforschung (Tokamak, Stellarator)
  - # Elektron-Positron-Laborplasmen



Nichtlineare Plasma-Dynamik

Wir entwickeln u.a. theoretische Modelle und numerische Methoden zur Simulation von Instabilitäten, Turbulenz und Transport in magnetisch eingeschlossenen Plasmen zur Fusionsenergie-Forschung.



Instabilitäten und Transport

Nichtlineare Plasma-Dynamik

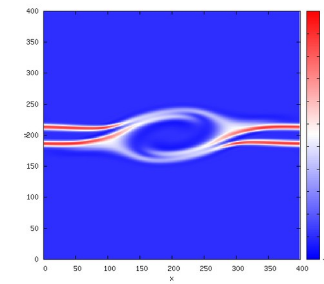
BSc

Aktuelle Themenvorschläge für Bachelor-Arbeiten 2024

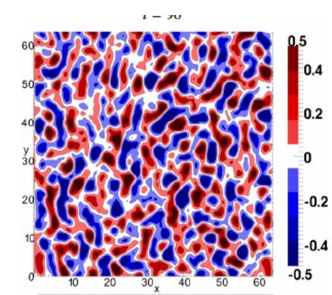
im 744087 SE Seminar mit Bachelorarbeit am Institut für Ionenphysik und Angew. Physik

Alle Themen beinhalten wesentliche eigene praktische Arbeiten (und nicht nur Literatur-Review)

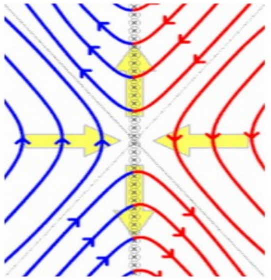
(1) **Phasenraum-Chaos in Plasmen :**
numerische Lösung und Analyse der 1D-1V Vlasov-Gleichung:
Untersuchung von Landau-Dämpfung und Gegenstrom-Instabilität.
Voraussetzungen: Kenntnisse in C/C++, Interesse an Numerik und Theorie



(2) **Turbulente Dynamik von Wetter und Plasmen im HM-CO Modell :**
numerische Lösung und Analyse der Hasegawa-Mima Gleichung:
Untersuchung von abklingender Turbulenz, Einbau eines spektralen Antriebs.
Voraussetzungen: Kenntnisse in C/C++, Interesse an Numerik und Theorie



(3) **Magnetische Rekonnexion in Plasmen :**
numerische Lösung und Analyse eines Full-f Gyrofluid-Modell Codes:
Untersuchungen zur turbulenten Rekonnexion von magnetischen Feldlinien.
Voraussetzungen: Kenntnisse in C/C++, Interesse an Numerik und Theorie

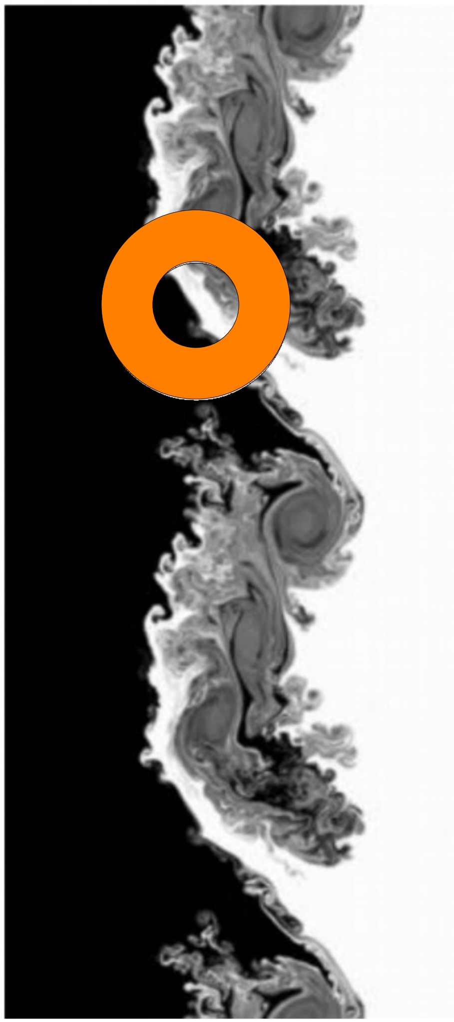


Nichtlineare Plasma-Dynamik

MSc

Aktueller Themenvorschlag für Master-Arbeit 2024

Finite Larmor radius effects on the Kelvin-Helmholtz instability in magnetised plasmas



An existing **2D gyro-fluid turbulence code** (written in C++) in magnetised plasmas shall be prepared for simulation of the Kelvin-Helmholtz (shear flow) instability.

The **gyro-fluid model** consistently includes effects of a finite Larmor (gyration) radius (FLR), which gets relevant when vortices have spatial extensions in the order of an ion gyration radius.

(1) Review the present status of literature on simulations including FLR effects on the KH instability;

(2) Prepare the code for simulations;

(3) Plan parameter studies for a series of simulations;

(4) Apply or further develop post-processing diagnostics of the simulations;

(5) Characterise the influence of FLR effects on mode numbers, growth rates, and transition to turbulence;

(6) Discuss possible relevance of the effect for applications (fusion, space).

Starting literature:

Faganello, J. Plasma Phys. 83, 535830601 (2017);

Kendl, Computer Physics Communications 294, 108952 (2024).

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Experimental Plasma Physics

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What is plasma?

Plasma is the so-called fourth state of matter:

It is the state of matter most abundant in the universe
(more than 99% of the visible matter of the universe are in the plasma state).

- **Any substance that is heated to more than a few thousand degrees will become plasma.**
  - Depending on its temperature, its molecules can be excited and/or ionized as such, or will be dissociated and then excited and/or ionized.
  - If the material consists of atoms these will directly be excited and/or ionized.
- **Eventually a plasma will consist of positive ions, free electrons, neutrals, photons and possibly also of negative ions.**
- **There are many types of plasmas, distinguished by their composition, density n, temperature T, and other parameters such as the plasma potential Φ_{pl}.**
- **Plasmas are usually quasineutral, i.e. per volume unit there are almost equal numbers $n_{+,-}$ of positive and negative charges $q_{+,-}$ so that:** $\left|\Sigma q_+ n_+ - \Sigma q_- n_-\right| << \Sigma q_+ n_+$
- **Any stronger deviation from quasineutrality leads to the creation of strong electric fields which try to re-establish quasineutrality – unless there is an external constraint.**

Plasma in Nature, Laboratory and Applications

- ***Plasma technology:*** Coating, etching, surface activation, plasma thrusters, welders and cutters, intensive light sources, plasma reactors for plasma chemistry processing and many more.
- ***Medical applications of plasma:*** Decontamination and sterilisation of medical devices and tissue, treatment of biomaterials to enhance their biocompatibility, plasma treatment of wounds and scars, and many more.
- ***Fusion research:*** For solving the future energy problems on the long run, nuclear fusion is the only realistic perspective. The most promising fusion confinement method is the tokamak*).
- ***Terrestrial plasma:*** Lightings, St. Elmo's fires, upper-atmospheric lightning: blue jets, sprites and elves
- ***Space plasma:*** All active stars as well as almost the entire visible interplanetary, interstellar and intergalactical matter is in the plasma state, including the magnetosphere and the ionosphere of the earth (e.g. auroras).

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What we do in Plasmas

We do research on:

- Plasma diagnostics with probes and spectroscopic methods,
- Basic plasma physics phenomena,
- Technical applications of plasmas,
- Fusion plasma physics

In particular:

- Development of plasma probes (emissive probes, resilient probes, armoured with Ultra-Nano Crystalline Diamond [UNCD]);
- Plasma spectroscopy;
- Localized plasma structures in various plasmas;
- Surface treatment by hollow cathode and dielectric barrier discharges (DBD).
- Transport phenomena in toroidal fusion plasma experiments (tokamaks and stellarators).

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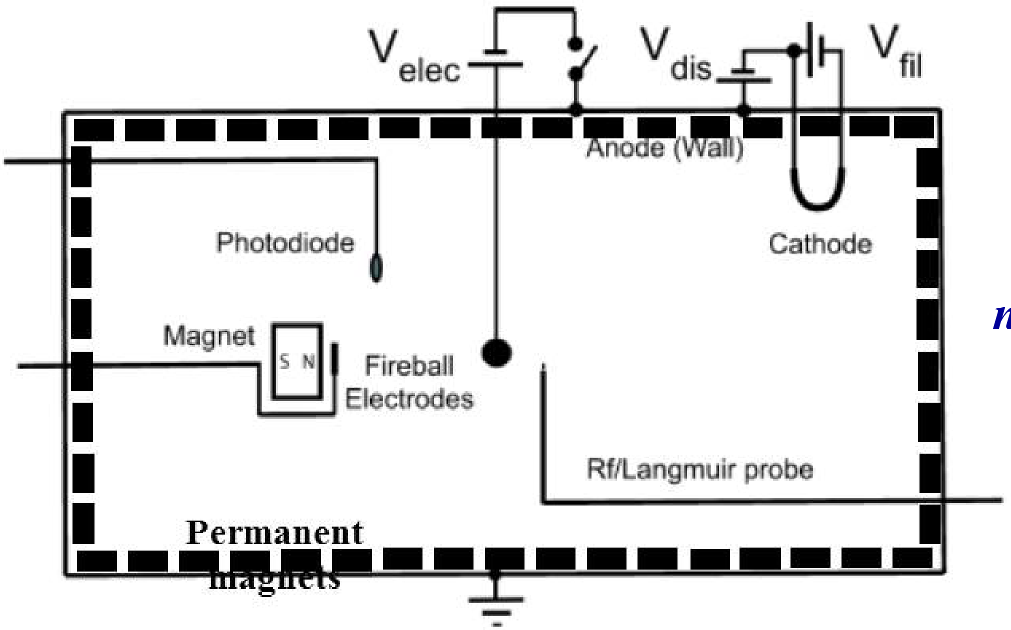
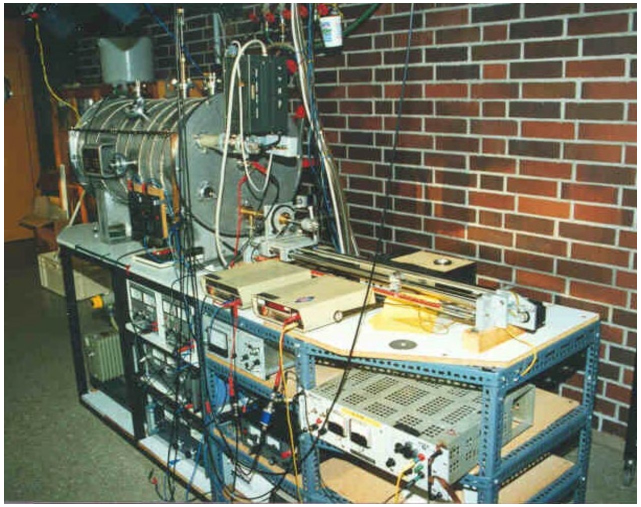
Double Plasma Machine (DP-Machine)

Inserting an additional positively or negatively biased electrode into a thin background plasma with sufficiently high background gas pressure will frequently lead to the creation of so-called Fireballs (luminous space charge structures):

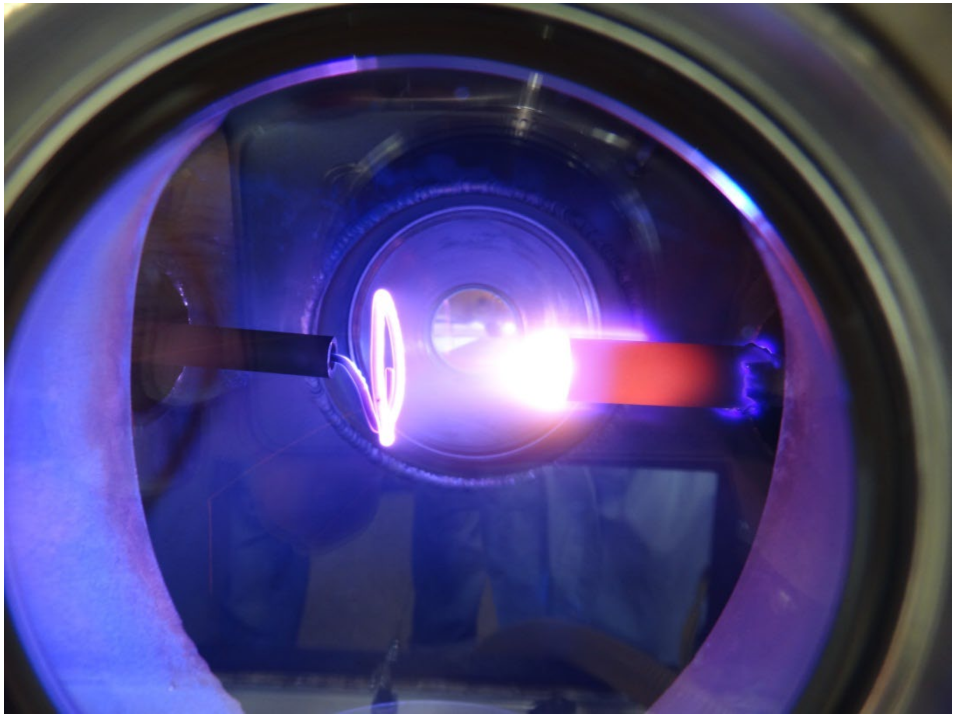


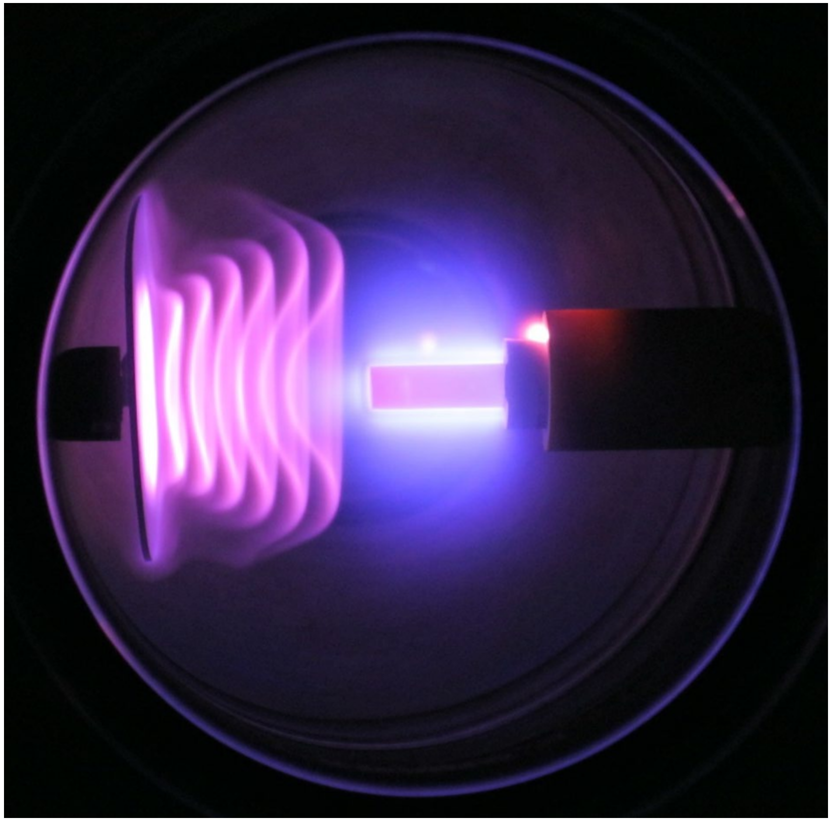


$n_{pl} \cong 10^{15}$-10^{16} m^{-3} and $p \cong 0{,}5$ Pa

Such phenomena have, by the way, also been observed on space shuttles upon re-entry.

Space Charge Structures





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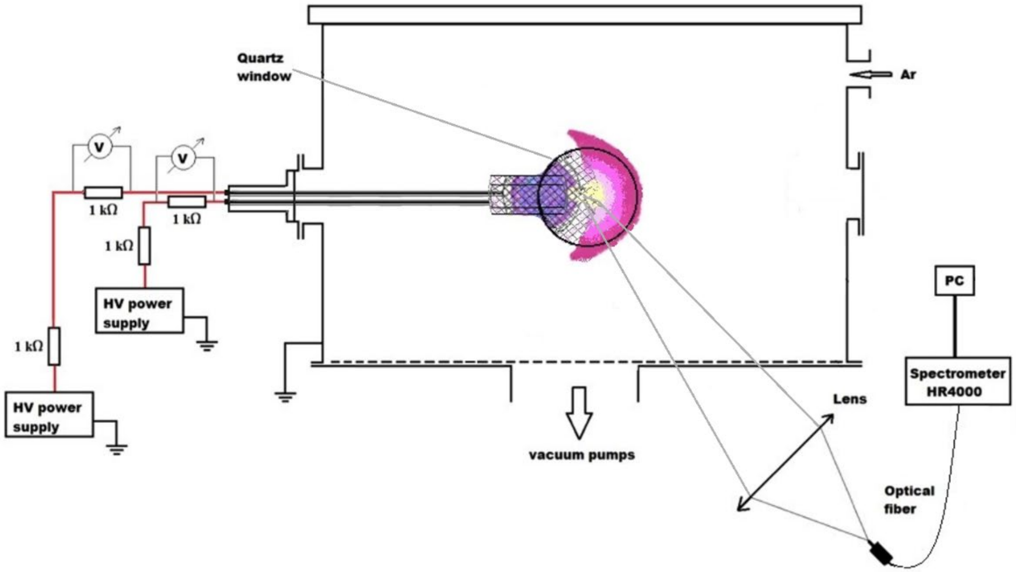
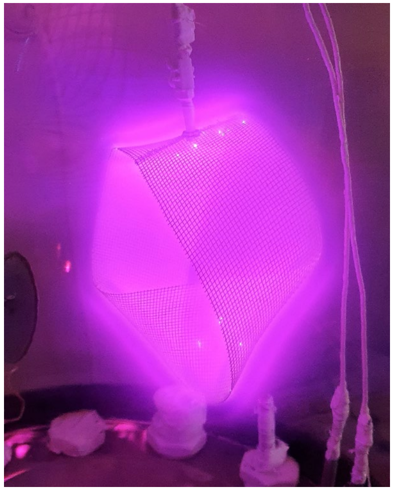
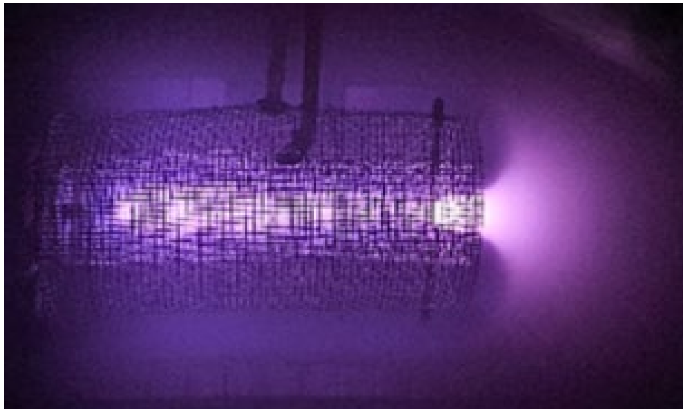
Space Charge Structures
Optical investigations

IEPPG

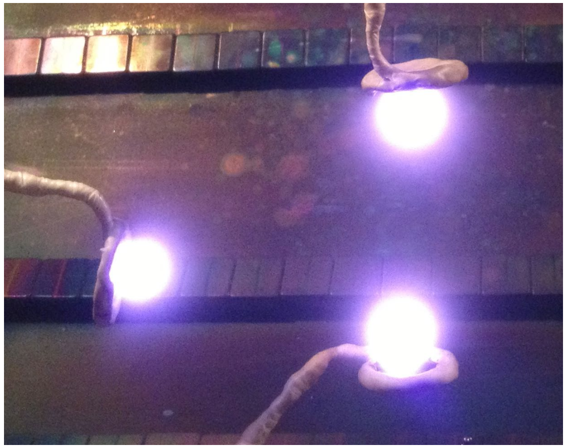




Discharge on a gridded Moebius band



Discharge in a concentric double cylindrical grid



Interaction between three “fireballs”

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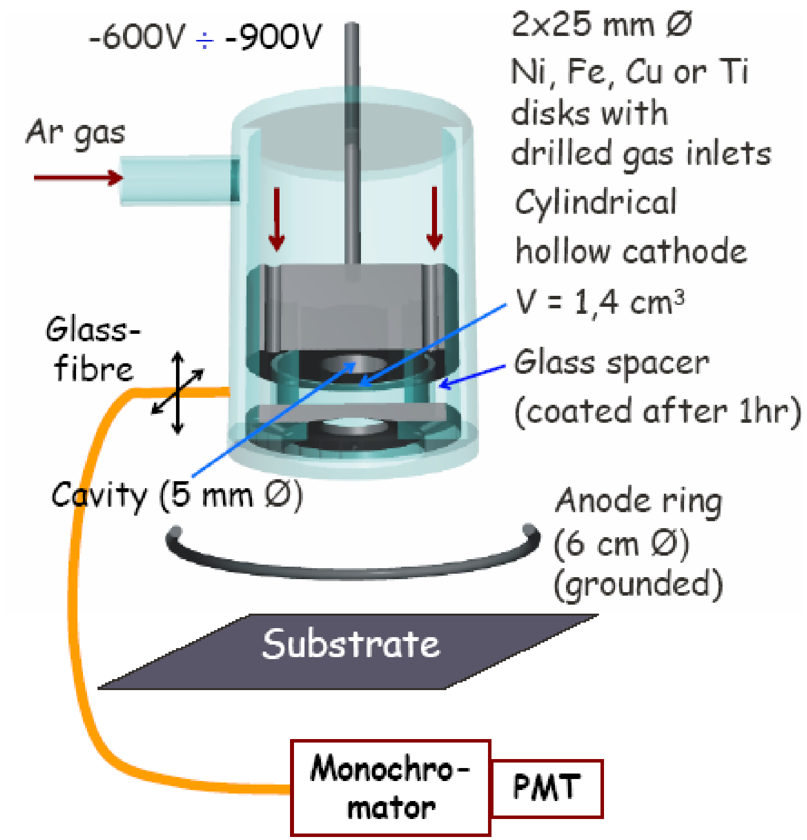
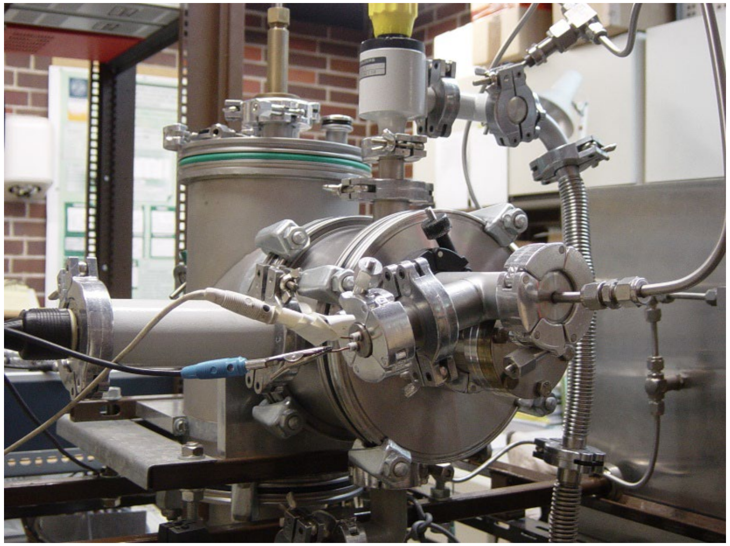
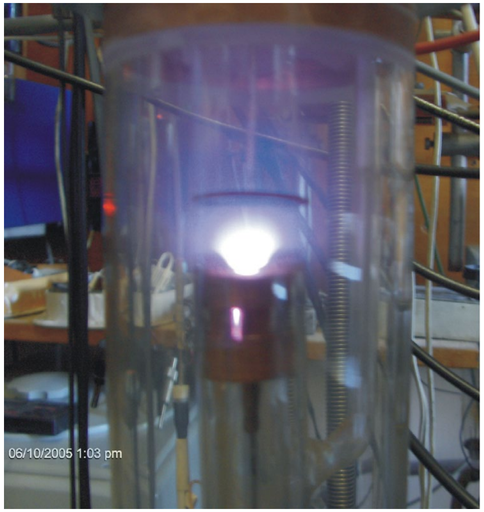
Hollow cathode

The Innsbruck hollow cathode for coating of various surfaces with various materials







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Hollow cathode

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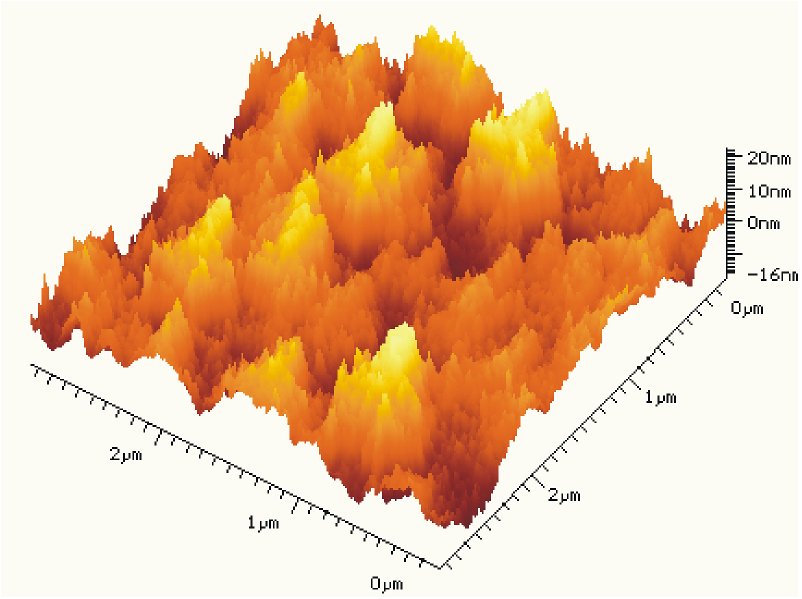
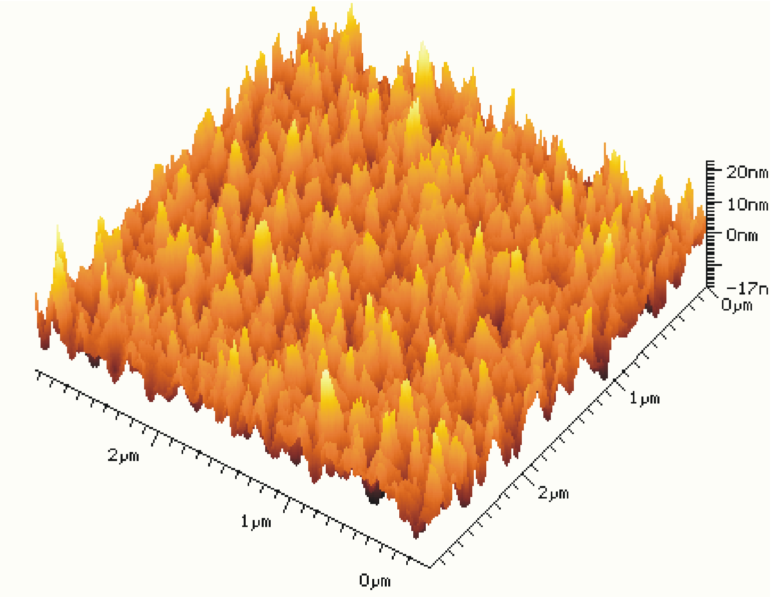




Pictures of a 3×3 µm^2 large glass substrate coated by nickel in the Innsbruck hollow cathode, recorded by an atomic force microscope.

Left: Coating in 1 cm distance from the hollow cathode.

Right: 2 cm distance.

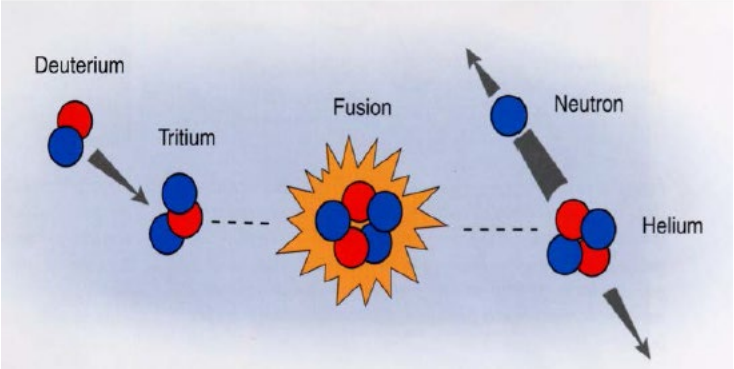
We clearly see that the coating becomes more regular and the grain size decreases for larger distance, i.e., the film becomes smoother.

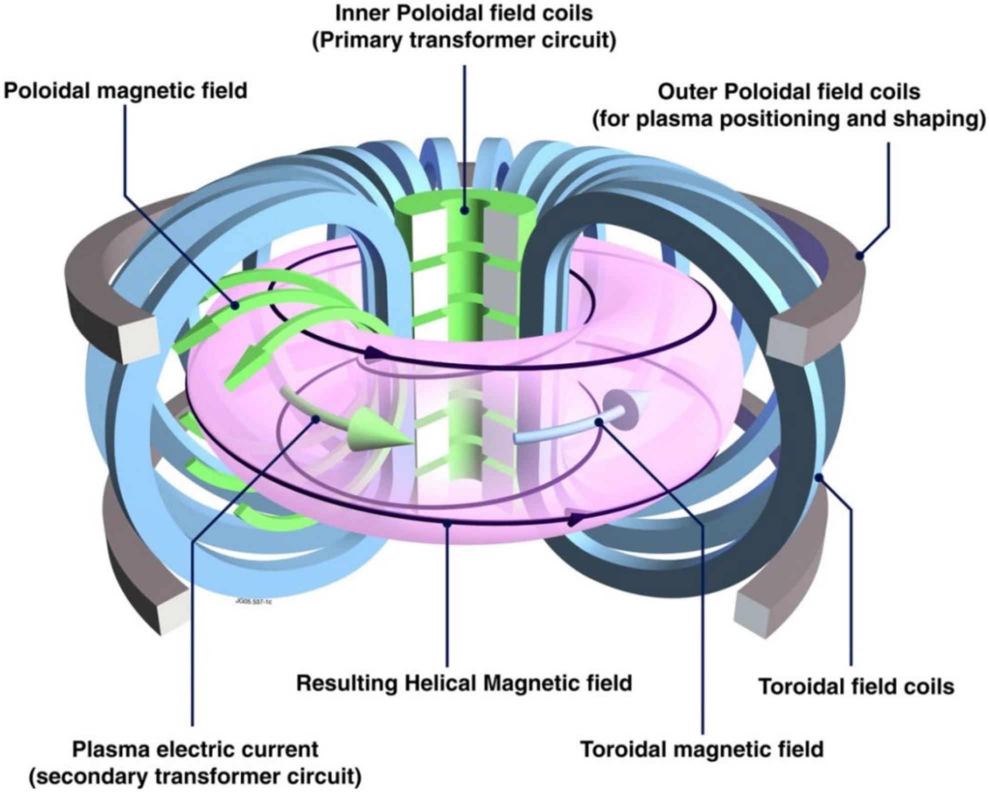
Probe Development for Toroidal Fusion Experiment

Principle of fusion and of a tokamak:

The fusion process with lowest threshold:

$$D + T \rightarrow He^4 + n + 17{,}6\ MeV$$





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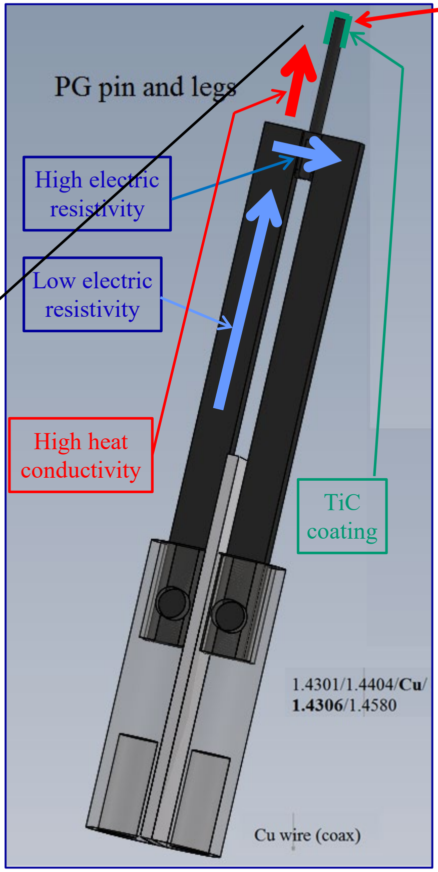
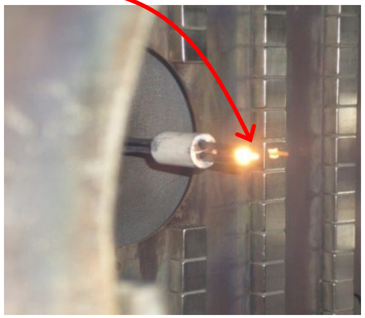
Probe Development for Toroidal Fusion Experiment

IEPPG

Indirectly heated Electron-Emissive Probe from HOPG (Highly Oriented Pyrolytic Graphite):



The protruding part of the pin will be coated by TiC after assembly.



Test of the EEP in the Innsbruck plasma chamber (cold Ar-plasma):

The (here uncoated) probe pin is heated to emission by heat conduction.

Bachelor-Themen

1. **Grundlegende Eigenschaften eines DP-Maschinenplasmas (Double Plasma Machine)** mit eigenen Messungen mit Sonden und/oder Spektroskopie im Innsbrucker Plasmaphysiklabor unter Anleitung.
2. **Medizinische Anwendungen von Plasmen**
3. **Fusion als saubere Energiequelle für die Zukunft**