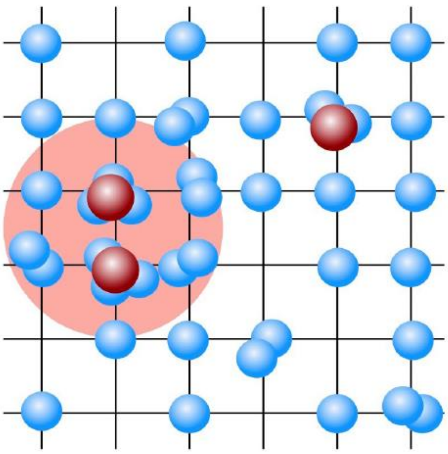

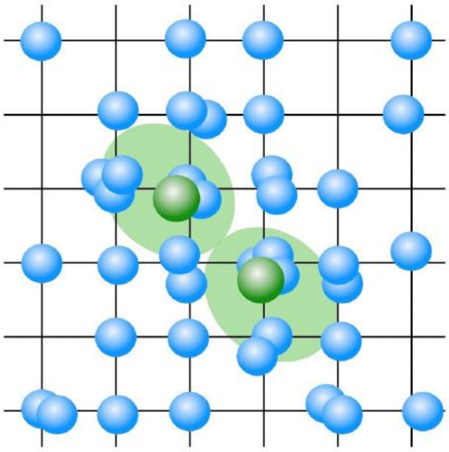

CONFERENCE: IMPURITY PHYSICS WITH COLD ATOMS AND IONS

21-23 AUGUST 2023

Monday 21 August

09:00 - 09:30	ARRIVAL AND REGISTRATION
09:30 - 09:35	**OPENING: Jan Arlt**
	Session chair: Michael Drewsen
09:40 - 10:15	René Gerritsma, University of Amsterdam
10:15 - 10:50	Thomas Walker, University of Freiburg
10:50 - 11:20	**COFFEE BREAK**
11:20 - 11:55	Michal Tomza, University of Warsaw
11:55 - 12:30	Carlo Sias, European Laboratory for Nonlinear Spectroscopy
12:30 - 14:30	**LUNCH**
	Session chair: George Bruun
14:30 - 15:05	Matteo Zaccanti, University of Florence
15:05 - 15:40	Pietro Massignan, Polytechnic University of Catalonia
15:40 - 16:10	**COFFEE BREAK**
16:10 - 16:45	Florian Meinert, University of Stuttgart
16:45 - 17:20	Niels Kjærgaard, University of Otago
18:00 -	**DINNER**
19:00 -	**POSTER + DRINKS**

Opening 09:30

Jan Arlt

Impurity physics and quantum chemistry in a trapped atom-ion mixture 09:40

Rene Gerritsma: I will the discuss the prospects of studying impurity physics in our trapped Yb^+-^6Li mixture in terms of attainable temperatures, spin exchange and relaxation and means to tune the interaction between the atoms and ions. Furthermore, I will discuss some results in quantum chemistry that we obtained some time ago when we immersed an ion into a cloud containing Li_2 Feshbach dimers. These results are of interest when considering charged impurity physics in the BEC to BCS crossover regime in a fermionic spin mixture. Moreover, they highlight the possibilities offered to study quantum chemistry in the system. Finally, I will briefly discuss the experimental implications of trap-assisted complexes that arise in trapped ion-atom mixtures for quantum impurity physics and chemistry.

10:15

Thomas Walker

Coffee break 10:50

Quantum simulation of the central spin model with a Rydberg atom and polar molecules in optical tweezers 11:20

Michal Tomza: Central spin models, where a single spinful particle interacts with a spin environment, find wide application in quantum information technology and can be used to describe, e.g., the decoherence of a qubit over time. We propose a method of realizing an ultracold quantum simulator of a central spin model with XX (spin-exchanging) interactions. The proposed system consists of a single Rydberg atom (``central spin'') and surrounding polar molecules (``bath spins''), coupled to each other via dipole-dipole interactions.
By mapping internal particle states to spin states, spin-exchanging interactions can be simulated. As an example system geometry, we consider a ring-shaped arrangement of bath spins, and show how it allows to exact precise control over the interaction strengths. We numerically analyze two example dynamical scenarios which can be simulated in this setup: a decay of central spin polarization, which can represent qubit decoherence in a disordered environment, and a transfer of an ``input'' spin state to a specific ``output'' spin, which can represent the transmission of a single bit across a quantum network. We demonstrate that this setup allows to realize a central spin model with highly tunable parameters and geometry, for applications in quantum science and technology.

Atom-ion hybrid systems: the Florence experiment 11:55

Carlo Sias: Ultracold atoms and trapped ions are among the most formidable sources of coherent matter available in a laboratory. In a hybrid quantum system of atoms and ions, ultracold atoms and trapped ions are combined in a single experimental apparatus, thus realizing an innovative platform to experimentally investigate open problems of quantum physics from a new standpoint.
In the talk, I will report on the most recent results achieved with our system of trapped Barium ions and fermionic Lithium gases. In particular, I will report on a number of technical advancements that we have implemented in order to achieve a high level of control over the atom-ion quantum mixture, and on the special features of our ion trap. These advancements include the realization of a linear cavity for confining the Lithium atoms. The goal of this cavity is to realize a deep optical potential where the atoms are transferred after the MOT stage. We have used an analytical model and a quantum Montecarlo simulation to calculate that the

energy of the particles can be reduced to a few quanta in less than 10ms by using an unconventional sideband cooling method [1].

Additionally, we have realized a bow-tie cavity for creating an optical lattice that will be used, together with an electric quadrupole, for confining the ions in a static potential [2]. This choice has been made in order to avoid micromotion-induced heating mechanisms and reach ultralow temperatures in the atom-ion mixture. The trap is also equipped with a linear Paul trap that is used to confine the ions after their creation through photoionization. The specific geometry of the electrodes composing the trap makes it possible to continuously change the structure of the ion crystal from a one-dimensional string to a two-dimensional Coulomb crystal by changing a DC voltage. Crucially, when the confining potential is made isotropic in the two-dimensional plane, we observe a change of configuration from a crystal of localized particles to a rotating crystal, in which the particles become delocalized along circular trajectories [3]. In a micromotion-free, static trap – and in the presence of atom-ion sympathetic cooling – this change of configuration can potentially be driven by quantum fluctuations, leading to a quantum orientational melting of the crystal.

Lunch 12:30

Ultracold lithium-chromium Fermi mixtures with resonant interactions 14:30

Matteo Zaccanti: Resonantly interacting mixtures of ultracold fermionic atoms provide versatile and highly controllable platforms with which to explore a wealth of phenomena occurring in strongly-correlated systems: from helium liquids and solid-state materials, up to nuclear and quark matter.
Here, I will discuss recent progress of my experimental team in making, probing and characterizing novel ^{6}Li-^{53}Cr ultracold Fermi mixtures under resonantly-interacting conditions: From the efficient production of highly-degenerate lithium and chromium Fermi gases, and the thorough characterization of the interspecies scattering properties, to the most recent realization of high phase-space density Bose gases of LiCr Feshbach molecules, and the exploration of degenerate Li-Cr Fermi mixtures with resonant interactions.

Mediated interactions between quasiparticles 15:05

Pietro Massignan: The notion of quasi-particles is essential for understanding the behaviour of complex many-body systems. A prototypical example of a quasi-particle is a polaron, formed by an impurity strongly interacting with a surrounding medium. Fermi polarons, created in a Fermi sea, provide a paradigmatic realization of this concept. Importantly, such quasi-particles interact with each other via modulation of the medium.
Here, we report the observation of mediated interactions between Fermi polarons consisting of potassium impurities embedded in a Fermi sea of lithium atoms [1]. Our results confirm two key predictions of Landau's Fermi liquid theory: the shift of the polaron energy due to mediated interactions, which is linear in the concentration of impurities, and its sign inversion with impurity quantum statistics.

Coffee break 15:40

Microscopy of molecular vibrations in ion-Rydberg-atom dimers 16:10

Florian Meinert: I will report on the direct imaging of molecular vibrations using ion microscopy of laser cooled atomic ensembles. Specifically, we have studied a novel type of a charged dimer composed of a Rubidium ion bound to a high-n Rydberg atom. The binding mechanism results from an ion-induced dipole in the Rydberg atom, which is position dependent and flips its orientation at the molecule's equilibrium bond length. Due to its small binding energy, the ion-Rydberg-atom dimer features a bond length on the micrometer scale and vibrates on timescales as long as hundreds of nanoseconds. We have constructed a novel pulsed ion microscope with high spatial and temporal resolution, which allows us to access these length and timescales and enabled the direct imaging of molecular alignment, orientation and vibration.

Cold Collisions of Ultracold Atoms in a Miniature Laser-based Accelerator 16:45

Niels Kjærgaard: I present results from experiments exploring two types of scattering resonances in the collision of ultracold clouds of atoms — shape resonances and Feshbach resonances. Using a laser-based accelerator that capitalizes on the energy resolution provided by the ultracold atomic setting, we unveil these resonance phenomena in their quintessential form by literarily photographing the halo of outgoing scattered atoms. Such images for example capture the quantum mechanical interference between partial waves and the interplay between S-matrix poles. In particular, the tunability of magnetic Feshbach resonances opens up a unique possibility to experimentally record the imprint from a flow of S-matrix poles in the complex energy plane.

Dinner 18:00

Poster + drinks 19:00

Tuesday 22 August

	Session chair: Niels Kjærgaard
09:00 - 09:35	Timon Hilker, Munich Center for Quantum Science and Technology
09:35 - 10:10	Kristian Knakkergaard Nielsen, Max Planck Institute of Quantum Optics
10:10 - 10:45	Tilman Enss, University of Heidelberg
10:45 - 11:20	**COFFEE BREAK**
11:20 - 11:55	Stephanie M. Reimann, Lund University
11:55 - 12:30	Artur Widera, University of Kaiserslautern-Landau
12:30 - 14:30	**LUNCH**
	Session chair: Henrik Stapelfeldt
14:30 - 15:05	Fransesco Scazza, University of Trieste
15:05 - 15:40	Roee Ozeri, Weizmann Institute
15:40 - 16:00	**COFFEE BREAK**
16:00 - 16:35	Jésus Perez Rios, Stony Brook University
16:35 - 17:10	David Hutchinson, University of Otago
17:45 – 19:00	**Tour at Den Gamle By**
19:00 -	**CONFERENCE DINNER**

Magnetic polarons and hole-hole attraction in mixed-dimensional Hubbard models 09:00

Timon Hilker: Unraveling the origin of unconventional superconductivity is one of the driving forces behind quantum simulations with Fermions in optical lattices. In these strongly correlated materials, the necessary pairing of charge carriers is often assumed to be related to the interplay of antiferromagnetic correlations and dopant motion. Despite impressive recent progress in the numerical treatment of the Hubbard model, many open questions remain in particular about the pseudo-gap regime and the relation of striped phases to superconductivity.

With our Lithium-6 quantum gas microscope, we can image strongly correlated many-body Fermi systems with full spin and density resolution and study individual holes' local distribution and spin environment. In addition, the microscope and a new phase-stable superlattice enable us to engineer large classes of Hubbardlike Hamiltonians with control on the level of individual sites. In antiferromagnets with weak doping, individual holes form magnetic polarons whose motion is strongly reduced due to the magnetic background. Pairs of dopants can overcome the frustrating effect but we find strong competition between this magnetically mediated hole-hole attraction and repulsion due to Pauli blocking. The binding energy for hole pairing in normal two-dimensional Hubbard models is thus strongly
reduced below the magnetic energy scale J.
However, in a mixed-dimensional system, where we restrict the hole motion to one dimension while keeping the spin order two-dimensional, we directly image tightly bound pairs of holes and find binding energies on the order of the spin exchange energy J. Upon increased doping, we observe first signatures of stripes, where holes align into 1D structures. Such stripes form the ground state of the normal Hubbard model and recent numerical results show that with a diagonal hopping term they support the emergence of dwave superconductivity.

Exact dynamics of dopants in a spin ladder 09:35

Kristian Knakkergaard Nielsen: The motion of dopants in quantum spin environments is crucial to the understanding of strongly correlated systems. In particular, the potential binding of two dopants should lead to key insights into the microscopic origin of high-temperature superconductivity. Motivated by new opportunities in quantum simulation experiments with ultracold atoms in optical lattices, I study a scenario, in which we may gain exact insights into the binding and dynamics of two such dopants.
The setup consists of a two-leg spin ladder with motion only along ladder and Ising-type nearest neighbor spin interactions.
First, I rigorously show that dopants may bind strongly to each other in such a system, as previously suggested in a Fermi-Hubbard system. Finally, I exactly characterize the non-equilibrium quench dynamics, following the sudden creation of two dopants next to each other in such a lattice. The latter scenario is particularly well-suited for inquiry using Rydberg-dressed atoms in optical lattices in which the spin interactions may be tuned essentially at will. Such investigations should be able to demonstrate the nonequilibrium crossover dynamics from the initial independent quantum walk of the dopants, to the long-time oscillatory motion driven by the presence of undamped string excitations akin to recent results for 2D square lattices. As an outlook, I will share very recent investigations into the motion of a single dopant in such a spin ladder at *infinite temperatures*.
I will argue that the resulting random spin ensembles leads to an effective disordered potential for the hole. Hence, the hole localizes as a result of thermally induced spin disorder, yielding what seems to be a novel type of Anderson localization.

Polaron interaction in superfluids 10:10

Tilman Enss: We investigate the induced Casimir interaction between two impurities in superfluid atomic gases. We find that a crossover between Efimov scaling at short distance between the impurities and Yukawa scaling at intermediate distance occurs for all impurity couplings. With the help of effective field theory (EFT) for a Galilean invariant superfluid, we show that the induced impurity-impurity potential at even longer distance does not fall off exponentially as a Yukawa potential, but instead exhibits a universal power-law scaling. We show that the exchange of two phonons leads to a relativistic van der Waals-like attraction (~1/r^7) at zero temperature and a nonrelativistic van der Waals attraction (~T/r^6) at finite temperature.

Coffee break 10:45

Persistent currents in binary and dipolar BEC's – from many atoms to the few-body limit 11:20

Stephanie M. Reimann: A dipolar Bose-Einstein condensate that is set rotating in a toroidal geometry may act in distinctly different ways, depending on whether it is in a superfluid or in the supersolid phase. It can support a supersolid persistent current that in part consists of states where a fraction of the condensate mimics solid-body rotation in a direction opposite to that of a vortex. Furthermore, a rotating toroidal supersolid may show hysteretic behavior that is qualitatively different depending on the superfluid fraction of the condensate. In this talk will discuss our recent work on stacked droplets in anti-dipolar condensates, which offer intriguing possibilities to investigate vorticity and persistent flow in a setting that is rather different from the typical filament structures. The presence of a vortex line impacts on the phase transition into the supersolid region. I will also give an outlook how this setup will be used to study persistent current and distribution of angular momentum in the transition to the supersolid regime.
In binary bosonic mixtures, for equal short-range intra-component interactions but an unequal number of atoms in the two components, there is an excess part that cannot bind to a droplet. Imposing confinement, the droplet then becomes amalgamated with the residual condensate. I will discuss the rotational properties of such a compound system which show that the residual condensate can carry angular momentum even in the absence of vorticity. In contradiction to the intuitive idea that the superfluid fraction of the system would be entirely made up of the excess atoms not bound by the droplet, this fraction is found to be higher than what one would expect, intriguingly mimicking a "one-droplet" analog to a supersolid.
I will also address the few-body limit of binary droplets in a diagonalization approach and show how the excitation spectra and ground-state pair correlations signal self-binding (in some analogy to our previous finding of few-body analogs of elementary modes to uncover fermion pairing fluctuations).

Impact of infinitely heavy yet mobile impurities in interacting fermionic quantum gases 11:55

Artur Widera: The combination of local perturbation via impurities, on the one hand, and interactions in a quantum gas, on the other hand, is a central problem in quantum science. An exciting situation arises when the system is rendered time-dependent, and the impurities change their properties on time scales faster than the typical many-body time scales of the gas.
I will report on recent experimental results investigating the impact of a time-controlled external perturbation on an interacting two-component Fermi gas in different scenarios. The perturbation is realized as a repulsive speckle potential, effectively contributing local impurities of infinite mass. The time dependence is induced either as a fast quench of the speckle amplitude, corresponding to a rapid change of the impurity coupling strength or as a finite correlation time of the speckle, corresponding to a motion of the impurities. The quantum gas is realized as an ultracold gas of fermionic Lithium atoms in the two lowest Zeeman sub-states. This system features a broad Feshbach resonance, where very different superfluid states can be prepared, such as molecular Bose-Einstein condensate, unitary Fermi gas, or BCS-type superfluid. Additionally, a spin-polarized noninteracting Fermi gas can be prepared.

I will report on the effect of speckle quenches on the decay and revival of long-range phase coherence, which we detect via the ability of the ultracold gas for quantum-hydrodynamic expansion when released to harmonic confinement. In the BEC regime, we find that long-range coherence is lost one order of magnitude faster than the density distribution of the gas can respond. When released from a disordered state, long-range phase coherence needs two orders of magnitude longer times to revive compared to the density distribution. For a unitary gas, the most strongly interacting gas with the largest critical velocity, we find that long-range coherence is lost even faster than for a BEC after disorder quenches. And surprisingly, we find that long-range coherence never revives after release from a disordered state. We find that the unitary gas features enhanced heating which we attribute to an additional dissipation channel via near-resonant pair breaking in the crossover.

Finally, we study the time evolution of a noninteracting Fermi gas in disorder with finite correlation time. As the correlation time decreases, corresponding to a faster motion of the impurities, we observe that the initially Anderson-localized Fermi gas shows anomalous diffusion, where the diffusion can be steered via the correlation time. We explain our observation by Fermi acceleration, which is proposed as a mechanism producing high-energy particles in outer space by motion through randomly fluctuating electromagnetic fields.

Lunch 12:30

A new ytterbium experiment for single-atom resolved quantum impurity problems 14:30

Francesco Scazza: Recent advances in the microscopic optical manipulation of cold atomic ensembles have extended our experimental control capabilities down to the level of single particles or single excitations, providing exciting opportunities to explore quantum many-body problems with a nobel bottom-up perspective. Here, I will describe ongoing work to develop a modern experimental apparatus in Trieste, aiming to trap, control, and detect individual ytterbium atoms to rapidly assemble mesoscopic many-particle systems with low entropy. Ytterbium presents several key features which make it an excellent system to investigate open questions in strongly correlated matter, especially regarding quantum impurities and their mediated long-range interactions. Equipped with the precise atomic clock toolbox of two-electron atoms, we will target the dynamical formation of Fermi polarons and Kondo resonances by controllably embedding individual impurities in an itinerant fermionic band, towards programmable simulations of two-orbital quantum Hamiltonians.

Trap-assisted formation of chaotic bound states in atom-ion collisions 15:05

Roee Ozeri: In this talk I will focus on three different recent observations in ultra-cold atom-ion scattering. Firstly i will discuss observations of the persistence of s-wave like behavior far from the s-wave regime. Secondly i'll show that the presence of the Paul trap breaks translation invariance and therefore allows for the formation of molecules in elastic binary collisions. Lastly i'll show that the dynamics of these loosely bound molecules is highly chaotic.

Coffee break 15:40

A single ion in an ultracold bath: coordination, snowballs and polaronic effect 16:00

Jésus Perez Rios: In this talk, we present a study on the ground state properties of a single ion in a bath of ultracold atoms. We use a quantum Monte Carlo approach to determine the most stable geometry and ground state energy as a function of the number of atoms and distinct atom-ion interaction potentials. As a result, we explore the coordination number of the ion—the number of atoms it can bind, and electrostriction effects within the first solvation shell that give rise to the so-called snowballs. Similarly, we investigate possible polaronic effects. Furthermore, we include the ion trap in our approach, thus, elucidating the role of the trapping potential on the stability of the system at hand and the geometry associated with the ground state energy.

Anderson Localisation in Two-Dimensional Ultracold Gases 16:35

David Hutchinson: In three-dimensional disordered systems there exists a well characterised quantum phase transition between conducting metallic and insulating phases called the Anderson Transition. In one-dimension only an insulating phase exists. Two-dimensions is the marginal dimension. In this talk I will discuss the physics of localisation in these two-dimensional systems including our recent demonstration of Anderson Localisation in an ultracold two-dimensional gas, and more recent work characterizing transitions in a two-component spinor gas, including the role of spin-orbit coupling. In particular, we will discuss physical signatures of the metal-insulator phase transition accessible via the momentum signature.

Tour at Den Gamle By **17:45**

Conference Dinner at Den Gamle By **19:00**

Wednesday 23. August

	Session chair: Jan Arlt
09:00 - 09:35	Ludwig Mathey, University of Hamborg
09:35 - 10:10	Jacques Tempere, University of Antwerp
10:10 - 10:45	Henrik Stapelfeldt, Aarhus University
10:45 - 11:20	**COFFEE BREAK**
11:20 - 11:55	Christoph Eigen, University of Cambridge
11:55 - 12:30	Francesco Minardi, University of Florence
12:30 - 14:30	**LUNCH**
14:30 -	**Tour at our labs**

Electron trimer states in conventional superconductors and Rydberg quantum computing 09:00

Ludwig Mathey: In this talk, I will primarily report on our study of electron trimer states in conventional superconduc-tors. Here, we expand the Cooper problem by including a third electron in an otherwise empty band. We demonstrate the formation of a trimer state of two electrons above the Fermi sea and the third electron, for su_ciently strong interband attractive interaction, see panel (a) and Ref. [1]. We show that the critical interaction strength is the lowest for small Fermi velocities, large masses of the additional electron, and large Debye energy. This trimer state competes with the formation of the two-electron Cooper pair, and can be created transiently via optical pumping.

Time permitting, I will summarize our study on machine learning assisted design of a two-qubit gate in a Rydberg tweezer system. Utilizing a hybrid quantum-classical optimizer, we generate optimal operational sequences that implement a CNOT gate with high fidelity, for experimentally realistic parameters and protocols, as well as realistic limitations. As the central point, we show that Rydberg-based quantum information processing in the weak-coupling limit, not only in the strong-coupling, blockade regime, is a desirable approach, being robust and optimal, with current technology.

Large polarons from solids to quantum gases and back 09:35

Jacques Tempere: I will start by reviewing the solid state polaron consisting of an electron coupled to a bath of lattice phonons, as described by the Frohlich Hamiltonian. In particular I will focus on Feynman's approach to calculate the polaronic energy shift. In contrast to the Lee-Low-Pines treatment that aims at eliminating the electron coordinate, this approach eliminates the phonon coordinates, resulting in a retardation potential for the electron. The path-integral approach also allows to compute the optical absorption of solid state polarons, which has been used to reveal the existence of these quasiparticles in a variety of materials. Although for the solid state polaron, Feynman's method is superior, there are still some discrepancies with diagrammatic monte carlo for very high electron-phonon coupling.

The high couplings needed to reveal this discrepancy are unreachable in the solid state, and fifteen years ago it was thought that quantum gases may offer a way forward. These provide a highly tunable quantum simulator for polarons, where the role of the electron is taken up by an impurity immersed in the Bose-Einstein condensate. I will review various works relating to Bragg spectroscopy as an analog for the optical absorption in solids, and multipolaron absorption. In 2016, impurity-BEC polarons were observed. Rather than allowing to study the strong-coupling Frohlich model, the experiments showed that the Frohlich Hamiltonian at strong coupling in the quantum gas should be extended with 2-phonon terms. Feynman's path integral method has had to be adapted to describe the impurity-BEC polaron. Specifically, generalized retardation kernels have to be introduced.

However, despite that the original goal of strong electron-phonon coupling could not be quantum simulated in a condensate, studying the impurity-BEC polaron still led to advances in the description of the solid state polaron. Mathematically similar "beyond Frohlich" terms appear in new classes of interesting materials such as the superconducting hydrides, and are related to the strong anharmonicity of the lattice vibrations in these materials. This leads to changes in the optical absorption, and to a stabilization of bipolarons in these solids.

The primary steps of ion solvation 10:10

Henrik Stapelfeldt: Solvation is an omnipresent process both in our daily life and in the natural sciences. I will present recent experimental results that have enabled us to observe the solvation dynamics of a single alkali cation ion in liquid helium with atomic resolution and on the natural femtosecond time scale. A single Na^+ ion is created instantly at the surface of a liquid He nanodroplet and we measured in real time the gradual attachment of individual He atoms to the ion. In addition, we determined how fast the solvent-solute binding energy is dissipated from the local region around the alkali ion.

Coffee break 10:45

Bose polarons in a box 11:20

Christoph Eigen: We experimentally study the paradigmatic many-body problem of mobile impurities interacting with a homogeneous Bose-Einstein condensate (BEC). We use a combination of injection spectroscopy and many-body interferometry to access the injection spectrum (frequency domain) and the impurity-coherence function (time domain). Our experiments start with a spin-polarized BEC confined in an optical box trap and we use rf pulses to transfer a fraction of atoms into the target spin state.
We map out the polaron energy and spectral response from weak to strong impurity-bath interactions (characterized by the interstate scattering length a) and study the effects of varying condensate properties, changing both the condensate (intrastate) interactions ($a_{\rm b}$) and density n. We observe that most of the physics is universally set by n and a. For strong repulsive interactions, we observe two distinct spectral features, corresponding to a repulsive polaron and a many-body state related to the Feshbach dimer. Curiously, despite the significantly reduced inhomogeneous-density broadening in our system, we observe that even at weak interactions the spectra have significant widths proportional to their shifts. Finally, our many-body interferometry provides new insights into the formation dynamics of the Bose polaron.

Collective oscillations of two Bose-Einstein condensates 11:55

Francesco Minardi: We investigate the coupled dynamics of a double species Bose-Einstein condensate with tunable interspecies interaction. With a degenerate mixture of 41K-87Rb we excite the center-of-mass ("dipole") oscillations of both atomic species in the linear response regime; we measure the frequencies and the composition of the two dipole eigenmodes as the interspecies interactions are varied from weakly to strongly attractive. Experimental results are compared with numerical simulations performed by solving two coupled Gross-Pitaevskii equations, to obtain a detailed picture of the dipole excitations in asymmetric bosonic mixtures.

Lunch 12:30

Tour at our labs 14:30

Poster session Monday at 19:00

Author: Krzysztof Myśliwy, in collaboration with Krzysztof Jachymski, University of Warsaw
Title: Polarons in Thomas--Fermi theory

We consider the problem of a single impurity interacting with an otherwise free Fermi gas via a bounded long--ranged potential by constructing the appropriate Thomas--Fermi theory. It is found that in two dimensions, the model results in a suitable Landau--Pekar functional known from the Bose polaron problem, describing a self--interacting impurity. The resulting Pekar problem displays the localisation transition in the Gaussian approximation, and the effective mass diverges at a finite critical coupling strength. In other dimensions, the impurity self--interacts with an infinite number of its own images, and no bosonization occurs. The localization persists in $3d$, now as a first--order transition. The results should be of relevance for the theory of ions immersed in cold Fermi gases as well as mobile impurities in metals.

Author: Tibor Jónás, University of Debrecen
Title: Multi-Channel Quantum Scattering Calculation for Electronic Excitation Exchange and Spin-Orbit Change in Rb + Sr+ Collision

Our theoretical study is related to the experimental investigations of a single Sr+ ion embedded in the cloud of ultracold Rb atoms [1]. Due to the presence of the trapping lasers, in the experiments the Sr+ ion can be excited to the Sr+(D3/2, 5/2) states. Usually the dominant process in atom-ion collisions is the charge-exchange process, which in the present experiment was not observed. Based on the kinetic energy distribution of the ions two relaxation processes have been identified experimentally: the electronic excitation exchange (EEE) and the spin-orbit change (SOC) process. In paper [1] a model has been proposed based on a semiclassical approach, which was not able to reproduce the experimental rates. Here we propose a multi-channel quantum description of the collisional processes.

Author: Tobias Krom, University of Heidelberg
Title: Characterization of an ultracold Li-Cs mixture to study polaron physics

Mixture experiments of ultracold atoms are well controlled testbeds for impurity physics theories. The presented experiment consists of bosonic 133Cs and fermionic 6Li atoms. Due to their mass-ratio, regimes close to the orthogonality catastrophe for Fermi polarons can be studied. For the Bose polaron, the expected avoided level crossing between the polaron and the Efimov trimer is noteworthy (Sun et. al, PRL **119**, 013401 (2017)). This contribution focuses on an in-detail characterization of the atomic samples as preparation for future studies.
In a theoretical and experimental analysis, the scattering properties, Cs-Li spin relaxation processes, and three-body recombination are investigated to determine suitable regimes. Characterizations of the magnetic field, showing its stability down to 10−5 of its absolute value. To characterize the degeneracy of the single spin state 6Li gas the cloud shape which is measured by absorption imaging is analyzed.
These results are benchmarked with a numerical simulation of the full imaging process considering the noise of the used CCD camera as well as the non-homogeneous and non-constant distribution of the imaging light.
A radio frequency source inside the vacuum chamber gives rise to the possibility to coherently change the Li spin state (ΩRabi=14 kHz). To control the Cs spin states a two-photon Raman process without momentum transfer is used, which is induced by laser light with 10 GHz detuning from the D2 line. We report about an effective Rabi frequency up to ΩRabi=18 kHz using a simplistic laser setup with a standard diode laser with 50 mW output power. Both

methods can be used as a spectroscopy probe for either the majority or the minority species of the polaron.

Author: Ubaldo Olivas,
Title: Polaron and bipolaron formation in a Bose gas

Ultracold quantum many-body systems constitute an interesting research playground due to their wide range of applications, from precision measurements to transport phenomena in the field of condensed matter. One particular example are hybrid systems of atoms and ions, which are rapidly developing. A distinctive property of these kind of systems at ultralow temperature is the emergence of the so-called polaron. A quantum bath composed of bosonic atoms weakly coupled to an ion can be properly described by means of Bogoliubov theory.
Nevertheless, this approach is no longer valid as soon as the strong coupling regime is taken into account, leading to an instability with an infinite number of bosons collapsing into the ion. Ion-atom systems feature long-range interactions which drive the system to form a many-body bound state with high density and large atom number. In order to explore this physics and circumvent the bosons unstable behavior, based on, a variational approach is adopted. Employing a regularized potential that retains the correct long-distance behavior, we study the properties of interest in the formation of ionic Bose polaron and bipolaron, such as their energy, the number of bosons that takes part in the cloud formation, and the induced interactions which are tunable by the potential parameters.

Author: Luis Ardila, University of Camerino
Title: Bose and Fermi polarons in atom-ion hybrid systems

We investigate the ground-state properties of ionic Bose and Fermi polarons employing quantum Monte Carlo techniques. Atom-ion impurity systems exhibit pronounced strong back-action effects, particularly within strong interactions. The interplay between the characteristic range of the atom-ion potential and inter-particle distance facilitates the emergence of polarons spanning a spectrum from conventional quasiparticles observed in neutral scenarios to intensely correlated polarons characterized by the formation of many-body bound states, where there is not a separation of length scales. In addition, we study induced interactions among bosonic ionic impurities, predicting the formation of ionic bipolaronic states.

Author: Cosetta Baroni, University of Innsbruck
Title: Polarons in Fermi-Fermi and Fermi-Bose mixtures

Author: Anton Andersen, Aarhus University
Title: TBA

Author: Jens Nyhegn, Aarhus University
Title: Magnetic polaron in a bilayer antiferromagnet
Adding a dopant to an antiferromagnetic spin background disturbs the spins and leads to the formation of a quasiparticle coined the magnetic polaron, which is theorised to be the charge carriers in the superconducting phase in cuprates. The dynamics of these charge carriers is a long-standing and fundamental problem. Recently, a new generation of quantum simulation experiments based on atoms in optical lattices has emerged that gives unprecedented insights into the detailed spatial and temporal dynamics of this problem, which compliments earlier results from condensed matter experiments. Focusing on observables accessible in

these new experiments, we explore here the equilibrium as well as non-equilibrium dynamics of a mobile hole in two coupled antiferromagnetic spin lattices.

Author: The Ion Trap Group, Center for Complex Quantum Systems, Department of Physics and Astronomy, Aarhus University, Denmark.

Title: Cryogenic ion trap setup for cold molecular science and ultracold ion-neutral many-body physics

We have recently initiated an experimental activity with the aim of investigate many-body phenomena governed by ultracold ion-atoms interactions. In entering this intriguing and challenging research field with already several very well-established groups, we have in an initial phase decided to focus on how to design an experiment that can deal with the many already known obstacles, and key limiting processes, as well as exploring theoretically new potential types of experiments. In addition to such aspects, we have designed our experiment such that various investigations within cold molecular ion science can also be pursued.

Author: Toke Vibel

Title: Understanding Atom Number Fluctuations in a Bose-Einstein Condensate.

Bose-Einstein condensation (BEC) of weakly interacting atomic gases is crucial in modern atomic physics research, requiring a deep understanding for practical applications.

While the mean atom number in partly condensed clouds is well-understood, the fluctuations have remained a puzzle until recently. Here, I present our breakthrough in characterizing these atom number fluctuations. Our observations reveal a reduction in the fluctuations below the canonical expectation for non-interacting gases, shedding light on the microcanonical nature of our system.

Finally, our recently enhanced data analysis, which considers various noise contributions in the experimental procedure will be presented.

Author: Søren Balling and Andreas Madsen Morgen

Title: Impurity physics with Bose-Einstein condensates

Spectroscopic and interferometric measurements complement each other in extracting the fundamental properties of quantum many-body systems. While spectroscopy provides precise measurements of equilibrated energies, interferometry can reveal the evolution of the system. For an impurity immersed in a bosonic medium, they allow for a complete understanding the quasiparticle physics of the Bose polaron. Comparing the interferometric and spectroscopic timescales to the underlying dynamical regimes of the impurity dynamics and the polaron lifetime, highlights the capability of the interferometric approach to clearly resolve polaron dynamics. Furthermore, interactions between impurities mediated by the bath have been theorized to result in a bound state, known as the bipolaron [3]. Using different spectroscopic methods we have investigated this state. Our results give a comprehensive picture of the many-body physics governing the Bose polaron and thus validate the quasiparticle framework for further studies.

Author: Shanshan Ding

Tile: Mediated Interaction between Ions in Quantum Degenerate Gases

We explore the interaction between two trapped ions mediated by a surrounding quantum degenerate Bose or Fermi gas. Using perturbation theory valid for weak atom-ion interaction, we show analytically that the interaction mediated by a Bose gas has a power-law behavior for large distances whereas it has a Yukawa form for intermediate distances. For a Fermi gas, the mediated interaction is given by a power law for large density and by a Ruderman-Kittel-Kasuya-Yosida form for low density. For strong atom-ion interaction, we use a diagrammatic theory to demonstrate that the mediated interaction can be a significant addition to the bare Coulomb interaction between the ions, when an atom-ion bound state is close to threshold. Finally, we show that the induced interaction leads to substantial and observable shifts in the ion phonon frequencies.