Q 9: Ultracold Atoms: Rydberg Gases / Miscellaneous (with A)

Time: Monday 16:30–19:00 Location: A 320

Prize Talk Q 9.1 Mo 16:30 A 320

Highly excited atoms in cold environments: From antihydrogen production to ultracold plasmas and Rydberg gases — •Thomas Pohl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden — Laureate of the Gustav-Hertz-Prize

The production of cold antihydrogen atoms at CERN marks a major development in AMO as well particle physics, as it holds great promise for high precession-spectroscopy tests of CPT invariance and for investigating matter-antimatter gravity. Since they form in highly excited states, successful cooling and trapping of antihydrogen atoms relies on the special properties of Rydberg atoms and how they form in the strong magnetic fields of anti-matter plasma traps.

Here, I will report on recent progress in understanding the formation of Rydberg atoms in antihydrogen traps as well as in ultracold neutral plasmas, as produced from laser-cooled atomic gases. This also includes fundamental questions concerning the nature of recombination processes in ultracold, so-called strongly coupled systems and is important for pushing the temperature limits of Rydberg plasmas. Controlling the temperature in ultracold plasmas and Rydberg gases is shown to open up a diverse range of interesting phenomena, such as dynamical crystallization processes in the classical as well as in the quantum domain.

Q 9.2 Mo 17:00 A 320

Coherent population trapping with controlled interparticle interactions — •Georg Günter[1], Hanna Schempp[1], Christian Giese[1], Sebastian Saliba[1], Christoph Hofmann[1], Brett D. DePaola[1], Sevilay Sevincli[2], Thomas Pohl[2], Thomas Amthor[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, 01187 Dresden

Coherent population trapping (CPT) and the related phenomenon of a "dark resonance" is a paradigm for quantum interference. Intense studies of this phenomenon have led to intriguing effects like electromagnetically induced transparency, lasing without inversion, adiabatic population transfer and subrecoil cooling. Whereas CPT is generally described within a single-atom framework, the situation becomes more involved when interparticle interactions have to be considered. To address this question, we investigate CPT in a strongly interacting, ultracold Rydberg-gas. In our experiment we tune the interaction strength by choosing the Rydberg state and control interactions effects using the ground state density. Even in the blockade regime we observe a resonance with sub-natural linewidth at the single-particle resonance frequency despite the strong van der Waals interactions among Rydberg atoms. Due to the correlations among the atoms the experimental observations cannot be explained within a meanfield model. A theoretical model that includes interparticle correlations is presented and nicely reproduces the observed features.

Q 9.3 Mo 17:15 A 320

Semiclassical analysis of Rydberg molecules — •Gordana Palavestric, Jörg Main, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

In cold gases ultra-long range Rydberg molecules have been predicted theoretically [1] and recently observed experimentally [2]. The molecular binding can be described with a Fermi pseudo-potential and the Born-Oppenheimer approximation. We present a semiclassical model to describe the interaction. The electron of the highly excited Rydberg atom is scattered at the ground state atom. The transferred momentum causes a force on the neutral atom. We solve the classical equations of motion and investigate the initial condition for the bound dynamics of the “Rydberg molecule”.

[1] C. H. Green, A. S. Dickinson, H. R. Sadeghpour, Phys. Rev. Lett. **85**, 2458 (2000).
[2] V. Bendkowsky, B. Butscher, J. Nipper, J. P. Shaffer, R. Löw and T. Pfau, Nature **458**, 1005 (2009).

Q 9.4 Mo 17:30 A 320

Strongly interacting Rydberg atoms in a one-dimensional lattice — •Hendrik Weimer and Hans Peter Büchler — Institut für Theoretische Physik III, Universität Stuttgart

We analyze the ground state properties of a one-dimensional lattice system, where Rydberg excitations are created by laser driving. In the classical limit the ground state is characterized by comensurate crystals with fractional exciations. We show that quantum fluctuations lead to a melting of the crystalline phases that is governed by condensation of the excitations. We compare the critical exponents obtained within perturbation theory to mean-field predictions for a homogeneous gas [1,2].

[1] H. Weimer, et al., Phys. Rev. Lett. **101**, 250601 (2008).
[2] R. Löw et al., Phys. Rev. A **80**, 033422 (2009).

Q 9.5 Mo 17:45 A 320

Antiblockade of Rydberg excitation in an ultracold gas — •Christoph S. Hofmann[1], Thomas Amthor[1], Christian Giese[2], Georg Günter[1], Hanna Schempp[1], Nele Müller[1], and Matthias Weidemüller[1] — [1]Physikalisches Institut, Universität Heidelberg, Philosophenweg 12, 69120 Heidelberg — [2]Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

The long-range character of strong Rydberg–Rydberg interactions gives rise to phenomena such as the interaction-induced blockade of Rydberg excitation. The opposite effect, the so-called antiblockade of excitation has recently been proposed for a three-level two-photon Rydberg excitation scheme, in which an Autler-Townes splitting is induced by strong coupling laser at the lower transition [1]. When the coupling energy matches the interaction energy of the long-range Rydberg interactions, the otherwise blocked excitation of close pairs becomes possible. We present the first experimental observation of the antiblockade in an ultracold Rydberg gas [2]. To reveal this effect we use time-resolved ionization detection. In this way we monitor the distribution of excited-pair distances, which allows us to clearly observe additional excitation (antiblockade) of pairs at small distances out of a random arrangement of atoms. A model based on a pair interaction Hamiltonian is presented which nicely reproduces our experimental observations and allows to analyze the distribution of nearest neighbor distances.

[1] C. Ates et al., Phys. Rev. Lett 98, 023002 (2007)
[2] T. Amthor et al., arXiv:0909.0837v1

Q 9.6 Mo 18:00 A 320

Occupation statistics of a Bose-Einstein condensate in a driven double-well potential — •Moritz Hiller[1], Katrina Smith-Mannschott[2,3], Maya Chuchem[4], Tsampikos Kottos[2], and Doron Cohen[4] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Wesleyan University, CT, USA — [3]MPI für Dynamik und Selbstorganisation, Bunsenstraße 10, 37073 Göttingen — [4]Department of Physics, Ben-Gurion University, Beer-Sheva, Israel

We consider the occupation statistics $P_t(n)$ of a Bose-Einstein condensate consisting of N particles loaded in a double-well trap with inter-site coupling K. Two dynamical scenarios are investigated: a) wave-packet dynamics and b) linear variation of the bias between the on-site energies of the two wells. In the latter case, we resolve three different behaviors as we increase the driving rate for intermediate values of the inter-atomic interaction $K/N < U < NK$: quantum adiabatic, diabatic, and sudden regime. We find that during the adiabatic to diabatic crossover, many-body Landau-Zener transitions play a dominant role, resulting in oscillations of the second moment of the occupation statistics. In contrast, the crossover to the sudden regime is characterized by a broad distribution $P_{t\to\infty}(n)$ which is reflected in a global maximum of its second moment.

Q 9.7 Mo 18:15 A 320

Spectral origin of decaying Bloch oscillations — •Hannah Venzl, Moritz Hiller, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

We study Bloch oscillations of ultra-cold bosonic atoms in tilted optical lattices. Our analysis is based on the Bose-Hubbard Hamiltonian amended by a static field term. For comparable values of the control parameters, namely the inter-atomic interaction, the inter-site hopping amplitude, and the static field, the system displays chaotic level statistics. In this regime, the Bloch oscillations exhibit an irreversible, fast decay. We discuss how the corresponding decay rate can be obtained from the spectral properties of the Bose-Hubbard Hamiltonian.

Q 9.8 Mo 18:30 A 320

Probing a Bose-Hubbard system with a scattering particle — •Stefan Hunn[1], Moritz Hiller[1], Tsampikos Kottos[2,3], Doron Cohen[4], and Andreas Buchleitner[1] — [1]Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg — [2]Department of Physics, Wesleyan University, CT, USA — [3]MPI für Dynamik und Selbstorganisation, Bunsenstrasse 10, 37073 Göttingen — [4]Department of Physics, Ben-Gurion University, Beer-Sheva, Israel

We consider a probe particle in a tight-binding geometry with two leads attached to a central site that is coupled to a Bose-Hubbard system consisting of two or three wells. We find that the characteristic properties of the target's underlying phase-space structure are reflected in the scattering signal. Hence, this scattering setup constitutes a non-destructive method to measure the properties of a Bose-Einstein condensate confined on an optical lattice. We focus on the parameter regime where the corresponding classical dynamics is chaotic and follow a three-fold approach to the scattering process: Besides the quantum mechanical scattering theory we employ an improved random matrix model and propose a time-dependent, semi-classical formulation of the scattering process where the Bose-Hubbard Hamiltonian is treated in the mean-field (Gross-Pitaevskii) limit.

Q 9.9 Mo 18:45 A 320

Connecting ultra hot with ultra cold: geometric phases in cold atoms — •Michael Merkl[1], Patrik Öhberg[1], Luis Santos[2], and Gediminas Juzeliunas[3] — [1]Heriot-Watt University Edinburgh — [2]Universität Hannover — [3]Vilnius University

Ultra-cold atoms have turned out to be an ideal playground for testing quantum physics. Recently analogies between ultra-cold systems and high energy physics have attracted a great interest. For kinetic energies below the photon recoil limit, the internal electronic states can be said to follow the optical field and hence a Berry phase emerges in the atom's centre of mass Schrödinger equation. Moreover, for a degenerate manifold of electronic states the geometric phase describes transitions within this pseudo-spin Hilbert space, which can also give rise to non-Abelian effects. In this work we show how a wide range of phenomena like Josephson effects, mass currents and soliton like objects in the presence of geometric gauge potentials can occur. These techniques can also be used to mimic aspects of relativistic quantum mechanics with cold atoms.