A 15: Ultracold atoms and BEC - III (with Q)

Time: Tuesday 14:30–16:30 Location: N 1

A 15.1 Tue 14:30 N 1

Efimov physics in ultracold atomic gases using finite-range potentials — •Thomas Secker, Paul Mestrom, and Servaas Kokkelmans — Eindhoven University of Technology, Eindhoven, The Netherlands

Three-body Efimov physics is relevant for the understanding of both dynamics and stability of ultracold gases. Efimov predicted the existence of an infinite sequence of three-body bound states, of which many properties scale universally, at diverging scattering length for a zero-range interaction potential. Experiments with ultracold atoms in which the scattering length is tuned through Feshbach resonances have also shown the universality of the negative three-body parameter. In order to investigate these universal aspects, we utilize a finite range interaction potential. We solve for this problem in a momentum-space treatment containing off-shell two-body scattering processes. To include the Feshbach formalism we have generalized it to an off-shell theory. First results show remarkable similarities with experimental data, especially in the case of broad resonances.

A 15.2 Tue 14:45 N 1

Novel states in a three-body system with a p-wave resonance — •Matthias Zimmermann[1], Santiago I. Betelu[2], Maxim A. Efremov[1], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, 89081 Ulm, Germany — [2]Department of Mathematics, University of North Texas, Denton, TX 76203-5017, USA

One of the most intriguing phenomena of few-body physics is the Efimov effect, which manifests itself in an infinite number of weakly bound three-body states if at least two of the three two-body subsystems exhibit a single s-wave resonance.

We present a novel class of purely quantum-mechanical bound states in the system of three particles in two dimensions provided: (i) the system consists of a light particle and two heavy bosonic ones, and (ii) the heavy-light short-range potential has a p-wave resonance. Within the familiar Born-Oppenheimer approach, the effective potential between the two heavy particles is shown to be attractive and of long-range, resulting in an infinite number of universal bound states corresponding to a vanishing total angular momentum of the three-body system.

In order to verify our analytical results we employ a numerical scheme utilizing spectral methods. This enables us to discretize the stationary Schrödinger equation in function space in order to achieve exponential convergence. We solve the resulting eigenvalue problem with the Data Vortex supercomputing system.

A 15.3 Tue 15:00 N 1

Impurities immersed in a BEC. Quantum simulator of the polaron? — •Luis Aldemar Ardila[1], Thomas Pohl[1], and Stefano Giorgini[2] — [1]Nöthnitzer Straße 38 01187 Dresden Germany — [2]Via Sommarive 14 I-38123 Povo, Italy

We investigate the properties of an impurity immersed in a Bose gas at zero temperature using both analytical and Quantum-Monte Carlo methods. The interaction between bosons are modeled by a hard-sphere potential with scattering length a, whereas the impurity-boson interaction is modeled by a short-range attractive square-well potential, where both the sign and the strength of the scattering length b can varied by adjusting the well depth. We characterize the repulsive and attractive [Fig. 1] polaron branch by calculating the binding energy and the effective mass [1]. Furthermore, we study the structure of the bosonic bath such as the boson-boson correlation function and the density profile around the impurity. For resonant interactions between the impurity and the bosonic bath, the Ground state properties are also investigated as well as Efimov Effects . The implication for the phase diagram of binary Bose-Bose mixtures is also discussed . We also discuss more complicated interactions between the impurity and the bosonic bath. For this case we consider a Quasi-2D Dipolar Bose gas at zero temperature. Furthermore, the impurity-Bose interaction is dipolar. Using perturbation theory, the Ground-state properties are investigated based on the low-energy Fröhlich Hamiltonian.

A 15.4 Tue 15:15 N 1

The Bose polaron in an ultracold Bose-Fermi mixture of Cs and Li — •Stephan Häfner, Binh Tran, Manuel Gerken, Melina Filzinger, Bing Zhu, Juris Ulmanis, and Matthias Weidemüller — Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany

An ultracold Bose-Fermi mixture of ^{133}Cs and ^{6}Li is well suited for the investigation of the Bose polaron. In this scenario a single Li impurity is immersed in a Cs BEC and interacts with its phonon excitations, mimicking the Fröhlich polaron problem from solid-state physics. Tuning the sign and strength of the interaction between Li and Cs via Feshbach resonances enables us to study repulsive and attractive polarons. The observation of different polaron states, ranging from the Landau-Pekar polaron to the bubble polaron is within reach for the Li-Cs system.

In this talk we describe the production of a Cs BEC by forced evaporative cooling in an optical dipole trap. The phase-space density is enhanced by modifying the trapping geometry with an additional small-sized dipole trap. This is the first step for the study of the Bose polaron in the Li-Cs system.

A 15.5 Tue 15:30 N 1

Observation of individual tracer atoms in an ultracold dilute gas — •Felix Schmidt[1,2], Daniel Mayer[1,2], Tobias Lausch[1], Daniel Adam[1], Steve Haupt[1], Michael Hohmann[1], Farina Kindermann[1], Nicolas Spethmann[1], and Artur Widera[1,2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Strasse 47, 67663 Kaiserslautern

Diffusion of particles in fluids and gases is an essential and omnipresent transport phenomenon in nature. While diffusion is well understood in the limit of a heavy particle in a dense gas (known as Brownian motion), much less is known, both theoretically and experimentally, about light particles diffusing in a dilute gas.

Here, we report on the experimental investigation of individual Cs atoms impinging on a dilute cloud of ultracold Rb atoms with variable density. We study the nonequilibrium relaxation of the initial nonthermal state of Cs and detect the effect of a of single collision, i.e. the fundamental building block of diffusion. We show that the diffusive motion of the single Cs atom in the Rb cloud is well described by a generalized Langevin equation with a velocity-dependent friction coefficient, an unfamiliar feature of the Langevin equation emerging for light particles.

A 15.6 Tue 15:45 N 1

angular self-localization of impurities rotating in a bosonic bath — •xiang li, mikhail Lemeshko, and robert seiringer — Institute of Science and Technology Austria, Am Campus 1, Klosterneuburg, Austria

The existence of a self-localization transition in the polaron problem has been under an active debate ever since Landau suggested it in 1933. Here we reveal the self-localization transition for the rotational analogue of the polaron - the angulon quasiparticle. The transition takes place at finite coupling strength already at the mean-field level, it is accompanied by a discontinuity in the first derivative of the angulon ground-state energy and a spherical-symmetry breaking of the angulon ground state. This symmetry breaking is demonstrated to be depend on the symmetry of the microscopic impurity-atom potential, which results in a number of distinct self-localized states. The predicted effects can potentially be addressed in experiments on cold molecules trapped in superfluid helium droplets and ultracold quantum gases, as well as on electronic excitations in solids and Bose-Einstein condensates.

[1] X. Li, R. Seiringer, M. Lemeshko, arXiv: 1610.04908

A 15.7 Tue 16:00 N 1

Rotation of cold molecular ions inside a Bose-Einstein condensate — •Bikashkali Midya[1], Michal Tomza[2], Richard Schmidt[3], and Mikhail Lemeshko[1] — [1]Institute of Science and Technology Austria, Am Campus 1, 3400 Klosterneuburg, Austria — [2]ICFO- The Barcelona Ins titute of Science and Technology, Barcelona, Spain — [3]ITAMP, Havard-Smithsonian Center for Astrophysics, Cambr idge, MA 02138, USA

We use recently developed angulon theory [1] to study the rotational spectrum of a cyanide molecular anion immersed into Bose-Einstein

condensates of rubidium and strontium. Based on *ab initio* potential energy surfaces, we provide a detailed study of the rotational Lamb shift and many-body-induced fine structure which arise due to dressing of molecular rotation by a field of phonon excitations. We demonstrate that the magnitude of these effects is large enough in order to be observed in modern experiments on cold molecular ions. Furthermore, we introduce a novel method to construct pseudopotentials starting from the *ab initio* potential energy surfaces, which provides a means to obtain effective coupling constants for low-energy polaron models.

[1] R. Schmidt and M. Lemeshko, Phys. Rev. Lett. 114, 203001 (2015).

[2] B. Midya, M. Tomza, R. Schmidt, M. Lemeshko, Phys. Rev. A 94, 041601(R) (2016).

A 15.8 Tue 16:15 N 1

Numerical Simulation of a mobile Impurity in a BEC — •Tobias Lausch[1], Fabian Grusdt[3], Artur Widera[1,2], and Michael Fleischhauer[1] — [1]TU Kaiserslautern and Forschungszentrum OPTIMAS, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler Strasse 47, 67663 Kaiserslautern, Germany — [3]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

Cooling atoms to ultracold temperatures, where quantum effects dominante, has become a standard approach in experimental quantum physics. An intriguing focus of research lies on impurity systems, aiming on elucidating microscopic properties of thermalization or quasiparticle formation in quantum systems. Recent experiments[(1,2)] shed light on the bose polaron and the interaction between impurities and a bose gas. We thoretically model the thermalization dynamics of a single impurity immersed into a BEC using Bogoliubov approximation. From the master equation, we derive the impurity's momentum resolved scattering and numerically simulate the ensuing cooling dynamics. We find a separation of relaxation time scales originating from the superfluid nature of the condensate, indicating a prethermalized state. Furthermore we discuss the possibuility to exploit the emerging non-thermal impurity states to realize low-entropy quantum states by applying external forces.

(1) Hu et al. PRL 117(2016), 055301

(2) Jørgensen et al. PRL 117 (2016), 055302