Q 31: Ultra-cold atoms, ions and BEC I (with A)

Time: Wednesday 11:00–13:00 Location: f107

Q 31.1 Wed 11:00 f107

Polaronic effects in one- and two-band quantum systems — •Tao Yin[1], Daniel Cocks[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt/Main, Germany — [2]College of Science, Technology & Engineering, James Cook University, Townsville 4810, Australia

In this work we study the formation and dynamics of polarons in a system with a few impurities in a lattice immersed in a Bose-Einstein condensate (BEC). This system has been experimentally realized using ultracold atoms and optical lattices. Here we consider a two-band model for the impurity atoms, along with a Bogoliubov approximation for the BEC, with phonons coupled to impurities via both intra- and inter-band transitions. We decouple this Fröhlich-like term by an extended two-band Lang-Firsov polaron transformation using a variational method. The new effective Hamiltonian with two (polaron) bands differs from the original Hamiltonian by modified coherent transport, polaron energy shifts and induced long-range interaction. A Lindblad master equation approach is used to take into account residual incoherent coupling between polaron and bath. This polaronic treatment yields a renormalized inter-band relaxation rate compared to Fermi's Golden Rule. For a strongly coupled two-band Fröhlich Hamiltonian, the polaron is tightly dressed in each band and can not tunnel between them, leading to an *inter-band self-trapping* effect.

[1] T. Yin, D. Cocks and W. Hofstetter, arXiv:1509.08283 (2015).

Q 31.2 Wed 11:15 f107

Probing superfluidity of Bose-Einstein condensates via laser stirring — •Vijay Pal Singh[1,2], Wolf Weimer[2], Kai Morgener[2], Jonas Siegl[2], Klaus Hueck[2], Niclas Luick[2], Henning Moritz[2], and Ludwig Mathey[1,2] — [1]Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]Institut für Laserphysik, Universität Hamburg, 22761 Hamburg, Germany

We investigate the superfluid behavior of a Bose-Einstein condensate of ^{6}Li molecules. In the experiment by Weimer *et al.*, Phys. Rev. Lett. **114**, 095301 (2015) a condensate is stirred by a weak, red-detuned laser beam along a circular path around the trap center. The rate of induced heating increases steeply above a velocity v_c, which we define as the critical velocity. Below this velocity, the moving beam creates almost no heating. In this paper [1], we demonstrate a quantitative understanding of the critical velocity. Using both numerical and analytical methods, we identify the non-zero temperature, the circular motion of the stirrer, and the density profile of the cloud as key factors influencing the magnitude of v_c. A direct comparison to the experimental data shows excellent agreement.

[1] V. P. Singh, W. Weimer, K. Morgener, J. Siegl, K. Hueck, N. Luick, H. Moritz, and L. Mathey, arXiv: 1509.02168.

Q 31.3 Wed 11:30 f107

Robustness of many-body localization in the presence of dissipation — •Emanuele Levi[1], Markus Heyl[2], Igor Lesanovsky[1], and Juan P. Garrahan[1] — [1]School of Physics and Astronomy, University of Nottingham, University Park, NG7 2RD, United Kingdom — [2]Physik Department, Technische Universität München, 85747 Garching, German

Many-body localization (MBL) has emerged as a novel paradigm for robust ergodicity breaking in closed quantum many-body systems. However, it is not yet clear to which extent MBL survives in the presence of dissipative processes induced by the coupling to an environment. In this talk I will discuss the findings of [1] about heating and ergodicity for a paradigmatic MBL system –an interacting fermionic chain subject to quenched disorder in the presence of dephasing. Even though the system is eventually driven into an infinite-temperature state, heating as monitored by the von Neumann entropy can progress logarithmically slowly, implying exponentially large time scales for relaxation. This slow loss of memory of initial conditions make signatures of non-ergodicity visible over a long, but transient, time regime. Time allowing I will discuss a potential controlled realization of the considered setup with cold atomic gases held in optical lattices.

[1] E. Levi, M. Heyl, I. Lesanovsky, J.P. Garrahan, What survives of many-body localization in the presence of dissipation, arXiv:1510.04634

Q 31.4 Wed 11:45 f107

Observation of mixing between singlet and triplet scattering channels in Rb_2 Rydberg molecules — •Karl Magnus Westphal, Fabian Böttcher, Anita Gaj, Michael Schlagmüller, Kathrin Sophie Kleinbach, Robert Löw, Tara Cubel Liebisch, Tilman Pfau, and Sebastian Hofferberth — 5. Physikalisches Institut and Center for Integrated Quantum Science and Technology, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

We present high-resolution spectroscopy of Rb_2 ultralong-range Rydberg molecules bound by mixed singlet-triplet electron-neutral atom scattering [1]. The mixing of the scattering channels is a consequence of the hyperfine interaction in the ground-state atom, as predicted recently by Anderson et al. [2]. Using our experimental data we determine the effective zero-energy singlet s-wave scattering length. Furthermore, we calculate molecular potentials using a full diagonalization approach including the p-wave contribution and all orders in the relative momentum k, and compare the obtained molecular binding energies to the experimental data. We show that an applied external magnetic field changes the contributions of the singlet and the triplet scattering and therefore the binding energies of the observed molecules. Ultimately, we extract the molecular magnetic moments, which differ from the magnetic moments of the asymptotic atomic states.

1 F. Böttcher et al., **arXiv:1510.01097**, (2015)

2 D. A. Anderson et al., **Phys. Rev. A 90**, 062518 (2014)

Q 31.5 Wed 12:00 f107

Towards the production of RbCs ground-state molecules from degenerate gases in an optical lattice — •Andreas Schindewolf[1], Lukas Reichsöllner[2], Silva Mezinska[1], Beatrix Mayr[1], Rudolf Grimm[1,2], and Hanns-Christoph Nägerl[1] — [1]Institut für Experimentalphysik, Universität Innsbruck — [2]Institut für Quantenoptik und Quanteninformation IQOQI, Innsbruck

Ultracold dipolar systems are of high interest for quantum chemistry, precision spectroscopy, quantum many-body physics, and quantum simulation. Our goal is the production of a low entropy sample of dipolar RbCs molecules in the rovibronic and hyperfine ground-state. To be able to mix degenerate samples of Rb and Cs, the inter-species scattering length a_{RbCs} has to be tuned close to zero by means of a magnetic Feshbach resonance. Since Cs three-body losses would cause a breakdown of a Cs BEC in the magnetic-field region, in which RbCs Feshbach resonances are available, we initially prepare a Cs Mott insulator with unity filling spatially separated from the Rb sample. The optical lattice wavelength and depth are chosen in a way that Rb is still superfluid and can be overlapped with Cs after switching the magnetic field to achieve $a_{\mathrm{RbCs}} = 0$. Precise control over the relative position of the two degenerate samples and high magnetic field stability will enable the formation of RbCs Feshbach molecules with a high filling factor of the optical lattice followed by the application of the STIRAP transfer to the absolute molecular ground-state, as demonstrated in Ref. [1].

[1] T. Takekoshi et al., Phys. Rev. Lett. **113**, 205301 (2014)

Q 31.6 Wed 12:15 f107

Out-of-equilibrium dynamics of two interacting bosons — •Tim Keller and Thomás Fogarty — Theoretische Physik, Universität des Saarlandes, D-66123 Saarbrücken, Germany

We study the out-of-equilibrium dynamics of two interacting bosons in a one-dimensional harmonic trap after a quench by a centrally located delta-function potential. We are interested in the role of interactions and correlations on this dynamics and have observed many complex phenomena. We make use of an approximate variational calculation called the Lagrange-mesh method to solve the Schrödinger equation numerically. We examine the dynamics by calculating the single particle density and through the time-dependent fidelity (Loschmidt echo) we investigate the irreversibility of the quenched system and its nonlinear dependence on the particles interactions. We discern distinct scattering states created by the quench through a thorough examination of its dynamical properties described by the spectral function. We link the probability distribution of the Loschmidt echo after a

long-time evolution to the structure of the spectral function and identify four characteristic distributions which are dependent on quench strength and particle interactions. We lay special focus on the case of a distorted bell-shaped distribution which is caused by a distinct beating in the Loschmidt echo due to the interference of different spectral components. This resonance also has consequences for the particles correlations which mirrors that of the Loschmidt echo.

Q 31.7 Wed 12:30 f107

Molecular ion formation in atom-ion three body recombination — •Amir Mohammadi, Artjom Krükow, Joschka Wolf, Amir Mahdian, and Johannes Hecker Denschlag — Universität Ulm, Institut für Quantenmaterie, Albert-Einstein-Allee 45, D-89069 Ulm, Deutschland

Producing transitionally and internally cold molecular ions is one of the challenges and long standing goals in cold atom-ion experiments. One good strategy for this purpose is creating initially cold molecular ions by associating cold ions and cold atoms. In our hybrid atom-ion experiment, we investigate the interaction of a laser-cooled trapped ^{138}Ba ion with an ultracold cloud of ^{87}Rb atoms. At very low kinetic energies (i.e. sub-mK) and densities of 10^{12} cm^{-3}, three-body atom-atom-ion recombination is the dominant reaction process in our experiment[1]. It has been predicted [2] that a weakly bound $BaRb^+$ ion should be the dominant molecular product. In this talk, we indeed report on the first experimental observation of these molecules after three-body recombination. Furthermore, we discuss the effects of secondary and ternary collisions of $BaRb^+$ with cold Rb atoms.

[1] A. Krükow et al., arXiv:1510.04938 (2015)
[2] J.Pérez-Rios and C.H. Greene, The journal of Chemical Physics **143**, 041105 (2015)

Q 31.8 Wed 12:45 f107

Nontrivial topological phases in quantum mechanical many-body systems with gain and loss effects — •Marcel Klett, Holger Cartarius, and Günter Wunner — 1. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart

Non-Hermitian $\mathcal{PT}$-symmetric potentials are capable of effectively describing quantum systems with balanced in- and outfluxes. They allow for the existence of a $\mathcal{PT}$-symmetric phase with purely real energy spectra of the non-Hermitian Hamiltonian. Good candidates for the realization of a genuine $\mathcal{PT}$-symmetric quantum system are Bose-Einstein condensates. Recently a possible relation between the appearance of the $\mathcal{PT}$-symmetric phase and topologically nontrivial states were found in two studies of simple model systems. However, they came to opposite conclusions. In the Su-Schrieffer-Heeger (SSH) model [1] the topological phase has a major influence. As soon as topologically nontrivial states appear $\mathcal{PT}$ symmetry gets broken. This is in contrast to the non-Hermitian Kitaev model [2], in which $\mathcal{PT}$ symmetry breaking does not depend on the topological phase. Our work is based on including different non-Hermitian potentials in the SSH model as well as the Kitaev model. We perform exact calculations of the eigenvalues and the eigenstates, clarify the relation between $\mathcal{PT}$ symmetry and topological phases, and explain why opposite results were found in the above mentioned systems. Consequences for $\mathcal{PT}$-symmetric Bose-Einstein condensates are discussed.

[1] Baogang Zhu et al., Phys. Rev. A **89**, 062102 (2014)*
[2] Xiaohui Wang et al., Phys. Rev. A **92**, 012116 (2015)