TT 32: MLT: Quantum Liquids, Bose-Einstein Condensates, Ultra-cold Atoms, ... 2

Time: Thursday 14:00–18:00 Location: H18

TT 32.1 Thu 14:00 H18

Interaction Quenches of Fermi Gases — •Götz S. Uhrig — Lehrstuhl Theoretische Physik I, TU Dortmund, 44221 Dortmund

Progress in the manipulation of fermionic atoms in optical lattices makes it possible to switch interactions at will. So non-equilibrium issues gain increasing interest. It is shown that the jump in the momentum distribution of Fermi gases evolves smoothly for small and intermediate times once an interaction between the fermions is suddenly witched on. The jump does not vanish abruptly. Explicit calculations are possible for the Tomonaga-Luttinger model with and without spin. For general interacting models in arbitrary dimension the structure of the equations of motion in the Heisenberg picture is analyzed. It is found that the loci in momentum space where the jumps occur are those of the noninteracting Fermi sea. No relaxation of the Fermi surface geometry takes place.

TT 32.2 Thu 14:15 H18

Generalized Gibbs ensemble prediction of prethermalization plateaus in nearly integrable systems — •Marcus Kollar[1], F. Alexander Wolf[1], and Martin Eckstein[2] — [1]Theoretische Physik III, Universität Augsburg, 86135 Augsburg — [2]Theoretische Physik, ETH Zürich, 8093 Zürich, Schweiz

A quantum many-body system which is prepared in the ground state of an integrable Hamiltonian will not directly thermalize after a sudden small parameter change away from integrability. Instead, it first reaches a quasistable prethermalized state, which can be related to the perturbative ground state of the Hamiltonian after the quench [1]. We show that under certain conditions such prethermalization plateaus are predicted correctly by generalized Gibbs ensembles, which are the appropriate extension of standard statistical mechanics in the presence of many constants of motion. As a consequence, the relaxation behaviors of integrable and nearly integrable systems are continuously connected and described by the same statistical theory. For example, our result applies to the prethermalization plateau of the fermionic momentum distribution that is observed after a quench from zero to small Hubbard interaction [1,2].

[1] M. Moeckel and S. Kehrein, Ann. Phys. **324**, 2146 (2009).
[2] M. Eckstein, M. Kollar, and P. Werner, Phys. Rev. Lett. **103**, 056403 (2009); arXiv:0910.5674.

TT 32.3 Thu 14:30 H18

Prethermalization and nonequilibrium BCS dynamics in ultracold Fermi gases — •Michael Möckel[1] and Stefan Kehrein[2] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]Department für Physik and Arnold-Sommerfeld-Center, LMU München, Theresienstr. 37, 80333 München

Dynamical experiments with ultracold fermions in optical lattices are a growing field of research for which the time dependent (Fermi-) Hubbard model provides a paradigmatic description. Moreover, predictions on the nonequilibrium behavior of the BCS Hamiltonian have been made; the later describes effectively fermionic pair processes which are contained in the much richer structure of the Hubbard Hamiltonian. This newly motivates the question whether nonequilibrium BCS dynamics can be excited by a nonadiabatic switching of the Hubbard interaction without overheating the system.

Starting from an uncorrelated Fermi gas at zero temperature and in d>1 dimensions, we apply a nonadiabatic, linear and weak ramp of the Hubbard interaction. This allows us to investigate the nonequilibrium properties of a Fermi liquid beyond the adiabatic switching requirement of Landau's theory. We study the real-time evolution of the excited state after the ramping and observe that the relaxation time scales for the kinetic energy and the momentum distribution separate. Therefore a transient regime of prethermalization arises. During that regime the momentum distribution continues to show a discontinuity around the Fermi energy, indicating zero temperature. The delay of thermalization simplifies experimental observations.

Invited Talk TT 32.4 Thu 14:45 H18

Dispersion of the Excitations of Fractional Quantum Hall States — •Jurgen Smet[1], Igor Kukushkin[1,2], Vito Scarola[3,4], Vladimir Umansky[5], and Klaus von Klitzing[1] — [1]Max-Planck-Institute for Solid State Research, Stuttgart, Germany — [2]Institute of Solid State Physics, Russian Academy of Science, Chernogolovka, Russia — [3]Department of Chemistry and Pitzer Center for Theoretical Chemistry, University of California at Berkeley, USA — [4]Theoretische Physik, ETH Zürich, Switzerland — [5]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel

The rich correlation physics in two-dimensional (2D) electron systems is governed by the dispersion of its excitations. In the fractional quantum Hall regime, excitations involve fractionally charged quasi particles, which exhibit dispersion minima at large momenta referred to as rotons. These rotons are difficult to access with conventional techniques because of the lack of penetration depth or sample volume. Our method overcomes the limitations of conventional methods and traces the dispersion of excitations across momentum space for buried systems involving small material volume. We used surface acoustic waves, launched across the 2D system, to allow incident radiation to trigger these excitations at large momenta. Optics probed their resonant absorption. Our technique unveils the full dispersion of such excitations of several prominent correlated ground states of the 2D electron system, which has so far been inaccessible for experimentation.

TT 32.5 Thu 15:15 H18

Massless Dirac-Weyl Fermions in a $\mathcal{T}_3$ Optical Lattice — •Daniel Urban[1,2], Dario Bercioux[1,3], Hermann Grabert[1,3], and Wolfgang Haeusler[1,4] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [2]Departamento de Física de la Materia Condensada C-XII, Facultad de Ciencias, Universidad Autónoma de Madrid, E-28049, Madrid, Spain — [3]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität, D-79104 Freiburg, Germany — [4]Institut für Physik, Universität Augsburg, D-86135 Augsburg, Germany

We propose an experimental setup for the observation of quasi-relativistic massless Fermions. It is based on a $\mathcal{T}_3$ optical lattice, realized by three pairs of counter-propagating lasers, filled with fermionic cold atoms. We show that in the long wavelength approximation the $\mathcal{T}_3$ Hamiltonian generalizes the Dirac-Weyl Hamiltonian for the honeycomb lattice, however, with a larger value of the pseudo-spin $S = 1$. In addition to the Dirac cones, the spectrum includes a dispersionless branch of localized states producing a finite jump in the atomic density. Furthermore, implications for the Landau levels are discussed.
Bercioux *et al.*, Phys. Rev. A (2009) *in press*, arXiv:0909.3035.

TT 32.6 Thu 15:30 H18

Resonant Superfluidity in an Optical Lattic — •Irakli Titvinidze[1], Michiel Snoek[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Institute for Theoretical Physics, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands

We study a system of ultracold fermionic Potassium (^{40}K) atoms in a three-dimensional optical lattice in the neighborhood of an s-wave Feshbach resonance. Close to resonance, the system is described by a multi-band Bose-Fermi Hubbard Hamiltonian. We derive an effective lowest-band Hamiltonian in which the effect of the higher band is incorporated by a self-consistent mean-field approximation. The resulting model is solved by means of Generalized Dynamical Mean-Field Theory [1,2]. In addition to the BEC/BCS crossover we find on the BCS side of the resonance a phase transition to a fermionic Mott insulator at half filling, induced by the repulsive fermionic background scattering length. We also calculate the critical temperature of the BEC/BCS-state across the resonance and find it to be minimal at resonance.

15 min. break

TT 32.7 Thu 16:00 H18

Strongly correlated fermions in disordered lattices — •Denis Semmler[1], Krzysztof Byczuk[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, J. W. Goethe-Universität, D-60438 Frankfurt, Germany — [2]Institute of Theoretical Physics, Warsaw University, ul. Hoża 69, 00-681 Warszawa, Poland

Strongly correlated fermions in a lattice exposed to a disorder potential are investigated by means of the Anderson-Hubbard model.

We employ the statistical dynamical mean-field theory, which incorporates both fluctuations due to disorder and local correlations due to interactions. In the case of binary disorder, the complete paramagnetic ground state phase diagram is obtained, which consists of disordered correlated metal, Anderson-Mott insulator and band insulator [1]. Binary disordered fermions can be realized by loading two species of atoms into an optical lattice of which one is immobile [2]. Furthermore, we investigate the effect of realistic speckle disorder in combination with hopping disorder, which is relevant for future experiments within the framework of ultracold atoms in optical lattices. [1] D. Semmler, K. Byczuk, and W. Hofstetter, arXiv:0911.0934.

[2] S. Ospelkaus, C. Ospelkaus, O. Wille, M. Succo, P. Ernst, K. Sengstock and K. Bongs, Phys. Rev. Lett. **96**, 180403 (2006).

TT 32.8 Thu 16:15 H18

Strong coupling expansion in the bosonic dynamical mean-field theory — •Anna Kauch[1], Krzysztof Byczuk[2], and Dieter Vollhardt[1] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86135 Augsburg, Germany — [2]Institute of Theoretical Physics, University of Warsaw, ul. Hoza 69, PL-00-681 Warszawa, Poland

The bosonic dynamical mean-field theory (B-DMFT), recently formulated by Byczuk and Vollhardt (Phys. Rev. B **77**, 235106 (2008)), provides a comprehensive and thermodynamically consistent description of correlated lattice bosons. Within the B-DMFT normal and Bose-Einstein condensed bosons are treated on equal footing. In the B-DMFT the lattice bosonic problem is replaced by a single impurity coupled to two bosonic baths (corresponding to normal and condensed bosons, respectively). This yields a set of B-DMFT equations which have to be solved self-consistently. We propose here an approximate method to solve the B-DMFT equations for the bosonic Hubbard model by performing a strong-coupling perturbation expansion (linked-cluster expansion) around the atomic limit. We investigate the validity of this approach by comparing our results to the known phase diagram of the Hubbard model.

TT 32.9 Thu 16:30 H18

Multiflavour fermions in optical lattices — •Antonio Privitera[1], Irakli Titvinidze[1], Soon-Yong Chang[2], Andrew Daley[2], and Walter Hofstetter[1] — [1]Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt am Main, Germany — [2]Institute for Theoretical Physics, University of Innsbruck, and IQOQI, A-6020 Innsbruck, Austria

We study the properties of three-flavor fermions [1,2] in a optical lattice with and without a (dynamically generated) large three-body repulsion. This can be induced in the form of a hard-core constraint by three-body losses [3]. We address the properties of this system by using dynamical mean-field theory and variational Monte Carlo technique. The phase diagram of the system is very rich and shows a strong interplay between magnetization and superfluidity. Without including the three-body repulsion, the system undergoes a quantum phase transition from a color superfluid to a trionic phase [4], which displays additional CDW modulation at half-filling. This transition is washed out when including a large three-body repulsion, in which case the system is always in the superfluid phase. In this latter case the color superfluid shows a strong tendency to fully polarize at strong coupling in marked contrast with the unconstrained case where the unpolarized trionic phase dominates.

[1] T.Ottenstein *et al.*, Phys. Rev. Lett. **101**, 203202 (2008)
[2] J. H. Huckans *et al.* Phys. Rev. Lett. **102**, 165302 (2009)
[3] A.Kantian *et al.*, arXiv:0908.3235
[4] A. Rapp *et al.*, Phys. Rev. B **77**, 144520 (2008)

TT 32.10 Thu 16:45 H18

Néel transition of fermionic atoms in an optical trap: real-space DMFT study — •Elena Gorelik and Nils Blümer — Institut für Physik, Universität Mainz, Mainz, Germany

We study theoretically the magnetic ordering transition for a system of repulsively interacting fermionic atoms harmonically trapped in a three-dimensional optical lattice. The real-space DMFT approach [1] combined with Hirsch-Fye quantum Monte Carlo (QMC) impurity solver is used to explore the temperature effects on the ordering phenomena, and to establish signatures of Néel transitions in experimentally accessible observables. We also provide estimates of the entropy for the calculated systems.

[1] M. Snoek et al., New Journal of Physics **10**, 093008 (2008).

TT 32.11 Thu 17:00 H18

Bose Josephson junction out of equilibrium — •Anna Posazhennikova[1], Mauricio Trujillo-Martinez[2], and Johann Kroha[2] — [1]Fachbereich Physik M703, Universitaet Konstanz, Konstanz, D-78457, Germany — [2]Physikalisches Institut adn Bethe Center for Theoretical Physics, Universitaet Bonn, Nussallee 12, D-53115 Bonn, Germany

We perform a detailed quantum dynamical study of nonequilibrium Josephson oscillations between interacting Bose-Einstein condesates confined in a double-well trap. We find, that the Josephson junction can sustain multiple undamped Josephson oscillations up to a certain characteristic time-scale, without quasiparticles being excited in the system. This might explain recent experimental data. Beyond the characteristic time scale the dynamics of the Josephson junction is governed by fast, quasiparticle assited Josephson tunneling as well as Rabi oscillations between the descrete quasiparticle levels. We predict, that an initially self-trapped state of the Bose Josephson junction will be destroyed by these fast oscillations.

TT 32.12 Thu 17:15 H18

Phonon-assisted currents of fermions in Bose–Fermi mixtures — •Martin Bruderer, Anna Posazhennikova, and Wolfgang Belzig — Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany

We present an analysis of Bose–Fermi mixtures in optical lattices for the case where a static force is applied to the fermions, and the bosons (in the superfluid phase) are described by Bogoliubov phonons. Accordingly, the static force lifts the degeneracy of the energy levels in the lattice potential and the fermionic states form a Wannier–Stark ladder. We show that the Bogoliubov phonons enable hopping transitions between different Wannier–Stark states; these transitions are accompanied by energy dissipation into the superfluid and result in a net fermionic current along the lattice. We determine the dependence of the fermionic current on the static force and find that the phonon density of states strongly affects the emergent current. In particular, if the energy splitting between the Wannier–Stark states exceeds the width of the phonon band, then the current is strongly suppressed. This effect should be observable in a realistic experimental set-up.

TT 32.13 Thu 17:30 H18

Luttinger liquid of trimers in the asymmetric Fermi Hubbard model — •Giuliano Orso[1], Evgeni Burovski[2], and Thierry Jolicoeur[2] — [1]LMU Muenchen, Germany — [2]LPTMS, University of Paris South, France

We investigate attractive fermions in a one dimensional optical lattice with unequal tunneling rates [1]. Due to the mass asymmetry, the microscopic model is not integrable and multi-particle bound states appear. We focus on trimers, namely three-body bound state made of one light and two heavy fermions. We first present the exact solution of the three-body problem, yielding the binding energy and the effective mass of a single trimer. Based on DMRG simulations, we then show that trimers can open an energy gap at finite commensurate densities, leading to a suppression of superconducting correlations and topological changes in the grand-canonical phase diagram. [1] G. Orso, E. Burovski and T. Jolicoeur, arXiv:0907.1533

TT 32.14 Thu 17:45 H18

Universal Onset of Quantum Turbulence in Oscillating Flows and Crossover to Steady Flows — Risto Hänninen[1] and •Wilfried Schoepe[2] — [1]Helsinki University of Technology — [2]Regensburg University

The critical velocity v_c for the onset of quantum turbulence in oscillatory flows of superfluid helium is universal and scales as $v_c \sim \sqrt{\kappa \cdot \omega}$, where κ is the circulation quantum and ω is the oscillation frequency. This result can be derived from a general argument based on the "superfluid Reynolds number". Only the numerical prefactor may depend somewhat on the geometry of the oscillating object because the flow velocity at the surface of the object may differ from the velocity amplitude of the body. A more detailed analysis derived from the dynamics of the turbulent state gives $v_c \approx \sqrt{8\kappa\,\omega/\beta}$, where $\beta \sim 1$ depends on the mutual friction parameters. This universality is compared with the recently discovered universality of classical oscillatory flows. We also discuss the effect of remanent vorticity on the onset of quantum turbulence. Finally, by employing the "superfluid Reynolds number" again, we argue how v_c changes when the steady case $\omega = 0$ is approached. In that case v_c scales as κ/R, where R is the size of the object.