TT 9: Quantum Liquids, Miscellaneous 1

Time: Monday 9:30–13:00 Location: H21

TT 9.1 Mon 9:30 H21

Effective interactions and renormalized Bose surface in the normal state of the two-dimensional Bose gas with Rashba spin-orbit coupling — •Casper Drukier, Kira Riedl, and Peter Kopietz — Institut für Theoretische Physik, J.W.Goethe-Universität Frankfurt, Frankfurt am Main, Germany

The non-interacting energy-dispersion of a two-dimensional system of bosons with Rashba spin-orbit coupling exhibits a continuum of degenerate minima on a circle in momentum space, which is the bosonic analogue of a Fermi surface. Recent theoretical studies [1,2] suggest that this degeneracy is broken by interactions. Using second order perturbation theory for the self-energy, we calculate the renormalization of the Bose surface as well as the damping of the bosonic quasiparticles. We finally discuss different condensation scenarios.

[1] Phys. Rev. A 84, 061604(R) (2011)
[2] Phys. Rev. Lett. 105, 160403 (2010)

TT 9.2 Mon 9:45 H21

Far-from-equilibrium lattice-transport at high temperatures: breaking Bloch-localization by interactions — •Stephan Mandt — Princeton Center for Complex Materials, Princeton University, USA

Diffusive transport of energy and mass is typically slower than ballistic transport. However, in some situations, non-interacting particles are localized, but may become delocalized by inter-particle collisions. This is the case for Bloch-oscillating fermions in the Hubbard model in the presence of an additional linear potential. In this talk, we will derive effective coupled diffusion equations for the Hubbard model in a regime governed by Bloch oscillations and rare scattering events. These equations and their solutions are relevant to describe the long-time dynamics of an almost non-interacting cloud of ultracold atoms in an optical lattice, where interactions lead to a breaking of the Bloch periodicity.

TT 9.3 Mon 10:00 H21

Correlated lattice fermions in a spin-dependent random potential — •Karol Makuch[1], Jan Skolimowski[1], Prabuddha B. Chakraborty[2], Krzysztof Byczuk[1], and Dieter Vollhardt[3] — [1]Faculty of Physics, Institute of Theoretical Physics, University of Warsaw, Hoza 69, 00-681 Warszawa, Poland — [2]Indian Statistical Institute, Chennai Centre, SETS Campus, MGR Knowledge City, Taramani, Chennai 600113, India — [3]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135, Augsburg, Germany

Motivated by the new possibilities for experiments with ultracold atoms in optical lattices we explore the thermodynamic properties of correlated lattice fermions in the presence of an external spin-dependent random potential. The corresponding Hubbard model with the local on-site spin-dependent disorder is solved within the dynamical mean-field theory. The spin-dependent disorder is found to drive the magnetic polarization of the system when the total number of fermions is fixed. The magnetic response of the system with finite magnetization differs from that of a system with spin-independent disorder. The spin-dependence of the disorder also affects the metal-insulator transition at half filling.

TT 9.4 Mon 10:15 H21

Long limit of momentum distribution functions in the sudden expansion a spin-imbalanced Fermi gas in one dimension — •Fabian Heidrich-Meisner[1,2], Carlos Bolech[3], Stephan Langer[1,4], Ian McCulloch[5], Giuliano Orso[6], and Marcos Rigol[7] — [1]LMU Munich — [2]FAU Erlangen-Nuremberg — [3]University of Cinncinati, USA — [4]University of Pittsburgh, USA — [5]University of Queensland, St Lucia, Australia — [6]Universite Paris-Diderot, France — [7]Georgetown University, USA

We study the sudden expansion of a spin-imbalanced Fermi gas with attractive interactions in an optical lattice after quenching the trapping potential to zero [1]. The initial state is of the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) type, i.e., a quasi- condensate of fermionic pairs that is modulated in real space. Using time-dependent DMRG, we demonstrate that the momentum distribution functions (MDFs) of majority and minority fermions become stationary after surprisingly short expansion times. This behavior can be understood in terms of a quantum distillation process [2] that leads to a spatial demixing of pairs and excess fermions. As a consequence, the FFLO correlations are rapidly destroyed. The expansion nevertheless yields relevant information on the initial state: we argue that the asymptotic form of the MDFs is directly related to the distribution of the Bethe-ansatz rapidities that characterize the initial conditions for this integrable model.

[1] C. Bolech et al., Phys. Rev. Lett. 109, 110602 (2012)
[2] F. Heidrich-Meisner et al., Phys. Rev. A 80, 041603(R) (2009)

TT 9.5 Mon 10:30 H21

Dynamical spin correlations in a quantum spin liquid. — •Johannes Knolle[1], Dima Kovrizhin[1], John Chalker[2], and Roderich Moessner[1] — [1]Max Planck Institut for the Physics of Complex Systems, Dresden, Germany — [2]Theoretical Physics, Oxford University, United Kingdom

We compute the exact time dependence of the spin-spin correlation function for arbitrary times in the gapped and gapless phases of Kitaev's honeycomb model. The resulting dynamical structure factor - observable in a standard inelastic neutron scattering experiment - exhibits signatures of fractional excitations in the spin liquid ground state, namely the gap to creating a pair of emergent static Z_2 fluxes, as well as various features of the density of states of the free fermions propagating in its background. Our analysis uncovers rich connections to the field of coherent nonequilibrium quantum dynamics, ranging all the way back to the physics of Andersons orthogonality catastrophe to the physics of Majorana fermions subject to a sequence of local potential quenches.

TT 9.6 Mon 10:45 H21

Kinetic equations for a system of parametrically excited magnons — •Andreas Rückriegel and Peter Kopietz — Institut für Theoretische Pysik, Universität Frankfurt

Using the functional integral formulation of the Keldysh technique, we derive kinetic equations for the normal and anomalous momentum distribution functions of a system of parametrically excited magnons with two-body interaction in contact with a thermal phonon bath. We then use the results of self-consistent mean field theory to obtain an effective kinetic equation of the Boltzmann type without particle number conservation. Close to thermal equilibrium, we can use a Kramers-Moyal expansion to replace the integral equation by a differential equation which has the form of a continuity equation with an explicit particle number conservation breaking source term. We use our theory to study the thermalization of magnons in the magnetic insulator yttrium-iron garnet.

15 min. break

TT 9.7 Mon 11:15 H21

Thermalization of magnons in yttrium-iron garnet: nonequilibrium functional renormalization group approach — •Johannes Hick[1], Andreas Rückriegel[1], Thomas Kloss[2], and Peter Kopietz[1] — [1]Institut für Theoretische Physik, Goethe Universität Frankfurt am Main, Germany — [2]Laboratoire de Physique et Modélisation des Milieux Condensé, CNRS and Université Joseph Fourier, Grenoble, France

Using a nonequilibrium functional renormalization group (FRG) approach we calculate the time evolution of the momentum distribution of a magnon gas in contact with a thermal phonon bath. As a cutoff for the FRG procedure we use a hybridization parameter Λ giving rise to an artificial damping of the phonons. Within our truncation of the FRG flow equations the time evolution of the magnon distribution is obtained from a rate equation involving cutoff-dependent nonequilibrium self-energies, which in turn satisfy FRG flow equations depending on cutoff-dependent transition rates. Our approach goes beyond the Born collision approximation and takes the feedback of the magnons on the phonons into account. We use our method to calculate the thermalization of a quasi two-dimensional magnon gas in the magnetic insulator yttrium-iron garnet after a highly excited initial state has been generated by an external microwave field. In this material interactions which do not conserve the magnon particle number are present and are considered in our approach.

TT 9.8 Mon 11:30 H21

Fractional Chern insulator in the triangular lattice — •Stefanos Kourtis and Maria Daghofer — Leibniz Institute for Solid-State & Materials Research, Dresden, Germany

The formation of fractional quantum-Hall (FQH) states in lattice systems without externally applied magnetic fields is a recent and promising theoretical proposal that has the potential to render the FQH effect experimentally more accessible. Motivated by the emergence of the relevant physics in 3-orbital Hubbard and Kondo-lattice models on the triangular lattice [1,2], we study numerically an effective interacting spinless-fermion model and show that it yields spontaneously occurring FQH states, recently dubbed fractional Chern insulators (FCI). The Hall conductivity of these states is evaluated and shown to be fractionally quantized. This quantization is found to persist against disorder, demonstrating that the Hall conductivity is characterizing FCI states as a topological invariant. Having thus identified FCI states, we highlight further signatures of their nature in the obtained eigenvalue spectra and discuss the consequences of disorder and competition with conventional ordering.

[1] J.W.F. Venderbos, S. Kourtis, J. van den Brink, and M. Daghofer, Phys. Rev. Lett. 108, 126405
[2] S. Kourtis, J.W.F. Venderbos, and M. Daghofer, arXiv:1208.3481

TT 9.9 Mon 11:45 H21

Topologically nontrivial and nearly flat bands arising through orbital degrees of freedom — •Maria Daghofer, Stefanos Kourtis, Jörn W.F. Venderbos, and Jeroen van den Brink — IFW Dresden

We discuss models, where electronic correlations can induce topologically nontrivial electronic states. In particular, we focus on a three-orbital model for t_{2g} orbitals on a triangular lattice [1]. Near half filling, onsite Coulomb repulsion and Hund's rule coupling induce a non-coplanar magnetic phase where electronic bands are topologically nontrivial and can become very flat [2]. Such topologically nontrivial bands with reduced dispersion have been argued [3-5] to support a lattice analog of fractional quantum-Hall states, fractional Chern-insulator (FCI) states, that arise in the absence of a magnetic field. We discuss the competition of FCI states with a charge density wave depending on properties of the nearly flat band [6].

[1] J. W. Venderbos, M. Daghofer, and J. van den Brink, Phys. Rev. Lett. **107**, 116401 (2011)
[2] J.W.F. Venderbos, S. Kourtis, J. van den Brink, and M. Daghofer, Phys. Rev. Lett. **108**, 126405 (2012)
[3] T. Neupert, L. Santos, C. Chamon, and C. Mudry, Phys. Rev. Lett. **106**, 236804 (2010)
[4] K. Sun, Z. Gu, H. Katsura, and S. D. Sarma, Phys. Rev. Lett. **106**, 236803 (2010)
[5] E. Tang, J.-W. Mei, and X.-G. Wen, Phys. Rev. Lett. **106**, 236802 (2010)
[6] S. Kourtis, J.W.F. Venderbos, and M. Daghofer, arXiv:1208.3481

TT 9.10 Mon 12:00 H21

A New Way to Create Energy Band: Crystal Formed in Phase Space — •Lingzhen Guo[1,2,3], Michael Marthaler[1,3], and Gerd Schön[1,3] — [1]Institut für Theoretische Festkörperphysik, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [2]Department of Physics, Beijing Normal University, Beijing, China — [3]DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, Karlsruhe, Germany

We propose a new way to create an energy band structure by properly driving a nonlinear system. In a natural solid, the energy band structure is a result of the periodicity of the Hamiltonian in the real space. For artificial materials, such as photonic crystals and many other quantum metamaterials, the energy band structure comes from artificial periodic structures fabricated in the laboratory. However, it is also possible to create a periodic structure in total phase space. We find that the Duffing oscillator, if driven by an external field via high order coupling, can exhibit such a periodic structure in phase space. We will calculate the resulting quasi-energy bandstructure and the emission spectrum. Compared to the conventional quantum metamaterials, the bandgaps and bandwidths of this phase space crystal can be tuned conveniently by changing the driving field's parameters.

TT 9.11 Mon 12:15 H21

Dynamical phase transitions and the connections to the nonequilibrium dynamics of local observables — •Markus Heyl[1], Anatoli Polkovnikov[2], and Stefan Kehrein[3] — [1]Technische Universität Dresden — [2]Boston University — [3]Georg-August-Universität Göttingen

We study general connections between the recently introduced dynamical phase transitions [1] and the dynamics of local observables after a quantum quench. In particular, we show that qualitative changes in the relaxational behavior of equilibrium order parameters occur through dynamical transitions between topologically different ground states. We demonstrate our findings for quantum quenches in the one-dimensional transverse field Ising chain.

[1] M. Heyl, A. Polkovnikov, and S. Kehrein, arXiv:1206.2505

TT 9.12 Mon 12:30 H21

Time-reversal-invariant Hofstadter-Hubbard model with ultracold fermions — •Peter Orth[1], Daniel Cocks[2], Stephan Rachel[3], Michael Buchhold[2], Karyn Le Hur[4], and Walter Hofstetter[2] — [1]Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, — [2]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt/Main — [3]Institute for Theoretical Physics, Dresden University of Technology, 01062 Dresden — [4]Center for Theoretical Physics, Ecole Polytechnique, CNRS, 91128 Palaiseau Cedex, France

We consider the time-reversal-invariant Hofstadter-Hubbard model which can be realized in cold-atom experiments [1]. In these experiments, an additional staggered potential and an artificial Rashba-type spin-orbit coupling are available. Without interactions, the system exhibits various phases such as topological and normal insulator, metal and semi-metal phases with two or even more Dirac cones. Using a combination of real-space dynamical mean-field theory and analytical techniques, we discuss the effect of on-site interactions and determine the corresponding phase diagram. We study the semi-metal to magnetic insulator transition, and find rich magnetic phases tunable by the spin-orbit coupling terms. We compute spectral functions which allow us to study the edge states of the strongly correlated topological phases.

[1] D. Cocks, P. P. Orth, S. Rachel, M. Buchhold, K. Le Hur, and W. Hofstetter, Phys. Rev. Lett. 109, 205303 (2012).

TT 9.13 Mon 12:45 H21

Utilizing nonequilibrium effects to probe the Mott-insulator-superfluid transition of a trapped gas of interacting bosons — •Lev Vidmar[1], Stephan Langer[2], Ian McCulloch[3], Ulrich Schollwöck[1], Ulrich Schneider[1,4], and Fabian Heidrich-Meisner[1,5] — [1]LMU Munich, Germany — [2]University of Pittsburgh, USA — [3]University of Queensland, Australia — [4]MPQ Garching, Germany — [5]FAU Erlangen-Nuremberg, Germany

An increased effort has been lately devoted to explore and establish the possible links between equilibrium and nonequilibrium properties of interacting quantum many-body systems. Recent experiments on optical lattices have shown the possibility of measuring the expansion velocity of an initially trapped system, which after the sudden release of the trap expands in an empty lattice [1]. Recent theoretical studies of interacting fermions indicated that the measurement of expansion velocity may provide information about the initial state [2]. In our work, we show that measuring the expansion velocity of an initially trapped gas of interacting bosons allows one to distinguish between a superfluid and a Mott insulating state in the initial ground state in 1D. We perform time-dependent DMRG calculations of the Bose-Hubbard model in a harmonic trap and a box trap. We derive a state diagram of a trapped system as a function of on-site repulsion and density from the expansion velocity. The resulting diagram is consistent with the state diagram obtained by measuring equilibrium properties such as local density fluctuations and on-site compressibility [3].

[1] Nat. Phys. 8, 213 (2012)
[2] PRA 85, 043618 (2012)
[3] PRA 79, 053605 (2009)