TT 3: Correlated Electrons: Low-Dimensional Systems - Models 1

Time: Monday 9:30–13:00 Location: H9

TT 3.1 Mon 9:30 H9

Charge and Spin Fractionalization of 1D Strongly Correlated Systems — Alexander Moreno[1], •Alejandro Muramatsu[1], and José M. P. Carmelo[2] — [1]Institut für Theoretische Physik III, Universität Stuttgart, Germany — [2]Center of Physics, University of Minho, Braga, Portugal

By means of time-dependent DMRG numerical simulations, we observe charge and spin fractionalization[1] of an electron injected into a 1D strongly correlated system, namely the t-J model, which is not expected on the basis of the Luttinger Liquid (LL) theory[2]. Our results for the supersymmetric (SUSY) point, $J = 2t$, are consistent with the Bethe-Ansatz exact solution[3] that we use as framework to explain the origin of the different fractions. Our method is able to identify more features related to fractionalization in comparison to those observed in the one-particle spectral function[4].

[1] A. Moreno, J. M. P Carmelo and A. Muramatsu, arXiv:1210.1398
[2] K.-V. Pham, M. Gabay, and P. Lederer, Phys. Rev. B **61**, 16397 (2000)
[3] P. A. Bares, G. Blatter, and M. Ogata, Phys. Rev. B **44**, 130 (1991); P. A. Bares, J. M. P. Carmelo, J. Ferrer, and P. Horsch, Phys. Rev. B **46**, 14624 (1992)
[4] C. Lavalle, M. Arikawa, S. Capponi, F. F. Assaad, and A. Muramatsu, Phys. Rev. Lett. **90**, 216401 (2003)

TT 3.2 Mon 9:45 H9

Luttinger liquid universality in the time evolution after an interaction quench — Christoph Karrasch[1], Jan Rentrop[2], •Dirk Schuricht[2], and Volker Meden[2] — [1]Department of Physics, University of California — [2]Institute for Theory of Statistical Physics, RWTH Aachen University

We provide evidence that the relaxation dynamics of one-dimensional, metallic Fermi systems resulting out of an abrupt amplitude change of the two-particle interaction has aspects which are universal in the Luttinger liquid sense: The leading long-time behavior of certain observables is described by universal functions of the equilibrium Luttinger liquid parameter and the renormalized velocity. We analytically derive those functions for the Tomonaga-Luttinger model and verify our hypothesis of universality by considering spinless lattice fermions within the framework of the density matrix renormalization group.

[1] C. Karrasch et al., Phys. Rev. Lett. 109, 126406 (2012).

TT 3.3 Mon 10:00 H9

Quench dynamics of the Tomonaga-Luttinger model with momentum-dependent interaction — •Jan Rentrop[1,2], Dirk Schuricht[1,2], and Volker Meden[1,2] — [1]Institut für Theorie der Statistischen Physik, RWTH Aachen University, Germany — [2]JARA Fundamentals of Future Information Technology, 52056 Aachen, Germany

We study the relaxation dynamics of the one-dimensional Tomonaga-Luttinger model after an interaction quench, paying particular attention to the momentum dependence of the two-particle interaction. Several potentials of different analytical forms are investigated that all lead to universal Luttinger liquid (LL) physics in equilibrium. The steady-state fermionic momentum distribution shows universal behavior in the sense of the LL phenomenology. For generic regular potentials, the large time decay of the momentum distribution function toward the steady-state value is characterized by a power law with a universal exponent that depends only on the potential at zero momentum transfer. The commonly employed ad hoc procedure fails to give this exponent.

TT 3.4 Mon 10:15 H9

Low-energy local density of states of the 1D Hubbard model — Stefan Söffing[1], Imke Schneider[2], and •Sebastian Eggert[1] — [1]Fachbereich Physik und Forschungszentrum Optimas, TU Kaiserslautern — [2]Institut für theoretische Physik, TU Dresden

We examine the local density of states (DOS) at low energies numerically and analytically for the Hubbard model in one dimension. The eigenstates represent separate spin and charge excitations with a remarkably rich structure of the local DOS in space and energy. The results predict signatures of strongly correlated excitations in the tunneling probability along finite quantum wires, such as carbon nanotubes, atomic chains or semiconductor wires in scanning tunneling spectroscopy (STS) experiments. However, the detailed signatures can only be partly explained by standard Luttinger liquid theory. In particular, we find that the effective boundary exponent can be negative in finite wires, which leads to an increase of the local DOS near the edges in contrast to the established behavior in the thermodynamic limit.

TT 3.5 Mon 10:30 H9

Density Oscillations in the 1D Hubbard Model in a Harmonic Trap at Finite Temperature — •Denis Morath, Stefan Söffing, and Sebastian Eggert — Department of Physics, Univ. Kaiserslautern, Erwin Schrödinger Str. , 67663 Kaiserslautern, Germany

We are investigating the Hubbard-Chain in a harmonic trapping-potential at finite temperatures which is an appropriate model to describe cold atoms in a trap. Depending on the interaction strength one observes $2k_F$- and $4k_F$-oscillations of the density. Here we show the temperature dependence of these oscillations using QMC and analyze them within the bosonization scheme. With increasing temperatures the amplitude of the oscillations is decreased. We will give an estimation at which temperature it will be possible to resolve the oscillations.

TT 3.6 Mon 10:45 H9

DMRG study of the optical conductivity of the 1D Hubbard model — •Alexander C. Tiegel, Piet E. Dargel, and Thomas Pruschke — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

The zero-temperature optical conductivity of the Hubbard model in one dimension is studied for various values of the on-site repulsion U and the electronic filling n by means of frequency-resolved density-matrix renormalization group (DMRG) methods. The focus of this work is the determination of the optical gap E_{opt} and the investigation of the leading frequency dependence at the onset of the finite-frequency conductivity. At half-filling, our data is compatible with a square-root increase above the band threshold, which is in agreement with conformal field theory and DDMRG results in the literature. Away from half-filling, we find an increasing pseudogap E_{opt} with the amount of doping. These results as well as the extracted exponents at the onset for $n < 1$ are directly compared to existing field-theoretical values.

15 min. break

TT 3.7 Mon 11:15 H9

Real-time dynamics of charge and spin densities in one-dimensional systems — •Michael Sekania and Arno P. Kampf — Theoretische Physik III, Elektronische Korrelationen und Magnetismus, Institut für Physik, Universität Augsburg, Germany

In the last decade great effort has been devoted to investigations of the real-time dynamics in strongly correlated systems. We present a theoretical investigation of the space-time evolution of the charge and spin perturbations induced by a local quench of the ground state of the one-dimensional Hubbard model. Employing the time-dependent Density-Matrix Renormalization Group methods we find that induced charge and spin perturbations expand ballistically in the Mott-insulating host system. The expansion velocities in the charge and spin sector are also found to be different as expected for the spin-charge separation scenario. For the metallic hosts close to the half filling, however, the character of the charge expansion changes from ballistic to diffusive and finally to subdiffusive regimes.

TT 3.8 Mon 11:30 H9

Phase diagram of frustrated ladder and 2D antiferromagnets — •Alexandros Metavitsiadis, Daniel Sellmann, and Sebastian Eggert — University of Kaiserslautern, Kaiserslautern, Germany

We investigate the low energy properties of the frustrated two leg diagonal ladder exhibiting both intra- and inter-chain frustration. The renormalization group is used to obtain the phase diagram while varying the microscopic lattice parameters. We particularly emphasize the role of the in-chain marginal operators, which is tuned by the in-chain frustration and can promote a dimer phase in the system. Finally, the physics of the quasi one dimensional diagonal ladder is incorporated into a two dimensional square lattice since the former is used as the

primary structure to build up the square lattice. Within the validity of our method, the classical phases—a Néel antiferromagnet and a collinear antiferromagnet—are predicted. The results are compared to numerical DMRG calculations.

TT 3.9 Mon 11:45 H9

Thermodynamics of the Two-Dimensional Hubbard Model — •James LeBlanc[1] and Emanuel Gull[2] — [1]Max Planck Institute For the Physics of Complex Systems, Dresden Germany — [2]University of Michigan, Ann Arbor MI

The application of a numerically exact continuous time impurity solver with the DCA dynamical mean field theory has allowed us to study the thermodynamics of the two-dimensional Hubbard model for finite, but large cluster sizes. Variation in cluster size, upwards of 50-sites, allows for extrapolation to the thermodynamic limit. We present results relevant to cold gas systems, such as entropy, double occupancy and nearest-neighbour spin correlations as well as discuss the implications of these calculations on pseudogap physics of the High-T_c Cuprate superconductors away from half filling.

TT 3.10 Mon 12:00 H9

Shear viscosity in a two-dimensional Fermi gas — •Carolin Küppersbusch[1], Tilman Enss[2], and Lars Fritz[1] — [1]Institut für Theoretische Physik, Universität zu Köln — [2]Physik Department, Technische Universität München

We consider a two-component, two-dimensional, interacting Fermi gas which is experimentally realized in ultra cold atomic systems. An experimentally accessible quantity that has received a lot of interest recently as a measure of the interaction strength is the shear viscosity. This quantity describes the resistance of the system towards establishing a flow gradient and is lowest for strongly interacting systems. Using a Boltzmann equation we calculate the viscosity in all temperature and interaction ranges. In contrast to earlier studies we include medium scattering which lowers the viscosity by a factor of about three.

TT 3.11 Mon 12:15 H9

Wigner Crystal in a Two-Dimensional Electron Gas with Strong Spin-Orbit Interaction — •Peter Silvestrov[1], Ora Entin-Wohlman[2], and Yoseph Imry[3] — [1]Dahlem Center for Complex Quantum Systems, Freie Universitaet Berlin, 14195 Berlin, Germany — [2]Physics Department, Ben Gurion University, Beer Sheva 84105, Israel — [3]Department of Condensed Matter Physycs, Weizmann Institute of Science, Rehovot 76100, Israel

The Wigner crystal phase of a two-dimensional electron gas with unscreened Coulomb repulsion and Rashba spin-orbit interaction is investigated. We assume that the electron density is sufficiently low such that the spin-orbit interaction dominates over the electrons kinetic energy. In this limit the degeneracy of the minimum of the lower spin-orbit-split subband results in a strong change of the crystals properties. We predict a spontaneous breaking of the ground state symmetry, where all electrons have a finite momentum corresponding to one point at the bottom of a Mexican-hat shaped subband. In this phase electrons in the Wigner crystal become in-plane polarized and the plasmon dispersion acquires a strong angular dependance. The symmetry breaking results also in a (slight) squeezing of the triangular lattice.

TT 3.12 Mon 12:30 H9

Topological characterization of fractional quantum Hall ground states from microscopic Hamiltonians — •Frank Pollmann[1], Michael P. Zaletel[2], and Roger S. K. Mong[3] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Department of Physics, University of California, Berkeley, California 94720, USA — [3]Department of Physics, California Institute of Technology, Pasadena, California 91125, USA

We show how to numerically calculate several quantities that characterize topological order starting from a microscopic fractional quantum Hall (FQH) Hamiltonian. For finding the ground state, we employ the infinite density matrix renormalization group (iDMRG) method which is based on the matrix-product state (MPS) representation of FQH states on an infinite cylinder. From the MPS representation, we compute the topological entanglement entropies and the quasiparticle charges. We furthermore show that the wave function obtained on the infinite cylinder geometry can be adapted to a torus of arbitrary modular parameter, which allows us to explicitly calculate the non-abelian Berry connection associated with the modular T-transformation. As a result, the topological spins, central charge, and Hall viscosity of the phase can be obtained using data contained entirely in the entanglement spectrum.

TT 3.13 Mon 12:45 H9

Characterization of Topological Phase Transitions: A Tensor-Product State Approach — •Siddhardh Chandra[1], Frank Pollmann[1], and Norbert Schuch[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]RWTH Aachen University, Aachen, Germany

We investigate phase transitions between phases with non-trivial topological order. Topological order is a kind of order that cannot be explained with the traditional approach of Landau's symmetry breaking and local order parameters. However, it can be characterized by other quantities such as the braiding statistics of the excitations in the model. Due to recent advances in numerical techniques, it has become possible to extract these statistics from the ground-state wavefunction of a model. We consider simple string-net models, which are known to have topological order, and analyze the behavior of various quantities as we move from one topological phase to another. The useful formalism of tensor-product states allows us to create a tunable representation which helps us to study the behavior of the entanglement spectrum and modular matrices which characterize the statistics of the anyonic excitations in the two phases. We identify some of the defining components of a topological phase transition as opposed to a symmetry breaking transition and discuss the possible extensions to other models with topological order.