TT 53: Low-Dimensional Systems: 1D - Theory

Time: Wednesday 15:00–18:15 Location: H21

TT 53.1 Wed 15:00 H21

Topological phases and phase transitions of interacting fermions in 1D — •Ruben Verresen — MPI-PKS, Dresden, Germany

Not all phases of matter can be described by local order parameters. One such unconventional class is that of Symmetry Protected Topological (SPT) phases, where the presence of a symmetry and a gap ensures interesting topological effects. Topological insulators are a prominent example, but the landscape of SPTs becomes more interesting when we allow for interactions. Here we focus on 1D fermionic systems. In 2010 it was discovered that if the Hamiltonian conserves fermionic parity and is time reversal invariant, there are exactly eight gapped phases– one being the celebrated Kitaev chain with Majorana edge modes. This analysis led to a general classification of SPT phases. We revisit these unconventional 1D fermionic phases in concrete models, both to discuss the conceptual underpinning of SPTs and to characterize the critical theories when tuning between these eight phases. The latter is of particular interest since the understanding of phase transitions between SPTs is still a very young field.

TT 53.2 Wed 15:15 H21

Dynamics of photo excitations in 1D-Hubbard systems — •Thomas Köhler and Salvatore R. Manmana — Institut für Theoretische Physik, Universität Göttingen, Germany

We compute the dynamics following a photo excitation in one dimensional Hubbard systems at different temperatures T using matrix product state (MPS) approaches. We discuss the effect of temperature on the propagation of these excitations and give an outlook for systems with time dependent Hamiltonians.

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TT 53.3 Wed 15:30 H21

Finite-temperature dynamics of Spin-1 Heisenberg chains via Matrix Product States — Thomas Köhler[1], Alexander Tiegel[1], •Salvatore R. Manmana[1], and Andreas Honecker[2] — [1]Institut für Theoretische Physik, Universität Göttingen, 37077 Göttingen — [2]LPTM, Université de Cergy-Pontoise, France

The S=1 Heisenberg chain is an archetypal model of quantum magnetism that realizes a 1D symmetry protected topological (SPT) insulator which is adiabatically connected to the AKLT state. Here, we investigate in detail the temperature dependence of dynamical spectral functions for S=1 Heisenberg chains using finite-temperature Matrix Product State (MPS) approaches. By applying open boundary conditions (OBC), we are able to investigate for signatures of the edge states and their evolution upon increasing the temperature.

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TT 53.4 Wed 15:45 H21

Quantum Monte Carlo studies of the spin dynamics in the spin-1 Heisenberg chain — •Jonas Becker and Stefan Wessel — Institut für Theoretische Festkörperphysik, JARA-FIT and JARA-HPC, RWTH Aachen University, 52056 Aachen, Germany

The dynamic spin structure factor $S(k,\omega)$ of the antiferromagnetic isotropic spin $S = 1$ Heisenberg chain is studied at finite temperature. Quantum Monte Carlo simulations with the stochastic series expansion scheme are performed to extract this dynamic observable for individual Matsubara frequencies. Then a stochastic analytic continuation method is applied to extract the real-frequency spin structure factor from the imaginary frequency data. Simulations for low temperatures are performed with high accuracy and the results are compared to DMRG data [1]. We also focus on the spectrum's multi-magnon continuum and show that performing the analytic continuation in the over-fitting regime produces additional features therein. Finally, the temperature dependence of the dynamic spin structure factor $S(k,\omega)$ is presented.

[1] S. White and I. Affleck. PRB **77**, 134437 (2008)

TT 53.5 Wed 16:00 H21

ESR modes in a Strong-Leg Ladder in the Tomonaga-Luttinger Liquid Phase — •S. Zvyagin[1], M. Ozerov[2], M. Maksymenko[3], J. Wosnitza[1], A. Honecker[4], C.P. Landee[5], M. Turnbull[5], S. Furuya[6], and T. Giamarchi[6] — [1]HLD-HZDR, Dresden, Germany — [2]Radboud University, Nijmegen, The Netherlands — [3]Weizmann Institute of Science, Rehovot, Israel — [4]Universite de Cergy-Pontoise, Cergy-Pontoise Cedex, France — [5]Clark University, Worcester, MA, USA — [6]University of Geneva, Geneva, Switzerland

Magnetic excitations in the strong-leg quantum spin ladder compound $(C_7H_10N)_2CuBr_4$ (known as DIMPY) in the field-induced Tomonaga-Luttinger spin liquid phase are studied by means of high-field electron spin resonance (ESR) spectroscopy. The presence of a gapped ESR mode with unusual non-linear frequency-field dependence is revealed experimentally. Using a combination of analytic and exact diagonalization methods, we compute the dynamical structure factor and identify this mode with longitudinal excitations in the antisymmetric channel. We argue that these excitations constitute a fingerprint of the spin dynamics in a strong-leg spin-1/2 Heisenberg antiferromagnetic ladder and owe its ESR observability to the uniform Dzyaloshinskii-Moriya interaction.

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TT 53.6 Wed 16:15 H21

Tomonaga-Luttinger to Luther-Emery crossover in spin-gapped metals — Jonas Greitemann[1,3], Stephan Hesselmann[1], Stefan Wessel[1], Fakher Assaad[2], and •Martin Hohenadler[2] — [1]RWTH Aachen, Germany — [2]University of Würzburg, Germany — [3]LMU Munich, Germany

We consider the crossover between the gapless Tomonaga-Luttinger and the spin-gapped Luther-Emery fixed point as a function of distance in models with attractive backscattering. Our quantum Monte Carlo results for extended Hubbard and Holstein models reveal the impact of this crossover on correlation functions, Luttinger parameters, and critical values for the charge-density-wave transition. The implications for our understanding of the Holstein-Hubbard model are discussed.

15 min. break

TT 53.7 Wed 16:45 H21

Effective few-leg ladder models for correlated wires on substrates — •Anas Abdelwahab[1], Eric Jeckelmann[1], and Martin Hohenadler[2] — [1]Leibniz Universität Hannover, Germany — [2]Universität Würzburg, Germany

Correlated quantum wires deposited on a substrate constitutes a challenge for existing analytical and numerical methods. We develop a mapping onto 2D ladder models based on the Lanczos algorithm. Possibilities and limitations of truncating the 2D ladder onto effective few-leg ladder models are discussed. We use DMRG and quantum Monte Carlo methods to investigate if an effective few-leg ladder model is a good approximation for a correlated wire on substrate. We perform a comparison with a two-leg effective model [1] and discuss the modeling of Luttinger liquids on semiconducting substrates.

Support from the DFG through the Research Units FOR 1700 and FOR 1807 is gratefully acknowledged.

[1] A. Abdelwahab, E. Jeckelmann, and M. Hohenadler, PRB **91**, 155119 (2015)

TT 53.8 Wed 17:00 H21

Thermodynamic and spectral properties of one-dimensional electron-phonon models in the adiabatic limit — •Manuel Weber, Fakher F. Assaad, and Martin Hohenadler — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

In one-dimensional electronic systems at half-filling, electron-phonon coupling can lead to lattice dimerization accompanied by charge-density or bond-density wave order. According to Peierls' theorem, the ground state is ordered for any nonzero coupling when quantum lattice fluctuations are neglected. In this adiabatic limit, the lattice displace-

ments become classical variables that can be sampled in a Monte Carlo simulation. For each phonon configuration, the resulting fermionic Hamiltonian can be diagonalized exactly. Considering the Holstein model and the Su-Schrieffer-Heeger model, we study the formation of the Peierls-insulating ground state as a function of temperature. At low temperatures, we observe a peak in the specific heat associated with the opening of a band gap, and the formation of shadow bands as well as polaron signatures in the single-particle spectrum.

TT 53.9 Wed 17:15 H21

Thermodynamics, contact and density profiles of the repulsive Gaudin-Yang model — •Andreas Klümper[1] and Ovidiu Patu[2] — [1]Universität Wuppertal, Gauss-Strasse 20, 42119 Wuppertal — [2]Institute for Space Sciences, Bucharest-Magurele, R 077125

We address the problem of computing the thermodynamic properties of the repulsive one-dimensional two-component Fermi gas with contact interaction (Gaudin-Yang model). We derive an exact system of only two non-linear integral equations for the thermodynamics of the homogeneous model. This system allows for an easy and extremely accurate calculation of thermodynamic properties circumventing the difficulties associated with the truncation of the thermodynamic Bethe ansatz system of equations. We present extensive results for the densities, polarization, magnetic susceptibility, specific heat, interaction energy, Tan contact and local correlation function of opposite spins. Our results show that at low and intermediate temperatures the experimentally accessible contact is a non-monotonic function of the coupling strength. As a function of the temperature the contact presents a pronounced local minimum in the Tonks-Girardeau regime which signals an abrupt change of the momentum distribution in a small interval of temperature. The density profiles of the system in the presence of a harmonic trapping potential are computed using the exact solution of the homogeneous model coupled with the local density approximation. At finite temperature the density profile presents a double shell structure (partially polarized centre and fully polarized wings) only when the polarization in the center of the trap is above a critical value.

TT 53.10 Wed 17:30 H21

Properties of the single-site reduced density matrix in the Bose-Bose resonance model in equilibrium and in quantum quenches — •Florian Dorfner and Fabian Heidrich-Meisner — Ludwig-Maximilians-Universität München, Germany

We study properties of the single-site reduced density matrix in the Bose-Bose resonance model as a function of system parameters. This model describes a single-component Bose gas with a resonant coupling to a molecular state, here defined on a lattice. We study the eigenstates of the single-site reduced density matrix in the various quantum phases of this system. Since the Hamiltonian conserves only the global particle number but not the number of bosons and molecules individually, these eigenstates, referred to as optimal modes, can be nontrivial linear combinations of bare eigenstates of the molecular and boson particle number. We numerically analyze the optimal modes and their weights, the latter giving the importance of the corresponding state, in the ground state of the Bose-Bose resonance model and find that the single-site von Neumann entropy is sensitive to the position of the phase boundaries. We explain the structure of the optimal modes and their weight spectra using perturbation theory and via a comparison to results for the one-species Bose-Hubbard model. Further, we study the dynamical evolution of the optimal modes and of the single-site entanglement entropy in two quantum quenches that cross phase boundaries between different phases of the model. For our numerical calculations, we use exact diagonalization and the density matrix renormalization group method.

TT 53.11 Wed 17:45 H21

Fractional Wigner oscillations in two-dimensional topological insulators — •Niccolo Traverso Ziani[1], Francois Crépin[2], and Bjoern Trauzettel[1,3] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [2]Laboratoire de Physique Théorique de la Matière Condensée, UPMC, CNRS UMR 7600, Sorbonne Universités, 4 place Jussieu, 75252 Paris Cedex 05, France — [3]Department of Physics, University of California, Berkeley, California 94720, USA

In finite electronic systems, when electron-electron interactions dominate over kinetic energy, electrons tend to form regular lattices, called Wigner molecules. One dimensional electrons do not represent an exception [1]. Importantly, for strong interactions, the Wigner molecule becomes an almost classical state and any dependence on the spin degree of freedom is lost. This behaviour is antithetical to the concept of spin-momentum locking characterizing the helical edges of two-dimensional topological insulators (helical Luttinger liquids) [2]. The compromise between strong interactions and spin-momentum locking leads, in helical systems, to a Wigner oscillation of fermions with fractional charge e/2 [3]. This fractional oscillation is also characterized by strongly anisotropic spin-spin correlations.

[1] I. Safi and H. J. Shulz, PRB **59**, 3040 (1999)
[2] C. Wu, B., A. Bernevig, S.-C. Zhang, PRL **96**, 105401 (2006)
[3] N. Traverso Ziani, F. Crépin, B. Trauzettel, PRL **115**, 206402 (2015).

TT 53.12 Wed 18:00 H21

Time-dependence of Spin-Orbital Excitations in the one dimensional Kugel-Khomskii model — •Mirco Marahrens and Maria Daghofer — Institut für Funktionelle Materie und Quantentechnologien, University of Stuttgart, Stuttgart, Baden-Wuerttemberg, Germany

Using the technique of time-dependent Density Matrix Renormalization Group (tDMRG) we investigating the behaviour of spin and orbital dynamics in the Kugel-Khomskii model. The model couples an SU(2) algebra for the spin with and orbital degree of freedom, where a crystal field breaks SU(2) symmetry. For the case of an orbital splitting larger than the magnetic coupling, the ground state has antiferromagnetic (AFM) and ferro-orbital (FO) order. Initial states are prepared as deviations from this order, as might arise through a temporary quench of crystal field. An example that will be analyzed is the spin-orbit separated propagation of fractionalized elementary excitations [1]. We discuss ongoing work on this issue and the different aspects of the results obtained so far.

[1] J. Schlappa et al., Nature **485**, 82 (2012)