TT 65: Low-Dimensional Systems: 1D – Theory

Time: Wednesday 15:00–19:15 Location: H 0104

Topical Talk TT 65.1 Wed 15:00 H 0104

Strong Correlations in Disordered One-Dimensional Systems — •Christoph Karrasch and Joel Moore — UC Berkeley, USA

We investigate the effects of strong electronic correlations in disordered one-dimensional systems such as XXZ spin chains. In order to study the problem from different perspectives, both semi-analytical methods (the functional renormalization group) and purely computational techniques (the density matrix renormalization group) are employed. First, we briefly discuss a recently-introduced 'disentangler' which allows to carry out finite-temperature dynamical DMRG simulations up to larger times. Thereafter, we study a variety of questions: How is Luttinger liquid behavior cut off by weak disorder? Are there new power laws? Can we identify many-body localized and metallic phases if the disorder is strong, and can we learn something about the transition between the two?

TT 65.2 Wed 15:30 H 0104

Efficient time-evolution for long-ranged one-dimensional Hamiltonians — •Frank Pollmann[1], Mike Zaletel[2], Roger S. K. Mong[3], Christoph Karrasch[2], and Joel E. Moore[2] — [1]Max-Planck-Institut f'ur Physik komplexer Systeme, 01187 Dresden, Germany — [2]University of California, Berkeley, California 94720, USA — [3]California Institute of Technology, Pasadena, California 91125, USA

We introduce a numerical algorithm to simulate the time evolution of a matrix product state under a long-ranged Hamiltonian. In the effectively one-dimensional representation of a system by matrix product states, long-ranged interactions are necessary to simulate not just many physical interactions but also higher- dimensional problems with short-ranged interactions. Since our method overcomes the restriction to short- ranged Hamiltonians of most existing methods, it proves particularly useful for studying the dynamics of both power-law interacting one-dimensional systems, such as Coulombic and dipolar systems, and quasi two- dimensional systems, such as strips or cylinders. First, we benchmark the method by verifying a long-standing theoretical prediction for the dynamical correlation functions of the Haldane-Shastry model. Second, we simulate the time evolution of an expanding cloud of particles in the two-dimensional Bose-Hubbard model, a subject of several recent experiments.

TT 65.3 Wed 15:45 H 0104

Rashba coupling and magnetic order in correlated helical liquids — •Martin Hohenadler and Fakher Assaad — Universität Würzburg, Germany

We study strongly correlated helical liquids with and without Rashba coupling using quantum Monte Carlo simulations of the Kane-Mele model with a Hubbard interaction at the edge. Independent of the Rashba coupling, we find that interactions enhance spin correlations and suppress the spectral weight at the Fermi level. For sufficiently strong interactions, a gap can be observed in the single-particle spectral function. However, based on a finite-size scaling analysis and theoretical arguments, we argue that this gap is closed by order parameter fluctuations in the Luttinger liquid phase even at zero temperature, and filled in by thermally induced kinks in the order parameter in the Mott phase at finite temperatures. While the bosonization suggests an umklapp-driven Mott transition only in the presence of Rashba coupling and hence an important impact of the latter, our numerical results are almost unaffected by Rashba coupling even at low temperatures.

TT 65.4 Wed 16:00 H 0104

Effective 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

The study of correlated quantum wires deposited on a substrate constitutes a challenge for existing analytical and numerical methods. We show that these systems can be mapped onto effective n-leg ladder models, which can then be investigated thoroughly using well-established methods for quasi-one-dimensional systems, such as the density-matrix renormalization group (DMRG) or bosonization. The possibilities and limitations of this approach are demonstrated with exact results for non-interacting systems as well as with DMRG and quantum Monte Carlo calculations for interacting wires. We present results for a two-leg effective model [1] and discuss the modeling of Luttinger liquids on semiconducting substrates. Support from the DFG through the Research Unit FOR 1807 is gratefully acknowledged.

[1] A. Abdelwahab, E. Jeckelmann, and M. Hohenadler, arXiv:1409.7315

TT 65.5 Wed 16:15 H 0104

Spin-charge-separated quasi-particles in 1D quantum fluids — •Imke Schneider[1], Rodrigo G. Pereira[2], and Fabian H. Essler[3] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Instituto de Fisica de Sao Carlos, Universidade de Sao Paulo, C.P. 369, Sao Carlos, SP, 13560-970, Brazil — [3]The Rudolf Peierls Centre for Theoretical Physics, Oxford University, Oxford OX1 3NP, United Kingdom

Interacting one-dimensional quantum fluids are well-studied examples of systems in which the Fermi liquid paradigm of electron-like quasi-particles is known to break down. Instead, Luttinger liquid theory predicts separate spin- and charge-density waves - bosonic in nature - as the fundamental collective excitations at low energies.

Recently, the idea of fermionic quasi-particles for 1D quantum fluids was revived by the interest in dynamics beyond the Luttinger liquid paradigm. Here we propose a constructive approach to introduce fermionic quasi-particles for two-component Luttinger liquids. We point out that a model with weakly interacting fermionic quasi-particles at low energies - a good starting point for the universal theory of nonlinear Luttinger liquids - is a double Luther-Emery Point which can only be reached by fine tuning of strong interactions. Using density matrix renormalization group(DMRG) methods, we search for a lattice realization of this point in an extended Hubbard model with longer-range density-density and spin exchange interactions.

TT 65.6 Wed 16:30 H 0104

Exact calculation of thermal correlation functions of the antiferromagnetic Heisenberg chain at large distances — •Frank Göhmann and Maxime Dugave — Bergische Universität Wuppertal

Thermal correlation functions of integrable models in the thermodynamic limit can be expanded in a basis of eigenstates of the corresponding quantum transfer matrix. This provides an asymptotic expansion in which every term is determined by a correlation length and by an amplitude. We have derived exact formulae for the amplitudes for the longitudinal and transverse correlation functions of the anisotropic Heisenberg chain in the spin liquid regime as functions of temperature and magnetic field. In the zero temperature limit infinitely many correlation lengths diverge, while the amplitudes decay algebraically with temperature, with the same critical exponents that determine the spatial decay of the ground state correlation functions. We have summed up these infinitely many terms exactly and, as a result, have obtained efficient expressions for the amplitudes of the critical correlation functions, generalizing well-known formulae of Lukyanov to finite magnetic fields.

TT 65.7 Wed 16:45 H 0104

Form Factor Expansions for the XXZ Chain in the Massive Regime — •Maxime Dugave and Frank Göhmann — Bergische Universität Wuppertal

We discuss the form factor approach to correlation functions of the integrable anisotropic spin-1/2 Heisenberg chain in the massive regime at zero temperature.

Using the transfer-matrix technique and Bethe ansatz, we characterize the spectrum of the Hamiltonian in the thermodynamic limit. By analyzing the non-linear integral equations which describe excited states, we rederive the classification of excitations found by Babelon, De Vega and Viallet (1983) and correct an error in the higher-level Bethe equations obtained in this classical work.

This lays the basis for the calculation of exact expressions for matrix elements of local operators in the thermodynamic limit. In the 2-particle case, we find agreement with results from the vertex operator approach (Jimbo and Miwa (1995), Lashkevich (2002)). We eventually obtain the leading large-distance asymptotics of the longitudinal correlation functions by a saddle-point integration.

15 min. break.

TT 65.8 Wed 17:15 H 0104

Dynamics of S=1 Heisenberg chains at finite temperatures — •Thomas Köhler[1], Salvatore R. Manmana[1], Stephan C. Kramer[2], Andreas Honecker[3], and Thomas Pruschke[1] — [1]Institut f. Theoretische Physik, Universität Göttingen — [2]Max-Planck-Institut f. biophysikalische Chemie, Göttingen — [3]LPTM, Université de Cergy-Pontoise, France

We compute dynamical spectral functions for S=1 Heisenberg systems at finite temperatures T using matrix product state (MPS) approaches. This is achieved by parallelizing the time evolution on GPUs, and via a linear prediction ansatz on the time evolution results. We discuss the effect of temperature on the spectral functions and provide an outlook on the fate of the Haldane state upon increasing T.

TT 65.9 Wed 17:30 H 0104

Spectral functions of one-dimensional quantum magnets — •Alexander C. Tiegel[1], Salvatore R. Manmana[1], Thomas Pruschke[1], and Andreas Honecker[2] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany — [2]LPTM, Université de Cergy-Pontoise, France

We present numerical results for experimentally relevant spectral functions of one-dimensional strongly correlated quantum systems. We focus on the electron spin resonance (ESR) modes of spin-1/2 XXZ Heisenberg chains with Dzyaloshinskii-Moriya interactions in magnetic fields at both zero and finite temperature. The spectral functions are computed directly in the frequency domain via a Chebyshev expansion of the Green's function in a density-matrix renormalization group (DMRG) framework using matrix product states (MPS). At finite temperature, the method is based on a purification of the density operator by exploiting a Liouville space formulation of the dynamics. Our results are compared to field-theoretical descriptions from the literature.

TT 65.10 Wed 17:45 H 0104

Work distribution in quantum quenches of the anistoropic Heisenberg (XXZ) chain — •Paolo Pietro Mazza[1], Elena Canovi[2], Vincenzo Alba[3], and Masudul Haque[4] — [1]Max Planck Institute for Physics of Complex Systems, Dresden — [2]Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL, Hamburg — [3]Department of Physics and Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität Munich — [4]Max Planck Institute for Physics of Complex Systems, Dresden

An important feature of a quantum quench is the distribution of overlaps of the initial state with the eigenstates of the final Hamiltonian. This distribution of overlaps is closely related to the distribution of work done in a quantum quench. We will present a study of the overlap distribution in the XXZ spin chain. We will consider quenches of the anisotropy parameter and describe which eigenstates get excited in such quenches.

TT 65.11 Wed 18:00 H 0104

Minimally entangled typical thermal states and matrix product purifications for the simulation of strongly-correlated quantum systems at T>0 — Moritz Binder[1] and •Thomas Barthel[2] — [1]LMU München — [2]LPTMS, Université Paris-Sud and CNRS

We describe different approaches for the study of equilibrium states and finite-temperature response functions of strongly-correlated quantum many-body systems in the framework of the density matrix renormalization group (DMRG). One is based on matrix product purifications. An alternative are so-called minimally entangled typical thermal states (METTS) which combine DMRG with sampling. We compare and explain the efficiencies of these methods and new variants using the spin-1/2 XXZ chain and the 1D Bose-Hubbard model as examples.

TT 65.12 Wed 18:15 H 0104

Exchange couplings in spin chains — •Kira Riedl, Harald O. Jeschke, and Roser Valenti — Institut für Theoretische Physik, Goethe-Universität Frankfurt, 60438 Frankfurt am Main, Germany

Within the framework of density functional theory, we investigate the variation of exchange couplings in $SrCuO_2$ and Sr_2CuO_3 spin chains[1] upon doping[2] with magnetic and non-magnetic impurities. In this talk we shall discuss the various cases and compare with experimental results.

This work is being performed in collaboration with C. Rüegg.

[1] N. Hlubek, X. Zotos, S. Singh, R. Saint-Martin, A. Revcolevschi, B. Büchner, and C. Hess, J. Stat. Mech. **12**, P03006 (2012).
[2] K. Karmakar, A. Singh, S. Singh, A. Pool, and C. Rüegg, Cryst. Growth Des. **14**, 1184 (2014).

TT 65.13 Wed 18:30 H 0104

Scaling of critical wave functions at topological Anderson transitions in 1D — •Eoin Quinn[1], Thomas Cope[2], Jens H. Bardarson[1], and Alexander Ossipov[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]University of Nottingham, Nottingham, United Kingdom

Topological Anderson transitions occur when a change in the strength of a system's disorder takes the system between two topologically distinct phases. The critical wavefunctions at such transitions display universal features. We present analytical and numerical results on the boundary scaling of critical wavefunctions for systems that are quasi-1D.

TT 65.14 Wed 18:45 H 0104

Quench dynamics of the entanglement spectrum in a dimerized chain — •Yi-Hao Jhu[1,4], Pochung Chen[1,2], Ming-Chiang Chung[2,3], and Frank Pollmann[4] — [1]Physics Department, National Tsing Hua University, Hsinchu, 30013, Taiwan — [2]Physics Division, National Center for Theoretical Science, Hsinchu, 30013, Taiwan — [3]Department of Physics, National Chung Hsing University, Taichung, 40227, Taiwan — [4]Max-Planck-Institut für Physik komplexer Systeme, Dresden, 01187, Germany

We investigate the quench dynamics of a dimerized chain of spin less fermions in the presence of nearest-neighbor interactions. We first obtain the ground state phase diagram and focus on the stability of a topological phase of "Su-Schrieffer-Heeger" type. We then study the evolution of the entanglement spectrum following a global quench in which the dimerization strength is changed. In the non-interacting case, degeneracies in the spectrum revive at long times which indicates the stability of the topological properties. When interactions between the fermions are present, the state thermalizes and the degeneracies are lost. We furthermore derive a topological invariant that shows a similar behavior.

TT 65.15 Wed 19:00 H 0104

Finite-temperature spectral functions: a Chebyshev-METTS approach — •Benedikt Bruognolo, Jan von Delft, and Andreas Weichselbaum — Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, Ludwig-Maximilians-Universität, Munich

While nowadays a wide range of techniques exist to access the static and dynamic ground state properties of strongly correlated 1D quantum systems, finite-temperature calculations of such models still represent a challenge.

We introduce a new and efficient approach for calculating finite-temperature spectral functions directly in the frequency domain; it combines the Minimally Entangled Typical Thermal States (METTS) approach for thermal averaging with a double Chebyshev expansion for obtaining spectral information. We discuss the key steps of our method and its applicability in the context of the exactly solvable XX model. Moreover, we present preliminary results for an anisotropic spin-3/2 Heisenberg model with in-plane magnetic field.