TT 4: Low-Dimensional Systems: 1D - Theory

Time: Monday 9:30–13:00 Location: HSZ 201

TT 4.1 Mon 9:30 HSZ 201

Diffusive and ballistic dynamics in local quenches in 1D spin-1/2 systems at finite temperatures — •Fabian Heidrich-Meisner[1], Christoph Karrasch[2], and Joel Moore[2] — [1]Ludwig-Maximilians-University Munich — [2]University of California, Berkeley

We study the spreading of local perturbations in the spin and energy density of spin-1/2 systems at finite temperatures [1], using the time-dependent density matrix renormalization group technique. In the integrable XXZ chain, we observe a ballistic dynamics of energy at all temperatures and for all exchange anisotropies. The spin dynamics, by contrast, is diffusive in the Ising phase at high temperatures. We extract the diffusion constant from these local quenches at infinite temperatures and show that the values are in quantitative agreement with the Einstein relation for sufficiently small local perturbations. We also study spin ladder systems, for which we observe examples of diffusive spin and energy dynamics at finite temperatures. The connection of our results to recent experiments with cold gases [2] and quantum magnets [3] is discussed.

[1] C. Karrasch, J. Moore, F. Heidrich-Meisner, in preparation.
[2] J.P. Ronzheimer et al., Phys. Rev. Lett. 110, 205301 (2013)
[3] M. Montagnese et al., Phys. Rev. Lett. 110, 147206 (2013)

TT 4.2 Mon 9:45 HSZ 201

Optimized tDMRG schemes for $T > 0$ response functions and application for quantum-critical bosons — •Thomas Barthel[1], Ulrich Schollwöck[2], and Subir Sachdev[3] — [1]Université Paris-Sud and CNRS — [2]LMU München — [3]Harvard University

I will present improved schemes for the precise and efficient evaluation of finite-temperature response functions of strongly correlated systems in the framework of the time-dependent density matrix renormalization group (tDMRG) [1,2]. The growth and scaling of entanglement in such simulations can be explained on the basis of quasi-locality. With the novel optimized schemes, the maximum times that can be reached are typically increased by at least a factor of two, when compared against the earlier approaches. These increased reachable times make many more physical applications accessible. I will show two applications: (a) the universal scaling form of the spectral function of 1D bosons in the quantum critical regime with dynamic critical exponent $z = 2$ [2], and (b) spin structure factors of the spin-1/2 XXZ chain in comparison to inelastic neutron scattering data for $KCuF_3$ [3].

[1] T. Barthel, NJP **15**, 073010 (2013)
[2] T. Barthel, U. Schollwöck, and S. Sachdev, arXiv:1212.3570
[3] B. Lake *et al.*, PRL **111**, 137205 (2013)

TT 4.3 Mon 10:00 HSZ 201

Finite temperature dynamics of Heisenberg spin chains with $S \geq 1/2$ — •Thomas Köhler[1], Salvatore R. Manmana[1], Christoph Karrasch[2], Thomas Pruschke[1], and Andreas Honecker[1] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, 37077 Göttingen, Germany — [2]Department of Physics, University of California, Berkeley, CA 95720, United States

We present results for spectral functions of one-dimensional Heisenberg systems at finite temperatures obtained via a density-matrix renormalization group (DMRG) matrix product state implementation with real-time evolution. We show results for systems with $S = 1/2$ at zero and finite magnetic fields, as well as for systems with Dzyaloshinskii-Moriya anisotropy. At zero field, we discuss results for $S = 1$ and $S = 2$ and focus on the features realized in the dynamical structure factor at infinite temperature.

TT 4.4 Mon 10:15 HSZ 201

Matrix product state formulation of frequency-space dynamics at finite temperatures — •Alexander C. Tiegel, Salvatore R. Manmana, Thomas Pruschke, and Andreas Honecker — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

We use the density-matrix renormalization group (DMRG) to compute dynamical correlation functions of one-dimensional strongly correlated quantum systems at finite temperatures. The approach allows for the frequency-resolved evaluation of experimentally relevant quantities like line shapes in neutron or light scattering experiments. As a proof of principle, we study finite-temperature spectral functions of spin-1/2 XXZ Heisenberg chains with Dzyaloshinskii-Moriya interactions in magnetic fields. Based on our results, we provide an outlook for further improvements and developments of finite-temperature DMRG approaches to dynamical response functions.

TT 4.5 Mon 10:30 HSZ 201

Effective gauge field description for the bilinear-biquadratic spin-one chain — •Shijie Hu[1], Ari M. Turner[2], Karlo Penc[3,4], and Frank Pollmann[1] — [1]Max-Planck-Institut fuer Physik komplexer Systeme, 01187 Dresden, Germany — [2]University of Amsterdam, 1090 GL Amsterdam, The Netherlands — [3]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, H-1525 Budapest, P.O.B. 49, Hungary — [4]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary

We study the one-dimensional bilinear-biquadratic spin-one model. For this model, the possible existence of a nematic phase between a dimerized and a ferromagnetic phase has been debated. We present strong evidence for the absence of such an intermediate phase by comparing prediction of an effective gauge theory with the results of large scale density-matrix renormalization group (DMRG) simulations. In particular we compare the scaling of the correlations length and the dimerization strength obtained from the gauge theory with the DMRG results. It is found that quantum fluctuations melt the nematic order and stabilize a gapped, dimerized phase which persists all the way to the edge of the ferromagnetic phase. We furthermore discuss the multiplet structure found in the entanglement spectrum of the ground state wave functions.

TT 4.6 Mon 10:45 HSZ 201

The Cirac-Sierra construction and long range SU(N) spin models — Roberto Bondesan and •Thomas Quella — University of Cologne, Cologne, Germany

The Haldane-Shastry model for SU(2) is a paradigmatic example of a long range spin chain. The model is remarkable in that it allows for the analytic determination of the complete energy spectrum and explicit expressions for the associated wave functions. Besides being relevant in the context of fractional quantum Hall physics, it also provides a discretization of the critical SU(2) Wess-Zumino-Witten (WZW) conformal field theory.

Recently, Cirac and Sierra found a conceptually new and intriguing perspective on long range spin chains by reverting the previous idea. Now long range spin models arise as parent Hamiltonians of a given WZW correlator. This construction provides a generalization of the Haldane-Shastry model in the sense that the symmetry group, the representations and the positions of the spins may be freely chosen. It even permits the construction of 2D models with a specific groundstate wave function.

In this talk, we apply this construction to different types of SU(N) spin models and discuss the physical implications.

15 min. break.

TT 4.7 Mon 11:15 HSZ 201

The gl(1|1) Lie superalgebra as a basis for the Nielsen-Cirac-Sierra construction — Thomas Quella, Roberto Bondesan, and •Jochen Peschutter — University of Cologne, Cologne, Germany

By explicitly constructing quantum spin Hamiltonians and their groundstates for the SU(2)_k Wess-Zumino-Witten model, Nielsen, Cirac and Sierra have proposed a general blueprint for the construction of quantum spin Hamiltonians with more general symmetries. The crucial ingredients in this pursuit are the so-called null vectors contained in the corresponding Verma module.

In this talk, we will present the status of our progress in specifically applying these ideas to the Lie superalgebra gl(1|1).

TT 4.8 Mon 11:30 HSZ 201

Self-assembling tensor networks and holography in disordered spin chains — •Andrew M. Goldsborough and Rudolf A. Römer — University of Warwick, Coventry, UK

We show that the numerical strong disorder renormalization group algorithm (SDRG) of Hikihara et al. for the disordered Heisenberg model

[1] naturally describes a tree tensor network (TTN) with an irregular structure defined by the strength of the couplings. Using developments from TTNs [2] and the multi-scale entanglement renormalization ansatz (MERA) [3] we can efficiently calculate expectation values and entanglement entropy directly from the tensor network wavefunction. We also analyse the effect of the disordered geometry of the TTN on the two-point correlation functions and entanglement entropy. We show that disorder averaged correlation scales with the average path length through the tensor network, as suggested by Evenbly and Vidal [4] in the context of regular tensor network geometries and that entanglement entropy increases with both disorder and length, resulting in an area-law violation consistent with the results of [5].

[1] T. Hikihara, A. Furusaki, M. Sigrist, Phys. Rev. B 60, 12116 (1999)
[2] L. Tagliacozzo, G. Evenbly, G. Vidal, Phys. Rev. B 80, 235127 (2009)
[3] G. Evenbly and G. Vidal, Phys. Rev. B 79, 144108 (2009)
[4] G. Evenbly and G. Vidal, J. Stat. Phys. 145, 891 (2011)
[5] G. Refael and J. E. Moore, Phys. Rev. B 76, 024419 (2007)

TT 4.9 Mon 11:45 HSZ 201

Dynamical response functions in the 1D Hubbard model — •Imke Schneider[1], Rodrigo G. Pereira[2], and Fabian H. Essler[1] — [1]The Rudolf Peierls Centre for Theoretical Physics, Oxford University, Oxford OX1 3NP, United Kingdom — [2]Instituto de Fisica de Sao Carlos, Universidade de Sao Paulo, C.P. 369, Sao Carlos, SP, 13560-970, Brazil

Dynamical response functions are of particular interest in view of experimental applications such as momentum resolved tunneling in quantum wires. However, in recent works it was demonstrated that neglecting curvature in the generic dispersion in 1D - resulting in Luttinger liquid theory - leads to incorrect results for singularities in dynamical responses. Using a mapping to a Luttinger liquid with an additional high frequency mobile impurity and taking the leading irrelevant operators into account nonperturbatively it is possible to determine the exact threshold singularities.

We present a constructive derivation of such a mobile impurity model for the 1D Hubbard model. Crucially, the Luther-Emery point for both charge and spin fermions constitutes the good starting point for a weak coupling expansion. As an application we discuss the zero temperature optical conductivity of the 1D Hubbard model in the gapless phase.

TT 4.10 Mon 12:00 HSZ 201

Entanglement entropies for interacting many-fermion systems — •Peter Bröcker and Simon Trebst — Institute for Theoretical Physics, University of Cologne, Germany

The precise determination of the entanglement of an interacting quantum many-body systems is now appreciated as an indispensable tool to identify the fundamental character of the ground state of such systems. This is particularly true for unconventional ground states harboring non-local topological order or so-called quantum spin liquids that evade a standard description in terms of correlation functions.

With the entanglement entropy emerging as one of the central measures of entanglement, recent progress has focused on a precise characterization of its scaling behavior, in particular in the determination of (subleading) corrections to the prevalent boundary-law. While much progress has been made for spin and bosonic quantum many-body systems, fermion systems have proved to be more difficult.

For a large class of interacting fermionic systems, the numerical method of choice for unbiased, large-scale simulations is Determinantal Quantum Monte Carlo (DQMC) for which a generalization of the replica techniques developed to calculate entanglement entropies for spin and bosonic systems has remained an open question. Here we show one possibility how to construct the corresponding algorithm in DQMC and demonstrate its strength by studying the thermal crossover of the entanglement entropy in one-dimensional Hubbard systems. We also compare our results to another recent approach based on free fermion Green's functions.

TT 4.11 Mon 12:15 HSZ 201

Spin and charge dynamics of Hubbard chains with Rashba spin-orbit coupling — •Florian Goth and Fakher F. Assaad — Institut für theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany

Interacting one-dimensional electrons have attracted considerable interest since the strong confinement marks the breakdown of the usual nearly free electron picture that is valid in higher dimensions. The experimental realization of these systems is often realized by considering adatoms on surfaces. Thereby, inversion symmetry is broken and a minimal model to capture the correlation physics is a Hubbard chain supplemented by a Rashba type spin-orbit interaction. We study this system using Quantum Monte Carlo methods as a function of doping and spin-orbit coupling strength. We present results on spin and charge dynamics as well as the single particle spectral functions.

TT 4.12 Mon 12:30 HSZ 201

Low-energy properties of fractional helical Luttinger liquids — •Tobias Meng[1], Lars Fritz[2], Dirk Schuricht[3], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937 Köln, Germany — [3]Institut für Theorie der Statistischen Physik, RWTH Aachen University and JARA - Fundamentals of Future Information Technology, 52056 Aachen, Germany

We discuss how fractional helical Luttinger liquids, a one-dimensional state related to the fractional quantum Hall effect, can emerge as a consequence of an intricate mixing of charge and spin degrees of freedom in a quantum wire. We discuss their unusual low energy physics with an emphasis on their fractional conductance, the optical conductivity and density of states.

TT 4.13 Mon 12:45 HSZ 201

Quantum particles in periodically driven harmonic trap — •Eoin Quinn and Masudul Haque — Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany

We describe the effect of periodically modulating the strength of a confining trap on a one-dimensional trapped quantum system. We consider the driven dynamics of strongly interacting bosons (Tonks Giradeau gas) and free fermions. Having a discrete spectrum, the system exhibits a set of resonances. Our description combines an exact solution with a Floquet analysis.