TT 1: Correlated Electrons: Low-dimensional Systems - Models 1

Time: Monday 9:30–13:15 Location: H 0104

TT 1.1 Mon 9:30 H 0104

Lithium purple bronze: strong renormalization of the perpendicular hopping — •L. Dudy[1,2], J. Denlinger[3], J. He[4], and J.W. Allen[1] — [1]Randall Laboratory, University of Michigan, Ann Arbor, MI, USA — [2]Julius-Maximilians-Universität Würzburg, Germany — [3]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA, USA — [4]Clemson University, Clemson, SC, USA

An interesting topic in condensed matter physics is the question of whether one dimensional (1d) behavior of the electronic structure can be realized in our 3d world. In the case of a network (or bundle) of one-dimensional chains, in the framework of the Tomonaga Luttinger model, it is found in theory that movement of electrons between neighboring chains, the "perpendicular hopping", can be greatly suppressed by the 1d behavior, although at a sufficiently low temperature a crossover to 3d is nonetheless expected. We will present results from angle resolved photoemission spectroscopy on single crystals of the quasi-1d lithium purple bronze ($Li_{0.9}MoO_{17}$) measured at a temperature of 6K on the Merlin beam line at the Advanced Light Source. We will show that the hopping parameter has to be extremely renormalized down from its LDA value in order to explain the experiment. Therefore, there might even be the rare possibility that the superconductivity of this material (at about 1.9K) evolves out of a 1d normal state.

TT 1.2 Mon 9:45 H 0104

Low-energy local spectral weights of the one-dimensional Hubbard chain — Stefan Söffing[1], Imke Schneider[2], and •Sebastian Eggert[1] — [1]TU Kaiserslautern and Research Center OPTIMAS — [2]TU Dresden

The Hubbard model in one dimension is a proto-typical model for a quantum wire with separate spin and charge excitations. We now examine the local spectral weights along a finite wire with the numerical Density Matrix Renormalization group in order to find signatures of strongly correlated excitations in the low-energy tunneling density of states. The resulting level structureis remarkably rich in space and energy. Comparing with the predictions from bosonization, we observe strong corrections from higher order operators and boundary effects.

TT 1.3 Mon 10:00 H 0104

Ballistic expansion of interacting fermions in one-dimensional optical lattices — •Stephan Langer[1], Martin Schuetz[3], Ian McCulloch[2], Ulrich Schollwöck[1], and Fabian Heidrich-Meisner[1] — [1]LMU München — [2]University of Queensland, Brisbane, Australia — [3]MPQ Garching and LMU München

In most quantum quenches, no net particle currents arise. Access to studying transport properties can be gained by letting a two-component Fermi gas that is originally confined by the presence of a trapping potential expand into an empty optical lattice. In recent experiments, this situation was addressed in 2D and 3D optical lattices [1]. We focus on the 1D case in which an exact numerical simulation of the time-evolution is possible by means of the DMRG method. Concretely, we study the expansion in the 1D Hubbard model with repulsive interactions, driven by quenching the trapping potential to zero, and we concentrate on the most direct experimental observable, namely density profiles [2]. In the strict 1D case, we identify conditions for which the expansion is ballistic, characterized by an increase of the cloud's radius that is linear in time. This behavior is found whenever initial densities are smaller or equal to one, both for the expansion from box and harmonic traps. We make quantitative predictions for the expansion velocity as a function of on-site repulsion and initial density that can be probed in experiments.

[1] Schneider et al., arXiv:1005.3545
[2] Langer et al., arXiv:1109.4364

TT 1.4 Mon 10:15 H 0104

Local density of states of the one-dimensional spinless fermion model — •Eric Jeckelmann — Leibniz Universität Hannover, Germany

We investigate the local density of states of the one-dimensional half-filled spinless fermion model with nearest-neighbor hopping $t > 0$ and interaction V in its Luttinger liquid phase $-2t < V \leq 2t$. The bulk density of states and the local density of states in open chains are calculated over the full band width $\sim 4t$ with an energy resolution $\leq 0.08t$ using the dynamical density-matrix renormalization group (DDMRG) method. We also perform DDMRG simulations with a resolution of $0.01t$ around the Fermi energy to reveal the power-law behaviour $D(\epsilon) \sim |\epsilon - \epsilon_{\mathrm{F}}|^{\alpha}$ predicted by the Luttinger liquid theory for bulk and boundary density of states. The exponents α are determined using a finite-size scaling analysis of DDMRG data for lattices with up to 3200 sites. The results agree with the exact exponents given by the Luttinger liquid theory combined with the Bethe Ansatz solution. The crossover from boundary to bulk density of states is analyzed. We have found that boundary effects can be seen in the local density of states at all energies even far away from the chain edges [1].

[1] E. Jeckelmann, arXiv:1111.6545v1 [cond-mat.str-el]

TT 1.5 Mon 10:30 H 0104

Relaxation and thermalization in the 1d Hubbard model — •Tilman Enss[1] and Jesko Sirker[2] — [1]TU München, Germany — [2]TU Kaiserslautern, Germany

The time evolution of a 1d quantum system after a quench is a challenging many-body problem which can be studied, e.g., numerically using time-dependent density matrix renormalization group (DMRG) techniques. As shown by Lieb and Robinson, information spreads at a finite velocity resulting in an effective "light cone". In my talk I will present a very efficient DMRG algorithm based on this light cone structure. With the help of the DMRG data I will discuss the relaxation and thermalization of doublon states in the fermionic Hubbard model.

TT 1.6 Mon 10:45 H 0104

Fractionalization of electron's spin and orbital degrees of freedom in 1D — •Krzysztof Wohlfeld[1], Maria Daghofer[1], Satoshi Nishimoto[1], Giniyat Khaliullin[2], and Jeroen van den Brink[1] — [1]IFW Dresden, Germany — [2]MPI-FKF Stuttgart, Germany

We show that electron's spin and orbital degrees of freedom can fractionalize in 1D antiferromagnets: although the orbital excitations are inherently coupled to spinons in antiferromagnetic Mott insulators, in 1D they separate into a *pure* orbiton and a single spinon. This is similar to the spin-charge separation in 1D but corresponds to an exotic regime where spinons are faster than holons [1]. The resulting large dispersion of the *pure* orbiton can be detected in e.g. quasi-1D cuprates [2].

[1] K. Wohlfeld, M. Daghofer, S. Nishimoto, G. Khaliullin, and J. van den Brink, Phys. Rev. Lett. **107**, 147201 (2011).
[2] J. Schlappa *et al.*, to be published (2011).

TT 1.7 Mon 11:00 H 0104

Fractionalization of Fractionalized Charges in the 1D t-J Model — •Alexander Moreno and Alejandro Muramatsu — Institut für Theoretische Physik III, Universität Stuttgart, Germany

On the basis of the density matrix renormalization group (DMRG) we study the ground-state phase diagram [1] of the model and the excitation content of each phase. The real time dynamics of a low-energy electron added to the system can be described by right and left propagating fractional excitation predicted by the Luttinger Liquid theory (LL) [2]. However, at higher energies the dynamics reveals one more level of fractionalization of the already fractional LL excitation. This new kind of fractionalization is also visible in the one-particle spectral function obtained in a previous quantum Monte Carlo simulation [3] where the branches were assigned to a spinon, a holon, and an antiholon, as in the supersymmetric t-J model with $1/r^2$ exchange [4]. By switching an electric field, we aim at identifying the charge of the fractionalized elementary excitations that result from the electron.

[1] A. Moreno, A. Muramatsu and S. Manmana, Phys. Rev. B **83**, 205113 (2011).
[2] K.-V. Pham, M. Gabay, and P. Lederer, Phys. Rev. B **61**, 16397(2000).
[3] C. Lavalle, M. Arikawa, S. Capponi, F. F. Assaad, and A. Muramatsu, Phys. Rev. Lett. **90**, 216401 (2003).
[4] M. Arikawa, Y. Saiga, and Y. Kuramoto, Phys. Rev. Lett. **86**, 3096 (2001).

15 min. break.

TT 1.8 Mon 11:30 H 0104

Entanglement spectrum in two dimensional systems — •Vincenzo Alba[1], Masud Haque[1], and Andreas Lauchli[2] — [1]Max Planck Institute for the Physics of the Complex Systems, Dresden, Germany — [2]University of Innsbruck, Innsbruck, Austria

We studied the entanglement spectrum of several two dimensional systems (2D Bose-Hubbard, XXZ, tight binding systems with staggered chemical potential). We found a physical description of the low part of the entanglement spectrum in terms of effective hamiltonians (entanglement hamiltonians). For the 2D Bose Hubbard we also characterized the behavior of the entanglement spectrum in the superfluid phase where we found that the entanglement hamiltonian shows clear signatures of the condensate wavefunction.

TT 1.9 Mon 11:45 H 0104

Robustness of the two-dimensional cluster phase in an external magnetic field — •Henning Kalis, Daniel Klagges, and Kai Phillip Schmidt — Lehrstuhl für Theoretische Physik I, TU Dortmund, Germany

The cluster state represents a highly entangled state which is one central object for measurement-based quantum computing. Here we study the robustness of the cluster state on the two-dimensional square lattice at zero temperature in the presence of external magnetic fields by means of high-order series expansions. Interestingly, the phase diagram contains a self-dual line in parameter space allowing many precise statements about the fate of the cluster phase at finite fields. We provide strong evidences for first- and second-order phase transitions between the cluster phase and polarized phases.

TT 1.10 Mon 12:00 H 0104

Quantum paramagnetism in the Kagomé transverse field Ising model — •Michael Powalski[1], Kris Cöster[1], Roderich Moessner[2], and Kai Phillip Schmidt[1] — [1]Lehrstuhl für Theoretische Physik I, TU Dortmund, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

We study the intriguing interplay of strong geometrical frustration and of quantum fluctuations. Using perturbative continuous unitary transformations to study the high-field phase, we have calculated the one-magnon excitation spectrum as a high-order series expansion for both Kagomé and for the triangular lattices. Most interestingly, the one-particle gap for the Kagomé transverse field Ising model shows no tendency to close for any finite magnetic field suggesting that the disordered quantum paramagnet is adiabatically connected to the low-field limit. In contrast, for the triangular lattice we find a quantum phase transition which is compatible with the 3dXY universality class. The different behaviour of both lattices can be traced back to the existence of an (almost) dispersionless lowest-energy band for the Kagomé lattice which is exactly flat up to order seven in perturbation theory. This behaviour is understood in terms of a local mode. Furthermore, we can understand the occurrence and the properties of such local modes for any lattice by the corresponding graph expansion.

TT 1.11 Mon 12:15 H 0104

Anomalous criticality near semimetal-to-superfluid quantum phase transition in a two-dimensional Dirac cone model — •Benjamin Obert[1], So Takei[2], and Walter Metzner[1] — [1]Max-Planck-Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany — [2]Department of Physics, The University of Maryland College Park, MD 20742, USA

We analyse a two-dimensional Dirac Cone model which undergoes a quantum phase transition between a semimetal and a superfluid. The model consists of attractively interacting electrons with a linear dispersion around a single Dirac point. We compute the renormalization group flow for the model and study both ground state and finite temperature properties. The electrons and the order parameter fluctuations exhibit power-law scaling with anomalous scaling dimensions. The quasiparticle weight and the Fermi velocity vanish at the quantum critical point. The order parameter correlation length turns out to be infinite everywhere in the semimetallic ground state.

[1] P. Strack, S. Takei, and W. Metzner, Phys. Rev. B **81**, 125103 (2010).
[2] B. Obert, S. Takei, and W. Metzner, Ann. Phys. (Berlin) **523**, No.8-9, 621-628 (2011)

TT 1.12 Mon 12:30 H 0104

Robustness of a Z(3) topological phase — •Marc Daniel Schulz[1,4], Sébastien Dusuel[2], Roman Orùs[3], Julien Vidal[4], and Kai Phillip Schmidt[1] — [1]Lehrstuhl für Theoretische Physik I, Technische Universität Dortmund, Otto-Hahn-Straße 4, 44221 Dortmund, Germany — [2]Lycée Saint-Louis, 44 Boulevard Saint-Michel, 75006 Paris, France — [3]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching, Germany — [4]Laboratoire de Physique Théorique de la Matière Condensée, CNRS UMR 7600, Université Pierre et Marie Curie, 4 Place Jussieu, 75252 Paris Cedex 05, France

Kitaev's toric code model is an exactly solvable lattice model, whose ground state(s) are topologically ordered. We study the robustness of a generalized version of this model with Z(N) degrees of freedom in the presence of local perturbations. For N = 2, this model reduces to the conventional toric code in a uniform magnetic field. A quantitative analysis is performed for the perturbed Z(3) toric code by applying a combination of high-order series expansions and variational techniques. We provide strong evidences for first- and second-order phase transitions between topologically-ordered and polarized phases. Most interestingly, our results also indicate the existence of topological multi-critical points in the phase diagram.

TT 1.13 Mon 12:45 H 0104

Magnetocaloric effect in Suzuki models. — Myroslava Topilko[1], Oleg Derzhko[1], and •Vadim Ohanyan[2] — [1]Institute for Condensed Matter Physics, National Academy of Sciences of Ukraine, 1 Svientsitskii Street, L'viv-11, 79011, Ukraine — [2]Department of Theoretical Physics, Yerevan State University, Al. Manoogian 1, 0025 Yerevan, Armenia

We consider the exactly solvable general spin-1/2 XX chain in an external (transverse) magnetic field with the multiple-spin(long range) interactions of the XZ...ZX+YZ...ZY and XZ...ZY-YZ...ZX types. The model can be mapped on the free spinless fermion system by means of Jordan-Wigner transformation. We focus on the magnetocaloric effect and entropic properties of the system. The simplest case of three-spin interaction which is equivalent to zigzag ladder is investigated in details. The plots of the adiabatic cooling rate are obtained. We examine the effect of coupling constants on the features of magnetocaloric effect. The main result is that tuning the parameters one can shift the position of magnetocaloric anomaly, but the magnitude of effect depends only on the properties of corresponding quantum phase transition. As the system under consideration possessed a quantum triple point, the maximal enhancement of magnetocaloric effect occurs at the quantum triple point.

TT 1.14 Mon 13:00 H 0104

(De)coherence in two-electron quantum dots — •Sebastian Schröter[1], Paul-Antoine Hervieux[2], Giovanni Manfredi[2], Johannes Eiglsperger[3], Moritz Schönwetter[1,4], and Javier Madroñero[1] — [1]TU München — [2]CNRS, IPCMS Strasbourg — [3]Universität Regensburg — [4]MPI PKS, Dresden

The coherence of a system can be evaluated by the quantum fidelity (QF). Investigations of many-body systems, based on a mean-field approach, have shown an unusual behaviour [1] of the QF decay. As an exactly treatable model, which exhibits all relevant features of the investigated many-body systems, we study a planar two-electron quantum dot with an anharmonic confining potential. It becomes apparent, that the behaviour of the QF strongly depends on the level distribution and the degree of mixing of the states, a property, which is closely connected to the chaoticity of the underlying classical analogue. For simple linear combinations of eigenstates the QF decay can be computed from static properties of the system, while for complex wave packets sophisticated numerical algorithms for the propagation of the time-dependent Schrödinger equation [2,3] are needed. We compare analytical and numerical results and address the question if the unusual behaviour gives physical insight into the decoherence of a strongly interacting system or if it is merely an artefact of the mean-field approximation.

[1] G. Manfredi, P.-A. Hervieux, New J. Phys. **11** (2009), 013050. – PRL **100** (2008), 050405. – PRL **97** (2006), 190404.
[2] J. Madroñero, B. Piraux, Phys. Rev. A **80** (2009), 033409.
[3] A. Hamido, *et al.*, Phys. Rev. A **84** (2011), 013422.