# TT 12 Correlated Electrons: Low-dimensional Systems - Models

Time: Tuesday 09:30–12:30 Room: HSZ 304

TT 12.1 Tue 09:30 HSZ 304

**Entropy of fermionic models on highly frustrated lattices** — •Andreas Honecker[1] and Johannes Richter[2] — [1]Technische Universität Braunschweig, Mendelssohnstrasse 3, 38106 Braunschweig, Germany — [2]Institut für Theoretische Physik, Otto-von-Guericke Universität Magdeburg, 39016 Magdeburg, Germany

Fermionic models and quantum antiferromagnets at high magnetic fields on highly frustrated lattices are characterized by a lowest single-particle band which is completely flat. On the one hand, this is known to give rise to *flat-band ferromagnetism* for the repulsive Hubbard model on such lattices. On the other hand, exact ground states consisting of *localized magnons* have recently been constructed and studied for the quantum Heisenberg antiferromagnet on the same lattices. Here we combine both aspects and discuss the entropy and ground state degeneracy on such lattices. Spinless fermions not only provide a simple soluble example, but also give rise to a class of ground states of the repulsive Hubbard model. The sawtooth chain is discussed in particular detail.

TT 12.2 Tue 09:45 HSZ 304

**Magnetic properties of 2D frustrated spin systems at finite temperatures** — •Burkhard Schmidt, Nic Shannon, and Peter Thalmeier — Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden

We present an analysis of the magnetic properties of two-dimensional frustrated spin systems at finite temperatures. Our numerical results are determined using the finite-temperature Lanczos method for small clusters of spins [1].

In particular, the magnetisation of the two-dimensional frustrated $J_1$-$J_2$ Heisenberg model on a square lattice will be discussed as a function of temperature, applied magnetic field, and frustration angle $\phi = \tan^{-1}(J_2/J_1)$. We will cover the full phase diagram of the model with $\phi = -\pi \ldots \pi$, with a focus on the two spin-liquid regions at the edges of the collinear antiferromagnetic phase (ordering vector $(\pi, 0)$ or $(0, \pi)$) for both ferro- and antiferromagnetic nearest-neighbour coupling $J_1$.

Experimental realisations of the model discussed are two-dimensional layered Vanadate compounds. A comparison to the available experimental data will be given.

[1] N. Shannon et al., Eur. Phys. J. B **38** (2004) 599

TT 12.3 Tue 10:00 HSZ 304

**Effective model for the band insulator - Mott insulator transition** — •Leonildo Tincani[1], Reinhard Noack[1], and Dionys Baeriswyl[2] — [1]Fachbereich Physik, Philipps Universität Marburg, D-35032 Marburg, Germany — [2]Département de Physique, Université de Friburg, CH-1700 Fribourg, Switzerland

Starting from the ionic Hubbard model, we derive an effective spin-one model which contains the relevant physics for the band insulator-Mott insulator transition found at half filling and study it numerically using the density-matrix renormalization group. We find that the effective model yields the same sequence of two transitions and critical behavior as the ionic Hubbard model. We then perform scaling studies of the charge, spin and mass gaps in order to clarify the nature of the two quantum phase transitions. We present numerical evidence that there is an Ising-like transition between the band insulator and a spontaneously dimerized insulating phase and a Berezinskii-Kosterlitz-Thouless-like transition between the dimerized and the Mott phase. We then discuss the application of similar methods to more general models such as one with three ions of two types in the unit cell.

TT 12.4 Tue 10:15 HSZ 304

**Charge and Spin Dynamics of Strongly Correlated Quasi One-Dimensional Insulators** — •Holger Benthien[1] and Eric Jeckelmann[2] — [1]Fachbereich Physik, Philipps-Universität Marburg — [2]Institut für Theoretische Physik, Universität Hannover

We calculate the momentum- and frequency-resolved dynamical spin and charge structure factors as well as the the one-particle spectral function of the extended Hubbard model. The method we apply is the dynamical density-matrix renormalisation group algorithm (DDMRG), which allows for an exact calculation of dynamical correlation functions for any range of energies and parameters. We present strong evidence that this simple model with a single set of parameters can qualitatively and quantitatively explain data from recent neutron scattering, photoemission (ARPES) and resonant inelastic X-ray scattering (RIXS) [1] experiments in the prototypical quasi one-dimensional insulator $SrCuO_2$.

[1] Y.-J. Kim, J.P. Hill, H. Benthien, F.H.L. Essler, E. Jeckelmann, H.S. Choi, T.W. Noh, N. Motoyama, K.M. Kojima, S. Uchida, D. Casa, and T. Gog, Phys. Rev. Lett. **92**, 137402 (2004).

TT 12.5 Tue 10:30 HSZ 304

**Finite temperature ac conductivity of disordered Luttinger liquids** — •Bernd Rosenow[1,2], Andreas Glatz[3,2], and Thomas Nattermann[2] — [1]Physics Department, Harvard University, Cambridge, Massachusetts 02138, USA — [2]Institut f"ur Theoretische Physik, Universeit"at zu K"oln, D-50937 K"oln — [3]Materials Science Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

Due to the strong effect of interactions in one spatial dimension, elementary charge excitations of a Luttinger liquid are plasmons. Backscattering of electrons from a random impurity potential creates single particle excitations, which strongly interact with these plasmons. In this way, backscattering from the impurity potential is modified by interactions and acquires a strong energy dependence first described in [1]. Based on a finite temperature renormalization group (RG) calculation [2], we determine the ac conductivity and include both the renormalization of the impurity strength and of the charge dynamics. The latter was neglected in [1], where the conductivity was calculated using the effective impurity strength obtained from the RG. We discuss the full frequency and temperature dependence of the conductivity and compare our results with those of [1].

[1] T. Giamarchi and H.J. Schulz, Phys. Rev. B 37, 325 (1988). [2] A. Glatz and T. Nattermann, Phys. Rev. Lett. 88, 256401 (2002).

TT 12.6 Tue 10:45 HSZ 304

**Quantum Monte Carlo studies of the one-dimensional t-J-model at finite temperature** — •Stefan Harrer, Catia Lavalle, and Alejandro Muramatsu — Institut für Theoretische Physik III, Universität Stuttgart, D-70550 Stuttgart, Germany

We developed a quantum Monte Carlo algorithm to simulate the one dimensional t-J-model at finite temperature. It is an extension of the previously developed zero-temperature hybrid-loop-algorithm [1]. As in the zero temperature case, the algorithm is a combination of the determinantal and the loop algorithm, however, simulations are performed in the grand canonical ensemble. Both equal-time as well as time displaced correlation functions can be obtained.

[1] C. Lavalle, M. Arikawa, S. Capponi, F.F. Assaad, and A. Muramatsu, Phys. Rev. Lett. **90**, 216401 (2003).

**— 15 min. break —**

TT 12.7 Tue 11:15 HSZ 304

**Hybridized mechanism of pairing of fermions in single-walled carbon nanotubes** — •Igor Karnaukhov — Institute of Metal Physics, Vernadsky Street 36, 03142 Kiev, Ukraine

The discovery of high-temperature superconductivity in new exotic and perspective materials such as carbon nanotubes has greatly stimulated the investigation of new mechanisms of the superconductivity, the formulation of adequate low-dimensional models of strongly correlated electron systems. The remarkable electronic properties of single-walled carbon nanotubes (SWNT) are due to the special band structure, the most important peculiarity of the band structure is the crossing of two subbands near the Fermi level. The two-band fermion model with boundary fields describing the band structure of SWNT is proposed and solved exactly by means of the nested Bethe ansatz. The fermions in two subbands shifted one another interact via inner- and inter-band on-site Coulomb interactions, one-particle and correlated on-site hybridizations. It is shown that two component electron liquid state, one of which is defined by an attractive effective electron-electron interaction, is realized in the case of a strong hybridized interaction. The attractive interaction leads to the formation of spinless bound state of Cooper-type pairs and 'superconducting' component of electron liquid. The strong boundary interaction leads to the formation of local spin-singlet boundary states, that induce the Mott-Hubbard metal-insulator phase transition (MIPT)

in the chain. MIPT is realized at increasing of the magnetic field, fixing a gigantic magneto resistivity in the region of fields of the phase transition, and a gapless dielectric state - at critical boundary field.

TT 12.8 Tue 11:30 HSZ 304

**Charge Response in Quasi-1D Wigner Lattice Systems** — •Anup Mishra[1], Matthias Mayr[2], and Peter Horsch[1] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany. — [2]Dept. of Physics, Univ. of Tennesse, Knoxville, USA

Doped edge-sharing Cu-O chain compounds are ideal realizations of 1D Wigner lattices(WL). Such chains are found in the recently synthesized $Na_3Cu_2O_4$ and $Na_8Cu_5O_{10}$ systems [1] and are also structural elements in the composite compound $Sr_{14-x}Ca_xCu_{24}O_{41}$. As a result of the structure the hopping matrix elements $t_l$ and hence the kinetic energy are small compared to the Coulomb energy. At low temperature the charge order resulting from Coulomb interaction $V_l \sim V/l$ generates modulated Heisenberg chains with varying distance between spins. We discuss the charge dynamics of WL starting from a model of spinless fermions. We give a detailed discussion of domain-wall excitation spectra and excitonic states at doping $x = 1/2$. In the model with $t_1$ only the resulting periodicity of WL charge modulation may also be explained by a $4k_F$ charge-density wave(CDW) arising from a Fermi surface instability. However due to the $\approx 90°$ Cu-O-Cu bond angle in edge-sharing chains $|t_2| > |t_1|$. Presence of $t_2$ does not affect the classical WL order, but it changes the Fermi surface topology. This allows to distinguish the WL from the CDW on the basis of the modulation period. We present a detailed phase diagram taking into account $t_1$, $t_2$ and $V_l$. [1] P. Horsch, M. Sofin, M. Mayr, and M. Jansen, Phys. Rev. Lett. **94**, 076403 (2005).

TT 12.9 Tue 11:45 HSZ 304

**Finite quantum wires with long-range interactions** — •Imke Schneider and Sebastian Eggert — FB Physik, Univ. Kaiserslautern, 67663 Kaiserslautern

We consider the local density of states of a finite quantum wire with more realistic long range interactions and a high energy cutoff. In order to use the Luttinger liquid formalism it is necessary to introduce a changing effective interaction parameter as a function of momentum. We show that it is possible to modify the formalism so that the electron distribution in individual states can be analyzed with help of a recursive formula. In limiting cases the well-known powerlaws can be recovered. Our results allow quantitative comparisons with numerical simulations of lattice models.

TT 12.10 Tue 12:00 HSZ 304

**Fermi edge singularities at finite temperature** — •Carsten von Zobeltitz and Holger Frahm — Institut für Theoretische Physik, Universität Hannover, 30167 Hannover

Fermi edge singularities (FES) as observed e.g. in X-ray absorption or tunneling experiments for non-interacting electrons can be described analytically by means of bosonization [1]. Within this approach we compute the thermal broadening of these singularities. This allows to collapse data from different temperatures onto a single curve. The same approach is used to describe edge singularities appearing in 1d correlated systems described by a Luttinger liquid. Applications to tunneling through semiconductor quantum dots are discussed.
[1] K.D. Schotte and U. Schotte, Phys. Rev. **182** (1969) 479

TT 12.11 Tue 12:15 HSZ 304

**Integrable spin-boson models including counter-rotating terms** — •Andreas Osterloh[1], Holger Frahm[1], and Luigi Amico[2] — [1]Institut für theoretische Physik, Universität Hannover, Appelstraße 2, D-30167 Hannover, Germany. — [2]MATIS-INFM & Dipartimento di Metodologie Fisiche e Chimiche (DMFCI), Universita' di Catania, viale A. Doria 6, I-95125 Catania, Italy

We study interacting spin-boson models related to integrable XXX spin-chains with generic open boundary conditions. We particularly focus on spin-boson interactions which contain rotating as well as counter-rotating terms. Models with either rotating or counter-rotating terms are termed (generalized) Jaynes-Cummings and Tavis-Cummings models, respectively, and they are known to be integrable. Those cases where the algebraic Bethe ansatz can be done after a static gauge transformation are demonstrated to have a conserved particle number and hence belong to the former class of models. In order to overcome this restriction, dynamic gauge transformations are taken into account. The resulting Hamiltonian is obtained and diagonalized by means of the algebraic Bethe ansatz. The Bethe equations are presented and discussed.