Second ReisensbuRG Workshop

June 29 – July 1, 2010

FOR 723

Functional Renormalization Group
for Correlated Fermion Systems

TUESDAY, JUNE 29

13:00 **Lunch**

14:00 *Stefan Flörchinger* U HEIDELBERG

Flowing Bosonization and Bound States

It is discussed how bound state properties emerge from functional renormalization group flow equations and how one can use flowing bosonization for a convenient description.

14:45 *Tilman Enss* TU MUNICH

Transport and Scale Invariance in the Unitary Fermi Gas

We compute the shear viscosity of the unitary Fermi gas above the superfluid transition temperature, using a diagrammatic technique that starts from the exact Kubo formula. The formalism obeys a Ward identity associated with scale invariance which guarantees that the bulk viscosity vanishes identically. For the shear viscosity, vertex corrections and the associated Aslamazov-Larkin contributions are shown to be crucial to reproduce the full Boltzmann equation result in the high-temperature, low fugacity limit. The frequency dependent shear viscosity $\eta(\omega)$ exhibits a Drude-like transport peak plus a power-law tail at large frequencies that is proportional to the Tan contact. The weight in the transport peak is given by the equilibrium energy density, consistent with a non-perturbative sum rule that has recently been derived by Taylor and Randeria. Near the superfluid transition, the peak width is of the order $0.5T_F$, thus invalidating a quasiparticle description. The ratio η/s between the static shear viscosity and the entropy density exhibits a minimum near the superfluid transition temperature whose value is larger than the string theory bound $\hbar/(4\pi k_B)$ by a factor of about five. Our results for η/s are in qualitative agreement with experimental data on the shear viscosity obtained from the damping of the radial breathing mode of a trapped unitary gas.

15:30 **Coffee**

16:30 *Christoph Husemann* U HEIDELBERG

Frequency Dependent Vertex Function of the 2D Hubbard Model

One-loop RG studies have calculated the detailed momentum structure of the interaction vertex in the 2D Hubbard model by assuming frequency independent vertex functions. The latter approximation is good for regular and curved Fermi surfaces at weak coupling and low RG scales. We study the validity of this approximation in case of competing instabilities by allowing a partial frequency dependence in a one-loop channel decomposition of the interaction vertex.

17:00 *Kay-Uwe Giering* U HEIDELBERG

Self-Energy Flow in the 2D Hubbard Model

In the framework of the flow equation for the generating functional of 1PI Green functions we investigate the fermionic 2-dimensional repulsive Hubbard model in one-loop order. We parametrise the interaction vertex by introducing exchange bosons in the magnetic, superconducting and scattering channel. Furthermore we write down an ansatz for the self-energy as a sum of corrections to hopping parameters of the free model. We compare different methods of extracting these self-energy coefficients out of the flow equation and examine the self-energy feedback to the flow of the interaction vertex.

17:30 *Andreas Eberlein* MPI FOR SOLID STATE RESEARCH STUTTGART

Parametrization of the Nambu Vertex in a Singlet Superconductor

We analyze general properties of the effective Nambu two-particle vertex and its renormalization group flow in a spin-singlet superconductor. In a fully spin-rotation invariant form the Nambu vertex can be expressed by only three distinct components. Solving exactly the flow of a mean-field model with reduced BCS and forward scattering interactions, we gain insight into the singularities in the momentum and energy dependences of the vertex at and below the critical energy scale for superconductivity. Using a decomposition of the vertex in various interaction channels, we manage to isolate singular momentum and energy dependences in only one momentum and energy variable for each term, such that the singularities can be efficiently parametrized.

18:00 *Lukas Janssen* U JENA

UV Fixed-Point Structure of the Three-Dimensional Thirring Model

We investigate the UV fixed-point structure of the three-dimensional Thirring model, that is, a relativistic field theory with a contact interaction between vector currents. We classify all possible 4-fermi interactions compatible with the present chiral and discrete symmetries and calculate the purely fermionic RG flow using a full basis of fermionic four-point functions in the point-like limit. Our results show that, besides the Thirring coupling, there is in fact another relevant coupling, which, even if not present in the bare action, is being generated by the RG flow. This may shed further light on the long-standing problem of the value of the critical number of fermion flavors, above which chiral symmetry remains unbroken for arbitrary value of the coupling.

19:00 **Dinner**

20:00 **Time for discussions and work**

WEDNESDAY, JUNE 30

10:00 *Johannes Reuther* KARLSRUHE INSTITUTE FOR TECHNOLOGY

An FRG Approach for Frustrated Quantum Heisenberg Antiferromagnets

We apply the Functional Renormalization Group to describe the phase diagrams of spin-1/2 Heisenberg antiferromagnets on two dimensional lattices. In particular we are interested in the melting of magnetic long-range order as an effect of frustration. Thereby we focus on the J_1-J_2-model as well as on geometrically frustrated systems like the Heisenberg model on a triangular or Kagome lattice. We find phase diagrams in good agreement with numerical studies. In order to be able to apply FRG for spin systems we use the auxiliary fermion representation for spin operators. Calculating the magnetic susceptibility and the spin-spin correlations we are able to distinguish between magnetically ordered and paramagnetic phases. It turns out that the inclusion of three-particle correlations in the form proposed by Katanin is essential to describe the phase diagrams correctly.

10:45 *Lorenz Bartosch* U FRANKFURT

Scaling Theory of the Mott Transition and Breakdown of the Grüneisen Scaling Near a Finite-Temperature Critical End Point

We discuss a scaling theory of the lattice response in the vicinity of a finite-temperature critical end point. The thermal expansivity is shown to be more singular than the specific heat such that the Grüneisen ratio diverges as the critical point is approached, except for its immediate vicinity. More generally, we express the thermal expansivity in terms of a scaling function which we explicitly evaluate for the two-dimensional Ising universality class. Recent thermal expansivity measurements on the layered organic conductor $\kappa-(BEDT-TTF)_2X$ close to the Mott transition are well described by our theory.

11:15 *Ronny Thomale* U PRINCETON

Theory of Nodal and Nodeless Superconductivity in Iron-Based Superconductors

The symmetry of the order parameter in iron-based superconductors, especially the presence or absence of nodes, is still unknown. Contradictory experiments can be explained by highly fine-tuned theories of nodeless superconductivity in the Iron-Arsenide compounds. However, for LaOFeP, all experiments clearly point to a nodal order parameter. We put forward a scenario that naturally explains the difference between the order-parameter character in these compounds, and use functional renormalization group techniques to analyze it in detail. Our results show that, due to the orbital content of the electron and hole bands, nodal superconductivity can naturally appear when the third hole pocket which lies at wavevector (π, π) in the unfolded Brilouin zone is absent, as is the case in LaOFeP. The third hole pocket has overwhelming d_{xy} orbital character, and the intra-orbital interaction with the d_{xy} dominated part of the electron Fermi surface is enough to drive the superconductivity nodeless and of $s_{\pm}$ form. However, in its absence, electron-electron interaction between the electron pockets render the gap on the electron pockets softly nodal. The gaps on the hole pockets are always nodeless.

11:45 *Stephan Grap* RWTH AACHEN

FRG and Real Systems: Multi-Level Quantum-Dots in Carbon Nanotubes

In the absence of any additional couplings and a magnetic field dot levels in carbon nanotubes are fourfold-degenerate (with respect to the spin and valley index K, K'). The degeneracy is lifted by intervalley coupling resulting from disorder and/or the confining potential, by spin-orbit interaction, and by the magnetic field along the tube axis. Increasing B leads to an interesting level-crossing/level repulsion scenario of levels resulting from different shells. Recent transport measurements on such systems show indications of this single-particle behavior. In addition the level crossings lead to surprising Kondo effects when the linear conductance as a function of a gate voltage shifting the level positions and the magnetic field is measured. Using estimates for model parameters extracted from the experiments the (static) FRG allows to reproduce these features and provides a deeper understanding of the relevant physics.

12:30 **Lunch**

Time for discussions and Work

17:00 *Aldo Isidori* U FRANKFURT

Spectral Function of the Anderson Impurity Model at Finite Temperatures

Using the functional renormalization group (FRG) and the numerical renormalization group (NRG), we calculate the spectral function of the Anderson impurity model at zero and finite temperatures. In our FRG scheme spin fluctuations are treated non-perturbatively via a suitable Hubbard-Stratonovich field, but vertex corrections are neglected. A comparison with our highly accurate NRG results shows that this FRG scheme provides a good description of the spectral line-shape at zero and finite temperatures both in the weak and strong coupling regimes, although at zero temperature the FRG is not able to reproduce the known exponential narrowing of the Kondo resonance at strong coupling.

17:30 *Oleksiy Kashuba* RWTH AACHEN

Pumping in Interacting Resonant Level Model

We examined the behaviour of the interacting resonant level model using the RTRG-FS approach in the case of adiabatic changing of the model parameters. We proposed a simple way for the calculation of the corrections to the instantaneous quantities, proportional to the initial values time derivatives. Two sorts of contributions to the adiabatic correction of the self-energy were found. Most of them can be calculated in the low-energy limit using perturbation theory with renormalized vertices, though there is a contribution requiring an RG calculation. The influence of the strong renormalisation on the pumping through the system was investigated and the charge transferred per cycle was calculated.

18:00 *Sarah Müller* RWTH AACHEN

Non-Equilibrium Transport Through a Two-Orbital Quantum Dot: A Renormalization-Group Analysis

Transport through quantum dots is in general characterized by asymmetric couplings to the leads. In particular, in molecules and nanowires the coupling of each individual orbital level can be different. Motivated by recent experiments, we therefore study the effects of asymmetric hopping parameters on the non-equilibrium current and occupation probabilities of a two-level quantum dot. Starting from a two-level Anderson model, we perform a generalized Schrieffer-Wolff transformation to derive an effective Kondo model. A first perturbative analysis of the cotunneling current allows to determine a regime of negative differential conductance arising for couplings being both asymmetric with respect to the leads as well as to the quantum dot levels. Due to the non-equilibrium occupation of the quantum dot levels inelastic cotunneling transitions are allowed not only from the ground state but from the excited state. The dependence of this so-called cascade resonance on the magnetic field is discussed in detail. Since we expect the cotunneling lines to be measured experimentally for strong values of the couplings to the leads, we study the logarithmic enhancement of the ascribed signatures by means of a poor-man's renormalization-group treatment out of equilibrium.

18:30 *Denes Sexty* U HEIDELBERG

Nonequilibrium Transport of Fermions Through a Quantum Dot

19:00 **Dinner**

THURSDAY, JULY 1

09:00 *Boris Nowak* U HEIDELBERG

Matter Wave Turbulence: Beyond Kinetic Scaling

Turbulent scaling phenomena in an ultracold Bose gas far away from thermal equilibrium are studied theoretically. These phenomena are characterized in terms of universal scaling of correlation functions like the momentum distribution of particles. Our results indicate that the Kolmogorov picture remains useful even in the strong turbulence regime at long wavelengths. It is shown, that new power-laws with anomalously large scaling exponents could be experimentally accessible in ultracold atomic gases.

09:30 *Matthias Kronenwett* U HEIDELBERG

Non-Thermal Equilibration of a One-Dimensional Fermi Gas

Equilibration of an isolated Fermi gas in one spatial dimension after an interaction quench is studied. Evaluating Kadanoff-Beym dynamic equations for correlation functions obtained from the two-particle- irreducible effective action in nonperturbative approximation, the gas is seen to evolve to states characterized by thermal as well as nonthermal momentum distributions, depending on the assumed initial conditions. For total energies near the Fermi temperature, stationary power laws emerge for the high-momentum tails while at lower momenta the distributions are of Fermi-Dirac type. The relation found between fluctuations and dissipation exhibits nonthermal final states.

10:00 **Time for discussions and work**

12:00 **Lunch**