TT 4 Correlated Electrons: Quantum Impurities, Kondo Physics

Time: Monday 11:00–13:00 Room: HSZ 301

Invited Talk

TT 4.1 Mon 11:00 HSZ 301

Current vs. Correlations: The Nonequilibrium Kondo Model — •Stefan Kehrein — LMU München, Department für Physik

Quantum dot experiments show new aspects of electron correlation physics that are inaccessible in bulk materials. One example is the realization of out-of-equilibrium situations far beyond the linear response regime. Such quantum many-body systems far away from equilibrium are theoretically not well-understood and are beginning to emerge as an exciting new frontier in quantum many-body physics. In this talk we examine the Kondo model as a paradigm for correlated impurity physics. While its equilibrium ground state with Kondo screening due to the formation of a many-body bound state is well-understood, much less is known about the steady state that develops when a constant voltage bias is applied across the impurity. In particular, the coherent Kondo screening processes turn out to be in competition with current-induced decoherence, and this competition determines the phase diagram of the nonequilibrium Kondo model. We will discuss various physical observables like the dynamic and static spin susceptibility and the T-matrix to get insights into this nonequilibrium steady state and to compare it with finite temperature equilibrium states. We will also see how the method of infinitesimal unitary transformations (flow equation method) serves as a suitable generalization of scaling concepts to such nonequilibrium situations [1].

[1] S. Kehrein, Phys. Rev. Lett. **95**, 056602 (2005)

TT 4.2 Mon 11:30 HSZ 301

Real Time RG for the non-equilibrium Kondo model: Cutoffs set by voltage and decoherence. — •Thomas Korb[1], Herbert Schoeller[1], and Jürgen König[2] — [1]Theoretische Physik A, RWTH Aachen, Germany — [2]Theoretische Physik III, Ruhr-Universität Bochum

While the equilibrium Kondo effect is well understood there is known less for the Kondo effect in non-equilibrium. The question was raised, if a finite voltage and current induced decoherence prevents the system from going into the strong coupling limit for $V > T_K$ and how to calculate the I-V [1,2]. In [2] a perturbative RG for the scaling of the verticies in non-equilibrium was developed, but the decoherence was included only on the basis of a perturbation calculation. A different approach was used in [3], where a flow equation analysis was performed on the expense to reside on a Hamiltonian description for the non-equilibrium. There it was found, that the scaling is cutted by balancing of second and third order contributions in the flow equations. We use the real time RG formalism developed in [4] to analyze the non-equilibrium Kondo effect. It is demonstrated how the cutoffs set by voltage and decoherence rate emerge naturally from a closed set of RG equations on the Keldysh contour (including dephasing of nondiagonal elements of the density matrix). Therefore we are able to calculate the I-V characteristic for $V > T_K$ within one scheme and within a full nonequilibrium formalism.

[1] P. Coleman *et al.*, Phys. Rev. Lett. 86, 4088 (2001).
[2] A. Rosch *et al.*, Phys. Rev. Lett. 90, 076804 (2003).
[3] S. Kehrein, Phys. Rev. Lett. 95, 056602 (2005).
[4] H. Schoeller and J. König, Phys. Rev. Lett. 84, 3686 (2000).

TT 4.3 Mon 11:45 HSZ 301

Transmission phase through a two-level quantum dot — •Theresa Hecht[1], Yuval Oreg[2], and Jan von Delft[1] — [1]Department für Physik, CeNS and Arnold Sommerfeld Center, Ludwig-Maximilians Universität München, Germany — [2]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel

The recent measurements of Schuster *et al.* [1] of the transmission phase through a quantum dot embedded in one arm of an Aharonov Bohm interferometer contradict the simple models that were used to describe the phase evolution so far, see e.g. [2]. Inspired by this experiment, we study the transmission phase of a quantum dot embedded in one arm of a two path electron interferometer. Following [3], where it was shown that in a two-level quantum dot the generic and experimentally realistic condition $\Gamma_{upper} \neq \Gamma_{lower}$ always leads to an occupation inversion, $n_{upper} > n_{lower}$, we study a two-level Anderson model by means of Wilson's numerical renormalization group method. Relating the scattering phase and the occupation of the levels at $T = 0$ using the Friedel sum rule, we can explain that for $\Gamma_{upper} \neq \Gamma_{lower}$, the transmission always experiences a phase lapse of π as a function of gate voltage, independent of the parameters of the quantum dot or the parity of the levels. We investigate both the temperature and magnetic field dependence of the transmission amplitude through the dot.

[1] R. Schuster, E. Buks, M. Heiblum, D. Mahalu, V. Umansky, H. Shtrikman, Nature **385**, 417 (1997).
[2] U. Gerland *et al.*, Phys.Rev.Lett. **84**, 3710 (2000).
[3] M. Sindel, A. Silva, Y. Oreg, J.von Delft, PRB **72**, 125316 (2005).

TT 4.4 Mon 12:00 HSZ 301

Signatures of orbital two channel Kondo in the conductance of metallic nanowires? — •Procolo Lucignano[1], Giuseppe E. Santoro[1,2], Michele Fabrizio[1,2], and Erio Tosatti[1,2] — [1]SISSA and INFM Democritos National Simulation Center, Via Beirut 2-4, 34014 Trieste, Italy — [2]International Centre for Theoretical Physics (ICTP), P.O. Box 586, I-34014 Trieste, Italy

We describe the transport properties of metallic nanowires by using a realistic generalization of the two level system kondo model[1]. The problem is attached by using numerical renormalization group method[2] and its results analyzed in the framework of conformal field theory[3]. Fractional values of the conductance have been observed in recent experiments. We show that for particular choices of the parameters, such fractional conductances can appear as a signature of a two channel kondo phase, for a reasonable window of temperatures[4].

[1] K. Vladar, A. Zawadowski, Phys. Rev. B **28** 1564 (1983).
[2] K. Wilson Rev. Mod. Phys. **47**, 773 (1975).
[3] I. Affleck, A. W. W. Ludwig, Nucl. Phys. B **352**, 849 (1991).
[4] P. Lucignano, G.E. Santoro, M. Fabrizio, E. Tosatti in preparation.

TT 4.5 Mon 12:15 HSZ 301

DMRG meets NRG — •Andreas Weichselbaum[1], Frank Verstraete[2], Ulrich Schollwöck[3], J. I. Cirac[4], and Jan von Delft[1] — [1]Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, Ludwig-Maximilians-Universität München, 80333 München, Germany — [2]Institute for Quantum Information, Caltech, Pasadena, US. — [3]Institut für Theoretische Physik C, RWTH-Aachen, D-52056 Aachen, Germany — [4]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, Garching, D-85748, Germany

We present a unified framework of renormalization group methods, including Wilson's numerical renormalization group (NRG) and White's density-matrix renormalization group (DMRG), within the language of matrix product states. This allows to improve over Wilson's NRG for quantum impurity models by a variational method optimal in this framework. We illustrate it for the single-impurity Anderson model; moreover we use a variational method for evaluating Green's functions. The proposed method is more flexible in its description of off-resonance spectral properties, opening the way to time-dependent, out-of-equilibrium impurity problems. It also substantially improves computational efficiency for one-channel impurity problems, suggesting *linear* scaling of complexity for n-channel problems.

TT 4.6 Mon 12:30 HSZ 301

Local moments formation in a t–J chain with an integrable impurity — •Guillaume Palacios and Holger Frahm — Institut für Theoretische Physik, Universität Hannover, D-30167 Hannover, Germany

We consider an integrable model describing an Anderson-like impurity coupled to an open t–J chain. Both the hybridization (coupling between the bulk chain and the impurity) and the local spectrum can be controlled without breaking the integrability of the model.

In the strong hybridization limit, we show the appearance of boundary bound states in the energy spectrum which, as a function of the parameters, permits us to distinguish four phases, from zero to three bound states. We then compute the contribution of these bound states to the response of the system to a) a uniform magnetic field and b) a local field at the impurity site. The results obtained by means of Bethe Ansatz techniques and finite size analysis allow to make contact with the physics of local moments and the Kondo effect. Results for the impurity compressibility are also presented.

TT 4.7 Mon 12:45 HSZ 301

Two-stage Kondo effect in a spin-1 quantum dot. — •Babak Bayani[1], Piers Coleman[2], and Anna Posazhennikova[1] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe, Wolfgang-Gaede-Str.1, D-76128 Karlsruhe — [2]Center for Materials Theory, Rutgers University, Piscataway, NJ 08855, USA

We study the transport through a quntum dot (QD) with spin-1, connected to metallic leads. In practice a spin-1 QD is expected to undergo a two-stage Kondo effect, with a large temperature region, dominated by the underscreened Kondo physics. At zero temperature conductance of such a dot vanish due to interference effects of two channels. We show how this behaviour arises in the detalied many-body calculation, based on the Schwinger boson description of the spin on the dot.