TT 38: CE: Quantum-Critical Phenomena 2

Time: Friday 10:15–12:45 Location: H18

TT 38.1 Fri 10:15 H18

Low field spin dynamics of a Cu(II) S=1/2 antiferromagnetic Heisenberg chain studied by ^{14}N-NMR spectroscopy — •Marco Günther[1], Hannes Kühne[1], Matthias Falkner[2], Hans-Henning Klauss[1], K. Doll[3], C.P. Landee[4], and M.M. Turnbull[4] — [1]Institut für Festkörperphysik, TU Dresden — [2]Institut für Physik der Kondensierten Materie, TU Braunschweig — [3]Institut für Mathematische Physik, TU Braunschweig — [4]DPC, Clark University, Worcester, USA

By means of ^{14}N-NMR spectroscopy we study the low field NMR frequency shift and electronic spin dynamics in $Cu(C_4H_4N_2)(NO_3)_2$ (CuPzN), which is one of the best experimental realizations of the antiferromagnetic S=1/2 Heisenberg chain model.

The observed pattern of angular dependent NMR frequencies is disentangled into magnetic and quadrupolar contributions. The electric field gradient tensor is determined and compared to density functional calculations at the nitrogen site. A comparison of the magnetic part of the NMR shift to a local dipole model of the electronic moments allows to construct the full hyperfine coupling tensor.

The experimentally observed anisotropy of the nuclear spin-lattice relaxation rate T_1^{-1} can be modulated with purely magnetic fluctuations, i.e. an isotropic dynamic structure factor and the magnetic coupling tensor derived from the static properties. Our results are compared with previous ^{13}C-NMR data in the low field regime of CuPzN [1].

[1] Kühne et al., Phys. Rev. B 80, 045110 (2009)

TT 38.2 Fri 10:30 H18

The concept of effective temperature in current carrying quantum critical states — •Stefan Kirchner[1] and Qimiao Si[2] — [1]Max Planck Institut fuer Physik komplexer Systeme — [2]Physics & Astronomy, Rice University, Houston, Texas

At a quantum critical point, a scale-invariant fluctuation spectrum implies the absence of intrinsic energy scales. The system is therefore readily driven out of equilibrium. The resulting non-linear response regime violates the fluctuation-dissipation theorem. We study the out-of equilibrium phenomena in a single electron transistor with ferromagnetic leads, which can be tuned through a quantum phase transition[1]. We consider the breakdown of the fluctuation-dissipation theorem and study the universal behavior of the fluctuation dissipation relation of various correlators in the quantum critical regime[2]. In particular, we explore the concept of effective temperature as a means to extend the fluctuation-dissipation theorem into the non-linear regime[3]. Such effective temperatures were introduced in the context of steady states in chaotic systems, and successfully used for non-stationary states in glassy systems.

[1] S. Kirchner et al.,PNAS 102, 18824 (2005).
[2] S. Kirchner and Q. Si, PRL 103, 206401 (2009).
[3] S. Kirchner and Q. Si, arXiv:0909.3925 (2009).

TT 38.3 Fri 10:45 H18

Quantum aging in a sub-Ohmic heat bath — •Peter Nalbach and Michael Thorwart — FRIAS, Albert-Ludwigs-Universität Freiburg, 79104 Freiburg i.Br.

We show that the low-frequency modes of a sub-Ohmic bosonic heat bath generate a dynamical asymmetry for an intrinsically symmetric quantum spin−1/2, which induces a slowly-decaying quasiequilibrium for the spin resembling a generic "aging" dynamics. The symmetry breaking is related to the dynamic crossover between coherent and overdamped relaxation of the spin polarization. For nonequilibrium initial conditions, we identify a so far unknown phase, characterized by damped coherent oscillations in the localized phase. A zero-temperature phase diagram is sketched.

Invited Talk TT 38.4 Fri 11:00 H18

Neutron Scattering Studies of Spin-Ladders — •Bella Lake[1,2], Alexei M. Tsvelik[3], Susanne Notbohm[1,4], D. Alan Tennant[1,2], Toby G. Perring[5,6], Manfred Reehuis[1], Chinnathambi Sekar[7,8], Gernot Krabbes[7], and Bernd Büchner[7] — [1]Helmholtz-Zentrum Berlin, Germany. — [2]Technische Universität Berlin, Germany. — [3]Brookhaven National Laboratory, U.S.A. — [4]University of St. Andrews, U.K. — [5]Rutherford Appleton Laboratory, U.K. — [6]University College London, U.K. — [7]IFW-Dresden, Germany. — [8]Periyar University, Salem, India.

This presentation will discuss magnetic excitations of two-leg spin-ladders with spin-1/2 moments and antiferromagnetic exchange interactions. Inelastic neutron scattering measurements will be presented for two ladders systems. $La_4Sr_{10}Cu_{24}O_{41}$ has a strong rung coupling and the excitations are found to consist of a gapped one-magnon mode and a two-magnon continuum. A large cyclic exchange is found which reduces the gap. In contrast $CaCu_2O_3$ has a weak rung interaction and a substantial cyclic exchange which drives the system gapless and quantum critical. At high energies the excitations are described well by the Bethe Ansatz and the field theory solution for a Luttinger liquid quantum critical point. At low energies a gap appears in the bonding susceptibility while the antibonding susceptibility remains gapless. The data is well described by a model where a gapped singlet bound-spinon mode is located at the bonding wavevector while a gapless triplet lies at the antibonding wavevctor. The antibonding susceptibility is critical and is at the Wess-Zumino-Novikov-Witten quantum critical point.

15 min. break

TT 38.5 Fri 11:45 H18

High-temperature signatures of quantum criticality in heavy-fermion compounds and the relation to two-impurity Kondo systems — •Johann Kroha[1], Laszlo Borda[1], Markus Klein[2], Friedrich Reinert[2], Pascal Simon[3], Oliver Stockert[4], and Hilbert von Löhneysen[5] — [1]Universität Bonn — [2]Universität Würzburg — [3]Université Joseph Fourier, Grenoble — [4]Max-Planck-Institut CPfS — [5]Karlsruhe Institute of Technology

We propose a new criterion for distinguishing the Hertz-Millis (HM) and local quantum critical (LQC) scenarios of magnetic quantum phase transitions (QPT) in heavy-fermion systems from their high-temperature behavior [1]. The criterion is based on our finding that the complete screening of a single Kondo spin can be suppressed by the RKKY coupling to the surrounding magnetic ions even without magnetic ordering. As a consequence, the signature of Kondo breakdown can be observed in spectroscopic measurements above the lattice coherence and magnetic ordering temperatures, where fluctuations of the Fermi surface and quantum critical fluctuations do not play a role. We show that the predicted dependence of the screening scale T_K on the RKKY coupling agrees in detail with recent scanning tunneling microscopy (STM) results on two-impurity Kondo systems. Applying the resulting high-temperature criterion to high-resolution photoemission measurements on $CeCu_{6-x}Au_x$ suggests that the QPT in this system is dominated by the LQC scenario.

[1] M. Klein *et al.*, Phys. Rev. Lett. **101**, 266404 (2008); Phys Rev. B **79**, 075111 (2009).

TT 38.6 Fri 12:00 H18

Multiscale Quantum Criticality: The Pomeranchuk Instability in Isotropic Metals — •Mario Zacharias[1], Peter Wölfle[2], and Markus Garst[1] — [1]Institut für Theoretische Physik, Universität zu Köln — [2]Institut für Theorie der kondensierten Materie, Universität Karlsruhe

As a paradigmatic example of quantum criticality with multiple scales, we study the Pomeranchuk instability of an isotropic metal in $d=2$ dimensions. The effective Ginzburg-Landau theory has two modes with different dynamics. There is a Landau-damped mode with a dynamical exponent $z_> = 3$ and a ballistic mode with $z_< = 2$. The two modes are coupled to each other and become critical at the very same point.

Since the effective dimension, $d+z_<$, of the ballistic mode equals the upper critical dimension, $d_+ = 4$, self-interactions lead to logarithmic singularities which we sum up by the renormalization group technique. We find that the ballistic mode governs the system at zero temperature, $T = 0$, although the $z_> = 3$ mode has the lower characteristic energy.

At finite T, the existence of two time scales results in a modified quantum-to-classical crossover, which extends over a parametrically large regime and leads to an intricate interplay of classical and quantum fluctuations. As a result, we find a universal T-dependence of the correlation length independent of the interaction amplitude.

The phase diagram and the critical thermodynamics also reflect the existence of multiple scales. In particular, there are two crossover lines between the low temperature and the quantum critical regime and the thermodynamic quantities differ in their sensitivity to them.

TT 38.7 Fri 12:15 H18

De-Haas van-Alphen oscillations in nonrelativistic U(1) gauge theories — •Lars Fritz[1] and Subir Sachdev[2] — [1]Universitaet zu Koeln, Institut fuer theoretische Physik, Zuelpicher Strasse 77, 50937 Koeln — [2]Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA

We investigate magento-oscillations in the specific heat of nonrelativistic fermions with a Fermi surface minimally coupled to a fluctuating U(1) gauge field. Our study is motivated by the recent observation of quantum oscillations in the underdoped cuprates, and by theoretical models of pocket Fermi surfaces realizing a non-Fermi liquid *algebraic charge liquid*. Our main result is the computation of the order 1/N correction to the Lifshitz-Kosevich expression for the oscillation amplitude in the dirty limit in a model with N species of fermions.

TT 38.8 Fri 12:30 H18

Real space renormalization group approach to the two-dimensional antiferromagnetic Heisenberg model with plaquette deformations — Andreas Fledderjohann, K.-H. Mütter, and •Andreas Klümper — Universität Wuppertal

The low energy behaviour of the $2d$ antiferromagnetic Heisenberg model is studied in the sector with total spins $S = 0, 1, 2$ by means of a renormalization group procedure, which generates a recursion formula for the interaction matrix of 4 neighbouring 'n clusters' of size $2^n \times 2^n$ from the corresponding quantities of the 'n clusters'. Conservation of total spin S is implemented. An inhomogeneous Heisenberg model with plaquette distortion is investigated. Depending on the plaquette-plaquette coupling J, we find two regimes: 'confinement' $J_c < J \leq 1$, where the singlet ground state forms an infinite ('confined') cluster in the thermodynamical limit. Here the singlet-triplet gap vanishes, which is the signature for long range spin-spin correlators. We find 'deconfinement' $0 \leq J < J_c$, where the singlet ground state 'deconfines' – i.e. factorizes – into finite n-clusters of size $2^n \times 2^n$, with $n \leq n_c(J)$. Here the singlet-triplet gap is finite and the gap exponent is determined. The critical value turns out to be $J_c = 0.4822...$ in the chosen truncation scheme.