TT 56: CE: Heavy Fermions

Time: Thursday 16:30–19:00 Location: HSZ 105

TT 56.1 Thu 16:30 HSZ 105

Symmetry enhancement at Kondo destroyed quantum critical points — •S. Kirchner[1,2], J.H. Pixeley[3], and Q. Si[3] — [1]Max-Planck-Institut PKS, Dresden, Germany — [2]Max-Planck-Institut CPfS, Dresden, Germany — [3]Physics & Astronomy, Rice University, Houston, USA

Recent studies in quantum critical heavy fermion metals have pointed towards a global phase diagram [1]. There is growing experimental evidence, that rare earth intermetallic systems in the vicinity of a quantum critical point show a linear in temperature magnetic and single-particle relaxation rate[2]. Among the proposed mechanisms is the critical destruction of the Kondo effect. We address this issue in several quantum impurity systems by a combination of techniques and determine the full scaling functions. In each case, the quantum relaxational regime is characterized by linear-in-temperature relaxation rates. This is naturally explained in terms of an emerging conformal symmetry at the quantum critical point that is absent in the bare models[3,4,5].

[1] Q. Si & F. Steglich, Science **329**, 1161 (2010).
[2] A. Schröder et al., Nature (London) **407**, 351 (2000); S. Friedemann et al. Proc. Natl. Acad. Sci. USA **107**, 14547 (2010).
[3] S. Kirchner & Q. Si, Phys. Rev. Lett. **100**, 026403 (2008).
[4] M. T. Glossop, S. Kirchner, J. H. Pixley and Q.Si, arXiv:0912.4521, to be published (2010).
[5] J. H. Pixley, S. Kirchner and Q.Si, arXiv:1010.3024, to be published (2010).

TT 56.2 Thu 16:45 HSZ 105

Hot lines on quantum critical Fermi surfaces from magneto oscillation measurements — •Lars Fritz and Achim Rosch — Universität zu Köln, Institut für theoretische Physik

Quantum criticality in electronic systems figures prominently in so-called heavy fermion systems. Many of these systems can be driven by either pressure, magnetic field, or chemical doping towards a point, where the anitferromagnetic Néel temperature is suppressed to zero resulting in a quantum critical point. One of the major questions which occur in the context of this quantum critical point is by which mechanism the antiferromagnetic state is converted into the heavy Fermi liquid. There exist two extreme cases: one in which the heavy Fermi liquid state is obtained in the framework of a spin density wave (SDW) scenario in the spirit of the Hertz-Millis-Moriya theory as opposed to a scenario of breakdown of the Kondo effect. On an elementary level, the scenarios also differ in the way the Fermi surface becomes critical. Whereas in a SDW scenario hot lines due to overdamping by spin density wave at certain points of the Fermi surface have to be expected, in more exotic scenarios the whole Fermi surface becomes critical ("hot"). It is thus desirable to have a probe which is sensitive to the existence or nonexistence of hot lines on the Fermi surface. We discuss the possibility to locate hot regions and extract the ordering wave vector in strongly correlated fermionic systems close to a collective instability by means of angle dependent magneto-oscillations measurements of the de-Haas-van-Alphen or Shubnikov-de-Haas type.

TT 56.3 Thu 17:00 HSZ 105

Interplay between Kondo effects in a Kondo lattice with two in-equivalent local moments — •Adel Benlagra[1], Lars Fritz[2], and Matthias Vojta[1] — [1]Institut für Theoretische Physik, TU Dresden, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, Germany

Usual theoretical studies of Kondo systems often assume the presence of a single spin$-1/2$ local moment per unit cell and little is known about the behavior of a Kondo lattice with multiple distinct local moments. Motivated by the recently studied family of ternary compounds $(RE)_3Pd_{20}X_6$ (Re=rare-earth, X=Ge, Si), which have two in-equivalent Kondo sites per unit cell, we study a Kondo lattice Hamiltonian with two local moments coupled to the sea of conduction electrons with different Kondo couplings ($J_2 < J_1$). In particular, we investigate the interplay between the resulting Kondo screenings and explore the thermodynamic properties of the heavy Fermi liquid regime using slave bosons in the mean-field approximation. It is found that the two effects compete or cooperate depending on the electronic filling number. The coherence scale governing the low temperature behavior of the heavy Fermi liquid is affected and, in particular, its ratio to the Kondo scales is not generically independent of the Kondo couplings as is the case for the standard Kondo lattice problem.

TT 56.4 Thu 17:15 HSZ 105

Tracing the Kondo Lattice in $YbRh_2Si_2$ — •Stefan Ernst[1], Stefan Kirchner[2,1], Steffen Wirth[1], Cornelius Krellner[1], Christoph Geibel[1], Frank Steglich[1], and Gertrud Zwicknagl[3] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden — [2]Max-Planck-institut für Physik Komplexer Systeme, Dresden — [3]Institut für Mathematische Physik, TU Braunschweig

Heavy fermion (HF) metals are often characterized by a variety of relevant energy scales and competing interactions which may result in the emergence of novel states of condensed matter. Therefore, these materials have advanced to suitable model systems by means of which electronic correlations can be studied in detail. For a further in-depth understanding of the underlying physics, the application of local electronic probes is of major importance.

We present recent results of Scanning Tunneling Microscopy and Spectroscopy (STM/S) at low temperature conducted on the prototypical HF compound $YbRh_2Si_2$. The topography confirms an excellent low temperature *in situ* cleave of the single crystals. The hybridization of conduction and $4f$ electrons results in a gap-like feature in the tunneling conductance. In addition, the crystal field excitations are unambiguously reflected in our STS data and hence, bulk properties are predominatly probed. A strongly temperature-dependent peak in the tunneling conductance is attributed to a Kondo–lattice resonance.

TT 56.5 Thu 17:30 HSZ 105

Magnetic ac susceptibility of $YbRh_2Si_2$ at ultra-low temperatures — •Lucia Steinke[1,2], Erwin Schuberth[2], Stefan Lausberg[1], Christoph Klingner[1], Cornelius Krellner[1], Manuel Brando[1], Christoph Geibel[1], and Frank Steglich[1] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden, Germany — [2]Walther Meissner Institut, 85748 Garching, Germany

Recent magnetization measurements on the heavy fermion compound $YbRh_2Si_2$ at ultra-low temperatures (ULT) below 1 mK show that the weak antiferromagnetic phase, which forms at $B = 0$ below $T_N = 70$ mK, is not the $T = 0$ ground state of the system. Instead, two additional ULT regimes were discovered [1]: a new phase below $T_A = 2.2$ mK, where the phase transition is observed as a pronounced magnetization peak, and a second regime below $T_B = 15$ mK, where zero-field-cooled / field-cooled measurements begin to show a hysteresis. To clarify the origin of these two new ULT regimes, particularly to seek evidence for possible superconducting states in $YbRh_2Si_2$, we measured the magnetic ac susceptibility at $B = 0$. Initial results indicate a decrease in the real part χ' of the ac susceptibility as the sample temperature is lowered beyond $T_B = 15$ mK and a pronounced drop in χ' as T drops below the transition temperature $T_A = 2.2$ mK. Whether the response is indeed diamagnetic depends on the yet unknown background signal.

[1] E. Schuberth *et al.*, J. Phys. C **150**, 042178 (2009)

15 min. break

TT 56.6 Thu 18:00 HSZ 105

Magnetic field dependence of the antiferromagnetic order in $YbCo_2Si_2$ — •A. Haase[1], O. Stockert[1], N. Mufti[1], C. Krellner[1], J.-U. Hoffmann[2], A. Hoser[2], S. Capelli[3], and C. Geibel[1] — [1]Max-Planck-Institut CPfS, Dresden, Germany — [2]Helmholtzzentrum Berlin, Berlin, Germany — [3]Institut Laue-Langevin, Grenoble, France

One of the model compounds to study quantum critical behaviour is $YbRh_2Si_2$, which orders antiferromagnetically at a very low $T_N \approx 0.07$ K. Due to the small ordered moment and the high neutron absorption of Rh the magnetic structure of $YbRh_2Si_2$ is still unknown. $YbCo_2Si_2$ with its body-centered tetragonal crystal structure is isoelectronic to $YbRh_2Si_2$ and serves as a reference system. $YbCo_2Si_2$ orders antiferromagnetically below $T_N = 1.7$ K with an additional first order transition at $T_L = 0.9$ K. This compound exhibits a complex magnetic (B, T) phase diagram for applied magnetic field and shows a pronounced basal plane anisotropy observed in magnetisation and magnetoresistance measurements. While at lowest temperature the magnetic order is commensurate with $\tau_1 = (0.25\ 0.25\ 1)$, the magnetic structure becomes incommensurate above T_L with $\tau_2 = (0.08\ 0.25\ 1)$. Using neutron diffraction we studied the magnetic structure in magnetic fields applied along [100], [110] and [001]. While in the commensurate phase no hysteresis was observed for all three directions of applied magnetic fields, a pronounced hysteresis of the intensity was detected in the incommensurate phase for fields along [100], which most likely can be attributed to different domain population.

TT 56.7 Thu 18:15 HSZ 105

Magnetically driven superconductivity in $CeCu_2Si_2$ — •S. Kirchner[1,2], O. Stockert[2], J. Arndt[2], E. Faulhaber[3,4], C. Geibel[2], H.S. Jeevan[2], M. Loewenhaupt[4], K. Schmalzl[5], W. Schmidt[5], Q. Si[6], and F. Steglich[2] — [1]Max-Planck-Institut PKS, Dresden, Germany — [2]Max-Planck-Institut CPfS, Dresden, Germany — [3]Institut für Festkörperphysik, TU Dresden, Dresden, Germany — [4]Gemeinsame Forschergruppe Helmholtz-Zentrum Berlin – TU Dresden, Garching, Germany — [5]Forschungszentrum Jülich, Jülich Centre for Neutron Science at Institut Laue-Langevin, Grenoble, France — [6]Dept. of Physics and Astronomy, Rice Univ., Houston, USA

The origin of unconventional superconductivity, including high-temperature and heavy-fermion superconductivity, is still a matter of controversy. Spin excitations instead of phonons are thought to be responsible for the formation of Cooper pairs. Based on inelastic neutron scattering data, we present the first in-depth study of the magnetic excitation spectrum in momentum and energy space in the superconducting and the normal state of $CeCu_2Si_2$ [1]. A clear spin excitation gap is observed in the superconducting state. Our findings identify the antiferromagnetic excitations as the major driving force for superconducting pairing in this prototypical heavy-fermion compound located near an antiferromagnetic quantum critical point. This study represents the first thorough comparison of the competing energetics for a superconductor near an antiferromagnetic quantum critical point, as well as for any unconventional low-temperature superconductor. [1] accepted for publication in Nature Physics.

TT 56.8 Thu 18:30 HSZ 105

Magnetic Phase Diagram of $CeAu_2Ge_2$ — •Veronika Fritsch, Bernd Pilawa, Peter Schweiss, Peter Pfundstein, and Hilbert v. Löhneysen — Karlsruher Institut für Technologie, Physikalisches Institut, 76131 Karlsruhe, Germany

$CeAu_2Ge_2$ single crystals (tetragonal $ThCr_2Si_2$ structure) have been grown in Au-Ge flux (AGF) as well as in Sn flux (SF). X-ray powder diffraction measurements and EDX measurements indicate that in the latter case Sn atoms from the flux are incorporated in the samples, leading to a decrease of the lattice constants by $\approx 0.3\%$ compared to AGF samples. The magnetization M demonstrates a strong dependence of the magnetic properties on the flux employed. While the SF samples adopt simple antiferromagnetic order below 9 K, a sequence of metamagnetic transitions with increasing magnetic field in the AGF samples points towards a more complex magnetic structure for $\mathbf{B}\|\mathbf{c}$. One the basis of the neutron scattering data of Loidl et al. (PRB **46**, 9341, 1992) we calculated the field-dependence of the magnetization at $T = 20$ K in the paramagnetic regime, as well as the temperature dependence, and found good agreement with our measured data for $\mathbf{B}\|\mathbf{c}$ and $\mathbf{B} \perp \mathbf{c}$. The complex phase diagram of the AGF samples in comparison to the simpler one of the SF samples is discussed within the framework of the ANNNI model, making $CeAu_2Ge_2$ a possible candidate for a Devil's Staircase.

TT 56.9 Thu 18:45 HSZ 105

Spin dynamics in $EuCu_2Si_{2-x}Ge_x$: from mixed valence to magnetic instability — •Kirill Nemkovski[1], Pavel Alekseev[2], Jean-Michel Mignot[3], Ross Stewart[4], Robert Bewley[4], and Alexandr Gribanov[5] — [1]Jülich Centre for Neutron Science, Forschungszentrum Jülich, Germany — [2]RRC "Kurchatov Institute", Moscow, Russia — [3]Laboratoire Léon Brillouin, CEA/Saclay, France — [4]ISIS, Rutherford Appleton Laboratory, Didcot, UK — [5]Department of Chemistry, Moscow State University, Russia

$EuCu_2Si_{2-x}Ge_x$ series represents the only known case among Eu- and Sm-based systems, where the state in the phase diagram is tuned from the valence-fluctuating one to heavy-fermion, and then to magnetic-ordered state, with quantum critical point near x=0.7. Here we present the inelastic neutron scattering study of spin dynamics in $EuCu_2Si_{2-x}Ge_x$ (x=0, 0.2, 0.5, 0.8), performed in a wide temperature range (5-200K). At x=0 the magnetic excitation spectrum was found to be represented by the double-peak structure just below the energy range of the Eu^{3+} spin-orbit (SO) excitation $^7F_0 \rightarrow {}^7F_1$, so that at least the high-energy spectral component can be assigned to the renormalized SO transition. Change of the Eu valence towards 2+ with increase of the temperature and/or Ge concentration results in further renormalization (lowering the energy) and gradual suppression of both inelastic peaks in the spectrum, along with developing sizeable quasielastic signal. The origin of the spectral structure and its evolution is discussed in terms of excitonic model for the mixed-valence state. This work was supported by RFBR grant No. 11-02-00121.