TT 8 Correlated Electrons: Heavy Fermions

Time: Monday 14:30–17:45 Room: HSZ 301

TT 8.1 Mon 14:30 HSZ 301

Tunneling spectroscopy experiments on epitaxial UNi_2Al_3 thin films — •Andrey Zakharov, Martin Jourdan, and Hermann Adrian — Johannes Gutenberg-University, Institute of Physics, Staudinger Weg 7, 55128 Mainz, Germany

We are presenting the results of tunneling spectroscopy experiments performed on the heavy fermion superconductor UNi_2Al_3. Planar junctions consisting of an a*-axis oriented UNi_2Al_3 thin film as a base electrode, AlOx insulating layer and a metal counter electrode were prepared employing an in vacuo process. The MESA structures made by photolitography were investigated as well as simple cross-junctions. The observation of the well-known superconducting density of states of the counter electrode (Pb) allows the evaluation of the junction quality. The tunneling conductivity will be discussed in the framework of density of states and barrier effects.

TT 8.2 Mon 14:45 HSZ 301

Electronic properties of a*-oriented thin films of the Heavy-Fermion superconductor UPd_2Al_3 — •Michael Foerster, Martin Jourdan, and Hermann Adrian — J.-Gutenberg-Universität Mainz

By combining epitaxial thin films in a*-orientation of the hexagonal unit cell with optical lithography, we were able to perform precision measurements of temperature dependent resistivity and Hall effect. In contrast to the isostructural, isoelectronical UNi_2Al_3, no dependence of the superconducting transition on the current direction was observed. Also the Hall measurements show only a small anisotropy, and the low temperature behaviour can be understood using Fermi liquid theory.

Additionally, resonant magnetic x-ray scattering confirmed the existence of complete long range magnetic order in the samples, proving the high quality of our thin films. Tunneling experiments in a*-direction are of high interest to further investigate the symmetry of the unconventional sc-order parameter in this model system for Heavy-Fermion superconductivity. First results of such experiments will be presented.

TT 8.3 Mon 15:00 HSZ 301

High pressure study of $YbIr_2Si_2$ — •M. Nicklas, H. Q. Yuan, Z. Hossain, C. Geibel, and F. Steglich — Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany.

We present a high pressure study of the electrical transport properties of the heavy fermion compound $YbIr_2Si_2$ in the temperature range down to 60 mK and for pressures up to 10 GPa. On basis of the resistivity data we establish a pressure-temperature phase diagram. At atmospheric pressure $YbIr_2Si_2$ exhibits a Landau Fermi-liquid state below 200 mK which persists upon applying pressure. For $P \geq 7$ GPa a drop in resistivity indicates the development of antiferromagnetic order at low temperatures. The Neél temperature is increasing with further increasing pressure. We compare our results on $YbIr_2Si_2$ to $YbRh_2Si_2$.

TT 8.4 Mon 15:15 HSZ 301

The role of geometrical frustration in $YbInCu_4$, where In is substituted with Cd or Rh — •Veronika Fritsch[1,2], Joe D. Thompson[1], and John L. Sarrao[1] — [1]Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [2]Physikalisches Institut, Universität Karlsruhe, D-76128 Karlsruhe, Germany

$YbInCu_4$, which is well-known for its unique first-order valence transition, crystallizes in the cubic $AuBe_5$-structure, as do all compounds RInCu$_4$ with R = Gd - Lu. In this structure the magnetic rare-earth ions are located on a fcc-lattice and therefore form networks of tetrahedra. Geometrical frustration of magnetism was discovered in the compounds RInCu$_4$ (R = Gd - Tm)[1]. Substitution of In in RInCu$_4$ with Cd increases the electrical conductivity significantly and therefore destroys the frustration. The high-temperature phase of $YbInCu_4$ is equivalent to the frustrated RInCu$_4$ compounds: the localized magnetic moments of the Yb form a fcc-lattice. However, the frustration found in the other RInCu$_4$ compounds can not be found in $YbInCu_4$ at low temperatures due to the valence transition destroying the localized magnetic moment. Substituting In with Cd or Rh initially raises the temperature of the valence transition and subsequently suppresses it. While Cd-substitution not only suppresses the valence transition but also the frustration due to enhancement of conductivity, Rh-substitution preserves the low electrical conductivity. Here we present measurements of the magnetic and transport properties of the two series $YbIn_{1-x}Cd_xCu_4$ and $YbIn_{1-x}Rh_xCu_4$ and discuss the role of geometrical frustration in both systems.

[1] V. Fritsch *et al.*, Phys. Rev. B **71**, 132402, (2005)

TT 8.5 Mon 15:30 HSZ 301

Quasi quartet CEF ground state with possible quadrupolar ordering in the tetragonal compound $YbRu_2Ge_2$ — •H. S Jeevan[1], Z Hossain[2], and C Geibel[1] — [1]MPI-CPfS Nöthnitzer Str. 40, 01187 Dresden, Germany — [2]Department of Physics, I.I.T-Kanpur, 208016. India

In search for new Yb-base stoichiometric systems which are close to quantum critical point at ambient pressure, we have synthesized and investigated single crystals of $YbRu_2Ge_2$, an homologue of $YbRh_2Si_2$. From the systematic of the known YbM_2X_2 (M = d elements, X = Si, Ge) we had hoped that this compound will be nonmagnetic and located close to a QCP. But surprisingly we found that in YbRu2Ge2, Yb is in a stable trivalent state and present some kind of ordering at a much higher temperature Tm =10K then in presently known Yb-compounds. High temperature magnetic susceptibility follows Curie-Weiss behavior with effective moment very close to that expected for trivalent Yb ions. Low temperature susceptibility exhibits a peak at ˜6 K presumably due to antiferromagnetic type of order. Resistivity linearly decreases with temperature down to about 50 K, then increases with further decreasing temperature due to Kondo interaction, passes though a maximum at 10 K below which the resistivity undergoes a rapid decrease due to freezing out of spin disorder scattering. The Specific heat of $YbRu_2Ge_2$ shows two large peaks, one at 10K and another at 6K, the low temperature anomaly corresponding to the antiferromagnetic transition as detected by chi(T). The nature of the high temperature anomaly in specific heat is under investigation.

TT 8.6 Mon 15:45 HSZ 301

Field-induced enhancement of the linear static susceptibility in heavy-fermion YbAgGe — •P. G. Niklowitz[1,2], C. Paulsen[3], S. L. Budko[4], P. C. Canfield[4], and J. Flouquet[1] — [1]DRFMC/SPSMS/CEA-Grenoble, F-38054 Grenoble Cedex 9, France — [2]Physik Department, E21, Technische Universität München, James-Franck-Str., D-85748 Garching — [3]CRTBT/CNRS, BP 166, F-38042 Grenoble Cedex 9 — [4]Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

Hexagonal YbAgGe is a recently discovered heavy-fermion (HF) system with $T_K \approx 25$ K, γ of a few hundred mJ/molK^2 and planar magnetic anisotropy $\chi_{ab}/\chi_c \approx 3$ at low temperatures. Two antiferromagnetic phases AF1 and AF2, become fully suppressed with fields $H_{c1} = 1.9$ T and $H_{c2} = 3.0$ T, when the field is applied in the ab-plane. Furthermore, there are indications for a transition or crossover at a field $H_{c3} = 4.9$ T and low-T resistivity measurements suggest a strong enhancement of thermally excited fluctuations close to H_{c3}. The resistivity is non-Fermi-liquid (NFL) like close to H_{c3}. We have now measured the magnetisation of single crystals of YbAgGe up to 8 T and down to 50 mK with the field applied along the a-axis. The results confirm the first-order character of the transition between the AF1 and AF2 phase. No clear signature of the suppression of the AF2 phase is found. However, the static linear susceptibility becomes enhanced when approaching H_{c3}, especially at the lowest temperatures. This enhancement suggests that magnetic fluctuations are at the origin of field-induced NFL behaviour in YbAgGe, but that ferromagnetic fluctuations are not the only ingredient.

— 15 min. break —

TT 8.7 Mon 16:15 HSZ 301

$CeCu_{6-x}Au_x$ NMR studies Part I - crystal field analysis and the assignment of Cu sites — •Bernd Pilawa, Max Winkelmann, Gerda Fischer, and Elmar Dormann — Physikalisches Institut, Universität Karlsruhe, D-76128 Karlsruhe, Germany

In $CeCu_{6-x}Au_x$ the Ce^{3+} $4f^1$ $^2F_{5/2}$ groundstate is split into three doublets. The crystal field splitting is known from neutron scattering forx=0.5 and 0. A calculation of the magnetic susceptibility using one antiferromagnetic molecular field constant λ as approximation for the

Kondo like shielding and the influence of orbit and spin scattering on the interaction of the Ce moments describes the experimental data quite well.

We managed to calculate the electric field gradients at the 5 inequivalent Cu sites of $CeCu_6$ with the WIEN2k-Software-Package. Spectra generated with these parameters fit to NMR-spectra measured for oriented single crystal powder samples at various temperatures between 5k and 100k at a magnetic field of 7T. Therefore the information in various NMR- and NQR-studies can now be compared to the crystallographic information.

TT 8.8 Mon 16:30 HSZ 301

$CeCu_{6-x}Au_x$ NMR studies Part II - Analysis of NMR line shift — •Max Winkelmann[1], Bernd Pilawa[1], M.S.S. Brooks[2], and Elmar Dormann[1] — [1]Physikalisches Institut, Universität Karlsruhe, D-76128 Karlsruhe, Germany — [2]Commission of the European Communities, Joint Research Center, Institut of Transuranium Elements, D-76021 Karlsruhe, Germany

We have carried out various NMR-measurements on the well-known heavy-fermion system $CeCu_{6-x}Au_x$. As a result we present Cu-site specific bare Knight shift data and transferred hyperfine interaction coupling constants α in thetemperature range from 100K down to 5K, derived from NMR-spectra in a magnetic field of 7T. The interaction coupling constants are showing alternating signs which can be understood by the variing contribution of s,p and d electrons which are calculated by ab initio self-consistent band structure calculations.

While substituting the Cu(2)-site with Au the transferred hyperfine interactioncoupling constants decrease, whereas the absolut line-shift is increasing. Thiscould be explained by a larger susceptibility of $CeCu_5Au_1$. For one of the Cu sites evidence for the anisotropy of the transferred field coupling constant is obtained.

TT 8.9 Mon 16:45 HSZ 301

Probing the Electronic Properties of the Heavy-Fermion Superconductor $CeCoIn_5$ — •G. Goll[1], T. Brugger[1], M. Marz[1], T. Sayles[2], and M. B. Maple[2] — [1]Phys. Inst., Universität Karlsruhe, 76128 Karlsruhe, Germany — [2]Inst. for Pure and Applied Phys. Sciences, University of California, San Diego, La Jolla, CA 92093, USA

In many U- and Ce-based heavy-fermion superconductors, as well as in the oxide superconductors, the superconducting (sc) properties differ from those of a classical superconductor due to the presence of strong electron-electron correlations [1]. A recent example is $CeCoIn_5$, a heavy-fermion superconductor with $T_c = 2.3$ K, where among other exotic properties a power-law behavior of the thermodynamic and transport properties in the sc state gives evidence that the order parameter (op) has line nodes and probably $d_{x^2-y^2}$ symmetry. Several groups performed point-contact (pc) experiments on $CeCoIn_5$ in order to elucidate the gap structure. However, there is still some controversy on the interpretation of the structures in the differential conductance dI/dV vs. V which has mainly to do with the determination of the regime of current flow through the pc. We report on measurements of dI/dV vs. V on Pt-$CeCoIn_5$ pc's in the normal and sc states down to 30mK in zero and applied magnetic fields and we discuss the pc regime in detail. In the normal state the spectra exhibit a pronounced asymmetry which is not affected by an applied field up to $B = 6$ T. The spectra in the sc state support a d-wave op scenario for $CeCoIn_5$, in line with the pc data obtained by other groups.
[1] G. Goll: *Unconventional Superconductors*, STMP, Vol. 214, Springer-Verlag 2005.

TT 8.10 Mon 17:00 HSZ 301

Fermi surface and renormalization effects in heavy fermion superconductors — •Andreas Koitzsch[1], Sergey Borisenko[1], Jochen Geck[1], Volodymyr Zabolotnyy[1], Dmytro Inosov[1], Martin Knupfer[1], Jörg Fink[1], Bernd Büchner[1], and Eric Bauer[2] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]Los Alamos National Laboratory, Los alamos, Mew Mexico 87545, USA

The heavy fermion compounds of the type $CeTIn_5$ (T = Co, Ir, Rh) show a rich variety of interesting solid-state phenomena which have shifted them under the focus of current research. Firstly, the compound $CeCoIn_5$ shows superconductivity below T = 2,3 K at ambient pressure. This is the record value for heavy fermion superconductors. The interplay between the Kondo effect and the RKKY interaction, the close neighborhood between magnetism and superconductivity and the vicinity to a quantum critical point decisively influence the low-energy physics of these systems.

We investigated the electronic structure of this materials by angle-resolved photoemission spectroscopy. We measured the Fermi surface and the band structure along the high-symmetry directions. We compare our results to de-Haas-van-Alphen experiments and to band structure calculations and discuss the signatures of the low-energy mass renormalization.

TT 8.11 Mon 17:15 HSZ 301

Low-energy interactions in the heavy-fermion state of $Ce_3Rh_4Sn_{13}$ — •Ulrike Köhler[1], André Strydom[2], Adam Pikul[1], Silke Paschen[3], Niels Oeschler[1], and Frank Steglich[1] — [1]MPI CPfS, Nöthnitzer Straße 40, 01187 Dresden, Germany — [2]Physics Dept., University of Johannesburg, South Africa — [3]Institut für Festkörperphysik, TU Wien, Austria

Previous magnetization measurements on $Ce_3Rh_4Sn_{13}$ were reported with a Curie-Weiss behaviour and a small Weiss temperature of -14 K. No magnetic ordering was observed down to 2 K. The resistivity displayed a negative temperature coefficient from room temperature down to 4.2 K apart from a minimum near 30 K, which was attributed to Kondo interactions. These intriguing properties, together with the lack of any thermodynamic data on $Ce_3Rh_4Sn_{13}$ prompted us to study this compound by magnetization, resistivity, Hall effect, specific heat and thermal transport between 40 mK and 300 K and in applied magnetic fields. The results point to the relevance of a particularly small crystal-electric field splitting together with a low-temperature Kondo interaction, both of which become evanescent in the ground state of strongly correlated electrons in $Ce_3Rh_4Sn_{13}$.

TT 8.12 Mon 17:30 HSZ 301

Crossover from divalent to valence fluctuating state of Eu in $EuCu_2(Ge_{1-x}Si_x)_2$ probed by ^{63,65}Cu-NMR — •M. Baenitz[1], Eva Brüning[1], Andrei Gippius[2], Anakan Rajarajan[1], Elena Morozova[2], Zakir Hossain[3], Christoph Geibel[1], and Frank Steglich[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Moscow State University, Moscow, Russia — [3]Department of Physics, Indian Institute of Technology, Kanpur, India

Temperature dependent ^{63,65}Cu field sweep NMR investigations on a series of $EuCu_2(Ge_{1-x}Si_x)_2$ powder samples (x = 0, 0.3, 0.65, 0.7, 1) are presented. $EuCu_2$ (Ge, Si)$_2$ is unique among Eu-intermetallics because, upon tuning from a divalent antiferromagnetically ordered state for x = 0 to a valence fluctuating state for x = 1, Heavy Fermion behaviour was found around $x \approx 0.7$. The Knight shift ^{63,65}K is negative for all stoichiometries. Hyperfine fields are largest for the antiferromagnetically ordered Ge-rich compounds, and smallest for the valence fluctuating pure silicon compound (x = 1). For the $x = 0.3$ compound, above $T_N \approx 19$K,$^{63}K(T)$ exhibits a Curie-Weiss like behaviour ($\approx -10\%$ at 20 K) whereas for $EuCu_2Si_2$ a temperature independent shift of $^{63}K(T) \approx -1.5\%$ is found. Our results are discussed in terms of formation of heavy quasiparticles and/or presence of valence fluctuations of Eu.