TT 4: CE: Quantum-Critical Phenomena 1

Time: Monday 10:30–13:00 Location: HSZ 201

TT 4.1 Mon 10:30 HSZ 201

Larmor diffraction studies on the ferromagnetic superconductor UGe_2 — •Robert Ritz[1], Dmitry Sokolov[2], Thomas Keller[3], Andrew D. Huxley[2], and Christian Pfleiderer[1] — [1]Physik Department E21, TU München, D-85748 Garching, Germany — [2]School of Physics and Astronomy, and Centre for Science at Extreme Conditions, The University of Edinburgh, Edinburgh EH9 3JZ, UK — [3]MPI für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany

Larmor diffraction (LD) is a novel technique based on the Larmor precession of polarized neutrons that surpasses the resolution of conventional scattering methods by two orders of magnitude [1,2,3]. For a long time it was thought that it is not possible to measure LD on systems with depolarizing properties, such as ferromagnets. We present thermal expansion measurements under pressure by means of Larmor diffraction (LD) on the superconducting Ising ferromagnet UGe_2. LD allowed us to measure magnetization and thermal expansion under pressure in the same setup and hence to directly compare transition temperatures. We found that the thermal expansion near T_X, the transition between two ferromagnetic phases which is believed to drive superconductivity, shows a clear transition in the *b*- and *c*-axis under pressure at a temperature a few K higher than for the *a*-axis and the ferromagnetic Bragg peak. We are considering different mechanisms how this may be connected with the superconductivity in UGe_2.

[1] M.T. Rekveldt et al., Eur. Phys. Lett. **54**, 342 (2001)
[2] T. Keller et al., Appl. Phys. **A 74** , S332 (2002)
[3] C. Pfleiderer et al., Science **316**, 1871 (2007)

TT 4.2 Mon 10:45 HSZ 201

Quantum Phase Transitions in $Mn_{1-x}Fe_xSi$ and $Mn_{1-x}Co_xSi$ — •Andreas Bauer[1], Tim Adams[1], Christian Franz[1], Andreas Neubauer[1], Maximilian Hirschberger[1], Christopher Krey[1], Robert Georgii[1,2], Peter Böni[1,2], Markus Garst[1,3], and Christian Pfleiderer[1] — [1]Physik Department E21/T30, Technische Universität München, Germany — [2]Forschungsneutronenquelle Heinz Maier-Leibnitz, Technische Universität München, Germany — [3]Institute for Theoretical Physics, Universität zu Köln, Germany

The helimagnetic order in MnSi may be suppressed by substitutional doping of Fe or Co on the Mn site. We report a comprehensive study of the magnetization, susceptibility, specific heat and small angle neutron scattering of single-crystal $Mn_{1-x}Fe_xSi$ and $Mn_{1-x}Co_xSi$ at low temperatures [1]. In contrast to the pressure dependence of pure MnSi the spin polarized state in applied magnetic fields is characteristic of a putative ferromagnetic quantum critical point at a critical concentration x_c. The magnetic phase diagram as a function of composition up to $x \approx 0.5\,x_c$ is thereby essentially unchanged, exhibiting the well known phases (helical order, conical order, and skyrmion lattice phase [2]). When further increasing x the regime of the skyrmion lattice and the cross-over between the paramagnetic and the helimagnetic state, which may be related to complex spin textures, extend over an increasing temperature and field range. This points at an important role of complex spin textures in the vicinity of x_c.

[1] A. Bauer et al., PRB **82**, 064404 (2010)
[2] S. Mühlbauer et al., Science **323**, 915 (2009)

TT 4.3 Mon 11:00 HSZ 201

Neutron spin echo measurements of magnetic fluctuations in helical $Mn_{1-x}Fe_xSi$ — •Alexander Tischendorf[1], Wolfgang Häussler[1,2], Andreas Bauer[1], Peter Böni[1], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik Department E21, 85748 Garching, Germany — [2]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM-II), 85748 Garching, Germany

Manganese silicide (MnSi) is a 3d intermetallic compound that crystallizes in the cubic B20 structure. In the absence of an applied magnetic field and for temperatures below $T_c = 29.5\,\mathrm{K}$ MnSi displays a long-period helimagnetic state with a wavelength of approximately 180 Å. Under substitutional doping with Fe, the helimagnetic transition temperature decreases and terminates in a set of complex quantum phase transitions (QPT) [1]. We have studied the line width of the spin fluctuations in $Mn_{1-x}Fe_xSi$ by means of neutron spin echo measurements. The high energy resolution and the small angle scattering set up of the spin echo instrument RESEDA at the Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II) thereby offered an ideal parameter range, that is not accessable in conventional triple-axes measurements. Our results will be discussed, in the context of the spin-fluctuation theory of weakly magnetic itinerant-electron compounds, which allows the identification of anomalous behavior at QPTs.

[1] A. Bauer et al., Phys. Rev. B **82**, 064404 (2010)

TT 4.4 Mon 11:15 HSZ 201

Incipient quantum criticality in single-crystal Fe_2TiSn — A. Neubauer[1], •M. Wagner[1], M. Schulz[1,2], A. Senyshyn[2], K. Hradil[2,3], R. Korntner[1], A. Bauer[1], S. Gottlieb-Schönmeyer[1], R. Jungwirth[2], G. Behr[4], J. Kübler[5], C. Felser[6], and C. Pfleiderer[1] — [1]Physik-Department, TU München, 85748 Garching — [2]FRM II, TU München, 85748 Garching — [3]Institut für physikalische Chemie, U Göttingen, 37077 Göttingen — [4]IFW Dresden, 01171 Dresden — [5]Institut für Festkörperphysik, TU Darmstadt, 64289 Darmstadt — [6]Institut für Anorganische und Analytische Chemie, U Mainz, 55099 Mainz

We have grown single-crystals of the Heusler compound Fe_2TiSn by optical float-zoning. Two parasitic effects, notably the formation of an impurity phase and surface segregations, account for the ferromagnetic (FM) properties of polycrystals of Fe_2TiSn previously attributed to atomic site interchanges. A detailed structural characterization establishes that our single crystals are phase-pure with a typical abundance of twinning domains and a trend to split site disorder of the Fe and Ti atoms. In phase-pure single crystals the temperature dependence of the susceptibility and specific heat suggest incipient FM quantum criticality, masked below a few K by a weak spin-glass transition. With decreasing temperature the resistivity increases characteristic of a small charge gap. The Hall effect corresponds to a charge carrier concentration $n_H \approx 10^{22}\,\mathrm{cm}^{-3}$ with an additional anomalous magnetic field dependence. Compared to conventional scenarios of FM quantum criticality the properties of Fe_2TiSn differ in a number of surprising ways.

TT 4.5 Mon 11:30 HSZ 201

Single-crystal growth and low temperature properties of the non-centrosymmetric heavy-fermion comound $CeAuAl_3$ — •Christian Franz, Andreas Bauer, Kilian Mittermüller, Alfonso Chacon, Marco Halder, and Christian Pfleiderer — Physik Department E21, Technische Universität München, München, Germany

Non-centrosymmetric heavy fermion compounds attract great interest as a platform for unconventional superconductivity and complex forms of magnetic order. We report the first successful single-crystal growth of $CeAuAl_3$ – an isostructural relative with space group I4mm of the heavy-fermion superconductors $CeRhSi_3$ and $CeIrSi_3$. Our single crystals were prepared from high-purity starting elements (> 5N) using a bespoke all-metal sealed rod casting furnace and a bespoke image furnace. High crystal quality was established by Laue x-ray scattering, x-ray powder diffraction and EDX microprobe analysis. The low temperature properties, notably magnetisation, heat capacity and electrical resistivity, identify $CeAuAl_3$ as an antiferromagnetic heavy fermion compound with a low Neel temperature.

15 min. break

TT 4.6 Mon 12:00 HSZ 201

Low-temperarture x-ray powder diffraction in the itinerant antiferromagnet YMn_2 — •Kilian Mittermüller, Saskia Gottlieb-Schönemeyer, Andreas Bauer, and Christian Pfleiderer — Physik Department E21, TU München

The cubic C15 Laves compound YMn_2 displays itinerant antiferromagnetism below a Neel temperature $T_N = 100\,\mathrm{K}$ that is accompanied by a large magnetoelastic expansion of order 5 %. We have set up a Siemens D5000 x-ray powder diffractometer with a pulse tube cryo-cooler for measurements at temperatures down to $\sim 8\,\mathrm{K}$. We report a detailed investigation of the structural modifications associated with the Neel transition in YMn_2 as inferred from the x-ray powder diffraction. In agreement with previous work the Neel transition is dominated by large changes of the lattice constants. In addition the transition is highly hysteretic possibly related to the presence of local strains in the powder. We will discuss putative evidence for a tetragonal lat-

tice distortion in the antiferromagnetic state and its consequences for competing electronic instabilities such as charge density wave order in YMn_2.

TT 4.7 Mon 12:15 HSZ 201

Neutron depolarization imaging at milli-Kelvin temperatures of the Kondo-cluster-glass formation in $CePd_{1-x}Rh_x$ — •Philipp Schmakat[1], Michael Schulz[1,2], Christian Pfleiderer[1], Peter Böni[1], Elbio Calzada[1,2], Sergey Masalovich[2], Manuel Brando[3], Christoph Geibel[3], and Micha Deppe[3] — [1]Physik-Department E21, Technische Universität München — [2]Forschungs-Neutronenquelle FRM-II, München — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden

In the f-electron compound $CePd_{1-x}Rh_x$ a new groundstate entitled as Kondo-Cluster-Glass has been proposed for $x > 0.65$ [1]. The origin of this cluster formation is assumed to be an interplay of metallurgical inhomogeneities and the effect of two competing interactions, namely the Kondo-screening and the long-range RKKY-interaction.

We have investigated the magnetic phase diagram of the Kondo-lattice $CePd_{1-x}Rh_x$ in the concentration range $0.40 \leq x \leq 0.80$ by means of neutron depolarisation imaging (NDI) down to 75 mK. The NDI technique allowed us to map out inhomogeneities of the transition temperature and the spontaneous magnetization over the sample, as well as the average domain size. Our data are consistent with previous studies and support the picture of the cluster formation where long-range order vanishes with increasing Rh content and short-range interactions become crucial.

[1] J.G. Sereni, Phys. Rev. B 75, 024432 (2007); T. Westerkamp, Phys. Rev. Lett. 102, 206404 (2009).

TT 4.8 Mon 12:30 HSZ 201

Violation of the Wiedemann-Franz law at the Quantum Critical Point of $YbRh_2Si_2$ — •Stefanie Hartmann[1], Cornelius Krellner[1], Stefan Kirchner[2], Ulrike Stockert[1], Christoph Geibel[1], and Frank Steglich[1] — [1]MPI CPfS, Nöthnitzer Str. 40, 01187 Dresden — [2]MPI PKS, Nöthnitzer Str. 38, 01187 Dresden

The prototype heavy-fermion system $YbRh_2Si_2$ appears to be situated extremely close to an antiferromagnetic (AF) quantum critical point (QCP). Besides the disappearance of the AF ordering ($T_N = 70$ mK) at a tiny critical magnetic field, $B_c \approx 60$ mT, applied perpendicular to the tetragonal c axis, the breakdown of the Kondo scale accompanied by an abrupt Fermi surface reconstruction is assumed to take place at the very same field. Beyond B_c a heavy Landau Fermi-liquid (FL) phase emerges.

We have studied the thermal conductivity $\kappa(T, B)$ as well as the electrical resistivity $\rho(T, B)$ in a wide temperature and field range ($T \geq 30$ mK, $B \leq 1$ T) using the same $YbRh_2Si_2$ single crystalline sample for both measurements. The comparison of both quantities evidences that, in the limit $T = 0$, the Wiedemann-Franz law, $\kappa\rho = L_0 T$, is fulfilled deep inside the AF phase as well as in the FL regime of $YbRh_2Si_2$. The universal relation between heat and charge conduction is, however, distinctly violated upon approaching the field-induced QCP from either side, caused by the emergence of a novel type of inelastic small-angle scattering processes.

TT 4.9 Mon 12:45 HSZ 201

Anomalous effect of hole-doping on $YbRh_2Si_2$ — •Yoshi Tokiwa, Hirale S. Jeevan, Maik Schubert, and Philipp Gegenwart — I. Physik. Institut, Georg-August Universität Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen, Germany

Substituting Fe at the Rh site in $YbRh_2Si_2$ causes both chemical pressure and hole doping. We have investigated single crystals of $Yb(Rh_{1-x}Fe_x)_2Si_2$ with x=0.05 by specific heat, magnetization, resistivity and magnetocaloric effect measurements down to ∼20 mK. The observed shift of the broad maximum in $\rho(T)$ from 140 to 115 K and the reduction of the Kondo temperature from 25 to 15 K could be ascribed to the effect of an effective chemical pressure of ∼0.8 GPa. Without charge carrier doping, such pressure enhances T_N from 0.07 to about 0.3 K. However, no magnetic order is found in $Yb(Rh_{0.95}Fe_{0.05})_2Si_2$ which might be due to the hole-doping effect. The energy scale $T^\star(H)$ that for undoped $YbRh_2Si_2$ collapses at a critical field of 0.05 T is moderately shifted and terminates at a slightly smaller field $H^\star(T \to 0) = 0.03$ T. Divergent behavior of the Sommerfeld coefficient, $\gamma \propto (H - H_c)^{G_r}$, and the magnetic Grüneisen ratio, $\Gamma_H = -G_r/(H - H_c)$ with $G_r = -0.18$ and $H_c = 0.03$ T, is found in the field-induced Landau Fermi liquid state at $H > H_c$ and suggests a quantum critical point in the absence of antiferromagnetic ordering in this system. Work supported by the DFG through research unit 960 (Quantum phase transitions).