TT 16: CE: Quantum-Critical Phenomena 1

Time: Tuesday 14:00–16:15 Location: H19

TT 16.1 Tue 14:00 H19

Specific heat and magnetocaloric effect at the field-induced quantum-critical point in $CeCu_{5.7}Au_{0.3}$ — •Michael J. Wolf, Gernot Goll, Veronika Fritsch, and Hilbert v. Löhneysen — Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany

The heavy-fermion system $CeCu_{6-x}Au_x$ can be tuned to a quantum critical point by application of different tuning parameters such as pressure or magnetic field. We present specific heat measurements on single crystalline $CeCu_{5.7}Au_{0.3}$ in the temperature range from 70 mK to 1.5 K and in magnetic fields up to 4 T with $B \parallel c$. In addition, the magnetocaloric effect was measured in the temperature range from 70 mK to 1 K and in magnetic fields up to 2 T. The critical magnetic field B_c was determined to be $B_c = 0.95 \pm 0.1$ T. At the critical magnetic field the specific heat data can be well described by the self-consistent spin-fluctuation model of Moriya and Takimoto [1]. The magnetocaloric data at low temperatures show a jump of the magnetic Grüneisen ratio at the phase boundary for $B < B_c$ as well as a monotonic increase towards the lowest measured temperatures for $B > B_c$. These results are compared to previous magnetization measurements and discussed within the framework of theoretical models.

[1] T. Moriya and T. Takimoto, J. Phys. Soc. Japan 64 (1995), 960.

TT 16.2 Tue 14:15 H19

Magnetocaloric effect in $Yb(Rh_{0.93}Co_{0.07})_2Si_2$ — •Alexander Steppke, Niels Oeschler, Cornelius Krellner, Manuel Brando, Christoph Geibel, and Frank Steglich — Max-Planck-Institut für Chemische Physik fester Stoffe Nöthnitzer Str. 40, 01187 Dresden, Germany

The magnetic Grüneisen ratio is defined as $\Gamma_H = -(dM/dT)_H/C_H = 1/T(dT/dH)_S$. Investigation of the magnetocaloric effect (MCE) therefore provides a direct measure of Γ_H. At a field-induced quantum critical point (QCP) the critical part of Γ_H, Γ_H^{cr}, is expected to diverge and to change its sign across the QCP, indicating the accumulation of entropy [1]. The heavy-fermion compound $Yb(Rh_{0.93}Co_{0.07})_2Si_2$ is a prototype system which allows us to study a field-induced QCP [2]. In zero field this compound exhibits two antiferromagnetic transitions at $T_N = 0.4$ K and $T_L = 0.07$ K, which can be continuously suppressed by small magnetic fields $\mu_0 H_N = 0.24$ T and $\mu_0 H_L = 0.05$ T, respectively. At these fields a maximum in $S(H)$, i.e. a minimum in $dT/dH(H)$, is anticipated. We measured the MCE and the specific heat of $Yb(Rh_{0.93}Co_{0.07})_2Si_2$ down to 0.025 K. Across both T_N and T_L, Γ_H^{cr} changes sign, since dT/dH shows a kink or a minimum. The kink at T_N follows the phase boundary $T_N(H)$ and disappears for $T \to 0$. However, the minimum at T_L is more pronounced in dT/dH, indicating a significant change in entropy. This change in entropy seems to be located near to but not at the phase boundary $T_L(H)$.

[1] L. Zhu *et al.*, PRL **91** (2003) 066404; M. Garst and A. Rosch, PRB **72** (2005) 205129
[2] S. Friedemann *et al.*, Nat. Phys. **5** (2009) 465.

TT 16.3 Tue 14:30 H19

Magnetocaloric effect of $YbRh_2Si_2$ at field-induced QCP — •Y. Tokiwa — I. Physik. Institut, Georg-August Universität Gottingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We develop a system to measure a magneto-caloric effect, dT/dH, at low temperatures down to ∼50 mK to study the field-induced QCP of $YbRh_2Si_2$. The key quantity for a study of field-induced QCP called magnetic Grüneisen ratio, $\Gamma_{mag}=1/T(dT/dH)=1/T(dT/dH)=-(dM/dT)/C$ (M: magnetization, C: specific heat), for this compound was previously obtained by measuring both M and C at the critical field H_{cr}=0.06 T and above. We obtained Γ_{mag} by measurements of dT/dH, which have the following advantages over the combination of M and C measurements. (1) Γ_{mag} can be obtained at very low fields (and also at zero-field), while it is very difficult with M and C because M becomes very small at low fields (impossible at zero-field because magnetization is zero). (2) Since it is a single measurement, possible error in Γ_{mag} is expected to be smaller compared to the two separated measurements combined. We discuss the details of the measurement technique and the results on $YbRh_2Si_2$ around H_{cr}, including the un-explored field-range below H_{cr}. This work is done by the collaboration with H. S. Jeewan and P. Gegenwart and supported by DFG through research unit 960 (Quantum phase transitions).

TT 16.4 Tue 14:45 H19

Magnetic properties of $YbCo_2Si_2$ studied by neutron diffraction — •Nandang Mufti, Oliver Stockert, Koji Kaneko, Cornelius Krellner, and Christoph Geibel — Max-Planck-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany

While for most rare earth element R magnetic ordering in RT_2X_2 (T= transition metal and X = Si, Ge) has been thoroughly investigated, only very few results are available for Yb homologous. In this context $YbCo_2Si_2$ is very interesting because it is isoelectronic to quantum critical system $YbRh_2Si_2$. It presents a stable Yb^{3+} state which shows magnetic ordering at 1.7 K. We recently grew single crystals and started a extensive study of the magnetic properties of this compound. Magnetic susceptibility, specific heat, and electrical resistivity results evidenced a pronounced easy plane anisotropy and two magnetic transitions at $T_N \sim 1.7$ K and $T_L \sim 0.9$ K. Magnetization, susceptibility and magnetoresistance measurements indicate a complex B-T phase diagram with some anisotropy in the basal plane. Here, we will present the results of our investigation with single crystal and powder neutron diffractions in absence and under magnetic field up to 2.5 T. A commensurate magnetic structure with q = (0.25, 0.25, 1) and incommensurate magnetic structure with q= (0.25, 0.08, 1) are observed for the ground state and intermediate phase, respectively. The critical exponent β for T_N is obtained as $\beta = 0.369 \pm 0.03$ which is close to the expected value of 3D Heisenberg system. We shall propose a magnetic structure for both ordered phases.

TT 16.5 Tue 15:00 H19

Tuning the Eu valence in $EuPd_3B_x$ by B substitution and pressure - a joint experimental and theoretical study — •Miriam Schmitt[1], Roman Gumeniuk[1], Andreas Leithe-Jasper[1], Walter Schnelle[1], Marcus Schmidt[1], Angela Trapananti[2], Giuliana Aquilanti[2], Ulrich Schwarz[1], and Helge Rosner[1] — [1]MPI for Chemical Physics of Solids, Dresden, Germany — [2]European Synchrotron Radiat Facil, Grenoble, France

Valence changes induced by doping as well as internal or external pressure often lead to quantum critical phenomena. For $EuPd_3B_x$, an isostructural phase transition upon B substitution, attended by a change of its magnetic properties, was predicted by band structure theory [1]. According to our calculational results, the phase transition in $EuPd_3B_x$ can be explained by a change of the Eu valence related to a change of the 4f occupation. Upon B insertion, the Eu^{3+} in $EuPd_3$ changes to Eu^{2+} in $EuPd_3B_x$ (x ≥ 0.2). By applying pressure this effect can be reversed, driving a magnetic Eu^{2+} to a non magnetic Eu^{3+} state. To challenge the prediction of the transitions we carried out XRD and XAS measurements for different B contents as well as for a fixed B content under high pressure. To elucidate the origin of the magnetic change, the experimental results are complemented by density functional based ab-initio band structure calculations using the LDA+U approach (to include strong electron correlations of 4f electrons) and the coherent potential approximation (CPA, to describe substitutional disorder).

[1] C. Loison *et al.*, Phys. Rev. B 75, 205135 (2007).

TT 16.6 Tue 15:15 H19

Larmor Diffraction in the Ferromagnetic Superconductor UGe_2 — •Robert Ritz[1], Dmitry Sokolov[2], Thomas Keller[3], Andrew 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 neutron resonance spin-echo technique which allows the study of the lattice constant as well the distribution of lattice constants. It was traditionally thought that neutron spin-echo measurements cannot be used in materials such as superconductors or ferromagnets, because they strongly depolarize a polarized neutron beam. In UGe_2 we are able to demonstrate that this technique may be applied in ferromagnetic superconductors with a magnetic Ising anisotropy. UGe_2 exhibits two ferromagnetic phases which are sepa-

rated by a transiton at temperature T_x. With increasing hydrostatic pressure superconductivity emerges at the pressure for which T_x is suppressed. Using LD we studied the temperature dependence of the lattice constant as well as the distribution of lattice constants for all three axis of UGe_2 down to 0.5 K and at pressures up to 12 kbar.

TT 16.7 Tue 15:30 H19

Exploring the magnetocaloric effect in Cs_2CuCl_4 close to the field-induced quantum-critical point — •Georg Hofmann, Berd Wolf, Sebastian Belz, Natalija Krüger, Franz Ritter, Wolf Assmus, and Michael Lang — Physikalisches Institut, SFB/TR 49, Goethe-University Frankfurt am Main, 60438 Frankfurt am Main, Germany

The compound Cs_2CuCl_4 is a quasi-2D geometrically frustrated $S = 1/2$ antiferromagnet which orders antiferromagnetically below $T_N = 1.6$ K. By increasing an external field to $B_c \approx 8.5$ T [1], T_N is suppressed to zero which marks a field-induced quantum-critical point (QCP). The QCP, although inaccessible by experiment, manifests itself at finite temperature in an unusual sensitiveness of thermodynamic properties on the tuning parameter [2]. In fact, for a field-induced QCP, a diverging magnetocaloric effect (MCE) $\Gamma_B = -\left(\partial S/\partial B\right)_T/C$ is expected [2, 3]. Here we present measurements of the MCE in the vicinity of B_c for the title compound by using a step-like measuring technique which ensures quasi-adiabatic conditions. Our results reveal incipient divergencies of Γ_B upon approaching the QCP both as a function of field and temperature, consistent with the expectations [3].

[1] Radu et al., Phys. Rev. Lett. **95**, 127202 (2005).
[2] Zhu et al., Phys. Rev. Lett. **91**, 066404 (2003).
[3] Garst et al., Phys. Rev. B **72**, 205129 (2005).

TT 16.8 Tue 15:45 H19

Low temperature properties of single crystal Fe_2TiSn under high pressure and magnetic field — •Andreas Neubauer[1], Michael Schulz[1,2], Christian Pfleiderer[1], Peter Böni[1], Klaudia Hradil[2], and Günther Behr[3] — [1]Physik Department E21, Technische Universität München, 85748 Garching, Germany — [2]Technische Universität München, Forschungsneutronenquelle Heinz Maier Leibnitz (FRM II),Lichtenbergstr. 1, 85748 Garching, Germany — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, PF270116, 01171 Dresden, Germany

Electronic structure calculations predict a paramagnetic ground state for the Heusler compound Fe_2TiSn. However, the experimental investigation of polycrystals showed weakly ferromagnetic behaviour ($T_C \sim 250$ K), where the magnetic properties are extremely sensitive to sample synthesis. We were able to grow, for the first time, single crystals of Fe_2TiSn by the optical float zoning using an UHV-compatible image furnace. The inverse AC susceptibility of the single crystals shows a paramagnetic Curie-Weiss-behaviour from room temperature down to around 5K, followed by a transition to a so far unidentified phase. Interestingly, the inverse susceptibility extrapolates through $T = 0$, a behaviour expected for ferromagnetic quantum criticality. We investigated the pressure dependence of the magnetization, the longitudinal magneto-resistance and the Hall effect. These data are supplemented by neutron depolarization measurements. Possible implications of our observations for the possible nature of quantum criticality in Fe_2TiSn will be discussed.

TT 16.9 Tue 16:00 H19

Vibrating Coil Magnetometry of quantum criticality in the Ising Ferromagnet $LiHoF_4$ — •Stefan Legl[1], Bastien Dalla Piazza[2], Karl Krämer[3], Henrik Ronnow[2], and Christian Pfleiderer[1] — [1]Physik Department E21, Technische Universität München, James-Franck-Strasse, D-85748 Garching, Germany — [2]EPFL, CH-1015 Lausanne, Switzerland — [3]Department of Chemistry & Biochemistry, University of Bern, CH-3012 Bern, Switzerland

$LiHoF_4$ develops Ising ferromagnetism below a Curie temperature, $T_C = 1.54$ K. The easy-axis magnetization of $LiHoF_4$ has recently attracted great interest as a testing ground for theoretical studies of domain formation in Ising systems. This is contrasted by the properties of $LiHoF_4$ for magnetic field applied transverse to the Ising axis, where susceptibility measurements suggest the existence of a quantum critical point at a critical field $H_c = 4.90$ T. An outstanding issue in studies of $LiHoF_4$ are direct measurements of the magnetization parallel to an applied magnetic field, $M_\parallel$, as the principle order parameter of the ferromagnetic state. We have used a newly developed vibrating coil magnetometer (VCM) as combined with a top loading dilution refrigerator for measurements of the field and temperature dependence of $M_\parallel$ in $LiHoF_4$ down to mK temperatures. We present first results of our measurements and a critical discussion of the agreement and disagreement with previous work.