TT 11: Heavy Fermions

Time: Monday 15:00–17:30 Location: H 3005

TT 11.1 Mon 15:00 H 3005

Controlling crystal-electric field levels through symmetry-breaking uniaxial pressure in a cubic super heavy fermion — •Elena Gati[1], Burkhard Schmidt[1], Sergey L. Bud'ko[2], Andrew P. Mackenzie[1,3], and Paul C. Canfield[2] — [1]MPI for Chemical Physics of Solids, 01187, Dresden, Germany — [2]Ames National Laboratory, US DOE, and Physics Dept., Iowa State University, Ames, IA, 50011, USA — [3]Scottish Universities Physics Alliance, School of Physics and Astronomy, University of St Andrews, UK

YbPtBi is one of the heavy-fermion systems with largest Sommerfeld coefficient γ and is thus classified as a 'super'-heavy fermion material. In this work, we resolve the long-debated question about the crystal-electric field (CEF) level scheme in YbPtBi, by deliberate breaking of its cubic symmetry through uniaxial pressure tuning. Through measurements of the novel a.c. elastocaloric effect and generic symmetry arguments, we identify an elastic level splitting under uniaxial pressure that is unambiguously associated with the symmetry-allowed splitting of a quartet CEF level at $\Delta/k_B \approx 1.6$ K. Our study shows the potential of the a.c. elastocaloric effect to control and quantify strain-induced changes of the CEF schemes, opening a different route to disentangle the CEF energy scales from other relevant energy scales in correlated quantum materials.

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[1] Gati *et al.*, npj Quant. Mat. **8** (2023) 69.

TT 11.2 Mon 15:15 H 3005

High-pressure Fermi surface studies in the Kondo lattice system YbPtBi — •Oliver Squire, Maximilian Daschner, Jiasheng Chen, Patricia Alireza, and Malte Grosche — Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

Quantum oscillation measurements provide valuable information about the electronic properties of heavy fermion materials. By performing these measurements under hydrostatic pressure, it is possible to detect the Fermi surface and quasiparticle mass enhancement at interesting points of the phase diagram, and to measure their evolution as the strengths of Kondo and magnetic interactions are varied.

Tunnel diode oscillator (TDO) circuits offer a technique to detect quantum oscillations in the skin depth and magnetisation of samples with high precision, and can be extended to high hydrostatic pressures using microcoils in anvil cells [1]. Using the TDO technique, we have performed a quantum oscillation study on the heavy fermion semimetal YbPtBi, measuring the variation of its Fermi surface properties as the material is tuned by pressure. We will discuss the role of f-electrons and the field dependence of the Fermi surface by comparing our results to electronic structure calculations and other RPtBi compounds.

[1] Semeniuk et al., PNAS 120 (2023) e2301456120.

TT 11.3 Mon 15:30 H 3005

Origin of the non-Fermi-liquid behavior in $CeRh_2As_2$ — •Pavlo Khanenko[1,2], Konstantin Semeniuk[1], Daniel Hafner[1], Jacintha Banda[1], Thomas Lühmann[1], Javier F. Landaeta[1], Florian Bärtl[3], Tommy Kotte[3], Joachim Wosnitza[2,3], Gertrud Zwicknagl[4], Christoph Geibel[1], Seunghyun Khim[1], Elena Hassinger[2], and Manuel Brando[1] — [1]Max Planck Institute for Chemical Physics of Solids, Germany — [2]Institut für Festkörper- und Materialphysik, TU Dresden, Germany — [3]Hochfeld-Magnetlabor Dresden (HLD-EMFL) and Würzburg-Dresden Cluster of Excellence, Germany — [4]Institute for Mathematical Physics, Technische Universität Braunschweig, Germany

Unconventional superconductivity appears near magnetic quantum critical points (QCPs). This seems to be the case also for $CeRh_2As_2$ which is a multi-phase heavy-fermion superconductor ($T_c = 0.31$ K). Furthermore, another ordered state is observed below $T_0 \approx 0.48$ K whose nature is unclear, possibly a quadrupolar order. In addition, NQR/NMR experiments have detected an antiferromagnetic order below T_c. The presence of a QCP is indicated by the non-Fermi-liquid (NFL) behavior observed above the ordered states in both the specific heat, $C(T)/T \propto T^{-0.6}$, and the resistivity, $\rho(T) \propto \sqrt{T}$. Here, we present specific-heat measurements taken at a field applied at various angles α with respect to the crystallographic c axis. We observe that the NFL behavior depends very weakly on the field and on the angle α, a result that is at odds with that observed in standard magnetic QCPs. Possible origins for this unusual NFL behavior are discussed.

TT 11.4 Mon 15:45 H 3005

Low-temperature muon spin relaxation (μSR) studies on quality-improved $CeRh_2As_2$ single crystals — •Seunghyun Khim[1], Oliver Stockert[1], Manuel Brando[1], Christoph Geibel[1], Thomas J. Hickens[2], Christopher Baines[2], and Hubertus Luetkens[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Paul Scherrer Institute, Villigen, Switzerland

The unusual superconducting (SC) state ($T_c = 0.3$ K) of the heavy-fermion compound $CeRh_2As_2$ emerges from an unknown ordered state below $T_o = 0.55$ K, the precise nature of which has not been determined. Nuclear quadrupole/magnetic resonance (NQR/NMR) studies have revealed a clear signature of an antiferromagnetic order with a T_N very close to the T_c of the SC state. However, thermodynamic bulk measurements have not yet detected any anomalies associated with this T_N transition. To elucidate the multiple identified phases and their correlations, we conducted muon spin relaxation (μSR) studies of local magnetic properties in quality-improved $CeRh_2As_2$ single crystals at low temperatures. The experimental results will be discussed based on the unique characteristics of the Ce-4f moments and its intricate relation with superconductivity.

TT 11.5 Mon 16:00 H 3005

Characteristic energy scales in $CeRh_2As_2$ — •O. Stockert[1], M. M. Koza[2], and S. Khim[1] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany — [2]Institut Laue-Langevin, Grenoble, France

The heavy-fermion superconductor $CeRh_2As_2$ is located close to a quantum critical point and attracts a lot of attention due to its interplay of unconventional heavy-fermion superconductivity with $T_c \approx 0.25$ K and a possibly quadrupolar ordered state setting in above T_c. Recent measurements suggest the existence of antiferromagnetic order above the superconducting transition temperature. To better understand the unusual low-temperature properties of $CeRh_2As_2$, a knowledge of the relevant characteristic energy scales is important. We performed inelastic neutron scattering on $CeRh_2As_2$ powder to study the crystalline-electric-field (CEF) excitations and to look for the Kondo fluctuations. Our experiments reveal a low-lying excited CEF above the ground state doublet in addition to a Kondo enery scale of around 30 K. We will discuss our results in comparison to the previously suggested quadrupolar ground state and their implications for the ordered state.

15 min. break

TT 11.6 Mon 16:30 H 3005

Paradigm for the search of d-electron heavy fermions: the case of Cr-doped $CsFe_2As_2$ — •Matteo Crispino[1,2], Pablo Villar Arribi[1,3], Anmol Shukla[4], Frédéric Hardy[4], Amir-Abbas Haghighirad[4], Thomas Wolf[4], Rolf Heid[4], Christoph Meingast[4], Tommaso Gorni[1], Adolfo Avella[5], and Luca de' Medici[1] — [1]Laboratoire de Physique et Etude des Matériaux, UMR8213 CNRS/ESPCI/UPMC, Paris, France — [2]Institut für Theoretische Physik und Astrophysik and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, 97074 Würzburg, Germany — [3]International School for Advanced Studies (SISSA), Via Bonomea 265, I-34136 Trieste, Italy — [4]Karlsruhe Institute of Technology, Institute for Quantum Materials and Technologies (IQMT), 76021 Karlsruhe, Germany — [5]Dipartimento di Fisica "E. R. Caianiello", Università degli Studi di Salerno, I-84084 Fisciano, Italy

We define a general strategy to find new heavy-fermion materials without rare-earth elements: doping towards half-filling a Hund metal with pronounced orbital-selective correlations. We argue that in general bandstructures a possible orbital-selective Mott transition is frustrated by inter-orbital hopping into a heavy-fermion behaviour - with d-orbitals providing both heavy and light electrons - which is enhanced by approaching half-filling. This phase ultimately breaks due to magnetic correlations, as in a standard Doniach diagram. Experimentally we have hole-doped the Hund metal CsFe2As2, and obtained a heavy-fermion state with the highest Sommerfeld coefficient for Fe-pnictides to date (270 mJ/mol K^2), before antiferromagnetism sets in.

TT 11.7 Mon 16:45 H 3005

Magnetic adatoms as a probe for topological surface states in SmB_6. — •Fabiola Neumann[1], Michael Turaev[1], and Johann Kroha[1,2] — [1]University of Bonn, DE — [2]University of St. Andrews, UK

Recent scanning tunneling spectroscopy (STS) experiments on the surface of the predicted topological Kondo insulator SmB_6 revealed that the peak in the local surface density of states (LDOS) is suppressed by a Gd impurity at the surface [1]. Surprisingly, this suppression extends spatially to a distance of several nm from the impurity, much larger than the range of the impurity potential. In the present work, we model the SmB_6 bulk-surface heavy-fermion system by a layered auxiliary boson mean-field theory at temperature $T = 0$, while the Gd impurity possesses a static spin $s = 7/2$ in the 4f shell and a spin $s = 1/2$ in the 5d shell. In particular, we investigate two possible scenarios for the LDOS suppression: (1) Coupling of the static Gd magnetic moment to the electron spin in the Dirac *surface* band by which the Dirac node acquires a gap [1], and (2) Local destruction of the SmB_6 *bulk* topological heavy-fermion band by the time-reversal-breaking impurity which consequently removes the topological surface band. The latter mechanism may explain the long-range nature of the LDOS suppression via the Kondo coherence length $\xi_K = v_F/T_K$ where v_F is the Fermi speed and T_K the Kondo temperature.

[1] L. Jiao *et al.*, Sci. Adv. **4** (2018) eaau4886.

TT 11.8 Mon 17:00 H 3005

Realization of heavy fermion phase diagram in van der Waals heterostructures — •Somesh Chandra Ganguli — Aalto University School of Science, Finland

The heavy fermion compounds host a rich playground for correlated quantum states. In these compounds, the itinerant electrons in s, p or d shells interact with the lattice of localized magnetic moments in f shell via Kondo effect giving rise to Kondo lattice, resulting in a large effective mass as well as a gap in the conduction electron spectra, known as heavy fermion hybridization gap, which upon chemical doping can host unconventional superconductivity and quantum criticality. Recently, we have been able to demonstrate that heavy fermionic behavior can be created artificially using vdW epitaxy, using heterostructure of 2 different phases of the same material TaS_2. Stacking 1H-TaS_2 hosting 2-D conduction electrons, and 1T-TaS_2 hosting localized magnetic moments gives rise to Kondo lattice and heavy-fermion hybridization gap. We also observe, that in vdW heterostructure of similar material $NbSe_2$, the Kondo coupling (JK) does not overcome the exchange coupling (JAF) between the localised magnetic moments. Furthermore, the chemical potential becomes site dependent, driving the 1T-$NbSe_2$/1H-$NbSe_2$ system into the doped Mott insulator regime with exotic charge order. These observations establish artificial vdW heterostructures as a versatile platform to navigate the heavy fermion phase diagram.

TT 11.9 Mon 17:15 H 3005

Kondo physics and magnetism with high-order Van Hove singularities — •Krzysztof P. Wójcik[1], Johann Kroha[2,3], and Peter Wahl[3,2] — [1]Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland — [2]Physikalisches Institut, Universität Bonn, Germany — [3]SUPA, School of Physics and Astronomy, University of St Andrews, United Kingdom

Despite vast experimental progress in strongly-correlated electron research over last decades, a number of major puzzles remain unsolved. In particular, in some materials (e.g. strontium ruthenates) the nature of magnetic-field-driven quantum criticality has not been determined. It may be caused mainly by quantum fluctuations, or rather a second-order Van Hove singularity present near the Fermi level may play the major role [1]. To better understand the tension between these two mechanisms, an analysis of a simple impurity model is proposed, which can clarify the fate of the Kondo effect in the host exhibiting a spin-split Van Hove singularity.

The model is solved with numerical renormalization group. It is shown that the spin-splitting of the band stabilizes a novel strong-coupling partially polarized fixed point. Such splitting is seen experimentally in surface spectroscopy of $Sr_3Ru_2O_7$, even in the absence of external magnetic field [1]. The results concerning spin susceptibility and entropy will be presented, followed by the predictions of spectral properties and discussion of their significance for the correlated lattices.

[1] C. A. Marques *et al.*, Sci. Adv. **8** (2022) eabo7757.