TT 25: Correlated Electrons: Quantum-Critical Phenomena 1

Time: Wednesday 9:30–12:45 Location: H 3010

TT 25.1 Wed 9:30 H 3010

Deconfined quantum criticality and logarithmic violations of scaling — •Flavio Nogueira[1] and Asle Sudbo[2] — [1]Institut für Theoretische Physik III, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany — [2]Department of Physics, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

Recently logarithmic corrections to scaling were observed numerically in the so called $J-Q$ model. These violations of standard scaling were seen in numerical measurements of the spin-stiffness at zero temperature and uniform susceptibility at finite temperature. This result led to speculations that the deconfined quantum criticality scenario has to be revised in order to explain this new feature. We use the CP^{N-1} representation to derive the leading contribution to the spin stiffness at large N near the quantum critical point and show that it exhibits a logarithmic correction to scaling. This result shows that such logarithmic violations of scaling are in fact predicted by deconfined quantum criticality. Furthermore, the $U(1)$ gauge symmetry plays a crucial role here, since models without such local gauge symmetry do not exhibit logarithmic violations of scaling in 2+1 dimensions.

TT 25.2 Wed 9:45 H 3010

Usadel equation approach to fluctuation conductivity in disordered superconductors — Konstantin Tikhonov[1,2], •Georg Schwiete[3], and Alexander Finkelstein[1,4] — [1]Texas A&M University, College Station, Texas, USA — [2]Landau Institute for Theoretical Physics, Moskow, Russia — [3]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Germany — [4]The Weizmann Institute of Science, Rehovot, Israel

We study fluctuation corrections to the longitudinal and transverse conductivities in disordered superconducting films. The calculation covers a broad range of perpendicular magnetic fields and temperatures, including the vicinity of the magnetic field-tuned quantum critical point. Our calculation scheme is based on the Usadel equation, which we adjust to account for the fluctuating order parameter field.

TT 25.3 Wed 10:00 H 3010

Quantum dynamical crossover from coherent to incoherent dynamics in a Sub-Ohmic independent Boson model — •Peter Nalbach and Michael Thorwart — I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany

The sub-Ohmic spin-boson model shows with increasing coupling to a Sub-Ohmic bath a crossover from coherent to incoherent dynamics at zero (and at low) temperatures. The same system shows a quantum phase transition. However, in general both effects happen for different coupling strength. In order to study the connection between the dynamic crossover and the quantum phase transition we investigate an asymmetric Sub-Ohmic spin boson model and focus on the limit of vanishing tunneling. This results in a Sub-Ohmic independent Boson model which is exactly solvable. For this, we calculate the time evolution of the correlation function of the tunneling operators at zero temperature which allows to study the coherence properties even in absence of a direct tunnel coupling. Thus, we can determine the crossover coupling strength analytically. Most importantly, we compare it with numerical findings in the symmetric Sub-Ohmic spin boson model.

TT 25.4 Wed 10:15 H 3010

Quantum criticality with multiple dynamics — •Tobias Meng, Markus Garst, and Achim Rosch — Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany

Close to a quantum critical point, physical properties obey scaling laws characterizing the nature of the quantum critical point and allowing to conveniently interpret experiments. Conventional quantum critical scaling however depends on the hypothesis that only a single time scale diverges at the critical point, $\tau \sim \xi^z$, where the correlation length ξ becomes infinite. We analyze systems with multiple degrees of freedom that have two distinct characteristic time scales. While in some cases, the different dynamics influence each other only mildly, the interplay of multiple dynamics can also generate new critical exponents and give rise to unusual scaling laws.

TT 25.5 Wed 10:30 H 3010

Quantum criticality of the sub-ohmic spin-boson model — •Stefan Kirchner[1,2], Kevin Ingersent[3], and Qimiao Si[4] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Max Planck Institute for Chemical Physics of Solids — [3]Department of Physics, University of Florida — [4]Department of Physics & Astronomy, Rice University

The sub-ohmic spin-boson model has a quantum critical point separating a delocalized phase in which the impurity degree of freedom is quenched and a boson-dominated localized phase that retains a two-fold local-moment degree of freedom. Whether this quantum phase transition is described by a ϕ^4-theory has recently received considerable attention. Here, we present an analysis of both the leading and subleading terms in the temperature dependence of the inverse static local spin susceptibility calculated using a numerical renormalization-group method. This provides evidence that the quantum critical point is interacting in cases where the quantum-to-classical mapping would predict mean-field behavior. We attribute the violation of the quantum-to-classical mapping to a Berry-phase term in a continuum path-integral representation of the model.

TT 25.6 Wed 10:45 H 3010

Functional renormalization group approach to singular interactions in 2D metals — •Casper Drukier, Lorenz Bartosch, Aldo Isidori, and Peter Kopietz — Universität Frankfurt, Frankfurt am Main, Germany

Using functional renormalization group methods we study an effective low-energy model describing the breakdown of Fermi-liquid behaviour in two-dimensional metals when gapless fermions at the Fermi surface are coupled by a fluctuating bosonic order parameter.

Using a field-theoretical approach, Metlitski and Sachdev [Phys. Rev. B 82, 075127] have recently found that certain three-loop diagrams strongly modify the one-loop results, and that the conventional 1/N expansion breaks down in this problem. We show that the three-loop diagrams discovered by Metlitski and Sachdev are contained in a rather simple truncation of the functional renormalization group flow equations, containing only irreducible vertices with two and three legs. An approximate solution of these flow equations yields explicit expressions for the vertex corrections, and allows us to calculate the scale-dependent anomalous dimension beyond one-loop level.

TT 25.7 Wed 11:00 H 3010

Tuning the spin dynamics of kagome systems — •Dirk Wulferding[1], Peter Lemmens[1], Hiroyuki Yoshida[2], Yoshihiko Okamoto[3], and Zenji Hiroi[3] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]NIMS, Tsukuba, Japan — [3]ISSP, Tokyo, Japan

Kagome lattice systems are among the most promising candidates for realizing a quantum spin liquid state. We compare the excitation spectra of different kagome compounds and demonstrate that the ground state properties depend critically on the underlying crystal structure. Work supported by DFG, B-IGSM and NTH School for Contacts in Nanosystems.

15 min. break.

TT 25.8 Wed 11:30 H 3010

Ferromagnetic quantum criticality in the new heavy-fermion system $YbNi_4P_2$ — •Manuel Brando, Alexander Steppke, Stefan Lausberg, Robert Kuechler, Edit Lengyel, Lucia Steinke, Cornelius Krellner, Robert Borth, Michael Nicklas, Christoph Geibel, and Frank Steglich — Max-Planck-Institut für Chemische Physik fester Stoffe Nöthnitzer Str. 40, 01187 Dresden, Germany

We present measurements of the ac-susceptibility, specific heat (C) and thermal expansion (α) on single crystals of the new quasi-one-dimensional heavy-fermion system $YbNi_4P_2$.
$YbNi_4P_2$ is a Kondo-lattice system that orders ferromagnetically at a very low temperature $T_c = 0.17$ K [1]. Ferromagnetism can be suppressed by arsenic substitution x on phosphorus site and a ferromagnetic (FM) quantum critical point (QCP) is approached at $x = 0.08$.
We provide evidence that such a FM-QCP exists in $YbNi_4(P_{0.92}As_{0.08})_2$ by showing that (i) the magnetic transition

remains ferromagnetic between $x = 0$ and $x = 0.08$, (ii) no phase transition nor Fermi-liquid ground state down to 0.02 K can be observed at $x = 0.08$, and finally (iii) the Grüneisen ratio $\Gamma = \alpha/C$ strongly diverges [2] with decreasing temperature as $\Gamma \sim T^{-0.3}$.
Part of this work has been supported by the DFG Research Unit 960 "Quantum Phase Transitions".
[1] C. Krellner *et al.*, New J. Phys. **13** (2011) 103014
[2] L. Zhu *et al.*, Phys. Rev. Lett. **91** (2003) 066404

TT 25.9 Wed 11:45 H 3010

Pressure dependence of the topological Hall effect in MnSi — •Robert Ritz, Marco Halder, Christian Franz, Michael Wagner, Andreas Bauer, Christoph Schnarr, and Christian Pfleiderer — Physik Department E21, Technische Universität München, D-85748 Garching, Germany

The observation of a topological Hall signal in the A-phase of MnSi [1] provides unambiguous, quantitative evidence of the non-trivial topology of the skyrmion lattice first inferred from small angle neutron scattering [2]. We report a comprehensive study of the pressure dependence of the topological Hall signal in MnSi. We connect the behaviour reported for the pressure range 6 to 12 kbar [3] with the properties at ambient pressure and explore the importance of various aspects of the experimental set up. Careful temperature and field dependent measurements reveal that the topological Hall signal in MnSi increases monotonically from 4 nΩcm at ambient pressure and appears to limit at a large intrinsic value of ~ 50 nΩcm as the helimagnetic transition temperature decreases.
[1] A. Neubauer et al., Phys. Rev. Lett. **102**, 186602 (2010).
[2] S. Mühlbauer et al., Science, Vol **323**, 915 (2009).
[3] M. Lee et al., Phys. Rev. Lett. **102**, 186601 (2010).

TT 25.10 Wed 12:00 H 3010

Electron Spin Resonance of the Yb $4f$-moment in $Yb(Rh_{1-x}Co_x)_2Si_2$ — Thomas Gruner, •Jörg Sichelschmidt, Christoph Klingner, Cornelius Krellner, Christoph Geibel, and Frank Steglich — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden

The evolution of spin dynamics from the quantum critical system $YbRh_2Si_2$ to the stable trivalent Yb system $YbCo_2Si_2$ was investigated by Electron Spin Resonance (ESR) spectroscopy. While the Kondo temperature changes by one order of magnitude all compositions of the single crystalline series $Yb(Rh_{1-x}Co_x)_2Si_2$ show well defined ESR spectra with a clear Yb^{3+} character for temperatures below ≈ 20 K. With increasing Co-content the ESR g-factor along the c-direction strongly increases indicating a continuous change of the ground state wave function and, thus, a continuous change of the crystal electric field. The linewidth presents a complex dependence on the Co-content and is discussed in terms of the Co-doping dependence of the Kondo interaction, of the magnetic anisotropy and the influence of ferromagnetic correlations between the $4f$ states. The results provide evidence that for low Co-doping the Kondo interaction allows narrow ESR spectra despite the presence of a large magnetic anisotropy whereas at high Co-concentrations the linewidth is controlled by ferromagnetic correlations. A pronounced broadening due to critical correlations at low temperatures is only observed at the highest Co-content. This might be related to the presence of incommensurate magnetic fluctuations.

TT 25.11 Wed 12:15 H 3010

Influence of charge carrier doping on the T^*-Scale in $YbRh_2Si_2$ — •Maik-Hendrik Schubert, Manuel Mchalwat, Elias Blumenröther, H. S. Jeevan, Yoshi Tokiwa, and Philipp Gegenwart — I. Physik. Institut, Georg-August Universität Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen, Germany

$YbRh_2Si_2$ is a prototype heavy-fermion metal which displays a magnetic field-induced antiferromagnetic (AF) quantum critical point (QCP). It has attracted much attention due to an additional low-energy scale $T^\star(B)$ merging at the QCP, whose origin is controversially discussed. Here, we report measurements of the electrical resistivity $\rho(T, B)$ on different single crystalline samples of charge-carrier doped $Yb(Rh_{1-x}T_x)_2Si_2$ (T=Fe, Ni) at temperatures down to 15 mK and in magnetic fields up to 7 T. The partial substitution of Rh by either Fe or Ni introduces holes or electrons, respectively. The evolution of the single-ion Kondo scale is similar as for isoelectronic Co substitution and in accordance with the chemical pressure effect. However, while chemical pressure has little influence on $T^\star(B)$, we observe a drastic reduction or increase of $B^\star(T = 0)$ by Fe- or Ni-doping, respectively. Most interestingly, $B^\star(T = 0)$ is always pinned at the field-induced AF QCP, in contrast to chemical pressure results. As AF order is completely suppressed by Fe-doping, a heavy Fermi liquid ground (without $T^\star(B)$ anomaly) is observed.

Work supported by the DFG through the research unit 960 (Quantum phase transitions).

TT 25.12 Wed 12:30 H 3010

Electron spin resonance on $YbRh_2Si_2$ at mK temperatures close to the quantum critical point — •Marc Scheffler[1], Conrad Clauss[1], Martin Dressel[1], Jörg Sichelschmidt[2], Cornelius Krellner[2], Christoph Geibel[2], and Frank Steglich[2] — [1]1. Physikalisches Institut, Universität Stuttgart, Germany — [2]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany

$YbRh_2Si_2$ is a prototypical heavy-fermion material close to a quantum critical point: the antiferromagnetic order can be suppressed by a small external magnetic field of 60mT. Above this quantum critical point, a broad region of the phase diagram displays signatures of quantum criticality. Furthermore, a Landau Fermi-liquid regime is found for magnetic fields higher than the quantum critical point. Previous electron spin resonance (ESR) measurements on $YbRh_2Si_2$ demonstrated that the ESR response of this Kondo lattice system is characterized by the properties of local Yb moments. So far, ESR studies on $YbRh_2Si_2$ were limited to temperatures above 500mK and could not access the quantum critical regime close to the QCP nor the antiferromagnetic phase.

Here we present ESR measurements on $YbRh_2Si_2$ single crystals performed in a dilution refrigerator down to temperatures below 100mK. With ESR frequencies of a few GHz, we can cover temperature and field regimes close to the quantum critical point. We present the temperature and field dependences of the ESR parameters, in particular the ESR g-factor, and discuss them in the context of recent theoretical models.