TT 38: Correlated Electrons: Spin Systems and Itinerant Magnets 1

Time: Thursday 9:30–13:00 Location: H 3010

TT 38.1 Thu 9:30 H 3010

Disentanglement of static and dynamic magnetism in itinerant $A\mathbf{Fe}_4X_2$ systems studied by Muon Spin Relaxation and Mössbauer Spectroscopy — •Til Goltz[1], Nandang Mufti[2], Christoph Geibel[2], Johannes Spehling[1], Hubertus Luetkens[3], and Hans-Henning Klauss[1] — [1]Institute of Solid State Physics, TU Dresden, Germany — [2]MPI for Chemical Physics of Solids, Dresden, Germany — [3]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, Villigen, Switzerland

The $A\mathrm{Fe}_4X_2$ (A=Y, Lu, Zr; X=Ge, Si) family of transition metal tetrels has shown to be a promising candidate for studying the change of the electronic ground state under chemical substitution [1]. Within the $\mathrm{ZrFe}_4\mathrm{Si}_2$-type structure ($\mathrm{P4}_2/\mathrm{mnm}$), the iron atoms are arranged in chains of edge-linked tetrahedra [2]. Their structure is prone for reduced dimensionality or frustration and is thus expected to lead to emergent phenomena near a quantum critical point.
In this talk, we give an overview of our recent experimental findings from Muon Spin Relaxation and Mössbauer Spectroscopy experiments for a variety of $A\mathrm{Fe}_4X_2$. We focus on the $\mathrm{ZrFe}_4\mathrm{Si}_2$ compound, where we observe electronic spin fluctuations already at 100 K whereas long-range magnetic order sets in only below 10 K.
[1] N. Mufti, T.G. et al., DPG Spring Meeting 2011 (TT 49.11)
[2] O.Ya. Oleksyn et al., Proc. 10th Int. Conf. Solid Compounds of Transition Elements, Münster, 1991

TT 38.2 Thu 9:45 H 3010

Non-magnetic impurities in a classical spin liquid — •Arnab Sen[1], Kedar Damle[2], and Roderich Moessner[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [2]Tata Institute of Fundamental Research, Mumbai, India

Impurities can potentially reveal the underlying correlations in spin liquid states that appear deceptively featureless in their ground state properties. We consider the archetypal frustrated antiferromagnet $\mathrm{SrCr}_{9p}\mathrm{Ga}_{12-9p}\mathrm{O}_{19}$ (SCGO) in which Ga ions act as non-magnetic impurities in the magnetic lattice composed of Cr^{3+} S=3/2 spins for disordered $p < 1$ samples. We show that a spin in direct proximity to a pair of vacancies is cloaked by a spatially extended spin texture that encodes the correlations of the parent spin liquid. In this spin liquid regime, our analytic theory predicts that the combined object has a magnetic response identical to a classical spin of length S/2=3/4, which dominates over the small intrinsic susceptibility of the pure system. We calculate the full texture on the lattice in the spin liquid regime and check that it agrees well with Monte-Carlo (MC) simulations. This texture leaves an unmistakable imprint on the measured ^{71}Ga NMR lineshapes, which we compute using MC simulations and compare with experimental data. These spin-textures have long range interactions with each other in the spin liquid regime. We show how these interactions can be understood in a simple manner from our analytic theory, and support the predictions using numerical simulations.

TT 38.3 Thu 10:00 H 3010

Magnetic excitations in disordered striped antiferromagnetic insulators — •Eric Andrade and Matthias Vojta — Technische Universität Dresden

The compounds of the $\mathrm{La}_{2-x}\mathrm{Sr}_x\mathrm{CoO}_4$ series are isostructural to the 214 family of cuprate superconductors, but nevertheless remain insulating over a wide range of doping. Recently, it was observed that the $x = 1/3$ compound displays a peculiar type of magnetism, with short-ranged static antiferromagnetic order and an hour-glass-like magnetic excitation spectrum, which can be directly associated with the presence of stripe order. Here we argue that inhomogeneities, coming from deviations of perfectly ordered stripes, are of central importance and, by calculating the magnetic excitation spectrum, we show that a scenario of disordered charge stripes (formed by Co^{2+} and Co^{3+} ions) is consistent with the experimental data.

TT 38.4 Thu 10:15 H 3010

Orbital and magnetic excitations in the weakly coupled spin chain system $\mathbf{CaCu_2O_3}$ — •Valentina Bisogni[1], Krzysztof Wohlfeld[1], Roberto Kraus[1], Jan Trinckauf[1], Claude Monney[2], Satoshi Nishimoto[1], Ke Jin Zhou[2], Vladimir Strocov[2], Bernd Büchner[1], Jeroen van den Brink[1], Thorsten Schmitt[2], and Jochen Geck[1] — [1]IFW Dresden, Dresden, Germany — [2]Paul Scherrer Institut, Villigen PSI, Switzerland

Recently, resonant inelastic X-ray scattering (RIXS) on the 1D spin chain system Sr_2CuO_3 has revealed an unprecedented and strong dispersion of d-d excitations. This result has been interpreted as the spin and orbital separation from the elementary electron in a 1D S=1/2 system. In this talk we report on Cu L_3 RIXS in quasi 1D $CaCu_2O_3$ consisting of two coupled spin chains. Due to its buckled geometry, the inter-chain interaction of this system is one order of magnitude smaller than the in-chain interaction. Therefore, $CaCu_2O_3$ is an ideal model system to study the effect of a weak inter-chain interaction on both the low (spin excitation) and the high (d-d excitations) energy scale. Although the dispersion of the spinon continuum can largely be accounted for by neglecting the presence of the inter-chain interaction, surprisingly the absence of a strong dispersion in the d-d excitations emerges from the raw data. A deep analysis of these results shows indeed that the various orbital channels feel different dimensionalities, 1D or 2D. The important role played by inter-chain interactions for the magnetic and orbital excitations in this class of compounds will be discussed in this context.

TT 38.5 Thu 10:30 H 3010

Pulse field ultrasonic experiments in the quasi-2d antiferromagnet $\mathbf{Cs_2CuBr_4}$ — •Bernd Wolf, Pham Thanh Cong, Natalia Krüger, Franz Ritter, Wolf Assmus, and Michael Lang — Physikalisches Institut Goethe-Universität, SFB/TR 49; Frankfurt

The insulator Cs_2CuBr_4 is a frustrated quasi-twodimensional triangular lattice (bc plane) spin-1/2 Heisenberg antiferromagnet (HAFM) with a weak interlayer coupling. The long-range antiferromagnetic order ($T_N = 1.4$ K at B = 0) can be suppressed to $T_N = 0$ in a magnetic field $B_c \sim 31$ T (B//a). For temperatures $T > T_N$ the magnetic properties of the material are dominated by quasi-2d spin fluctuations, which are also present in the ordered magnetic state. Here we present pulsed field measurements up to 50 T of the longitudinal elastic constants c_{11} for 1.2 K < T < 4.2 K. A large softening, caused by the coupling of the quasi-2d spin fluctuations, is observed for magnetic fields smaller than B_c, which is more pronounced for lower temperatures. As expected, in the fully polarized state, the c_{11} mode is field independent for all temperatures. In addition, we compare the magnetoelastic properties of Cs_2CuBr_4 with those of the isostructural quasi-2D HAFM Cs_2CuCl_4.

TT 38.6 Thu 10:45 H 3010

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TT 38.7 Thu 11:00 H 3010

Low temperature thermal and electrical transport properties of $\mathbf{ZrZn_2}$ in high magnetic field — •Yang Zou[1], Michael Sutherland[1], Stephen Hayden[2], Daniel Rothfuss[3], Andreas Fleischmann[3], Christian Enss[3], and F. Malte Grosche[1] — [1]University of Cambridge, UK — [2]University of Bristol, UK — [3]Universität Heidelberg, Germany

Metals close to a ferromagnetic quantum critical point offer a comparatively clear and well-defined environment to investigate the breakdown of Landau's Fermi liquid theory. The low temperature band ferromag-

net $ZrZn_2$ violates the predictions of Fermi liquid theory over a wide temperature range at low temperatures. Transport and heat capacity measurements suggest the presence of a marginal Fermi-liquid, predicted to occur close to a ferromagnetic quantum critical point by spin fluctuation theory [1]. In order to investigate the nature of the Fermi-liquid breakdown in this material, we have implemented electrical and thermal conductivity measurements down to temperatures of 100 mK and in high magnetic field. In zero field our measurements confirm the finding reported in [2] that, to leading order in temperature T, the electrical and effective thermal resistivities at low temperature take a $T^{5/3}$ and T form, respectively. These are the signatures of the marginal Fermi-liquid. At very low temperatures and in finite magnetic field we find that the electrical resistivity assumes quadratic temperature dependence, consistent with a return to conventional Fermi-liquid behaviour.

[1] Sutherland et al. ArXiv:1110.5240v1 [cond-mat.str-el].
[2] Smith et al. Nature **455** 7217 (2008).

15 min. break.

Invited Talk TT 38.8 Thu 11:30 H 3010

Emergent electrodynamics of skyrmions in chiral magnets — •Christian Pfleiderer — Technische Universität München, D-85748 Garching, Germany

Small angle neutron scattering and measurements of a topological Hall signal identify the formation of skyrmion lattices in the non-centrosymmetric B20 compounds MnSi, $Mn_{1-x}Fe_xSi$, $Mn_{1-x}Co_xSi$ and the strongly doped semiconductor $Fe_{1-x}Co_xSi$. This observation has been confirmed by Lorentz force microscopy in thin samples of $Fe_{1-x}Co_xSi$, FeGe and, most recently, MnSi, where even individual skyrmions have been spotted. Because the skyrmion lattices are exceptionally weakly pinned to the crystal lattice, extreme care has to be exercised when studying the precise intrinsic morphology of related spin textures in bulk samples. As a particularly striking property each skyrmion supports precisely one quantum of emergent magnetic flux. This permits a highly efficient coupling between skyrmions and conduction electrons which results in spin torque effects at ultra-low current densities as seen in small angle neutron scattering and the emergent electric field when the skyrmions move.

Work in collaboration with: T. Adams, A. Bauer, B. Binz, P. Böni, G. Brandl, R. A. Duine, K. Everschor, C. Franz, M. Garst, R. Georgii, S. Gottlieb-Schönmeyer, M. Halder, W. Heusler, M. Janoschek, F. Jonietz, T. Keller, K. Mittermüller, S. Mühlbauer, W. Münzer, A. Neubauer, P.G. Niklowitz, R. Ritz, A. Rosch, C. Schnarr, T. Schulz, A. Tischendorf and M. Wagner

TT 38.9 Thu 12:00 H 3010

Fluctuation-driven first order transition in the chiral magnets — •M. Garst[1], M. Janoschek[2,3,4], P. Krautscheid[1], A. Bauer[3], C. Pfleiderer[3], P. Böni[3], and R. Georgii[3,5] — [1]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, D-50937 Köln — [2]Department of Physics, University of California, San Diego, La Jolla, CA 92093-0354, USA — [3]Physik Department E21, Technische Universität München, D-85748 Garching — [4]Laboratory for Neutron Scattering, Paul-Scherrer Institut & ETH Zürich, CH-5232 Villigen, PSI, Switzerland — [5]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), Technische Universität München, D-85748 Garching

Chiral magnets such as MnSi, $Fe_{1-x}Co_xSi$, MnGe or FeGe possess a weak Dzyaloshinskii-Moriya spin-orbit interaction that leads to a twist of the magnetization on long length scales resulting in chiral magnetic textures. We discuss theoretically and experimentally how this chiral spin-orbit interaction is reflected in the spin dynamics close to the magnetic transition at T_c in MnSi and related compounds. As the transition is approached chiral fluctuations become soft resulting in neutron scattering intensity concentrated on a sphere in reciprocal space. At a characteristic Ginzburg temperature $T^* > T_c$ these fluctuations start to interact strongly resulting in pronounced renormalization effects, causing a turning point in the susceptibility $\partial_T^2 \chi(T) = 0$ and an invariant point in the specific heat $\partial_H C(H) = 0$, also known as Vollhardt invariance. Perhaps even more importantly, these chiral critical fluctuations drive the magnetic transition at T_c first order consistent with a Brazovskii theory for chiral magnetic fluctuations.

TT 38.10 Thu 12:15 H 3010

On the magnetic phase diagram of B20 compounds inferred from magnetization and ac susceptibility — •Andreas Bauer and Christian Pfleiderer — Physik Department E21, Technische Universität München, D-85747 Garching, Germany

We report comprehensive, simultaneous measurements of the magnetisation, M, and the ac susceptibility, χ_{ac}, across the magnetic phase diagram of optically float-zoned high-quality single crystals of MnSi, where we explore the importance of the excitation frequency, excitation amplitude, sample shape, and crystallographic orientation. We show that the temperature dependence of the magnetisation of MnSi reported by Kadowaki et al. [1] is connected with a single skyrmion phase. Moreover, our data establishes consistently for all major crystallographic directions a well defined, slightly broadened first order transition at the helical to conical phase boundary, as well as for the skyrmion lattice phase. The same general features are also observed for typical temperature and field scans in $Mn_{1-x}Fe_xSi$ and $Fe_{1-x}Co_xSi$. Taken together, our results question the phase diagram of FeGe reported by Wilhelm et al., which was purely inferred from the ac susceptibility at 1 kHz of a vapour grown single crystal with ill-defined sample shape for a single field direction [2].

[1] K. Kadowaki et al., J. Phys. Soc. Japan, **51**, 2433 (1982)
[2] H. Wilhelm et al., PRL **107**, 127203 (2011)

TT 38.11 Thu 12:30 H 3010

Relevance of magnetic anisotropies for the skyrmion lattice in MnSi — •Tim Adams[1], Andreas Bauer[1], Marco Halder[1], Robert Georgii[1,2], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik-Department E21, D-85748 Garching, Germany — [2]Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II), D-85748 Garching, Germany

We used high-precision small angle neutron scattering and magnetisation measurements to determine the strength of the magnetic anisotropies in MnSi. To minimise the effects of uncontrolled demagnetising fields a spherical sample was studied. The strength of the leading order quartic anisotropy terms, which by symmetry arguments cannot couple to the skyrmion lattice, are thereby inferred from variations of the transition field to the conical state. This is followed by anisotropy terms beyond fourth order, which are inferred from the orientation of the skyrmion lattice in the plane perpendicular to the applied field and tiny systematic tilts out of this plane. Taken together our data allows us to discuss the relevance of magnetic anisotropies for the morphology and stabilityof the skyrmion lattice in bulk samples of MnSi and related systems.

TT 38.12 Thu 12:45 H 3010

Uniaxial pressure studies of helimagnetic order and the skyrmion lattice phase in MnSi — •Alfonso Chacón Roldán[1], Andreas Bauer[1], Tim Adams[1], Georg Brandl[1,2], Robert Georgii[2], Peter Böni[1], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik-Department E21, D-85748 Garching, Germany — [2]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), D-85748 Garching, Germany

We report small angle neutron scattering and ac susceptibility measurements of the uniaxial pressure dependence of the helimagnetic order and the skyrmion lattice phase in MnSi. For our studies a bespoke sample stick with a He-activated bellow system has been built that permits simultaneous neutron scattering and susceptibility measurements. We find that both the helimagnetic order as well as the skyrmion lattice phase are very sensitive to the application of uniaxial stress. Besides a reorientation of the skyrmion lattice the most prominent effect is either a pronounced suppression or an enhancement of the skyrmion lattice phase depending on the field and stress direction. We discuss our results in the context of the mechanism that stabilises the skyrmion lattice phase.