# TT 3: Correlated Magnetism – General

Time: Monday 9:30–12:45 Location: H32

TT 3.1 Mon 9:30 H32

**The zoo of states in the 2D Hubbard model** — •Robin Scholle[1], Pietro Bonetti[1,2], Demetrio Vilardi[1], and Walter Metzner[1] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Harvard University, Cambridge, USA

We use real-space Hartree-Fock theory to construct a magnetic phase diagram of the two-dimensional Hubbard model as a function of temperature and doping. We are able to detect various spin- and charge order patterns including Néel, stripe and spiral order without biasing the system towards one of them. For an intermediate interaction strength we predominatly find Néel order close to half-filling, stripe order for low temperatures or large doping, and an intermediate region of spiral order.

I will give a short summary of the method followed by a presentation of our current results and an outlook for possible further applications.

TT 3.2 Mon 9:45 H32

**Hidden quantum correlations in the ground states of quasi-classical spin systems** — •Levente Rózsa[1,2], Dennis Wuhrer[3], Sebastián A. Díaz[3], Ulrich Nowak[3], and Wolfgang Belzig[3] — [1]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest, Hungary — [3]University of Konstanz, Konstanz, Germany

Entanglement is a unique property of quantum systems, which is widely studied in strongly correlated materials and in quantum information theory. Here, we investigate the entanglement between magnons, the quanta of spin waves, around a classical spin-spiral ground state stabilized by frustrated exchange interactions [1]. We find that the entanglement between pairs of sites completely vanishes in certain parameter regimes, where quantum correlations can only be observed in multi-site clusters. We analyze the magnitude and the spatial dependence of the entanglement in the vicinity of classical phase transitions, and discuss the role of the symmetries of the ground state.

[1] L. Rózsa et al., arXiv:2411.08394.

TT 3.3 Mon 10:00 H32

**Measurement of magnetic anisotropy in $CsV_3Sb_5$ using torque magnetometry** — •Tobi Gaggl[1], Toshiki Kiyosue[2], Ryo Misawa[3], Tomoya Asaba[2], Max Hirschberger[3], and Yuji Matsuda[2] — [1]Technical University of Munich, Germany — [2]Kyoto University, Japan — [3]The University of Tokyo, Japan

Materials with a kagome lattice have emerged as a fertile ground for exploring nontrivial electronic states arising from the interplay between band topology and magnetic frustration. The kagome metals $AV_3Sb_5$ (A=K, Cs or Rb), which exhibit charge density wave ordering (CDW), may host such exotic states. It is believed that the CDW in kagome metals is of unconventional nature, thus advanced techniques for precise measurements are required for characterization.

This study investigates the CDW phase transition in $CsV_3Sb_5$ using a piezoresistive cantilever rotating in a magnetic field as an angular-dependent torquemeter. This method enables precise measurements of magnetization in single crystals and a powerful setup sensitive to changes in rotational symmetry. The results show a distinct two-fold out-of-plane magnetic anisotropy, which is due to the two-dimensional nature of the kagome lattice and consistent with previous calculations. The progression of the measured temperature-dependent magnetic anisotropy shows a clear kink at 94 K, confirming previously published results for the onset of CDW. My current work focuses on the development of novel kagome materials that could exhibit CDWs.

TT 3.4 Mon 10:15 H32

**Detection of skyrmion lattices by dilatometric measurements** — •Mathias Doerr[1], Justus Grumbach[1], Sergey Granovsky[1], Martin Rotter[1], and Max Hirschberger[2,3] — [1]Technische Universität Dresden, Institut für Festkörper- und Materialphysik, 01062 Dresden, Germany — [2]Department of Applied Physics and Quantum-Phase Electronics Center, University of Tokyo, Tokyo 113-8656, Japan — [3]RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan

Magnetic skyrmion lattices (SkL) with a characteristic structure size smaller than 3 nm in metallic $Gd_3Ru_4Al_{12}$ with a planar breathing kagome lattice, already demonstrated by X-ray diffraction and topological Hall effect studies [1], open up new possibilities for the effective transmission of information. The interplay between helically determined skyrmion patterns and underlying crystallographic structures offers the possibility to clearly determine the stability region of skyrmions by dilatometric measurements. We report high-precision measurements of magnetostriction and thermal expansion on $Gd_3Ru_4Al_{12}$ and construct the magnetic phase diagram. Additional MonteCarlo simulations with *McPhase* confirm an asymmetric magnetic triple-$\boldsymbol{q}$ structure without symmetry breaking at the ordering temperature. The relationship between crystallographic distortion and formation of the SkL is also discussed.

[1] M. Hirschberger *et al.*, Nat. Commun. 10, 5831 (2019).

TT 3.5 Mon 10:30 H32

**Electronic structure of the noncentrosymmtric tetragonal antiferromagnet $EuPtSi_3$** — •Katharina Müller[1], André Deyerling[1], Andreas Bauer[1,2], Wolfgang Simeth[1,3], Christian Franz[1,4], Christian Pfleiderer[1,2,5,6], and Marc A. Wilde[1,2] — [1]Physik Department, TUM School of Natural Sciences, TUM, Germany — [2]Zentrum für Quantum Engineering (ZQE), TUM, Germany — [3]Los Alamos National Laboratory, Los Alamos, NM, USA — [4]Jülich Centre for Neutron Science (JCNS) at MLZ, Forschungszentrum Jülich GmbH, Germany — [5]Munich Center for Quantum Science and Technology (MCQST), TUM, Germany — [6]Heinz Maier-Leibnitz Zentrum (MLZ), TUM, Germany

The localized $Eu^{2+}$ moments of the rare-earth compound $EuPtSi_3$ were reported to show magnetic ordering below the Néel temperature $T_N = 17$ K [1]. With a magnetic field applied in the magnetically hard basal plane, four different types of noncollinear antiferromagnetic order emerge, one of which is commensurate with the lattice [2]. This coplanar canted magnetic structure breaks the crystal symmetry such that Berry curvature contributions are allowed and electronic transport phenomena may be affected. We study this link between the magnetic and the electronic structure with ab initio calculations, in particular highlighting the effect of changing the canting angle from the antiferromagnetic towards the spin-polarized state.

[1] A. Bauer et al., PRM **6**, 034406 (2022).
[2] W. Simeth et al., PRL **130**, 266701 (2023).

TT 3.6 Mon 10:45 H32

**Thermal Hall transport driven by spin fluctuations** — •Ignacio Salgado-Linares[1,2], Alexander Mook[3], and Johannes Knolle[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Johannes Gutenberg University Mainz, Institute of Physics, Staudingerweg 7, Mainz 55128, Germany

In recent years, the thermal Hall effect has emerged as a powerful tool for probing topological phenomena of magnetic systems. At low temperatures, the thermal Hall transport of long-range ordered magnets can be described in the framework of linear spin-wave theory (LSWT). However, how to treat regimes with increased thermal fluctuations or non-linearities beyond LSWT is an outstanding question. Therefore, within this project, we developed a numerical technique to extract the thermal Hall transport properties, which intrinsically includes non-linear effects. In particular, we use semi-classical spin dynamics simulations to compute thermal currents due to chiral spin fluctuations in a square lattice model with Heisenberg interaction and DMI. The results are expected to shed new light on the topological thermal transport in systems where topology does not arise from static spin textures, but from spin fluctuations.

TT 3.7 Mon 11:00 H32

**Pressure tuning of ferromagnetism in the Kagome metal CrNiAs** — •Bin Shen[1], Franziska Breitner[1], Victoria A. Ginga[2], Philipp Gegenwart[1], and Alexander A. Tsirlin[2] — [1]EP VI, EKM, University of Augsburg, Germany — [2]Felix Bloch Institute, University of Leipzig, Germany

Ferromagnetic Kagome metals attract considerable interest as quantum materials with nontrivial topological electronic states. Here, we present our extensive study on single crystals of CrNiAs, crystallizing in a hexagonal structure with space group of P$\overline{6}$2m, featuring a distored kagome lattice of magnetic Cr. CrNiAs undergoes a ferromagnetic phase transition at $T_C = 135$ K, where the *c*-axis is the easy axis. At $T^\star = 90$ K another phase transition is found, likely driven by magnetism, associated with a shrinkage of the *c*-axis while the *ab*-plane expands. Anomalous Hall effect is observed in the magnetically ordered state of CrNiAs. We also report the pressure tuning of ferromagnetism.

Supported by DFG-TRR 360-492547816 and the Alexander von Humboldt Foundation.

**15 min. break**

TT 3.8 Mon 11:30 H32

**Electronic transport measurements in Kagome metal $Yb_{0.5}Co_3Ge_3$** — •Zhiyuan Cheng[1], Heng Wu[2], Yaojia Wang[2], Peter van Veldhuizen[1], Federica Galli[1], Mazhar Ali[2], Julia Chan[3], and Semonti Bhattacharyya[1] — [1]Leiden University, Leiden, the Netherlands — [2]Delft University of Technology, Delft, the Netherlands — [3]Baylor University, Waco, United States

Kagome lattice has a unique geometry that gives rise to interesting band structures. As a result, Kagome lattices exhibit various properties, such as superconductivity, topological surface states, and complex magnetism. However, it is still yet to be well understood how these quantum properties intertwine with each other. Electrical doping, strain, and pressure can be utilized as powerful tools to modulate and investigate the rich physics of such complex systems.

In this project, we investigate a Kagome metal $Yb_{0.5}Co_3Ge_3$ that is known to exhibit charge density wave and complex magnetism. Susceptibility measurements performed in this material demonstrate the presence of $Yb^{3+}$ moments with anti-ferromagnetic interactions and an onset of a week magnetic transition below 25 K. Yet, this complex magnetism is not completely understood.

We carried out magnetotransport measurements on $Yb_{0.5}Co_3Ge_3$ to study the interplay of its quantum properties at both ambient pressure (0 GPa) and high pressure (up to 2.0 GPa). Our ambient-pressure measurement shows that this complex magnetism gives rise to Kondo effect. High-pressure measurements reveal a clear signature of an enhancement of the Kondo effect with respect to the pressure.

TT 3.9 Mon 11:45 H32

**Altermagnetism from interaction-driven itinerant magnetism** — Samuele Giuli[1], •Carlos Mejuto-Zaera[1,2], and Massimo Capone[1,3] — [1]International School for Advanced Studies (SISSA), Trieste, Italy — [2]Current: Laboratoire de Physique Théorique (LPT), Toulouse, France — [3]CNR-IOM Democritos, Trieste, Italy

Altermagnetism is a phase of collinear spin-ordering presenting anisotropic magnetic properties, leading to great interest in its potential application for spintronic and thermoelectric devices. Realizing this promise will likely hinge on the design of tunable altermagnetic platforms, in which the magnetic and electric responses can be reliably controlled. A viable path towards this goal concerns leveraging electron interactions for the stabilization of altermagnetism, a strategy which is developing increasing traction in the field. In this work, we propose a mechanism driven by the interplay between a local Hubbard repulsion and the presence of a van Hove singularity in a two-band model. Here, the itinerant magnetism caused by the van Hove singularity colludes with the exchange mechanism driven by the Hubbard repulsion to generate an altermagnetic state in a sizeable portion of the phase diagram. Importantly, this correlated altermagnetic phase exhibits a tuneable spin-current, whose sign can be changed by tuning the interaction strength and/or particle doping. We study the role of strong electronic correlations in the stabilization of this phase by leveraging on the ghost rotationally invariant slave boson embedding. Further, we comment on the stability of the phase, and potential material realizations.

TT 3.10 Mon 12:00 H32

**Investigation of the magnetoelastic coupling in $CaMn_2P_2$ and $SrMn_2P_2$** — •Sven Graus, Ashiwini Balodhi, N. S. Sangeetha, Teslin R. Thomas, Maximilian van de Loo, Andreas Kreyssig, and Anna E. Böhmer — Experimentalphysik IV, Ruhr-Universität Bochum, 44801 Bochum, Germany

Mn-based 122-compounds exhibit complex magnetic ordering in the antiferromagnetic state. In contrast to other related materials $CaMn_2P_2$ shows a strong first-order and $SrMn_2P_2$ a weak first-order antiferromagnetic phase transition [1]. Since the antiferromagnetic ordering breaks the three-fold symmetry of the lattice, one expects lattice distortions, which we investigated by high-resolution thermal expansion measurements. Thermal-expansion data of $CaMn_2P_2$ show a significant decrease of the sample length upon entering the antiferromagnetic state. Applying different uniaxial pressures along the [1 1 0] and [1 -1 0] directions alters the transition in qualitatively distinct ways. Increasing uniaxial pressure shifts the transition temperature upwards which shows magnetoelastic coupling and is consistent with the interpretation of an orthorhombic lattice distortion in the antiferromagnetic phase. In $SrMn_2P_2$, an anomaly in the thermal expansion is clearly resolvable upon entering the antiferromagnetic state. From 300 K to 6 K the linear thermal expansion coefficient $\alpha$ continuously decreases, reaching negative values below ∼100 K.

We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG) under CRC/TRR 288 (Project A02).

[1] Sangeetha et al., PNAS **118**, e2108724118 (2021).

TT 3.11 Mon 12:15 H32

**Synthesis of $CsMn_2P_2$ and study of its low temperature physical properties** — •Matthias Kroll, N. S. Sangeetha, Sven Graus, Maik Golombiewski, Andreas Kreyssig, and Anna E. Böhmer — Experimentalphysik IV, Ruhr-Universität Bochum, 44801 Bochum, Germany

The growth of $CsMn_2P_2$ single crystals is challenging due to the high vapor pressure of cesium and phosphorus and the high melting point of manganese. We optimized the growth conditions for the reproducible synthesis of $CsMn_2P_2$ single crystals by systematically studying various growth techniques. The quantity and quality of the phase of interest in the resulting samples was characterized by x-ray powder diffraction, electron microscopy and energy-dispersive x-ray analysis. We perform thermal-expansion and magnetic field-dependent resistivity measurements at low temperatures to analyze the nature of the three phase transitions at 64, 17 and 11 K that cannot be explained conclusively so far [1,2]. At 17 K, a dramatic change of the electrical-transport behavior as well as a large thermal-expansion anomaly are observed.

We acknowledge support by the Deutsche Forschungsgemeinschaft (DFG) under CRC/TRR 288 (Project A02).

[1] F. Hummel, Magnetism and superconductivity in layered manganese and iron pnictides. Diss. LMU (2015).
[2] H. G. von Schnering et al., ZAAC 628, 2772 (2002)

TT 3.12 Mon 12:30 H32

**Strain-tuning of magnetic properties of $Ca_{1-x}Sr_xCo_{2-y}As_2$ and elastoresistance measurements in different symmetry channels** — •Teslin Rose Thomas, Michael Paul, N. S. Sangeetha, Sven Graus, Max Brückner, Andreas Kreyssig, and Anna E. Böhmer — Experimentalphysik IV, Ruhr-Universität Bochum, 44801 Bochum, Germany

The $Ca_{1-x}Sr_xCo_{2-y}As_2$ system belongs to the well-studied $ThCr_2Si_2$ structural family where Sr substitution induces a crossover from a collapsed tetragonal (cT) phase to an uncollapsed tetragonal (ucT) phase, along with different magnetic anisotropies [1,2].

In this study, we investigate how the cT-ucT crossover and the associated magnetic orders respond to in-plane symmetric and asymmetric strain in different configurations. We show that large in-plane symmetric strain can effectively tune the magnetic properties of the system. We also find a significant response of the resistance to in-plane symmetric strain with a temperature dependence that varies dramatically based on the doping level. The resistance response to symmetric strain dominates the response to asymmetric strain.

We acknowledge support from the Deutsche Forschungsgemeinschaft (DFG) under CRC/TRR 288 (Project A02).

[1] N. S. Sangeetha et al., Phys. Rev. Lett. 119, 257203 (2017).
[2] Bing Li et al., Phys. Rev. B 100, 024415 (2019).