MA 44: Frustrated Magnets II

Time: Thursday 15:00–17:30 Location: HSZ 403

MA 44.1 Thu 15:00 HSZ 403

Magnetic Force Microscopy Investigations of the Kagome Spin Ice Host HoAgGe — •Tsuei-Shin Wu[1], Subhajit Roychowdhury[2], Samuel D. Seddon[1], Peter Milde[1], Claudia Felser[2], and Lukas M. Eng[1,3] — [1]Institute of Applied Physics, Technische Universität Dresden, Dresden, Germany — [2]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [3]Dresden-Würzburg Cluster of Excellence * Complexity and Topology in Quantum Matter (ct.qmat), TU Dresden, 01062 Dresden, Germany

The recent discovery of the quasi-2D spin ice on a Kagome lattice in HoAgGe [1] has highlighted this material system as the perfect environment in order to explore emerging questions and to clarify ongoing discussions regarding 2D spin ices within the scientific community. The presence of several high-order magnetization plateaus implies the possible existence of quantum magnetic states and/or non-collinear spin textures that may originate from quantum or thermal fluctuations [2]. Peaks in the topological Hall effect, which correlate with these magnetization plateaus, also potentially imply the presence of exotic spin textures - or at the very least non-collinear spin textures, which low-temperature (LT) Magnetic Force Microscopy (MFM) is perfectly placed to uncover. Here we present LT-MFM results when investigating the magnetic textures and their behaviors in HoAgGe samples under magnetic fields applied along the relevant crystallographic Kagome lattice directions.

Reference [1] Zhao et al., Science 367, 1218 (2020). [2] Baran et al., Journal of Alloys and Compounds 281, 92 (1998).

MA 44.2 Thu 15:15 HSZ 403

Coexistence of antiferromagnetism and ferrimagnetism in adjacent honeycomb layers — •Dávid Szaller[1], Lilian Prodan[2,3], Korbinian Geirhos[2], Viorel Felea[2,3,4], Yurii Skourski[4], Denis Gorbunov[4], Tobias Förster[4], Toni Helm[4], Toshihiro Nomura[4,5], Atsuhiko Miyata[4], Sergei Zherlitsyn[4], Jochen Wosnitza[4,6], Alexander A. Tsirlin[2], Vladimir Tsurkan[2,3], and Istvan Kezsmarki[2] — [1]Tu Wien — [2]University of Augsburg — [3]Institute of Applied Physics, R. Moldova — [4]Hochfeld-Magnetlabor Dresden — [5]University of Tokyo, Kashiwa — [6]TU Dresden

Ferro/ferri- and antiferromagnetic orders are typically exclusive in nature, thus, their co-existence in atomic-scale proximity is expected only in heterostructures. Breaking this paradigm we report the observation of a new, atomic-scale hybrid spin state. This ordering is stabilized in three-dimensional crystals of the polar antiferromagnet $Co_2Mo_3O_8$ by magnetic fields applied perpendicular to the *Co* honeycomb layers and possesses a spontaneous in-plane ferromagnetic moment. Our microscopic spin model, capturing the observed field dependence of the longitudinal and transverse magnetization as well as the magnetoelectric/elastic properties, reveals that this novel spin state is composed of an alternating stacking of antiferromagnetic and ferrimagnetic honeycomb layers. We show that the proper balance of magnetic interactions can extend the stability range of this hybrid phase down to zero magnetic field. The layer-by-layer stacking of distinct spin orders via suitable combinations of microscopic interactions opens a new dimension toward the nanoscale engineering of magnetic states.

MA 44.3 Thu 15:30 HSZ 403

Coupled frustrated ferromagnetic and antiferromagnetic quantum spin chains in the quasi-one-dimensional mineral antlerite, $Cu_3SO_4(OH)_4$ — A.A. Kulbakov[1], D.Y. Kononenko[2], S. Nishimoto[2,3], Q. Stahl[1], A. Mannathanath Chakkingal[1], M. Feig[4], R. Gumeniuk[4], Y. Skourski[5], L. Bhaskaran[5], S.A. Zvyagin[5], J.P. Embs[6], I. Puente-Orench[7,8], A. Wildes[8], J. Geck[1,9], O. Janson[2], D.S. Inosov[1,9], and •D.C. Peets[1] — [1]IFMP, TU Dresden — [2]Leibniz IFW-Dresden — [3]ITP, TU Dresden — [4]IEP, TU Bergakademie Freiberg — [5]HLD-EMFL, HZRD Dresden — [6]PSI, Villigen, Schweiz — [7]INMA, CSIC-U. Zaragoza, Spain — [8]ILL, Grenoble, France — [9]ct.qmat

Magnetic frustration, the competition among exchange interactions, often leads to novel magnetic ground states with unique physical properties which can hinge on details of interactions that are otherwise difficult to observe. Such states are particularly interesting when it is possible to tune the balance among the interactions to access multiple types of magnetic order. We present antlerite, $Cu_3SO_4(OH)_4$, as a potential platform for tuning frustration. Contrary to previous reports, the low-temperature magnetic state of its three-leg zigzag ladders is a quasi-one-dimensional analogue of the magnetic state recently proposed to exhibit spinon-magnon mixing in botallackite. Density-functional-theory calculations indicate that antlerite's magnetic ground state is exquisitely sensitive to fine details of the atomic positions, with each chain independently on the cusp of a phase transition, indicating an excellent potential for tunability.

MA 44.4 Thu 15:45 HSZ 403

High-Frequency Electron Spin Resonance Studies on the Quasi One-Dimensional Spin-1/2 Quantum Magnet $PbCuSeO_4(OH)_2$ — •Rahel Ohlendorf, Daniel Knauer, Changhyun Koo, and Rüdiger Klingeler — Kirchhoff Institute for Physics, Heidelberg, Germany

We report high-frequency ESR studies on a polycrystalline sample of the frustrated quasi-1D spin-1/2 quantum material $PbCuSeO_4(OH)_2$, isostructural to the well-studied natural mineral linarite ($PbCuSO_4(OH)_2$). Magnetisation data show the evolution of a magnetically ordered phase below $T_N = 4.8$ K and a spin-flop transition at $B_{SF} = 2.8$ T. A complex magnetic phase diagram is constructed from the data. ESR measurements on a loose powder evidence a gapless linear excitation mode within the ground state, which can be traced across the spin-flop transition, as well as two linear excitation modes within the in-field phase with a zero field gap of -31 ± 9 GHz and 32.9 ± 1.4 GHz, respectively. Measurements on fixed powder reveal a gapped magnon mode in the ground state with a zero field splitting of 70 ± 20 GHz. This mode might be accounted for by assuming an excitation of a spiral spin order in the ground state. Tracing the resonance positions with temperature suggests an easy-axis-type anisotropy with the paramagnetic g-factors 2.3 and 2.07. Changes in resonance position evidence the onset of short range fluctuations at around 70 K corresponding to $14 \times T_N$.

15 min. break

MA 44.5 Thu 16:15 HSZ 403

K_2ReCl_6: an unconventional Jahn-Teller system? — •Alexandre Bertin[1], Tusharkanti Dey[1], Daniel Brüning[1], Dmitry Gorkov[1,2], Kevin Jenni[1], Astin Krause[1], Petra Becker[3], Ladislav Bohatý[3], Daniel Khomskii[1], Thomas Lorenz[1], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München — [3]Abteilung Kristallographie, Institut für Geologie und Mineralogie, Universität zu Köln

Antifluorite compounds of chemical formula K_2MX_6 (where M is a transition metal and X=Cl,Br) can exhibit various crystallographic phase transitions, often understood by the softening of rotary phonon modes of the ligand octahedra surrounding the central transition metal. Among this family, K_2ReCl_6 exhibits on cooling four distinct structural phases and may constitute a playground to investigate the interplay between spin-orbit coupling (SOC) and Jahn-Teller (JT) effect. The question whether one of the crystallographic phase transitions is JT driven will be tackled by presenting a detailed temperature dependent structural study of K_2ReCl_6 and of its non magnetic counterpart K_2SnCl_6 by means of powder and single crystal XRD. With neutron diffraction experiments and by taking the low temperature monoclinic symmetry into account, the magnetic structure was solved. Frustration is only partially lifted by the structural distortions and the magnetic order causes further symmetry reduction. Finally, the strong magneto-elastic effect seen in thermal expansion measurements will be discussed in terms of domain re-orientation and weak ferromagnetism.

MA 44.6 Thu 16:30 HSZ 403

Non-collinear magnetism and Fe-R interaction in $R_3Fe_3Sb_7$ — •Felix Seewald[1], Falk Pabst[2,5], Sabrina Palazzese[1,3,5], Vadim Grinenkov[1,6], Hubertus Luetkens[7], Thomas Herrmannsdörfer[3], Shingo Yamamoto[3,5], Denis Gorbunov[3,5], Sumanta Chattopadhyay[3,5], Clemens Ritter[4], Kati Finzel[2], Thomas Doert[2,5], Michael Ruck[2,5], Jochen Wosnitza[1,3,5], and Hans-Henning Klauss[1] — [1]IFMP, TU Dresden, Germany — [2]Fakultät für Chemie und Lebensmittelchemie, TU

Dresden, Germany — [3]HLD-EMFL, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [4]Institute Laue-Langevin Grenoble, France — [5]Würzburg-Dresden Cluster of Excellence ct.qmat — [6]Tsung-Dao Lee Institute, Shanghai, China — [7]PSI, Villingen, Switzerland

In $R_3Fe_3Sb_7$ (R = Pr, Nd) Fe and R atoms form columns of stacked triangles separated by Sb. Fe exhibits non-collinear ferromagnetic order below $T_c \approx 380\,K$. On cooling at the onset of R order a spin reorientation ($T_{SRT,Pr} \approx 40\,K$, $T_{SRT,Nd} \approx 50\,K$) and magnetization reversal is observed [1].

Mössbauer spectra show two distinct magnetic Fe sites between T_c and T_{SRT}, both collapsing into one new site below T_{SRT}, reaching a static magnetic hyperfine-field of $B_{Hyp} = 20.59(21)\,T$ at 4.2 K. The data is the same for Nd and Pr except for the value of T_{SRT}. The local field obtained from μSR investigations is consistent with Mössbauer hyperfine-field at high temperatures. We will discuss the implications of our findings on the magnetic structure of the system.

[1] Falk Pabst, Sabrina Palazzese et. al., Advanced materials, accepted

MA 44.7 Thu 16:45 HSZ 403

Reentrant topological magnetic order and a spin-cholesteric phase in the $Sr_3Fe_2O_7$ perovskite — •Nikita Andriushin[1], Nikolai Pavlovskii[1], Yuliia Tymoshenko[1], Darren C. Peets[1], Alexandre Ivanov[2], Jacques Ollivier[2], Bernhard Keimer[3], Oksana Zaharko[4], and Dmytro Inosov[1] — [1]TU Dresden, Germany — [2]ILL, Grenoble, France — [3]MPI for Solid State Research, Stuttgart, Germany — [4]PSI, Villigen, Switzerland

Topologically nontrivial magnetic structures, e.g., skyrmion lattices and magnetic vortex crystals, are well known in noncentrosymmetric materials, so that antisymmetric exchange interactions are allowed. Only recently, topological multi-**q** magnetic textures that spontaneously break the chiral symmetry, for example three-dimensional hedgehog lattices, were discovered in centrosymmetric compounds, where they are instead driven by frustrated interactions. Here we show that the bilayer perovskite $Sr_3Fe_2O_7$, previously believed to adopt a simple single-**q** spin-spiral order, hosts two distinct types of multi-**q** topological spin textures. Its ground state represents an unusual multi-**q** spin texture with unequally intense helical spin modulations at the two ordering vectors. It is followed in temperature by a new "spin cholesteric" phase, in which the chiral symmetry is spontaneously broken along one of the crystal directions, but the weaker modulation along the orthogonal direction melts, giving rise to intense short-range dynamical fluctuations. Shortly before the transition to the paramagnetic state, a more conventional skyrmion-lattice order spanned by two equivalent **q** vectors emerges.

MA 44.8 Thu 17:00 HSZ 403

Incommensurate and multiple-q magnetic misfit order in $Cu_3SO_4(OH)_4$ — •Anton Kulbakov[1], Elaheh Sadrollahi[1], Florian Rasch[1], Maxim Avdeev[2,3], Sebastian Gass[4], Laura Bohorquez[4], Anja Wolter[4,5], Manuel Feig[6], Roman Gumeniuk[6], Hagen Poddig[7], Markus Stötzer[8], Jochen Litterst[9], Ines Puente-Orench[10,11], Andrew Wildes[11], Eugen Weschke[12], Jochen Geck[1,5], Dmytro Inosov[1,5], and Darren Peets[1] — [1]IFMP, TU Dresden, Germany — [2]ANSTO, Australia — [3]USYD, Australia — [4]IFW Dresden, Germany — [5]ct.qmat, TU Dresden, Germany — [6]TUBA Freiberg, Germany — [7]ACII, TU Dresden, Germany — [8]ACI, TU Dresden, Germany — [9]IPKM, TU Braunschweig, Germany — [10]INMA, Spain — [11]ILL, Grenoble, France — [12]HZB, Berlin, Germany

In antlerite, $Cu_3SO_4(OH)_4$, Cu^{2+} ($S = \frac{1}{2}$) quantum spins populate three-leg zigzag ladders in a highly frustrated quasi-one-dimensional structural motif. We demonstrate that at zero applied field, in addition to its recently reported low-temperature phase of coupled ferromagnetic and antiferromagnetic spin chains, this mineral hosts an incommensurate helical+cycloidal state, an idle-spin state, and a multiple-q phase which is the magnetic analog of misfit crystal structures. The antiferromagnetic order on the central leg is reentrant. The high tunability of the magnetism in antlerite makes it a particularly promising platform for pursuing exotic magnetic order.

MA 44.9 Thu 17:15 HSZ 403

Spin-liquid and Spin-glass states in Frustrated Tetragonal Pyrochlore $Zn_{0.8}Cu_{0.2}FeMnO_4$ — •Suchit Kumar Jena[1], Manfred Reehuis[2], and Subhash Thota[1] — [1]Department of Physics, Indian Institute of Technology Guwahati, Assam-781039, India — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, D-14109 Berlin, Germany

Spinel (AB_2O_4) Pyrochlore lattices are capable of generating high degree of magnetic frustration owing to tunable competing exchange interactions achieved via suitable magnetic elements on B site together with non-magnetic A site, which leads to quantum spin-liquid/Ice state [1]. One such compound is cubic $ZnFe_2O_4$, which manifests high magnetic frustration index ($f \simeq 12$) with antiferromagnetic Néel temperature, $T_N \sim 10$K [2]. Our results based on the neutron powder diffraction analysis shows that polycrystalline tetragonal $Zn_{0.8}Cu_{0.2}FeMnO_4$ (ZCFMO) lacks presence of long-range magnetic ordering. The dynamic ac magnetic susceptibility (χ' and χ'') measurements show multiple anomalies across 9K, 47K and 79K. Frequency dispersion in the loss spectrum ($\chi''(f,T)$) analyzed by employing empirical scaling-laws such as Vogel-Fulcher law and Power Law: $\tau = \tau_0[(T - T_{SG})/T_{SG}]^{-z\nu}$, yields cluster spin-glass state in ZCFMO with the spin freezing temperature (T_{SG}) at 41.8K and critical exponent $z\nu = 8.9$, below the ferrimagnetic Néel temperature $T_{FiM} \simeq 79$K. These results are further supported by the heat capacity ($C_p(T)$) studies. Below 9K, $C_p \sim T^2$, indicates co-existence of spin-glass and spin-liquid states in ZCFMO.

[1] *Phys. Rev. B* **28**, 1 (1983). [2] *Phys. Rev. B* **66**, 064401 (2002).