KFM 28: Topological Insulators (joint session MA/KFM)

Time: Thursday 15:00–17:45 Location: H37

Invited Talk KFM 28.1 Thu 15:00 H37

Neutron scattering on magnetic topological materials: From topological magnon insulators to emergent many-body effects
— •Yixi Su — Jülich Centre for Neutron Science JCNS at MLZ, Forschungszentrum Jülich, 85747 Garching, Germany

Recent theoretical predictions and experimental realizations of exotic fermions and topologically protected phases in condensed matter have led to tremendous research interests in topological quantum materials. Especially, magnetic topological materials, such as magnetic Dirac and Weyl semimetals, and intrinsic magnetic topological insulators etc., in which non-trivial topology of single-electron band structures and electronic correlation effects are often intertwined, have emerged as an exciting platform to explore novel phenomena. Here I will present our recent neutron scattering studies. In the Dirac semimetal EuMnBi2, the evidence for the possible impact of magnetism on Dirac fermions is obtained via a detailed neutron diffraction study of the spin-flop transition [1]. Based on our inelastic neutron scattering study and theoretical analysis of spin-wave excitations, the exotic topological magnon insulators, the bosonic analogs of topological insulators, have been experimentally realized in the two-dimensional van der Waals honeycomb ferromagnets CrSiTe3 and CrGeTe3 [2]. Furthermore, in the magnetic Weyl semimetal Mn3Sn, an unusual magnetic phase transition that is driven by emergent many-body effects is revealed via a combined neutron scattering study and band-structure calculations [3].

[1] F. Zhu, et al., Phys. Rev. Research 2, 043100 (2020). [2] F. Zhu, et al., Sci. Adv. 7, eabi7532 (2021). [3] X. Wang (unpublished)

KFM 28.2 Thu 15:30 H37

Tuning the magnetic gap of a topological insulator
— •Marcus Liebmann[1], Philipp Küppers[1], Jannik Zenner[1], Stefan Wimmer[2], Gunther Springholz[2], Oliver Rader[3], and Markus Morgenstern[1] — [1]II. Phys. Inst. B, RWTH Aachen Univ., Germany — [2]Inst. Halbleiter- u. Festkörperphysik, Johannes Kepler Univ., Linz, Austria — [3]Helmholtz-Zentrum Berlin f. Mater. u. Energie, Germany

Mn-rich $MnSb_2Te_4$ is a ferromagnetic topological insulator with yet the highest Curie temperature $T_C = 45 - 50\,K$. It exhibits a magnetic gap at the Dirac point of the topological surface state that disappears above T_C. We probe the gap size by scanning tunneling spectroscopy, varying in-plane magnetic field $B_{||}$ and temperature. We demonstrate shrinkage of the average gap size with $B_{||}$ revealing that the gap opening originates from out-of-plane magnetization. In line, the gap does not close completely up to $B_{||} = 3\,T$ as the magnetization is only partially rotated in-plane. In addition, we demonstrate significant spatiotemporal fluctuations of the gap size at temperatures as low as $T_C/2$, above which the remanent magnetization indeed decays. Thus, the gap is tightly bound to the out-of-plane magnetization, as expected theoretically but not demonstrated experimentally yet. The partial in-plane rotation at $B_{||} = 3\,T$ and the low temperature onset of fluctuations stress the important role of competing magnetic orders in the formation of the favorable ferromagnetic topological insulator in Mn-rich $MnSb_2Te_4$, providing insight into the complex magnetic gap opening that is decisive for quantum anomalous Hall devices.

KFM 28.3 Thu 15:45 H37

Local magnetic and electronic properties of the intrinsic magnetic topological insulator $MnBi_6Te_{10}$
— •Abdul-Vakhab Tcakaev[1], Volodymyr Zabolotnyy[1], Bastian Rubrecht[2], Laura Corredor[2], Jorge Facio[2], Laura Folkers[3], Anja Wolter[2], Anna Isaeva[2], and Vladimir Hinkov[1] — [1]Experimentelle Physik IV and R ontgen Research Center for Complex Materials (RCCM), Fakult at f ur Physik und Astronomie, Universit at W urzburg, Am Hubland, D-97074 W urzburg, Germany — [2]Leibniz IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany — [3]Faculty of Physics, Technische Universit at Dresden, D-01062 Dresden, Germany

The recent observation of novel phenomena in the intrinsic magnetic topological insulator $MnBi_2Te_4$, such as the quantum anomalous Hall effect and the topological magnetoelectric effect has prompted research of the higher-n members of the $(MnBi_2Te_4)(Bi_2Te_3)_n$ family. Here we combine x-ray absorption spectroscopy, and x-ray circular and linear dichroism at the Mn $L_{2,3}$ edges, with density-functional (DFT) and multiplet ligand-field (MLFT) theory to investigate the ground state of Mn in $MnBi_6Te_{10}$ single crystals. Our magnetometry data reveal FM state with finite remanence consistent with the spectroscopy data. Our spectroscopy results together with DFT and *ab initio* MLFT calculations allow us to determine in full detail the local magnetic and electronic properties of the Mn ions in the bulk and near the surface, and deliver important microscopic physical parameters, including Mn $3d$-shell occupation, the spin and orbital magnetic moments.

KFM 28.4 Thu 16:00 H37

Probing the Superconductor / Quantum Anomalous Hall Interface
— •Anjana Uday[1], Gertjan Lippertz[1,2], Andrea Bliesener[1], Alexey Taskin[1], and Yoichi Ando[1] — [1]University of Cologne, Cologne, Germany — [2]KU Leuven, Leuven, Belgium

Recently, crossed Andreev conversion was reported in a hybrid quantum Hall (QH) / Superconductor (SC) system [1]. The evidence was based on the observation of a negative downstream resistance R_D in a three-terminal measurement of a Hall-bar device with respect to the grounded SC electrode. Similar experiments would be of great interest in the quantum anomalous Hall (QAH) / SC hybrid system, where superconductivity can be suppressed for control experiments by applying a magnetic field while keeping the 1D edge state unchanged. We fabricated Hall-bar devices from V-doped $(Bi_xSb_{1-x})_2Te_3$ thin films contacted with Nb electrodes having various widths. We found a finite positive R_D which increases with decreasing the widths of the SC electrode due to the QAH breakdown mechanism [2]. We also found a clear increase in R_D upon killing the superconductivity with a magnetic field for Nb electrodes narrower than 200 nm; this can be attributed to either non-local Andreev reflections on top of the breakdown-induced finite R_D or local Andreev reflections on the 2D normal metal/SC interface, which can be created by the charge transfer from the Nb electrode to the gapped VBST surface state. In both cases our observation implies a high transparency of the SC/QAH interface.

[1] G.-H. Lee et al., Nat. Phys. 13, 693-698 (2017)
[2] G. Lippertz et al., arXiv:2108.02081 (2021)

KFM 28.5 Thu 16:15 H37

Magnetotransport Properties of MnSb2Te4
— •Michael Wissmann[1,2,3], Joseph Dufouleur[2], Anna Isaeva[4], Bernd Büchner[2,3], and Romain Giraud[1,2] — [1]Université Grenoble-Alpes, CNRS, CEA, SPINTEC, F-38000 Grenoble, France — [2]Leibniz Institute for Solid State and Materials Research IFW Dresden, 01069 Dresden, Germany — [3]Institute of Solid State Physics, TU Dresden, 01069 Dresden, Germany — [4]Department of Physics and Astronomy, University of Amsterdam,1098 XH Amsterdam, Netherlands

The new family of intrinsically magnetic van-der-Waals layered topological insulators Mn(Bi,Sb)Te, with strong spin-orbit coupling, is of great interest to investigate the interplay between topology and magnetic order in electronic band structures. When introducing magnetism into a 3D topological insulator, this interplay can generate topological quantum states like the quantum anomalous Hall effect (QAH) or the axion insulator, which can be modified by tuning the magnetization.

Our recent studies consider the MnSb2Te4 compound, a ferromagnet with a perpendicular-to-plane anisotropy and a critical Curie-Weiss temperature as high as 50K. MnSb2Te4 has been controversially discussed to be a magnetic Weyl semimetal or a candidate to realize the axion insulator. We investigated the thickness-dependent properties of exfoliated nanoflakes using magneto-transport, revealing the change in important parameters such as the resistivity, the Curie temperature and the magnetic coercive field. The influence of both the intrinsic electrical doping and disorder in magnetic topological insulators is considered as well.

KFM 28.6 Thu 16:30 H37

Investigation of the magnetic and electronic properties of topological insulator/ferromagnet heterostructures
— •Simon Marotzke[1,2], André Philippi-Kobs[1,2], Leonard Müller[1,3], Matthias Kallåne[2], Jens Buck[2], Wojciech Roseker[1], Nils Wind[3], Sanjoy Mahatha[4], Nils Huse[3], Gerhard Grübel[1,3], Martin Beye[1], and Kai Rossnagel[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Christian-Albrechts-Universität zu Kiel, Germany — [3]Universität Hamburg, Germany — [4]Thapar Institute of Engineering and Technology, Patiala, India

Heterostructures of the design Bi_2Se_3/X/Co/Pt, with X = None, Pt, B_4C or B_4C/Pt as separation layer between the topological insulator (TI) and the ferromagnetic overlayer are studied. By means of magneto-optical Kerr effect, the magnetic behaviour is characterised, showing that perpendicular magnetic anisotropy can be achieved in the overlayer and minutely tuned by changing layer properties. In X-ray photoemission spectroscopy measurements, two Bi phases are identified in the heterostructures. By systematically varying the photon energy, the depth, in which the two Bi phases are located, is analysed. Significant differences of the chemical properties at the interface to the TI are found for heterostructures consisting of Bi_2Se_3 with a metallic or insulating overlayer, respectively. Finally, a scheme to invert the heterostructures is presented, potentially enabling angle-resolved photoemission spectroscopy measurements on the TI's surface in future in order to study the influence of the magnetisation state on the TI's surface states.

KFM 28.7 Thu 16:45 H37

Current-induced breakdown of the quantum anomalous Hall effect — •Gertjan Lippertz[1,2], Andrea Bliesener[1], Anjana Uday[1], Lino M.C. Pereira[2], Alexey Taskin[1], and Yoichi Ando[1] — [1]University of Cologne, Cologne, Germany — [2]KU Leuven, Leuven, Belgium

The quantum anomalous Hall (QAH) effect is characterised by zero longitudinal resistivity and quantized Hall resistance without the need of an external magnetic field. However, when reducing the device dimensions or increasing the current density, an abrupt breakdown of the dissipationless state occurs. In this talk, the mechanism of breakdown will be adressed, and the electric field created between opposing chiral edge states will be shown to lie at its origin. Electric-field-driven percolation of two-dimensional charge puddles in the gapped surface states of compensated topological-insulator films is proposed as the most likely cause of the breakdown [1].

Moreover, it was recently reported that the interplay between the 1D chiral edge state and the 2D surface state can give rise to nonreciprocity in the longitudinal resistance [2]. In this talk, it will be shown that the onset of 2D conduction due to breakdown is sufficient to create the nonreciprocal effect, allowing for efficient switching between the dissipationless and nonreciprocal transport regime of the QAH state.

[1] G. Lippertz et al., arXiv:2108.02081 (2021)
[2] K. Yasuda et al., Nat. Nanotechnol. 15, 831-835 (2020)

KFM 28.8 Thu 17:00 H37

Thermal Hall Effect of Magnons in Collinear Antiferromagnets: Signatures of Magnetic and Topological Phase Transitions — •Robin R. Neumann[1], Alexander Mook[2], Jürgen Henk[1], and Ingrid Mertig[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany — [2]Department of Physics, University of Basel, Basel, Switzerland

While chiral edge states of topological bosons lack clear hallmarks and are difficult to detect, topological electrons can directly be identified by means of the quantized transverse conductivity intrinsic to the quantum anomalous Hall effect. In this talk I consider magnons, the bosonic quanta of collective spin excitations, in a collinear antiferromagnet that is driven from its antiferromagnetic phase via a spin-flop phase to the field-polarized phase by an external magnetic field. Besides the magnetic phase transitions, topological phases occur in the spin-flop and field-polarized phases. To identify these phase transitions, the thermal Hall effect (THE), i. e. the transversal heat transport induced by a longitudinal temperature gradient, is studied across the phase transitions. It is demonstrated that the THE exhibits pronounced signatures of the phase transitions and the temperature tunes the sensitivity to these phase transitions oppositely, allowing for their distinction in transport experiments.

KFM 28.9 Thu 17:15 H37

Topology, Colossal Magnetoresistance, and Complex Magnetic Domains in Eu5In2Sb6 — •Marein Rahn[1,2], Murray N. Wilson[3], Priscila F. S. Thomas[2], Tom Lancaster[3], Filip Ronning[2], and Marc Janoschek[4,5] — [1]IFMP, TU Dresden, 01062 Dresden, Germany — [2]LANL, Los Alamos, New Mexico 87545, USA — [3]Department of Physics, Durham University, Durham, DH1 3LE, UK — [4]Laboratory for Neutron and Muon Instrumentation, Paul Scherrer Institute, CH-5232 Villigen, Switzerland — [5]Physik-Institut, U. Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland

The axion insulating state is a paradigm of topological correlated matter which has been particularly difficult to demonstrate in real materials. Using neutron scattering, resonant elastic x-ray scattering, muon spin-rotation and bulk measurements, we demonstrate how the combination of co-planar glide symmetries and large Eu2+ magnetic moments in the Zintl phase Eu5In2Sb6 produces an unusual two-step ordering process. At 14 K, Eu5In2Sb6 first forms a complex non-collinear weak Ising-ferrimagnet, which we identify as a trivial insulator. Below 7.5 K, this phase is continuously displaced by a growing volume fraction of a compensated antiferromagnetic arrangement that may have axion insulating character. This discovery also implies the presence of a solitonic antiferromagnetic domain structure on the mesoscale, which demonstrably couples to charge transport and, due to the net magnetization of some domains, should be highly susceptible to manipulation. This may open up a platform to engineer interfaces of trivial and non-trivial insulators on the mesoscale.

KFM 28.10 Thu 17:30 H37

Invisible flat bands on a topological chiral edge — •Youjiang Xu, Irakli Titvinidze, and Walter Hofstetter — Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

We prove that invisible bands associated with zeros of the single-particle Green's function exist ubiquitously at topological interfaces of 2D Chern insulators, dual to the chiral edge/domain-wall modes. We verify this statement in a repulsive Hubbard model with a topological flat band, using real-space dynamical mean-field theory to study the domain walls of its ferromagnetic ground state. Moreover, our numerical results show that the chiral modes are split into branches due to the interaction, and that the branches are connected by invisible flat bands. Our work provides deeper insight into interacting topological systems.