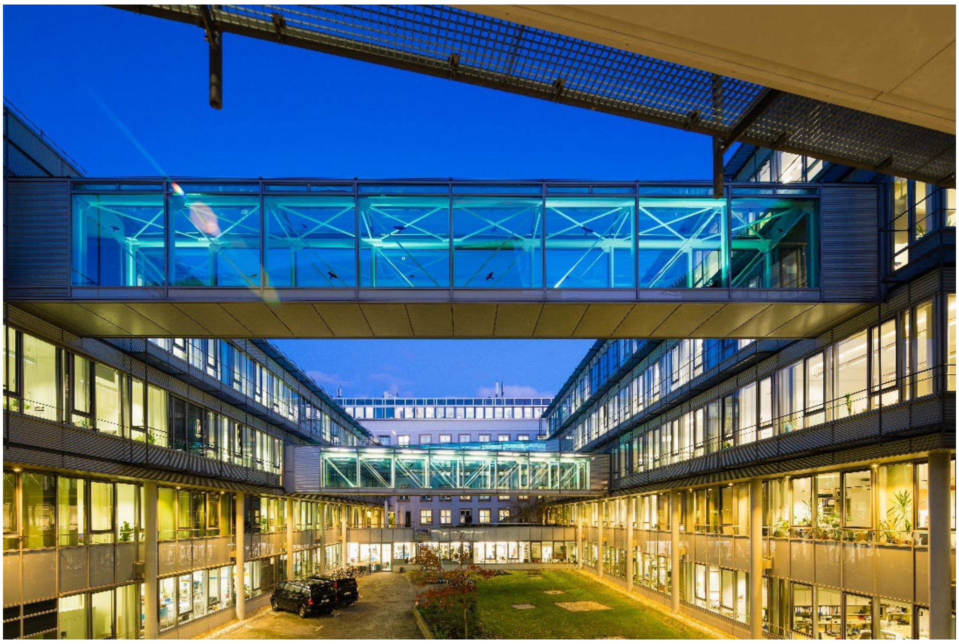
3rd Joint Workshop

IFW Dresden - S.N. Bose National Center for Basic Sciences

23-26 June 2025

IFW Dresden, D2E.27



Organizers: Bernd Büchner, Thirupathaiah Setti

Leibniz Institute for Solid State and Materials Research Dresden

S. N. Bose National Centre for Basic Sciences

Programme overview

Monday 23 / Tuesday 24 / Wednesday 25 June		
(Meetings in closed session)		
Thursday 26 June (public session, D2E.27)		
09:00	*Welcoming words* **Bernd Büchner**, IFW/IFF	*Chair: van den Brink*
09:05	*Welcoming words* **Tanusri Saha Dasgupta**, SNBNCBS	
09:10	*Vacancy ordered Double Perovskites: Host for unconventional Magnetism* **Tanusri Saha-Dasgupta,** SNBNCBS	
09:55	*Frustration causing multiferroicity in hauerite MnS_2* **Oleg Janson**, IFW/ITF	
10:40	Coffee break	
11:00	*Stability of Weyl node merging processes under symmetry constraints* **Cosma Fulga**, IFW/ITF	*Chair: Nogueira*
11:45	*Quantum Geometry and Dynamical Axion in antiferromagnetic topological insulator $MnBi_2Te_4$* **Barun Ghosh**, SNBNCBS	
12:30	Lunch break	
13:00	*Instability of the Haldane Phase under Charge Fluctuations and Doping Effects* **Satoshi Nishimoto**, IFW/ITF	*Chair: Saha-Dasgupta*
13:45	*Insights into Quantum Manybody Phenomena: Topology and Geometry-induced Effects in Quantum Spin Systems* **Arijit Haldar**, SNBNCBS	
14:30	Coffee break	
15:00	*Observation of nodal superconductivity on the Fermi arcs of $PtBi_2$* **Susmita Changdar**, IFW/IFF	*Chair: Borisenko*
15:45	*Designing and Synthesis of Skyrmion Lattice Superconductors* **Thirupathaiah Setti**, SNBNCBS	
16:30	*Acoustic and optical plasmon excitations in cuprate and ruthenate "strange metals" studied by EELS, RIXS, and optical spectroscopy* **Jörg Fink**, IFW/IFF	

Friday 27 June (public session, D2E.27)		
09:00	*Dissipationless transport signature of topological nodal lines* **Joseph Dufouleur**, IFW/IFF	*Chair: Büchner*
09:45	*Higher-order moments of resistance fluctuation across the superconducting transition in FeSe thin films* **Saquib Shamim,** SNBNCBS	
10:30	Coffee break	
11:00	*Nanoscale Mapping of Magnetic Textures in 2D and 3D Using Electron Holography and Electron Tomography* **Axel Lubk**, IFW/IFF	*Chair: Setti*
11:45	*Emergent phases, unconventional magnetotransport and magnetic anisotropy in a vdW ferromagnet Fe_4GeTe_2* **Riju Pal**, IFW/IFF	
12:30	Lunch break	
13:00	*Structural and physical properties of novel magnetically frustrated Rh/Ir (IV) based complex oxides* **Tamara Rubrecht**, IFW/IFF	*Chair: Janson*
13:45	*A Heisenberg model for g-wave altermagnets: the comparative analysis of CrSb and MnTe* **Volodymyr Kravchuk**, IFW/ITF	
14:30	Coffee break	
15:00	*Emergent altermagnetic anomalous Hall effect from electronic correlations* **Toshihiro Sato**, IFW/ITF	*Chair: Haldar*
15:45	*Quantum criticality in altermagnets* **Flavio de Souza Nogueira**, IFW/ITF	
16:30	*Topological magnons in an altermagnet* **Subhankar Khatua**, IFW/ITF	

Abstracts

Vacancy ordered Double Perovskites: Host for unconventional Magnetism

Tanusri Saha-Dasgupta, SNBNCBS

In this talk, we will discuss on a relatively new class of double perovskites, namely vacancy ordered double perovskite. These compounds consist of isolated BX_6 octahedra with monovalent A site cations to balance charge, more in fashion of molecular crystal – thus better chance of mimicking atomic limit in a solid state structure. We argue that these compounds can be a perfect host for spin-orbit coupling driven unconventional magnetism.

Frustration causing multiferroicity in hauerite MnS_2

Oleg Janson, IFW/ITF

Hauerite MnS_2 is a natural mineral with a cubic pyrite structure. Below 55 K, its S=5/2 moments localized on Mn atoms develop a collinear antiferromagnetic order that doubles the unit cell. Recently, MnS2 has been proposed as a multiferroic material. We show that the magnetic ordering indeed gives rise to a ferroelectric polarization along the [111] direction, accompanied by a jump in the dielectric constant. The experimental behavior is reproduced by DFT+U calculations. Based on these calculations, we develop a simple microscopic model that explains the emergence of ferroelectric polarization; the key element of this model are S_2 dimers that acquire an electric dipole moment due to the asymmetric arrangement of the neighboring Mn moments, in turn underpinned by frustration. We also show that the energy barrier for switching between the two magnetic domains -- in contrast to standard antiferromagnets -- is set by the magnetic exchange energy scale.

Stability of Weyl node merging processes under symmetry constraints

Cosma Fulga, IFW/ITF

Changes in the number of Weyl nodes in Weyl semimetals occur through merging processes, usually involving a pair of oppositely charged nodes. More complicated processes involving multiple Weyl nodes are also possible, but they typically require fine tuning and are thus less stable. In this work, we study how symmetries affect the allowed merging processes and their stability, focusing on the combination of a two-fold rotation and time-reversal (C2T) symmetry. We find that, counter-intuitively, processes involving a merging of three nodes are more generic than processes involving only two nodes. Our work suggests that multi-Weyl-merging may be observed in a large variety of quantum materials, and we discuss $SrSi_2$ and bilayer graphene as potential candidates.

Quantum Geometry and Dynamical Axion in antiferromagnetic topological insulator $MnBi_2Te_4$

Barun Ghosh, SNBNCBS

Antiferromagnetic topological insulators have recently become a versatile platform for uncovering novel fundamental physics in quantum materials. I will present our recent findings in the antiferromagnetic topological insulator system $MnBi_2Te_4$, highlighting quantum geometry-related effects and the realization of dynamical axion quasiparticles. I'll discuss the quantum metric, which refers to the real part of the complex quantum geometric tensor. Although the imaginary part (Berry curvature) of this tensor has been the basis of discoveries in the field of topological materials for many years, the importance of the quantum metric in driving new phenomena has emerged very recently. In this connection, I'll discuss our recent efforts in probing the quantum metric through transport and optical responses [1-4]. Finally, I'll present our recent work on the experimental observation of the dynamical Axion quasiparticle in $MnBi_2Te_4$ [5]. These discoveries extend our fundamental understanding of quantum geometry and axion electrodynamics and provide exciting new avenues for technological innovations leveraging topological quantum materials.

[1] B. Ghosh et al., Science Advances 10, eado1761 (2024)

[2] A. Gao, Y.-F. Liu, J.-X. Qiu, B. Ghosh et al., Science 381, 181–186 (2023)

[3] A. Gao et al., Nature 595, 521–525 (2021)

[4] A. Gao, S.-W. Chen, B. Ghosh et al., Nature Electronics 7, 751–759 (2024)

[5] J.-X. Qiu, B. Ghosh et al., Nature 641, 62–69 (2025)

Instability of the Haldane Phase under Charge Fluctuations and Doping Effects

Satoshi Nishimoto, IFW/ITF

Understanding the stability of topological phases in the presence of charge fluctuations and competing interactions is a central question in condensed matter physics. One-dimensional symmetry-protected topological phases, such as the Haldane phase in spin-1 chains, exhibit nonlocal string order and edge states protected by discrete symmetries. While these features are well understood in spin models, their robustness in itinerant systems remains less explored.

Here, we study two coupled spin-1/2 chains with ferromagnetic rung coupling - realized either as a spin-1 Heisenberg ladder or a half-filled two-leg Hubbard ladder with interchain Hund's coupling - using density-matrix renormalization group simulations. We find that both models support a Haldane-like topological phase, but in the Hubbard ladder this phase is destabilized by strong charge fluctuations, giving way to a trivial Mott insulator. Upon hole doping, we observe the emergence of dominant superconducting correlations, indicating a transition to a metallic phase with possible pairing tendencies. Our results reveal how charge dynamics both compete with and give rise to novel phases beyond topological order in correlated ladder systems.

Insights into Quantum Manybody Phenomena: Topology and Geometry-induced Effects in Quantum Spin Systems

Arijit Haldar, SNBNCBS

Manybody phenomena continue to be at the forefront of condensed-matter physics research. In recent years, several exciting concepts have emerged in areas such as non-Fermi liquid theory, non-equilibrium processes, topological phases, and quantum entanglement. In this talk, I will first introduce our group's research activities to push these ideas forward. Next, I will focus on the role of topology and quantum band geometry in the context of quantum spin systems. In particular, I will discuss how a new class of topology, called higher-order topology (HOT), can be realized in quantum paramagnets, naturally leading to the prediction of a novel quasiparticle that we dub HOT-triplon. Further, I will demonstrate that even when quantum spin systems are topologically trivial, unconventional transport responses can still occur in these systems. Notably, in a class of quantum magnetic insulators, the elusive Berry curvature dipole of magnons can generate interesting and novel Hall responses upon the application of thermal gradients and spin injection.

Observation of nodal superconductivity on the Fermi arcs of $PtBi_2$

Susmita Changdar[1,2,3]*, Oleksandr Suvorov*[1,4]*, Andrii Kuibarov*[1]*, Setti Thirupathaiah*[3]*, Grigoriy Shipunov*[1]*, Saicharan Aswartham*[1]*, Klaus Koepernik*[1]*, Carsten Timm*[5,6]*, Bernd Büchner*[1,6]*, Ion Cosma Fulga*[1,6]*, Sergey Borisenko*[1,6]*, and Jeroen van den Brink*[1,6]

1 Leibniz Institute for Solid State and Materials Research, IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

2 Institute for Solid State and Materials Physics, TU Dresden, D-01062 Dresden, Germany

3 Department of Condensed Matter and Materials Physics, S. N. Bose National Centre for Basic Sciences, Kolkata, West Bengal 700106, India

4 Kyiv Academic University, 36 Vernadsky blvd, Kyiv, 03142, Ukraine

5 Institute of Theoretical Physics, TU Dresden, 01062 Dresden, Germany

6 Würzburg–Dresden Cluster of Excellence ct.qmat, TU Dresden, 01062 Dresden,

We study the topological Fermi arcs on the two opposing terminations of the non-centrosymmetric Weyl semimetal $PtBi_2$ using angle-resolved photoemission spectroscopy. We find that the Fermi arcs become superconducting below ~10 K while the rest of the bulk bands remain unaffected [1]. Unlike previously studied Weyl superconductors, where bulk superconductivity plays a dominant role, our results indicate that superconductivity in $PtBi_2$ can occur exclusively at the surface. To precisely investigate the gap function, we use Laser source of hν = 5.9 eV for ARPES measurements and zoom in near the M point of the Brillouin zone where the arc is located. With the improved resolution we are able to capture the presence of a node in the superconducting gap at the center of the Fermi arc of PtBi2. Identification of the node implies unconventional superconducting pairing mechanism, potentially offering new avenues for exploring topological superconductivity.

[1] A. Kuibarov, O. Suvorov, R. Vocaturo, et al., Evidence of superconducting Fermi arcs. Nature 626, 294–299 (2024).

Designing and Synthesis of Skyrmion Lattice Superconductors

Thirupathaiah Setti, SNBNCBS

Topological superconductors are an exciting class of quantum materials from the fundamental sciences and potential technological applications points of view. Here, we present the successful introduction of superconductivity in a ferromagnetic layered skyrmion system Cr_3Te_4, obtained by the Sn intercalation, below a superconducting transition temperature of 3.5 K. We observe several interesting physical properties, such as superconductivity, magnetism, and the topological Hall effect, simultaneously in this system. Despite the magnetism and Meissner effects being anisotropic, the superconductivity observed from the in-plane electrical resistivity is nearly isotropic, suggesting separate channels of conduction electrons responsible for the superconductivity and magnetism of this system, which is also supported by our spin-resolved DFT calculations. We identify two orders of higher carrier density in superconducting $Sn_{0.06}Cr_3Te_4$ than the parent Cr_3Te_4. A jump in heat capacity around the T_c with a volume fraction of 33% confirms the bulk superconductivity in $Sn_{0.06}Cr_3Te_4$. In addition to the introduction of superconductivity, tuning of topological Hall properties is noticed with Sn intercalation. Our observation of superconductivity in a skyrmion lattice brings up a new class of topological quantum materials.

References:

1. $Sn_{0.06}Cr_3Te_4$: A Skyrmion Superconductor, Shubham Purwar, Anumita Bose, Achintya Low, Satyendra Singh, R. Venkatesh, Awadhesh Narayan, and Setti Thirupathaiah, Applied Materials Today 39, 102328 (2024).

2. Investigation of the Anomalous and Topological Hall Effects in Layered Monoclinic Ferromagnet $Cr_{2.76}Te_4$, Shubham Purwar, Achintya Low, Anumita Bose, Awadhesh Narayan, S. Thirupathaiah, Physical Review Materials 7, 094204 (2023).

Acoustic and optical plasmon excitations in cuprate and ruthenate “strange metals” studied by EELS, RIXS, and optical spectroscopy

Jörg Fink, IFW/IFF

Conventional metals show at low temperature a scattering rate which is quadratic in temperature or energy. In "strange metals", the scattering rate is enhanced at low energies leading to a linear dependence due to correlation effects. This is possibly related to strong quantum fluctuations which are also supposed to mediate superconductivity in cuprates and Sr_2RuO_4. There are theories based on holographic calculations which predict an over-damping of plasmons due to a low-energy continuum. These theories are supported by recent EELS measurements in reflection (R-EELS). The results are at variance with our early EELS experiments in transmission (T-EELS) and RIXS data on various cuprates and more recent T-EELS data on Sr_2CuO_4. In all cases we see well-defined optical plasmons which decay into particle-hole excitations only for large momentum in the range of the classical Lindhard continuum. The dispersion of the optical plasmon can be well described within the RPA without a mass renormalization. In contrast, the acoustic plasmon dispersion in p-type and n-type cuprates, studied by RIXS can be explained using a mass renormalization of $m^*=2\text{-}4$, also detected by ARPES at low energies. These conflicting results can be described by an energy dependent renormalization of the charge carriers, being large at low energy due to a coupling to spin excitations and turning small in the energy range of the optical plasmon well above the spin fluctuation energy. In addition, recent results on the plasmon width are discussed. They strongly support an origin based on interband transitions and not on correlation effects.

References

J. Schultz, A. Lubk, F. Jerzembeck, N. Kikugawa, M. Knupfer, D. Wolf, B. Büchner & J. Fink, Nature Comm. 16:4287 (2025).

Peter Abbamonte and Jörg Fink, Collective Charge Excitations Studied by Electron Energy-Loss Spectroscopy, Annu. Rev. Condens. Matter Phys. 16, 465 (2025).

Abhishek Nag, Luciano Zinni, Jaewon Choi, J. Li, Sijia Tu, A. C. Walters, S. Agrestini, S. M. Hayden, Matías Bejas, Zefeng Lin, H. Yamase, Kui Jin, M. García-Fernández, J. Fink, Andrés Greco, and Ke-Jin Zhou, Physical Review Research 6, 043184 (2024).

M. Knupfer, F. Jerzembeck, N. Kikugawa, F. Roth, J. Fink, Propagating charge carrier plasmons in Sr2RuO4, Physical Review B 106, L241103 (2022).

Dissipationless transport signature of topological nodal lines

Joseph Dufouleur, IFW/IFF

Topological materials, such as topological insulators or semimetals, usually not only reveal the nontrivial properties of their electronic wavefunctions through the appearance of stable boundary modes, but also through very specific electromagnetic responses. The anisotropic longitudinal magnetoresistance of Weyl semimetals, for instance, carries the signature of the chiral anomaly of Weyl fermions. However, for topological nodal line (TNL) semimetals – materials where the valence and conduction bands cross each other on one-dimensional curves in the three-dimensional Brillouin zone – such a characteristic has been lacking. Here we report the discovery of a peculiar charge transport effect generated by TNLs: a dissipationless transverse signal in the presence of coplanar electric and magnetic fields, which originates from a Zeeman induced conversion of TNLs into Weyl nodes under infinitesimally small magnetic fields. We evidence this dissipationless topological response in trigonal PtBi2 persisting up to room temperature, and unveil the extensive TNLs in the band structure of this non-magnetic material [1,2]. These findings provide a new pathway to engineer Weyl nodes by arbitrary small magnetic fields and reveal that bulk topological nodal lines can exhibit non-dissipative transport properties.

[1] A. Veyrat et al. Dissipationless transport signature of topological nodal lines, arXiv:2410.02353, accepted at Nature Communications

[2] A. Veyrat et al. Room temperature Planar Hall effect in nanostructures of trigonal-PtBi2, arXiv:2410.12596, under review

Higher-order moments of resistance fluctuation across the superconducting transition in FeSe thin films

Saquib Shamim, SNBNCBS

Low-frequency resistance fluctuations are sensitive to various phase transitions, for example, structural or electronic phase transitions. In this talk, we will report on the preliminary measurements of low-frequency noise across the superconducting transition in MBE-grown FeSe thin films. The variance of resistance fluctuations, as calculated from the power spectral density, increases by more than four orders of magnitude as the system transitions to the superconducting state with decreasing temperatures. We also calculated the second spectrum of noise to investigate the non-Gaussian nature of fluctuations.

Nanoscale Mapping of Magnetic Textures in 2D and 3D Using Electron Holography and Electron Tomography

Riju Pal[2], Banik Rai[2], Jimmy Steinweh[1], Daniel Wolf[1], Axel Lubk[1]

[1] Leibniz Institute for Solid State and Materials Research Dresden, Dresden, Saxony, Germany
[2] S. N. Bose National Centre for Basic Sciences

Out-of-focus Lorentz imaging and electron holography (EH) in the Transmission Electron Microscope (TEM) enable imaging magnetic textures and domain patterns at the nanometer scale. EH reconstructs the Aharonov-Bohm phase shift on the wave function of highly-energetic beam electrons after passing a thin magnetic sample in a TEM. Projections of the two in-plane components of the B-field of the magnetic structure can be readily computed from that phase shift. This experiment can be carried out at low temperatures and under application of an external out-of-plane field, thereby studying the field dependency of the textures. For investigation of three-dimensional (3D) nanomagnetism[1] involving 3D magnetic textures such as exotic domain walls (e.g. of Bloch point type) or magnetic solitons (e.g. (braided) skyrmion tubes, chiral bobbers, hopfions), EH can be combined with electron tomography to holographic vector-field electron tomography (VFET)[2]. VFET consists of recording and reconstructing two 360° holographic tilt series around perpendicular tilt axis allowing to reconstruct two B-field components (parallel to the two tilt axes). The third B-field component can be computed by solving div B=0. We discuss state-of-the-art EH and VFET. Furthermore, we present EH and VFET studies on magnetic textures in van der Waals magnets (e.g., Cr5Te8, Fe4GeTe2) and helimagnets (e.g., FeGe[3]).

References

[1] A Fernandez-Pacheco et al., Nat Commun 8 (2017) p. 15756. https://doi.org/10.1038/ncomms15756

[2] D. Wolf et al., Commun. Phys. 1 (2022). p. 87. https://doi.org/10.1038/s42005-019-0187-8

[3] D. Wolf et al., Nat. Nanotechnol. 17, (2022) p. 250. https://doi.org/10.1038/s41565-021-01031-x

We have received funding from the DFG by the Collaborative Research Center SFB 1143.

This work was partly carried out in the framework of the Memorandum of Understanding between IFW Dresden and S.N. Bose National Center for Basic Sciences.

Emergent phases, unconventional magnetotransport and magnetic anisotropy in a vdW ferromagnet Fe_4GeTe_2

Riju Pal, IFW/IFF

Nontrivial spin textures driven by strong exchange interaction, magneto-crystalline anisotropy, and electron correlation in a low-dimensional magnetic material often lead to unusual electronic transitions. Through a combination of transport experiments and first-principle calculations, we unveil new electronic phases in quasi-2D vdW ferromagnet Fe_4GeTe_2 (F4GT) with $T_C \sim 270$ K and spin reorientation ($T_{SR} \sim 120$ K) with the change of magnetic easy axis. Two electronic transitions are identified. The first transition near T_{SR} exhibits a sharp fall in resistivity, followed by a sign change in the ordinary Hall coefficient (R_0), together with maximum negative magnetoresistance (MR) and anomalous Hall conductivity. Another unusual electronic transition, hitherto unknown, is observed near $\sim$ 40 - 50 K (T_Q), below which R_0 again changes sign, the resistivity shows a quadratic temperature dependence, and MR becomes positive. The analysis exposes competing inelastic scattering processes, while the DFT-based calculations propose two magnetic phases, elucidating observed magnetotransport phenomena. ESR spectroscopic study provides quantitative insights into the non-trivial temperature evolution of the magnetic anisotropy in F4GT. At high temperatures, the total magnetic anisotropy (MA) is dominated by the demagnetization effect, with a slight contribution from the counteracting intrinsic easy-axis MA, whose growth below a characteristic temperature $T_{shape} \approx 150$ K renders the sample seemingly isotropic at T_{SR}. Below T_Q, the intrinsic MA becomes more complex. Observed characteristic temperatures align in both ESR and transport measurements, revealing inherent coupling between magnetic and electronic degrees of freedom. Thus, F4GT behaves as an ideal system to study the interaction of microwave radiation with the system's spins through changes in conductance induced by the portion of dynamically activated spins, employing electrically detected electron spin resonance (ED-ESR) spectroscopy. Such a plausible mutual dependence of the spin waves and the charge carriers can open a possibility to tune the transport properties of F4GT by controlling the magnetic excitations, and vice versa, which could find an application in the next generation spintronic devices.

Structural and physical properties of novel magnetically frustrated Rh/Ir (IV) based complex oxides

Tamara Rubrecht, IFW/IFF

La_2BRhO_6 (B = Zn, Mg) double perovskites containing Rh^{4+} ($4d^5$) were investigated as potential quantum spin liquid candidates. Despite structural similarities, La_2MgRhO_6 exhibits long-range antiferromagnetic order below 7 K, while La_2ZnRhO_6 shows no such ordering down to 50 mK. Structural analysis was performed via X-ray and neutron diffraction, while magnetic properties were probed using SQUID magnetometry and specific heat measurements. In parallel, novel layered oxides $La_2Sr_2MgRhO_8$ and $La_2Sr_2MgIrO_8$ were synthesized and analyzed. These Ruddlesden-Popper compounds exhibit 3D cation ordering revealed by pair distribution function analysis, undetectable with conventional diffraction. Magnetic susceptibility anomalies around 40–50 K were observed, though long-range order was excluded by neutron diffraction. These findings contribute to the growing interest in spin-liquid behavior and cation-ordering phenomena in complex oxides.

A Heisenberg model for g-wave altermagnets: the comparative analysis of CrSb and MnTe

Volodymyr Kravchuk, IFW/ITF

Altermagnets (AMs) constitute a novel class of spin-compensated materials in which opposite-spin sublattices are connected by a crystal rotation, causing their electronic iso-energy surfaces to be spin-split.

While cubic and tetragonal crystal symmetries tend to produce AMs in which the splitting of electronic iso-energy surfaces has d-wave symmetry, hexagonal AMs, such as CrSb and MnTe, are g-wave AMs. Here we investigate the purely magnetic modes and spin-textures of g-wave AMs and show that they are drastically different for easy-axial (CrSb) and easy-planar (MnTe) materials. We show that in CrSb the splitting of the chiral magnon branches possesses g-wave symmetry, with each branch carrying a fixed momentum-independent magnetic moment. The altermagnetic splitting is not affected by the easy-axial anisotropy and is the same as that in the nonrelativistic limit. The magnon splitting of MnTe, however, does not strictly possess g-wave symmetry due to its easy-planar anisotropy. Instead, the magnetic moment of each branch becomes momentum-dependent, with a distribution that is of g-wave symmetry. To generalize the concept of the altermagnetic splitting beyond the nonrelativistic limit, we introduce alternative, directly observable splitting parameter which comprises both the magnon eigenenergy and its magnetic moment, and possesses the g-wave symmetry in both easy-axial and easy-planar cases.

Emergent altermagnetic anomalous Hall effect from electronic correlations

Toshihiro Sato, IFW/IFF

Magnetism has long been understood to comprise essentially two classes of materials: ferromagnets and antiferromagnets. The former are characterized by finite magnetization and a spin-polarized electronic band structure, whereas the latter possess zero net magnetization and a spin-degenerate band structure. Recently, a new class, altermagnets, has been uncovered; these systems exhibit a spin-split band structure while still maintaining zero net magnetization. Symmetry analysis suggests that altermagnets can support an anomalous Hall effect even though their total magnetization vanishes. We introduce a two-dimensional interacting fermion model that realizes altermagnetism in which the anomalous Hall effect is driven by electronic correlations [1]. Employing approximation-free auxiliary-field quantum Monte Carlo simulations, we reveal that the system undergoes a finite-temperature phase transition governed by a primary antiferromagnetic order parameter, accompanied by a secondary altermagnetic one. This emergent secondary order is key to inducing an anomalous Hall effect, as evidenced by our calculation of anomalous Hall conductivity. Moreover, we derive a low-energy effective continuum description that substantiates our findings within the context of a recently developed Landau theory of altermagnetism.

[1] T. Sato, S.Haddad, I. C. Fulga, F. F. Assaad, and J. van den Brink, Phys. Rev. Lett. 133, 086503 (2024).

Quantum criticality in altermagnets

Flavio de Souza Nogueira, IFW/ITF

The term altermagnetism has recently been introduced to describe the Néel order of a class of materials whose magnetic sublattices are neither related by translation nor inversion. While these materials arguably have large technological potential, little effort has been devoted to studying the universal distinction of this phase of matter compared to collinear antiferromagnetism. We discuss the quantum critical behavior of a minimal microscopic model from which a nonlinear sigma model can be derived. It describes the long-wavelength fluctuations of the staggered magnetization in the system, including quantum effects to leading order. The term that distinguishes the altermagnetic nonlinear sigma model from its antiferromagnetic counterpart is an interaction term that derives directly from the Berry phase of the microscopic spin degrees of freedom. Extending the theory to describe the fermionic excitations of the metallic altermagnet, we find an effective low-energy model of d-wave spin-split Dirac fermions interacting with the magnetic fluctuations.

Topological magnons in an altermagnet

Subhankar Khatua, Volodymyr P. Kravchuk, Kostiantyn V. Yershov, and Jeroen van den Brink

IFW/ITF

Altermagnets present a newly identified class of magnetic ordering, distinct in symmetry from conventional ferromagnets and antiferromagnets. They exhibit collinear compensated Néel ordering where the two sublattices are not related just by time-reversal combined with lattice translation or inversion; instead, it requires an additional lattice rotation. This altermagnetic symmetry is reflected in the magnon or spin-wave spectrum as degeneracies along specific lines in the Brillouin zone. We consider a two-dimensional d-wave altermagnetic spin model -- the checkerboard lattice spin model, and introduce perturbations such as an external magnetic field and Dzyaloshinskii-Moriya interactions to lift the magnon band degeneracies imposed by altermagnetism. We find that the resulting gapped magnon bands are topologically non-trivial. We further discuss the implications of this topology, including the emergence of thermal Hall conductivity and topologically protected chiral edge modes.