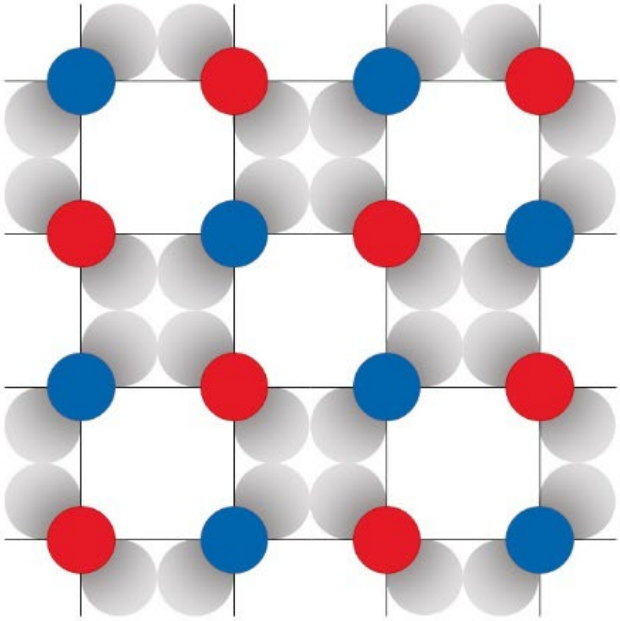

GU. QuMat

German-Ukrainian Research Center for Quantum Materials

International Workshop on Unconventional Magnetism in Quantum Materials

14 – 15 July 2025

Kyiv, Ukraine

Organizers: Bernd Büchner, Helen Gomonay, Alexander Kordyuk, Jeroen van den Brink

With funding from the:

Federal Ministry of Research, Technology and Space

Monday 14 July	
10:00 (EEST)	*Welcoming words* **Jeroen van den Brink**, IFW Dresden/**Alexander Kordyuk**, Kyiv Academic University & G.V. Kurdyumov Institute for Metal Physics
10:15	**TUTORIAL** *The emergence of altermagnetism: unconventional time reversal symmetry breaking and beyond* **Jairo Sinova**, Johannes Gutenberg University Mainz
11:05	*Altermagnetism from a symmetry perspective* **Paul McClarty,** CEA-Saclay + Université Paris-Saclay
11:35	*p-wave magnetism in spin spiral magnets* **Riccardo Comin**, Massachusetts Institute of Technology
12:05	Lunch break
13:00	*Viscoelastic tensor and hydrodynamics of altermagnets* **Eduard Gorbar**, Taras Shevchenko National Kyiv University
13:30	*Altermagnet properties at a cuprate/manganite interface* **Yurii Pashkevich**, Donetsk Institute for Physics & Engineering named after O.O. Galkin, NAS of Ukraine
14:00	*Unconventional superconductivity in altermagnets* **Asle Sudbø**, Norwegian University of Science and Technology
14:30	*Quantum criticality in the nonlinear sigma model for altermagnets* **Flavio Nogueira**, IFW Dresden
15:00	Coffee break
15:30	*Local and Nonlocal Chiral Symmetry Breaking in Curvilinear Magnetism* **Denis D. Sheka**, Taras Shevchenko National University of Kyiv
16:00	*Chiral breakdown in domain wall dynamics in biaxial magnetic nanotubes* **Svitlana Kondovych**, IFW Dresden
16:20	*Controling domain wall mobility in ferromagnetic nanostripes with variable cross section* **Dmytro Karakuts**, Taras Shevchenko National University of Kyiv
16:40	*Topological magnonics: the Berry phase, the Aharonov–Casher effect, and quantum control of spin-wave dynamics in magnetic insulators* **Vladimir Krivoruchko**, Donetsk Institute for Physics and Engineering named after O.O. Galkin of the NAS of Ukraine

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Monday 14 July (cont.)	
17:00	*Density of states in graphene in crossed magnetic and in-plane electric fields* **Sergei Sharapov**, Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine
17:30	Coffee break
18:00	*Hubbard models for non-relativistic spin-splitting* **Daniel Agterberg**, University of Wisconsin
18:30	*Altermagnetic MnTe thin films grown by molecular beam epitaxy* **Badih Assaf**, University of Notre Dame
19:00	End of the day's programme – Workshop dinner

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Monday 14 July – Abstracts

TUTORIAL

The emergence of altermagnetism: unconventional time reversal symmetry breaking and beyond

Jairo Sinova, Johannes Gutenberg University Mainz

Antiferromagnetic spintronics has been a very active research area of condensed matter in recent years. As we have learned how to manipulate collinear antiferromagnets actively and their emergent topology by means of new types of spin-orbit torques, a key problem remained: the inefficiency of relativistic mechanism. The necessity of relativistic effects to manipulate and detect Néel order arises from the spin degeneracy of collinear antiferromagnets in the non-relativistic limit – or at least it was thought. The discovery of d-wave magnetic order in momentum space motivated a closer look at the symmetry classification of collinear magnetic systems. This has emerged as the third basic collinear magnetic ordered phase of altermagnetism, which goes beyond ferromagnets and antiferromagnets. Altermagnets exhibit an unconventional spin-polarized d/g/i-wave band structure in reciprocal space, originating from the local sublattice anisotropies in direct space. This gives properties unique to altermagnets (e.g., the spin-splitter effect), while also having ferromagnetic (e.g., polarized currents) and antiferromagnetic (e.g., THz spin dynamics and zero net magnetization) characteristics useful for spintronics device functionalities. I will cover the basic introductory view to altermagnetism and its consequences to spintronics as well as new emerging exchange driven phenomena akin to spin-orbit coupling effects, such as p-wave magnetism, emerging from the basic concepts that gave rise to the discovery of altermagnetism.

[1] Libor Šmejkal, Rafael González-Hernández, T. Jungwirth and J. Sinova, Sci. Adv. 6, 23 (2020)
[2] Libor Šmejkal, Jairo Sinova and Tomas Jungwirth, Phys. Rev. X 12, 031042 (2022)
[3] Libor Šmejkal, Jairo Sinova and Tomas Jungwirth, Phys. Rev. X 12, 040501 (2022)
[4] Zexin Feng, et al, Nature electronics 5, 735-743 (2022)
[5] Libor Šmejkal, et al, Phys. Rev. X 12, 011028 (2022)
[6] Rafael González-Hernández, et al, Phys. Rev. Lett. 126, 127701 (2021)
[7] J. Krempaský, L. Šmejkal, et al, Nature 626, 517–522 (2024)
[8] O. Fedchenko, et al, Sci. Adv. 10, eadj4883 (2024)

Altermagnetism from a symmetry perspective

Paul McClarty, CEA-Saclay + Université Paris-Saclay

Altermagnets are collinear compensated magnets whose band structures have a characteristic pattern of spin splitting in momentum space. They have attracted the interest of people especially in spintronics for various attractive properties combining features of simple ferromagnets and antiferromagnets. In this talk, I introduce altermagnets through their distinctive symmetries. In particular, they are most cleanly defined in the zero spin-orbit coupled limit, so we formulate Landau theories that capture their residual spin-space symmetries that allows us to perform a complete classification of altermagnets and make statements about their properties. We give further insight about their underlying multipolar order parameters and connections between the zero and finite spin-orbit coupled cases.

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p-wave magnetism in spin spiral magnets

Riccardo Comin, Massachusetts Institute of Technology

Altermagnets are a new class of magnetic materials that combine aspects of ferromagnets and antiferromagnets, possessing zero net magnetization like antiferromagnets but exhibiting (potentially large) spin splitting of the electronic bands and anomalous Hall responses like ferromagnets. Recent research has focused on magnetic systems with odd-parity spin splitting of nonrelativistic origin (p-wave magnets), which are promising for spintronic applications. Symmetry considerations suggest the possibility of coupling altermagnetism with ferroelectricity in polar chiral magnets, potentially allowing for novel mechanisms for electric-field control of magnetism.

Nickel iodide (NiI_2) is a van der Waals magnetic insulator and multiferroic when in its chiral magnetic phase ($T < 59$ K). The spin helices (pitch ~ 7 unit cells) that characterize this phase breaks inversion symmetry, leading to an induced electrical polarization of purely electronic origin. I will start by discussing prior work on the evolution of the multiferroic down to the two-dimensional (single-layer) limit. I will then focus on more recent work characterizing the nonrelativistic spin splitting of electronic bands in NiI_2, and its connection to symmetry and chirality. I will present a demonstration of the electrical (voltage-based) switching of chirality and consequent reversal of the momentum-space spin polarization. I will conclude with an outlook for potential applications of spin-chiral multiferroics for information storage.

Viscoelastic tensor and hydrodynamics of altermagnets

Eduard Gorbar, Taras Shevchenko National Kyiv University

The viscoelasticity tensor for altermagnets is calculated and the corresponding hydrodynamic equations are formulated. It is shown that the anisotropy of altermagnetic Fermi surfaces allows for additional terms in the viscoelasticity tensor and is manifested in transport properties including electron and spin flows in channel and nonlocal responses. In the channel geometry, the altermagnetic spin splitting leads to nontrivial spin density and spin current. Like the electric current, the spin current acquires a Poiseuille profile for no-slip boundary conditions. In nonlocal responses, the altermagnetic anisotropy affects current streamlines and electric potential distributions in the viscous regime. The obtained results provide signatures of the hydrodynamic transport regime in altermagnets potentially facilitating its experimental studies and discovery.

Altermagnet properties at a cuprate/manganite interface

Yurii Pashkevich, Donetsk Institute for Physics & Engineering named after O.O. Galkin, NAS of Ukraine

Using resonant inelastic X-ray scattering study, we observe a new 2D magnetic quantum state in the interface of $YBa_2Cu_3O_7/Nd_{0.65}(Ca,Sr)_{0.35}MnO_3$ heterostructure [1]. The interfacial cuprate monolayer hosts a particularly combined spin and orbital order, which manifests in a non-trivial magnon excitation having reduced exchange interaction and atypical intensity dispersion, distinctive from the usual 3D magnons in cuprates. This coupled antiferromagnetic and orbital order leads to a new kind of 2D altermagnetic state, which is not bound by the typical symmetry restrictions as previously expected [2].

[1] S. Sarkar et al PNAS Nexus 3, pgae100 (2024), https://doi.org/10.1093/pnasnexus/pgae100
[2] L. Šmejkal, J. Sinova, T. Jungwirth Phys Rev X. 12:040501 (2022)

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Unconventional superconductivity in altermagnets

Asle Sudbø, Norwegian University of Science and Technology

We consider the possibility of phonon-mediated unconventional superconductivity in a recently discovered new class of antiferromagnets, dubbed altermagnets. Within a weak-coupling approach, and using a minimal Lieb lattice model for altermagnets, we find a dominant superconducting instability odd in momentum and even in spin with spin-polarized Cooper pairs. We discuss the origin of this unusual result in terms of the spin-structure of the altermagnetic Fermi surface, in combination with the momentum-space structure of the effective phonon-mediated electron-electron interactions on the Fermi surface.

Quantum criticality in the nonlinear sigma model for altermagnets

Flavio Nogueira, IFW Dresden

We discuss the quantum critical behavior of a nonlinear sigma model for altermagnets. It is shown that criticality is strongly influenced by a topological term living at the boundary. The secondary order parameter, which has an octupolar form for d-wave altermagnets, plays an important role in determining the critical behavior in the bulk. We discuss these effects in detail and connect the effective theory to different fermionic models in checkerboard and Lieb lattices.

Local and Nonlocal Chiral Symmetry Breaking in Curvilinear Magnetism

Denis D. Sheka, Taras Shevchenko National University of Kyiv

The nanotechnology rush extended conventional flat architectures to curved space, showcasing the fundamental importance of the mutual interplay between geometry, topology and the order parameter. In the case of magnetism, a mutual interplay of material properties such as magnetization texture and geometrical properties, such as curvature, thickness, topology becomes a playground for curvilinear magnetism [1]. By tailoring geometric properties of the conventional magnetic materials, a variety of possibilities emerge to control material response, leading to modification or even launching new functionalities [2].

This talk focuses on the peculiarities emerging from geometrically curved magnetic objects, including 3D bent and twisted curved wires and films. We discuss family of novel geometry-governed effects emerge, which include magnetochiral effects and topological patterning, resulting in theoretically predicted domain wall automotion, unlimited domain wall velocities, chirality symmetry breaking, mesoscale Dzyaloshinskii-Moriya interaction etc. Our special focus is chiral effects, which can be local driven by exchange and stemming from local curvature and torsion or stemming from the varying cross-section [3], but also can be nonlocal driven by magnetostatics and supported by topology [4]. We discuss the nonlocal symmetry breaking effect is validated experimentally in the vortex state magnetic cap [5]: due to the symmetry break the vortex string becomes deformed into a helix. Moreover, the geometric chirality of the vortex string is determined by the magnetic helicity of the vortex texture, constituting coupling of two chiral parameters within the same texture.

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2. G. Gubbiotti et al, “2025 Roadmap on 3D Nano-magnetism”, J. Phys: Cond Matt (2025); doi: 10.1088/1361-648x/ad9655
3. K. Yershov, D. Sheka, Phys. Rev B 107 (2023) L100415; doi: https://doi.org/10.1103/PhysRevB.107.L100415; D. Karakuts, K. Yershov, D. Sheka, in Functional Magnetic and Spintronic Nanomaterials (2024), doi: 10.1007/978-94-024-2254-2_6
4. D. Sheka, O. Pylypovskyi, P. Landeros, Y. Gaididei, A. Kákay, D. Makarov, “Nonlocal chiral symmetry breaking in curvilinear magnetic shells”, Comm. Phys. 3 (2020) 128, doi: 10.1038/s42005-020-0387-2
5. O. Volkov, D. Wolf, O. Pylypovskyi, A. Kákay, D. Sheka, B. Büchner, J. Fassbender, A. Lubk, D. Makarov, “Chirality coupling in topological magnetic textures with multiple magnetochiral parameters”, Nature Comms, 14 (2023) 1491, doi: 10.1038/s41467-023-37081-z.

Chiral breakdown in domain wall dynamics in biaxial magnetic nanotubes

Svitlana Kondovych, IFW Dresden

The interplay between symmetry and geometry in magnetic nanotubes offers a powerful framework for exploring topological effects and curvilinear magnetization dynamics. In this work [1], we examine the combined effects of curvilinear geometry, intrinsic DMI, and long-range dipole-dipole interactions on the statics and field-driven motion of magnetic domain walls in biaxial magnetic nanotubes, with a focus on the setups that exhibit chiral effects. Our findings provide insights into the controlled manipulation of domain walls and offer new strategies to engineer magnetic textures for applications in nanoelectronics.

1. Yershov, K. V., Kondovych, S., & Sheka, D. D. (2025). Chiral breakdown engineered by mesoscale Dzyaloshinskii-Moriya interaction in biaxial magnetic nanotubes. arXiv preprint arXiv:2502.08283. Accepted to Physical Review B.

Controling domain wall mobility in ferromagnetic nanostripes with variable cross section

Dmytro Karakuts, Taras Shevchenko National University of Kyiv

Here, we aim to theoretically and numerically describe how the dynamics of domain walls in thin ferromagnetic nanostripes with variable cross section are affected by an external magnetic field. Namely, we show the competition between the influence of the cross-section gradient and the external magnetic field, which leads to pinning of the domain wall. Two types of nanostripe geometries are studied: nanostripe with localised constriction and a wedge-shaped nanostripe. The behavior of domain walls in the nanostripe is described by collective variable approach by adapting the q-. model to stripes with varying cross section. We obtain the domain wall pinning position, as well as a field sufficient for domain wall depinning. The linear dynamics of the domain wall near the pinning position are considered and the oscillation frequency near the pinning position is calculated. All analytical predictions are well-confirmed by the data of NMAG micromagnetic simulations.

Topological magnonics: the Berry phase, the Aharonov–Casher effect, and quantum control of spin-wave dynamics in magnetic insulators

Vladimir Krivoruchko, Donetsk Institute for Physics and Engineering named after O.O. Galkin of the NAS of Ukraine

The fundamental dynamic characteristics of spin wave (SW) are phase, amplitude, and propagation direction. Modifying and tuning these SW characteristics in real time is one of the most

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important requirements for integrating magnonics into quantum technologies and devices. This motivates research activities to find mechanisms to control the dynamic characteristics of SWs or their quanta, magnons. We discuss the electric field effects on magnons' dynamics in magnetic insulators - the magnonic Aharonov–Casher effect. From quantum mechanical physics, this effect is the accumulation of a geometric phase by chargeless quasiparticles with a magnetic dipole moment moving in an electric field. This theoretically predicted topological quantum effect has been recently experimentally detected in SWs' dynamical characteristics propagating in ferromagnets under the electric field effect. Compared to conventional ferromagnetic insulators, antiferromagnetic (AFM) and ferrimagnetic (FIM) insulators, which have antiferromagnetically coupled magnetic sublattices, have the advantages of minimized stray field and fast magnetization dynamics up to the terahertz range. Furthermore, unlike ferromagnets, magnons in AFMs and FIMs possess both right-handed and left-handed chirality and thus can also carry the information in their polarization. The topological Aharonov-Casher effect on different chirality magnetization dynamics is also discussed.

Density of states in graphene in crossed magnetic and in-plane electric fields

Sergei Sharapov, Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine

The density of states and differential entropy per particle are analyzed for Dirac-like electrons in graphene subjected to a perpendicular magnetic field and an in-plane electric field. The study considers ballistic electrons and also includes the effect of small impurity scattering. In the latter case, the limit of zero magnetic field and the so-called collapse of Landau levels in grapheme are examined analytically. By comparing the results with numerical calculations on graphene ribbons, we demonstrate that the Landau state counting procedure must be modified for Dirac-like electrons, leading to a fields-dependent Landau level degeneracy factor.

A.A. Chaika, Ye. Kulynych, D.O. Oriekhov, and S.G. Sharapov, "Density of states and differential entropy in the Dirac materials in crossed magnetic and in-plane electric fields'', Phys. Rev. B 111, 085426 (2025).

Hubbard models for non-relativistic spin-splitting

Daniel Agterberg, University of Wisconsin

Altermagnets and odd-parity magnets have recently emerged as important classes of magnetic materials for spintronics due to their vanishing net magnetization and large, strongly momentum dependent, energy splittings between opposite spin electronic states. Most existing theoretical research on these magnetic states stems from density functional theory (DFT). Here I present recent progress [1,2,3,4] on developing Hubbard Hamiltonians for altermagnets and odd-parity magnets that faithfully reproduce important features found in DFT electronic bandstructures. These Hubbard Hamiltonians provide microscopic descriptions for d-wave, g-wave, and i-wave altermagnets and for p-wave, f-wave, and h-wave odd-parity magnets. Using these Hubbard Hamiltonians, we provide insight into the stability, the microscopic origin of the electronic spin-textures, and response properties of these states.

[1] Minimal models for altermagnetism, M. Roig, A. Kreisel, Y. Yu, B. M. Andersen, and D. F. Agterberg, Phys. Rev. B 110, 144412 (2024).
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Altermagnetic MnTe thin films grown by molecular beam epitaxy

Badih Assaf, University of Notre Dame

α-MnTe is the most widely studied altermagnet. Its emergence as the prototypical altermagnetic material has spurred efforts to study its properties in both thin films and single crystals. Thin films reveal challenges and opportunities, stemming from their unique sensitivity to lattice and thermal expansion matching. In this talk, I will present our recent findings from a holistic study of the electrical, magnetic, structural and chemical properties of α-MnTe thin films grown by molecular beam epitaxy. The talk broadly reviews challenges encountered when growing α-MnTe on both lattice matched and mismatched substrates. It also discusses our finding of a tunable anomalous Hall effect in α-MnTe grown on GaAs, which may present an opportunity to tune the order parameter of this material. The ability to grow high quality thin films of α-MnTe enables the realization of tunnel junctions and magnetic memory devices that exploit its spin texture to store and manipulate information. The control of material properties through synthesis is therefore a crucial step towards this goal.

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Tuesday 15 July	
10:00 (EEST)	**TUTORIAL** *Spin Transport Experiments in Altermagnets* **Helena Reichlova**, Institute of Physics, Czech Academy of Sciences
10:50	*Is RuO_2 an altermagnet?* **Roser Valenti**, Goethe University Frankfurt
11:20	*Heisenberg models of altermagnets* **Volodymyr Kravchuk,** Leibniz Institute for Solid State and Materials Research
11:50	*In-situ magnetotransport investigations of $Mn_{1.4}PtSn$* **Andy Thomas**, IFW Dresden
12:20	Lunch break
13:00	*Noncollinear Altermagnets* **Maia Vergniory**, Université de Sherbrooke
13:30	*Altermagnetic polarons* **Krzysztof Wohlfeld**, University of Warsaw
14:00	*Control of memory cell magnetisation by combined pulses of local magnetic fields* **Pavlo Polynchuk**, V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine
14:20	*Current-driven dynamics of domain walls in low-dimensional helimagnets* **Roman Teslia**, V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine
14:40	*Size effects and surface states in spin-1 semimetals* **Artem Prykhodko**, Taras Shevchenko National Kyiv University
15:00	Coffee break
15:30	*Altermagnetism and spin symmetries* **Libor Šmejkal**, MPI PKS
16:00	*Why A in ARPES is important* **Sergey Borisenko**, IFW Dresden
16:30	*Magnetic-field-tunable density waves in a layered altermagnet $Co_{0.25}NbSe_2$* **Ilija Zeljkovic**, Boston College
17:00	*Altermagnet MnF_2, viewed by inelastic neutron scattering* **Oksana Zaharko**, Paul Scherrer Institut

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Tuesday 15 July (cont.)	
17:30	Coffee break
18:00	*Electronic properties of odd-parity magnets* **Pavlo Sukhachov**, University of Missouri
18:30	*Topology in altermagnets from minimal models* **Jorn Venderbos**, Drexel University
19:00	*Linear magneto-birefringence: an optical probe of complex (alter)magnetism* **Veronika Sunko**, UC Berkeley
19:30	End of workshop

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Tuesday 15 July – Abstracts

TUTORIAL

Spin Transport Experiments in Altermagnets

Helena Reichlova, Institute of Physics, Czech Academy of Sciences

Altermagnets combine features of ferromagnets and antiferromagnets, making them promising for spintronic technologies. This talk presents experimental studies confirming key altermagnetic properties. I will highlight the emergence of the anomalous Hall effect—absent in conventional antiferromagnets—due to broken time-reversal symmetry in their electronic bands. I'll also cover the related anomalous Nernst effect and the role of altermagnetism in magnon-mediated spin currents.

Is RuO_2 an altermagnet?

Roser Valenti, Goethe University Frankfurt

The metallic rutile oxide RuO_2, long believed to be a textbook Pauli paramagnet, recently emerged as a workhorse altermagnet when resonant X-ray and neutron scattering studies reported nonzero magnetic moments and long-range collinear order. While experiments on thin films seem consistent with altermagnetic behavior, the origin and size of magnetic moments in RuO_2 still remain controversial. In this talk I will discuss through a combined theoretical and experimental study that RuO_2 is nonmagnetic and will show results on bulk and thin films.

Heisenberg models of altermagnets

Volodymyr Kravchuk, IFW Dresden

Being collinear-compensated magnets, altermagnets differ from conventional antiferromagnets by a more complex symmetry transformation connecting two sub-lattices. Due to the specific local surrounding of the magnetic atoms, the symmetry transformation involves also the rotation operation in addition to the translation and time reversal. Here we propose Heisenberg models for d-wave (rutiles) as well as for g-wave (CrSb, MnTe) altermagnets. The models capture the altermagnetic properties due to the additional superexchange interactions whose bonds orientations respect the symmetry of the local nonmagnetic surrounding of the magnetic atoms. Using our models, we reproduce the altermagnetic splitting in the magnon spectra, and predict a number of new effects induced by altermagnetism, namely fluctuation-induced piezomagnetism and thermal spin conductivity for d-wave altermagnets, emergent magnetization of domain walls for both d- and g-wave altermagnets. Based on our models, we generalize the concept of the altermagnetic splitting beyond the nonrelativistic limit by introducing alternative, directly observable splitting parameter which comprises both the magnon eigenenergy and its magnetic moment and possesses the corresponding d- or g-wave symmetry even in the presence of spin-orbital coupling.

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In-situ magnetotransport investigations of $Mn_{1.4}PtSn$

Andy Thomas, IFW Dresden

The (anomalous) Hall effect is linked to topologically protected spin textures like skyrmions, an active area of research. To understand their role, we need to separate their contributions from other effects. We present a novel measurement platform that acquires high-resolution Lorentz transmission electron microscopy images and in-situ measurements of the anomalous Hall voltage simultaneously. Applying this approach to $Mn_{1.4}PtSn$, we investigate chiral soliton lattices and antiskyrmions' transport signatures. Our results show a clear correlation between transversal Hall voltage and magnetic textures, indicating non-topological contributions.

Noncollinear Altermagnets

Maia Vergniory, Université de Sherbrooke

Altermagnets are a newly discovered class of magnetic phases that combine the spin polarization behavior of ferromagnetic band structures with the vanishing net magnetization characteristic of antiferromagnets. Initially proposed for collinear magnets, the concept has since been extended to include certain non-collinear structures. A recent development in Landau theory for collinear altermagnets incorporates spin-space symmetries, providing a robust framework for identifying this class of materials. Here we expand on that theory to identify altermagnetic multipolar order parameters in non-collinear magnetic materials.

Altermagnetic polarons

Krzysztof Wohlfeld, University of Warsaw

Spin-dependent band splitting is a characteristic feature of altermagnets; however, a conventional band picture may not be applicable in the case of Mott altermagnets. To investigate this, we calculate ARPES spectra for two canonical Mott altermagnets: the checkerboard J-J' model and the Kugel–Khomskii spin–orbital altermagnet, which is realized in the cubic vanadates RVO_3 (R=La, Pr, Nd, Y). Our results reveal that spin-dependent spectral-weight transfer is the dominant signature of Mott altermagnetism. This pronounced spin–momentum locking of the quasiparticle spectral weight arises from the formation of altermagnetic polarons, whose dynamics are governed by the interplay between free hole motion and the coupling of the hole to magnon excitations in the altermagnet.

Control of memory cell magnetisation by combined pulses of local magnetic fields

Pavlo Polynchuk, V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine

The process of controlling the magnetisation of a memory cell under the combined action of local external magnetic fields created by passing pre-programmed electric currents through control electric conductors in a standard layout is theoretically studied. It is shown that by optimising the shape and duration of current pulses I(t) (t - time), a high-speed relaxation-free mode of switching the magnetic state of the memory cell is achieved. The optimal parameters of field (current) pulses for achieving a fast relaxation-free mode of memory cell magnetisation are determined.

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Current-driven dynamics of domain walls in low-dimensional helimagnets

Roman Teslia, V.G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine

A broad class of (magneto-electric) multiferroics is represented by the so-called frustrated magnetic systems in which the magnetization (or Néel vector) forms a helical periodic structure intermediate between ferromagnets and antiferromagnets [1].

Schemes for controlling the helimagnetic structure using a magnetic field with a change in magnetotransport properties due to the formation of a magnetic kink crystal [2] and discrete helicoidal states [3] have been demonstrated. However, the dynamics of domain walls driven by spin-polarized currents in these materials remain largely unexplored; the translational motion of domain walls in helimagnets may be accompanied by the formation of magnetization “vortices” [4].

In our work, we theoretically investigate the motion of chiral domain walls under the action of a spin-polarized current in a one-dimensional helimagnet. Using a continuum approach, we demonstrate the possibility of translational motion of the domain wall using short-term spin current pulses. Furthermore, the long-term action of the current leads to a renormalization of the helical pitch (magnetization rotation rate), and samples larger than the characteristic domain wall width allow the formation of pairs of such walls along the system.

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Surface states and finite size effects in pseudospin-1 semimetals

Artem Prykhodko, Taras Shevchenko National University of Kyiv

Triple-fold or pseudospin-1 semimetals belong to a class of multi-fold materials in which linearly dispersive bands and flat bands intersect at the same point, forming triple-fold crossing points. We conduct an analytical investigation of topologically protected Fermi arc surface states and finite-size effects in three-dimensional (3D) triple-fold and doubly degenerate triple-fold semimetals in continuum low-energy models. Higher topological charge of the triple-fold crossing points leads to two Fermi arcs connecting the nodes. For a single triple-fold crossing point, we found that no term in the Hamiltonian with momentum-independent elements can open a gap, prompting us to consider a doubly-degenerate triple-fold fermion, where the gap can be opened by mixing the degenerate copies. Thin films of triple-fold semimetals allow for mixing between the surface and bulk states in addition to the discretization of energy levels of the latter.

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Altermagnetism and spin symmetries

Libor Smejkal, MPI PKS

Since the 1930s, magnets have been classified into two main branches: ferromagnets and antiferromagnets. Recently, we have identified a third fundamental branch: altermagnets [1,2]. Altermagnetism is characterized by a compensated d-, g-, or i-wave alternating spin order, which distinguishes it from ferromagnets and antiferromagnets. The discovery of the altermagnetic class emerged from our systematic classification of crystallographic spin groups [1], which is analogous to the well-established frameworks used in superconductivity, superfluidity, and the Standard Model.

In this talk, we will outline our decade-long journey leading to the discovery of altermagnets, including the prediction[3] and experimental observation[4] of the anomalous Hall effect and unconventional electronic structure in compensated collinear magnets. We will also present our systematic classification, which—beyond even partial-wave altermagnets—recently revealed a new class of odd partial-wave magnets [5].

Furthermore, we will showcase experimental evidence supporting altermagnetism, including its distinct signatures in photoemission spectra [6] and nanoscale mapping [7]. Finally, we will explore emerging research directions exploiting unique altermagnetic effects unavailable in ferromagnets and antiferromagnets. These include altermagnetic spintronics [8], magnonics [9], two-dimensional magnetism [10], and multiferroics [11]. The possibility of altermagnetism in a wide range of materials, ranging from metals to insulators [1], is promising for potential applications both within and beyond solid-state physics, including ultrafast and low-power nanoelectronics.

[1] PRX 12, 031042 (2022).
[2] https://www.economist.com/science-and-technology/2024/01/24/scientists-have-found-a-new-kind-of-magnetic-material, https://www.science.org/content/article/researchers-discover-new-kind-magnetism
[3] Science Adv. 6, 23 (2020), PNAS 118 42 (2021),
[4] Nature Electronics 5, 735 (2022), Nature Commun. 15, 4961 (2024).
[5] arXiv:2309.01607v3 (2024).
[6] Nature 626, 517 (2024), Nature Commun. 15, 2116 (2024), PRL 132, 036702 (2024).
[7] Nature 636, 348 (2024).
[8] PRX 12, 011028 (2022), arXiv:2503.12203 (2025).
[9] PRL 131, 256703 (2023), arXiv:2309.02355 (2023), arXiv:2411.19928 (2024).
[10] arXiv:2309.02355
[11] arXiv:2411.19928

Why A in ARPES is important

Sergey Borisenko, IFW Dresden

The basic result obtained by modern ARPES is very often associated with the two-dimensional intensity distribution with coordinate axes labeled as "Binding energy" and "Momentum". Such datasets are usually directly compared to the band structure calculations along high symmetry directions of the Brillouin zone. We show that this is the result of a widespread misunderstanding of the experimental ARPES data and suggest ways to avoid this in both data collection and analysis.

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Magnetic-field-tunable density waves in a layered altermagnet $Co_{0.25}NbSe_2$

Ilija Zeljkovic, Boston College

Altermagnets recently came into the spotlight as a new class of magnetic materials, arising as a consequence of specific crystal symmetries. They are characterized by a spin-polarized electronic band structure similar to ferromagnets, but with net zero magnetization, and touted as a promising platform to host a slew of exotic properties, many of which are yet to be explored. Here we study a new layered triangular lattice altermagnet, Co-intercalated $NbSe_2$ using scanning tunneling microscopy and spectroscopy (STM/S). Differential conductance dI/dV spectra at low temperature reveal a surprising partial gap opening centered at the Fermi level, which is not captured by density functional theory calculations of the system in the pure altermagnetic state. Spatial mapping using spectroscopic-imaging STM and spin-polarized STM further reveals emergent tri-directional charge and spin density modulations with a $2a_0$ wave length. Interestingly, we discover that out-of-plane magnetic field can serve as a knob to tune the amplitudes of the modulations as well as alter the overall electronic density-of-states in a manner that is strongly dependent on the field direction and strength. This can be attributed to the tilting of spins by the external magnetic field, which can have profound implications on the electronic properties of the altermagnet. By providing elusive atomic-scale insights, our work uncovers a tunable density wave accompanied by concomitant changes in the electronic band structure, and sets the foundation for studies of correlated electronic phenomena in altermagnets.

Altermagnet MnF_2, viewed by inelastic neutron scattering

Oksana Zaharko, Paul Scherrer Institut

Theoretical studies identify MnF_2 as an altermagnet—a spin-compensated collinear magnet that breaks Kramers spin degeneracy even in the nonrelativistic limit. A hallmark feature of this class of magnets is the splitting of magnon modes and their associated chirality. Through inelastic neutron scattering experiments, we demonstrate that the magnon mode splitting in MnF_2 is smaller than the energy resolution achievable with current spectrometers. This suggests that, even if a material exhibits altermagnetic symmetry, it may remain experimentally undetectable when the relative strength of the "anisotropic" exchange interactions is minimal.

Electronic properties of odd-parity magnets

Pavlo Sukhachov, University of Missouri

Unconventional magnets such as altermagnets and p-wave magnets exhibit even- and odd-parity spin polarization in their electronic band structures, leading to rich and unconventional transport phenomena and interaction effects. In this talk, I will focus on odd-parity or p-wave magnets, which have only recently drawn attention in the condensed matter community due to their spin-polarized energy bands and the absence of net magnetization. Starting with the derivation of a minimal model, I will evaluate transport responses of p-wave magnets, revealing large magnetoresistance, equilibrium spin current, and anisotropic bulk spin conductivity beyond linear response. Furthermore, I will demonstrate that p-wave magnets are compatible and can coexist with spin-singlet superconductivity. I will also show that these unconventional magnets allow for a charge-to-

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spin conversion in planar junctions, which can be strongly enhanced by superconductivity, providing a way to probe the coexistence in experiments.

Topology in altermagnets from minimal models

Jorn Venderbos, Drexel University

The discovery of materials commonly referred to as altermagnets has revealed intriguing properties of magnetic materials which expose connections with other phenomena. Perhaps the most interesting and consequential connection is that between altermagnetism and topology. This connection is clearly reflected in the allowed intrinsic anomalous Hall response, which results from a topological quantity encoded in the quantum geometric structure of the electronic bands: the Berry curvature. More generally, the lack of constraining symmetry requirements in altermagnets gives rise to a variety of different phenomena sourced by the quantum geometric structure of the band eigenstates, such as quantum geometry-induced nonlinear transport and nonlinear optoelectronic responses. This talk will discuss the connection between altermagnetism and topology from the perspective of minimal miscroscopic models, both in two and three dimensions.

Linear magneto-birefringence: an optical probe of complex (alter)magnetism

Veronika Sunko, UC Berkeley

The combination of ferromagnetic and antiferromagnetic properties in altermagnets is both fundamentally intriguing and functionally promising. A central challenge in this emerging field is the detection and control of altermagnets: distinguishing them from time-reversal invariant antiferromagnets and achieving single-domain samples are critical for uncovering new phenomena and leveraging their functionalities. Optical probes, with their sensitivity to symmetry and spatial resolution, offer a promising solution to these challenges. Notably, Kerr rotation has been proposed as a tool to identify altermagnets and map their domains. However, symmetry constraints mean that not all altermagnets exhibit Kerr rotation, as it is forbidden by vertical mirror planes.

In this context, I will discuss linear magneto-birefringence (LMB), an optical probe of time-reversal symmetry breaking that complements Kerr rotation. I will introduce LMB as both a phenomenon and an experimental technique, using $EuIn_2As_2$ as an example to illustrate its ability to reveal complex magnetic structures. Additionally, I will present a symmetry-based argument demonstrating that LMB can identify altermagnets even in cases where Kerr rotation is prohibited and explore a mechanism by which this effect can arise in altermagnets. Remarkably, the same experimental setup can be easily adapted to measure both Kerr rotation and LMB, making LMB a powerful addition to symmetry-sensitive optical tools, as well as a valuable technique for research in altermagnets.

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