MA 2: Altermagnets I

Time: Monday 9:30–12:45 Location: HSZ/0004

MA 2.1 Mon 9:30 HSZ/0004

Electric Control of Spin and Valley Polarization in the XMoTeO6 Family of Two-dimensional Altermagnets — •Avijeet Ray[1], Fatemeh Haddadi[2], Antimo Marrazzo[3], and Marco Gibertini[1,4] — [1]University of Modena and Reggio Emilia, Italy — [2]EPFL, Switzerland — [3]SISSA, Italy — [4]Istituto Nanoscienze-CNR, Italy

Altermagnets are a special class of antiferromagnets with zero net magnetization but spin-split bands, even in the absence of spin-orbit-coupling. In semiconducting altermagnets, this spin-splitting can give rise to spin-valley locking, where valleys located at specific k-points have a well-defined spin. Still, symmetries connecting the spin sublattices impose an overall degeneracy between valleys of opposite spins. An external electric field can break these symmetries, enabling controllable spin (and valley) polarization. This is particularly promising in two-dimensional (2D) materials where it is easy to apply a vertical electric field in a double-gate field-effect setup, provided that 2D altermagnets with suitable crystal symmetries are found. Here, by using first-principles simulations, not only we put forward an interesting family of 2D altermagnets that display the correct symmetries, but we also show that the electric field effect is sizable in these materials and reaches the requirements needed for applications in spin-valleytronics.

MA 2.2 Mon 9:45 HSZ/0004

Zeeman Quantum Geometry as a Probe of Unconventional Magnetism — •Snehasish Nandy[1], Neelanjan Chakraborti[2], and Sudeep Kumar Ghosh[2] — [1]National Institute of Technology Silchar, Silchar, India — [2]Indian Institute of Technology Kanpur, Kanpur, India

Unconventional magnets with momentum-dependent spin-splitting but zero net magnetization form a recently identified class of collinear magnets that are challenging to probe via conventional means. We show that these systems can be distinguished through intrinsic gyrotropic magnetic (IGM) currents, enabled by the Zeeman quantum geometry, which captures the coupled response of electronic states to momentum translation and spin rotation. Examining two prototypical two-dimensional unconventional magnets with Rashba spin-orbit coupling, a time-reversal-broken d-wave altermagnet and a time-reversal-symmetric p-wave magnet, we uncover a direct link between crystalline symmetry, spin-split band structures, and transport signatures. The d-wave altermagnet exhibits both transverse conduction and longitudinal displacement IGM currents, whereas p-wave magnet supports only transverse conduction IGM current. Remarkably, the mixed d-wave altermagnet supports all four types of IGM currents, including a longitudinal conduction current enabled by symmetric (Zeeman) Berry curvature that is forbidden in conventional quantum geometry. These responses, measurable via Hall transport and optical probes, persist even when conventional quantum geometry-driven linear responses vanish, offering unique access to hidden spin-split band structures.

MA 2.3 Mon 10:00 HSZ/0004

Spin demons in d-wave altermagnets — •Pieter Gunnink[1], Jairo Sinova[1], and Alexander Mook[2] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Staudingerweg 7, Mainz 55128, Germany — [2]University of Münster, Institute of Solid State Theory, 48149 Münster, Germany

Demons are a type of plasmons, which consist of out-of-phase oscillations of electrons in different bands. Here, we show that d-wave altermagnets, a recently discovered class of collinear magnetism, naturally realize a spin demon, which consists of out-of-phase movement of the two spin species [1]. The spin demon lives outside of the particle-hole continuum of one of the spin species, and is therefore significantly underdamped, reaching quality factors of > 10. We show that the spin demon carries a magnetic moment, which inherits the d-wave symmetry. Finally, we consider both three and two dimensional d-wave altermagnets, and show that spin demons exists in both.

[1] Gunnink, Sinova, Mook, Phys. Rev. Lett. 135, 126701 (2025)

MA 2.4 Mon 10:15 HSZ/0004

Altermagnetism in magnetic nanoisland arrays — •Rhea Hoyer[1], Lukas Körber[2], Tobias Wagner[3], and Alexander Mook[1] — [1]Institut für Festkörpertheorie, Universität Münster, Münster, Germany — [2]Institute of Molecules and Materials, Radboud University, Nijmegen, The Netherlands — [3]Department of Physics, Johannes Gutenberg University Mainz, Mainz, Germany

We present a macrospin model for magnetic island arrays engineered with altermagnetic symmetries. The islands interact purely via dipole-dipole coupling, which makes the strict spin-orbit-free limit of altermagnetism inaccessible. Although the magnon dispersion is split by spin-orbit coupling, the magnon bands remain spin-polarized, exhibiting a characteristic d-wave-like pattern of the spin expectation value across the Brillouin zone. This residual altermagnetic character gives rise to direction-dependent spin dynamics and suggests the possibility of anisotropic spin-transport phenomena in mesoscopic artificial magnets.

MA 2.5 Mon 10:30 HSZ/0004

Magnons in Antialtermagnets — •Robin R. Neumann[1,2,3], Rodrigo Jaeschke-Ubiergo[2], Ricardo Zarzuela[2], Jairo Sinova[2,4], and Alexander Mook[1,2] — [1]University of Münster, Münster, Germany — [2]Johannes Gutenberg University Mainz, Mainz, Germany — [3]Martin Luther University Halle-Wittenberg, Halle, Germany — [4]Texas A&M University, College Station, USA

Altermagnets and antialtermagnets are unconventional magnetic phases with compensated magnetization and nonrelativistic spin splitting in their electronic band structures. In altermagnets, this spin splitting has even parity, whereas in antialtermagnets it has odd parity. In this talk we go beyond electrons and demonstrate that magnons, the collective spin excitations of magnetically long-range ordered systems, inherently feature an odd-parity spin polarization in antialtermagnets without spin-orbit or dipolar coupling. We present minimal model spin Hamiltonians free of spin-orbit coupling that stabilize antialtermagnetic ground states, discuss their symmetries, and characterize the spin-polarized magnon band structures.

MA 2.6 Mon 10:45 HSZ/0004

Magnetization processes and spin-lattice coupling in the hexagonal easy-plane altermagnet α-MnTe — •Sahana Rössler[1], Victoria Ginga[1], Ece Uykur[2], Yurii Skourski[3], Jeremy Sourd[3], Sergei Zherlitsyn[3], Marcus Schmidt[4], Yurii Prots[4], Helge Rosner[4], Ulrich Burkhardt[4], Ulrich K. Rössler[5], and Alexander A. Tsirlin[1] — [1]Felix Bloch Institute for Solid State Physics, Leipzig University, Leipzig, Germany — [2]HZDR, IBP and Materials Research, Dresden, Germany — [3]HLD, HZDR, Dresden, Germany — [4]MPI CPfS, Dresden, Germany — [5]Institute for Theoretical Solid-State Physics, Leibniz IFW Dresden, Germany

We investigated the magnetization dynamics associated with domain behavior in α-MnTe using magnetization, magnetostriction, sound velocity, and attenuation measurements. Angle- and field-dependent magnetization data reveal complex magnetic responses with a distinct anomaly around 1 T, reflecting domain-related processes. Magnetostriction and elastic constant measurements indicate strong lattice effects at the field-induced reorientation transition. These features were analysed using a phenomenological micromagnetic model incorporating higher-order anisotropic exchange interactions that couple the weak ferromagnetic component to the antiferromagnetic order parameter. The model successfully reproduces the generic behaviour of the magnetic states and demonstrates that the observed uniaxial and unidirectional anisotropies arise from metastable domain configurations and irreversible magnetization processes [1].

[1] S. Rößler et al., arXiv:2511.01388

15 min break

MA 2.7 Mon 11:15 HSZ/0004

Emergent Altermagnetism in Antiferromagnetic Surfaces — •Colin Lange[1], Rodrigo Jaeschke Ubiergo[1], Alexander Mook[2], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [2]Institut für Festkörpertheorie, Universität Münster, Germany

Three-dimensional altermagnets with collinear compensated order and non-relativistic spin splitting have recently been realized, but experimental access to their 2D counterparts remains limited. We show that surfaces of the most abundant class of collinear magnets – conventional 3D antiferromagnets – provide a general route to 2D altermagnetism through surface-induced symmetry breaking. We implement this in a semi-infinite stack geometry, effectively modeling a thin film to establish a direct connection to experimental systems. This way, the symmetry analysis made here has direct implications for readily available experiments and materials. Using our novel definition of "surface spin groups", which lies between the 3D and 2D cases due to the semi-infinite geometry, we provide a full symmetry classification of all possible cases of altermagnetic surface termination. We scan available databases of magnetic materials, and conclude that almost half of the collinear antiferromagnets can host an altermagnetic surfaces. We present calculations of spin-split surface states in realistic candidates, that can serve for future experimental verification of surface induced altermagnetism. Our work positions the broadly accessible landscape of antiferromagnets as a promising foundation for 2D altermagnetism, whose experimental realization remains limited.

MA 2.8 Mon 11:30 HSZ/0004

Angle-dependent magnetoresistance induced by interface-generated spin current in RuO_2/permalloy heterostructures — Akashdeep Akashdeep[1], Ewiese Mohammad Ababneh[2], Christin Schmitt[1], Edgar Galíndez-Ruales[1], Felix Fuhrmann[1], Timo Kuschel[1], Mathias Kläui[1], Vivek Amin[2], and •Gerhard Jakob[1] — [1]Johannes Gutenberg University, Mainz, Germany — [2]Indiana University, Indianapolis, USA

Ruthenium dioxide (RuO_2) is a promising altermagnetic candidate. In our PLD grown films clear signs of altermagnetism were found by photoemission [1] and optically induced spin polarization with d-wave symmetry [2]. However, recent reports suggest that RuO_2 may be nonmagnetic in its ground state. (100)-oriented RuO_2 films are expected to generate spin currents with transverse spin polarization parallel to the Neel vector. We investigated magnetotransport in epitaxial RuO_2/permalloy (Py) heterostructures to examine spin Hall magnetoresistance and interfacial effects. Our measurements revealed a pronounced negative angular-dependent magnetoresistance that we attribute to interface-generated spin current (IGSC) at the RuO_2/Py interface supported by drift-diffusion calculations. The interface effects predominate over possible altermagnetic contributions [3]. This finding is in accord with recent muon spin resonance on our films [4].

[1] O. Fedchenko et al., Sci. Adv. 10, eadj4883 (2024);
[2] M. Weber et al., arXiv2408.05187 (2024);
[3] A. Akashdeep et al., Phys. Rev. Appl. 24, 054018 (2025);
[4] A. Akashdeep et al., arXiv2510.08064 (2025);

MA 2.9 Mon 11:45 HSZ/0004

X-ray magnetic circular dichroism of altermagnet α-Fe2O3 based on multiplet ligand-field theory using Wannier orbitals — Ruiwen Xie, Hamza Zerdoumi, and •Hongbin Zhang — TU Darmstadt, Darmstadt, Germany

Hematite α-Fe2O3 is a g-wave altermagnet, possessing an easy-axis and easy-plane weak ferromagnetic phase below and above Morin temperature, respectively. The presence of these phases renders it a good candidate to study the characteristic spin splitting in altermagnets under the impacts of relativistic effect and finite temperature. We have calculated the band structure of α-Fe2O3 based on density functional theory (DFT) considering the Coulomb correction and spin-orbit coupling effects. Additionally, the DFT + dynamical mean-field theory calculations have been performed at finite temperatures. It is found that the spin splitting in α-Fe2O3 preserves with either SOC or temperature effect included. Furthermore, we present a numerical simulation of the x-ray magnetic circular dichroism (XMCD) of the L2,3 edge of Fe using a combination of DFT with multiplet ligand-field theory. In terms of the different Néel vectors present in α-Fe2O3, we calculate the x-ray absorption spectroscopy of the L2,3 edge of Fe in the form of conductivity tensor and analyze the XMCD response from a perspective of symmetry. A characteristic XMCD line shape is expected when the Néel vector is along [010] direction and the light propagation vector is perpendicular to the Néel vector, which can be further distinguished from the XMCD response originated from weak ferromagnetism with the light propagation vector parallel to the Néel vector.

MA 2.10 Mon 12:00 HSZ/0004

Magnetic circular dichroism in resonant Auger electron diffraction from altermagnets — •Peter Krüger — Chiba University, Chiba, Japan

Recently we demonstrated that in altermagnets, there exists a large magnetic circular dichroism (MCD) in resonant photoelectron diffraction (RPED) [1]. The MCD-RPED signal is time-reversal odd and characteristic of the altermagnetic state. It is proportional to the local XMCD signal from a single magnetic sublattice and thus provides a direct probe of the sublattice magnetization. Here we show that MCD-RPED occurs in all altermagnets independently of the orientation of the Néel vector. This is a major difference to the weak XMCD observed in some altermagnets [2]. We also extend the theory to resonant Auger electron diffraction, whose MCD gives similar information as that of RPED, while being conceptually simpler. We discuss the symmetry properties of the MCD signal and explain its physical origin with a simple model. [1] P. Krüger, Phys. Rev. Lett. 135, 196703 (2025). [2] A. Hariki et al, Phys. Rev. Lett. 132, 176701 (2024).

MA 2.11 Mon 12:15 HSZ/0004

Heisenberg models of altermagnets — •Volodymyr Kravchuk[1,2], Kostiantyn Yershov[1,2], and Jeroen van den Brink[1] — [1]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, 03143 Kyiv, Ukraine

Being collinear-compensated magnets, altermagnets differ from conventional antiferromagnets by a more complex symmetry transformation that connects two sublattices. Due to the specific local nonmagnetic surroundings of the magnetic atoms, the symmetry transformation also involves rotation or mirror reflection, in addition to translation and time reversal. Here we propose Heisenberg models for a number of materials, including d-wave (rutiles), bulk g-wave (CrSb, MnTe), and planar g-wave (FeS2) alternagnets. 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, and emergent magnetization of domain walls for both d- and g-wave altermagnets. For planar g-wave altermagnets, we demonstrate that mechanical stress can induce the effective g-wave – d-wave transition for low-energy magnons. As a result, the stress-induced thermal spin conductivity appears.

MA 2.12 Mon 12:30 HSZ/0004

Multiferroic altermagnet $BiFeO_3$ investigated by DFT+DMFT and XMCD — •Hamza Zerdoumi, Ruiwen Xie, Fu Li, and Hongbin Zhang — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

As an emergent magnetic ordering, altermagnets with finite nonrelativistic spin splitting exhibit a wide spectrum of fascinating properties. In this work, combining density functional theory (DFT) and dynamical mean-field theory (DMFT), we investigate how such splitting evolves as a function of temperature in $BiFeO_3$. Moreover, by solving the DFT-derived atomic Hamiltonian, we evaluated x-ray magnetic circular dichoism (XMCD) with detailed symmetry analysis, which can be considered as a characteristic feature for altermagnetic ordering. Furthermore, as $BiFeO_3$ is a well-established multiferroic compound, we evaluate the nonlinear transport properties such as shift current originated from the quantum geometry, and further explore how such altermagnetic properties can be tailored by external electric fields.