MA 9: Altermagnets I

Time: Monday 15:00–18:30 Location: H20

MA 9.1 Mon 15:00 H20

Tuning the Octupolar Degrees of Freedom in the Altermagnetic Candidate MnF_2 by Strain and Magnetic Field — •Rahel Ohlendorf[1,2], Hilary M. L. Noad[1], Jörg Schmalian[3], Elena Hassinger[2], Andrew P. Mackenzie[1,4], and Elena Gati[1] — [1]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [2]Technical University, Dresden, Germany — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]University of St Andrews, UK

Altermagnetism can unambiguously be differentiated from the known ferro- and antiferromagnetic phases within the framework of spin-group symmetry [1]. In centrosymmetric altermagnets the ordered state can be described in terms of ferroically ordered magnetic octupoles [2]. The experimental conjugate field that is predicted to couple to this order parameter is a combination of strain and magnetic field. Consequently the application of strain and magnetic field should enable the exploration of the physics near the ferrooctupolar critical point, including its associated crossover lines.

We discuss experimental phase diagrams on the centrosymmetric altermagnetic candidate MnF_2 in magnetic field and strain, mapped out by means of elastocaloric measurements and compare our results to theoretical predictions based on a Landau free energy [3].

[1]L. Smejkal et al., Phys. Rev. X 12, 031042 (2022)
[2]S. Bhowal et al., Phys. Rev. X 14, 011019 (2024)
[3]P. McClarty et al., Phys. Rev Lett. 132, 176702 (2024)
*Work is supported by the DFG through TRR288 (Elasto-Q-Mat).

MA 9.2 Mon 15:15 H20

Tuning the magnetic anisotropy of the altermagnet CrSb — •Miriam Fischer[1], Lukas Odenbreit[1], Sonka Reimers[1], Toni Helm[2], Mathias Kläui[1], and Martin Jourdan[1] — [1]Johannes Gutenberg Universität, Mainz — [2]Helmholtz-Zentrum Dresden-Rossendorf

CrSb is an altermagnetic compound, whose band structure we recently investigated by SX-ARPES [Rei24]. For the utilization of this compound in spintronics, a rotation of the magnetic easy axis is required. Thus, we study the tunability of the magnetic anisotropy of CrSb and related compounds by measurements of the spin-flop field.

[Rei24] S. Reimers et al., Nat Commun. 15, 2116 (2024)

MA 9.3 Mon 15:30 H20

Local signatures of altermagnetic order — •Jannik Gondolf[1], Andreas Kreisel[1], Mercè Roig[1], Daniel F. Agterberg[2], and Brian M. Andersen[1] — [1]Niels Bohr Institute, University of Copenhagen, DK-2200 Copenhagen, Denmark — [2]Department of Physics, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201, USA

Altermagnets are known to share properties of ferromagnets and antiferromagnets. They feature time-reversal symmetry breaking, non-relativistic anisotropic band splitting and compensated net magnetization. Fundamental properties of altermagnetism include the anomalous Hall effect, a spin-polarized band structure in angle-resolved photoemission spectroscopy and spin-polarized currents. We employ a minimal model to investigate the local signatures of altermagnetism in the vicinity of impurities using T-matrix theory and exact diagonalization. Our findings suggest that the altermagnetic symmetry breaking is directly imprinted in the local density of states. These signatures can be quantified by scanning tunnel microscopy, offering a new approach for identifying and characterizing potential altermagnetic materials experimentally. Further, we explore potential interplay between altermagnetism and superconductivity.

MA 9.4 Mon 15:45 H20

Spin-wave theory and magnon transport properties of altermagnetic hematite (α-Fe2O3) — •Rhea Hoyer[1], P. Peter Stavropoulos[2], Libor Šmejkal[1,3,4], and Alexander Mook[1] — [1]Department of Physics, Johannes Gutenberg University Mainz, 55128 Mainz, Germany — [2]Institut für Theoretische Physik, Goethe-Universität Frankfurt, 60438 Frankfurt am Main, Germany — [3]Max Planck Institute for the Physics of Complex Systems, Nothnitzer Str. 38, 01187 Dresden, Germany — [4]Institute of Physics, Czech Academy of Sciences, Cukrovarnická 10, 162 00 Praha 6, Czech Republic

We develop a four-sublattice spin-wave theory for the g-wave altermagnet hematite (α-Fe2O3) in its two magnetic phases: the easy-axis phase below, and the weak ferromagnetic phase above the Morin temperature. We estimate the Morin temperature with a free energy calculation. The relativistic magnon dispersion relation in the easy-axis phase shows the spin (or chirality) splitting typical of altermagnets. We investigate magnon transport properties with a particular focus on the crystal thermal Hall effect.

MA 9.5 Mon 16:00 H20

Giant spatial anisotropy of magnon lifetime in altermagnets — •António Costa[1,2], João Henriques[1,3], and Joaquín Fernández-Rossier[1] — [1]International Iberian Nanotechnology Laboratory, Braga, Portugal — [2]Physics Center of Minho and Porto Universities (CF-UM-UP), Braga, Portugal — [3]Universidade de Santiago de Compostela, Santiago de Compostela, Spain

Altermagnets are a new class of magnetic materials with zero net magnetization (like antiferromagnets) but spin-split electronic bands (like ferromagnets) over a fraction of reciprocal space. As in antiferromagnets, magnons in altermagnets come in two flavours, that either add one or remove one unit of spin to the $S = 0$ ground state. However, in altermagnets these two magnon modes are non-degenerate along some directions in reciprocal space. Here we show that the lifetime of altermagnetic magnons has a very strong dependence on both flavour and direction. Strikingly, coupling to Stoner modes leads to a complete suppression of magnon propagation along selected spatial directions. This giant anisotropy will impact electronic, spin, and energy transport properties and may be exploited in spintronic applications.

MA 9.6 Mon 16:15 H20

Chiral spin-flip magnons in metallic altermagnets from many-body perturbation theory — •Wejdan Beida[1], Ersoy Sasioglu[2], Gustav Bihlmayer[1], Christoph Friedrich[1], Yuiry Mokrousov[1], Ingrid Mertig[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, 06120 Halle, Germany

Altermagnets represent a novel class of magnetic materials that bridge the gap between conventional ferro- and antiferromagnets. A unique feature of altermagnets is the lifting of degeneracy of their spin-wave modes (magnons) along the same crystallographic directions in which electronic bands also exhibit spin splitting. This non-degeneracy leads to chirality and directional anisotropy in spin-wave dispersions. In this presentation, we present the spin splitting of electronic bands and chiral spin-wave excitations in a series of metallic altermagnets, which have NiAs-type crystal structure, using DFT and many-body perturbation theory [1]. Our findings reveal a pronounced anisotropic splitting in chiral magnon bands, a small chiral asymmetry in the magnon lifetime, and demonstrate that magnon damping due to Stoner excitations is minimal. This results in long-lived magnons with efficient propagation, underscoring the potential of altermagnets for advanced spintronic and magnonic applications.

W.B. acknowledges support by the Palestinian-German Science Bridge.

[1] E. Sasioglu et al., Phys. Rev. B 81,054434 (2010).

MA 9.7 Mon 16:30 H20

Fingerprints of altermagnetism in the optical properties of MnTe — •Luca Felipe Haag[1], Marius Weber[1,2], Jairo Sinova[2], and Hans Christian Schneider[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern-Landau, Germany — [2]Institut für Physik, Johannes Gutenberg University Mainz, Germany

It has recently been demonstrated by magneto-optical Kerr effect (MOKE) measurements that the spin system in planar d-wave altermagnets can be controlled by linearly polarized optical excitation [2] as one can selectively address spin-up or spin-down electrons by choosing the polarization of the optical pulse. The objective of this study is to investigate whether similar optical effects can be observed in bulk g-wave altermagnets. To this end, we focus on MnTe, which has been demonstrated to be altermagnetic by ARPES measurements [3]. Using ab-initio techniques together with a time-dependent calculation of the

absorption process, we study theoretically the optically induced spin polarization for all polarization angles. Our results show an intriguing interplay between the complex nodal-plane structure in bulk g-wave altermagnets and the anisotropic excitation due to the polarized pulses, causing planar d-wave or g-wave signatures depending on the laser's incident direction.
References: [1] L. Šmejkal et al., Phys. Rev. X 12, 040501 (2022) [2] M. Weber et al., arXiv:2408.05187 (2024) [3] Krempaský et al., Nature 626, 517-522 (2024)

15 min. break

MA 9.8 Mon 17:00 H20

Optical Excitation of Spin Polarization in the Altermagnet RuO_2 — •Marius Weber[1], Stephan Wust[1], Luca Haag[1], Akashdeep Akashdeep[2], Kai Leckron[1], Christin Schmitt[2], Rafael Ramos[3], Takashi Kikkawa[4], Eiji Saitoh[4], Mathias Kläui[2], Libor Šmejkal[2], Jairo Sinova[2], Martin Aeschlimann[1], Gerhard Jakob[2], Benjamin Stadtmüller[5], and Hans Christian Schneider[1] — [1]University of Kaiserslautern-Landau, Germany — [2]Johannes Gutenberg University Mainz, Germany — [3]CIQUS, Universidade de Santiago de Compostela, Spain — [4]The University of Tokyo, Japan — [5]Augsburg University, Germany

We explore the ultrafast response of altermagnetic materials after optical excitation with femtosecond light pulses. For the case of RuO_2, we employ ab-initio based dynamical calculations to predict the spin polarization of the optically excited carriers. Our theoretical results are confirmed by time-resolved MOKE experiments[1], which demonstrate that highly spin-polarized carrier distributions can be generated in ultrathin, strained RuO_2 by tuning the excitation conditions, in particular the orientation of the light polarization vector.

[1] M. Weber et al., arXiv:2408.05187 (2024)

MA 9.9 Mon 17:15 H20

Magnetotransport in altermagnetic CrSb — •Christoph Müller — FZU Prague

Altermagnets (AMs) constitute a recently established category of magnetically ordered materials distinguished by an antiparallel alignment of identical magnetic moments, however with an alternating spin polarization in the electronic band structure. This unique attribute has ignited considerable interest in exploring novel applications within the realm of spintronics. Furthermore, AMs host transport and optical effects, associated with spin-polarized currents and strongly spin-split bands otherwise only observed in ferromagnets. Chromium Antimonide (CrSb) is due to its crystal symmetry and its compensated order classified as an altermagnet. CrSb exhibits a sizable spin splitting of 1.2 eV which is enabled by the non-relativistic crystal field origin. In my work I investigated the magnetotransport properties of the material in bulk and thin films. The bulk samples were also measured in a high field laboratory in search for a spin-flop transition or the anomalous Hall effect.

MA 9.10 Mon 17:30 H20

Altermagnetic spin wave dispersion in atomistic spin models — •Tobias Dannegger[1], Levente Rózsa[2,3], László Szunyogh[3], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, Konstanz, Germany — [2]Department of Theoretical Solid State Physics, Institute for Solid State Physics and Optics, HUN-REN Wigner Research Centre for Physics, Budapest, Hungary — [3]Department of Theoretical Physics, Institute of Physics, Budapest University of Technology and Economics, Budapest, Hungary

Altermagnets have a broken symmetry reflected in the shape of the spin density around the magnetic atoms. Using an ab initio parametrised atomistic spin model of hematite (α-Fe_2O_3), we show that this altermagnetic symmetry breaking induces a remarkably high splitting of 2.8 meV in the isotropic exchange couplings between the Fe spins for equidistant neighbours within the thirteenth coordination shell. We further study the resulting spin-wave dispersion relation and find that, in addition to the relativistic band splitting on the order of 10 GHz present almost throughout the entire Brillouin zone, the altermagnetic asymmetry of the isotropic interactions causes a much larger band splitting of the order of 1 THz, but only along low-symmetry directions in the Brillouin zone.

MA 9.11 Mon 17:45 H20

First-principles calculations of Luttinger ferrimagnets — •Jan Priessnitz[1], Igor Mazin[2], and Libor Šmejkal[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany — [2]Department of Physics and Astronomy, and Quantum Science and Engineering Center, George Mason University, Fairfax, VA, USA

The discovery of altermagnets demonstrated that it is possible to have a material with zero net magnetization, but broken Kramers' spin degeneracy and large spin-splitting, even without considering relativistic effects (spin-orbit coupling) [1]. The altermagnetic spin polarization promises applications in the field of spintronics.

Apart from altermagnets, there are several other classes of magnets showing such properties, such as the Luttinger compensated ferrimagnets. These are materials containing two or more magnetic sublattices which are not connected by symmetry, but which perfectly compensate each other by the virtue of Luttinger's theorem [2].

In this talk, we will give a brief introduction into Luttinger compensated ferrimagnets and present first-principle calculations of several candidate materials and unconventional properties not seen in conventional magnetic materials.

[1] Šmejkal, L., Sinova, J., & Jungwirth, T. (2022). Physical Review X, 12(3).

[2] Mazin, I. (2022). Editorial, Physical Review X, 12(4).

MA 9.12 Mon 18:00 H20

Magnetic domain features in the altermagnetic Mn_5Si_3 — •Gregor Skobjin[1], Javier Rial[2], Sebastian Beckert[3], Helena Reichlová[3,4], Andy Thomas[3,5], Vincent Baltz[2], Lisa Michez[6], Richard Schlitz[1], Michaela Lammel[1], and Sebastian T.B. Goennenwein[1] — [1]Department of Physics, University of Konstanz, Germany — [2]Université Grenoble Alpes, CNRS, CEA, IRIG-Spintec, France — [3]IFMP, TU Dresden, Germany — [4]Institute of Physics ASCR, Czech Republic — [5]Aix-Marseille Université, CNRS, CINaM, France — [6]IFW Dresden, Germany

Altermagnets are an intriguing novel class of magnetic materials. We exploit the anomalous Hall effect response of micropatterned Mn_5Si_3 thin films to investigate their magnetization relaxation behavior. In experiments at $T < 200\,K$ i.e., in the altermagnetic phase, and for magnetic fields for which the samples exhibit large magnetic susceptibility, we observe a strong magnetic aftereffect as well as Barkhausen-like steps in the time-dependent Hall voltage evolution. More specifically, we recorded the evolution of the Hall voltage in micropatterned Hall bars with widths of 10 microns down to 0.1 microns at a series of different magnetic field magnitudes to gain insights into potential domain effects in the altermagnetic phase of Mn_5Si_3. We critically analyze our experimental results and discuss implications for the micromagnetic structure of altermagnetic thin films.

MA 9.13 Mon 18:15 H20

Altermagnetism in twisted magnetic bilayers — •Venkata Krishna Bharadwaj[1], Libor Šmejkal[1,2], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

A recent development in the field of magnetism has introduced a new category of magnetic materials known as altermagnets [1]. These materials form a distinct class of magnetic compounds, characterized by magnetic compensation and the breaking of time-reversal symmetry, leading to a spin-split band structure. This unique band structure exhibits alternating spin polarization in both real and reciprocal spaces. The spin splitting originates from variations in local crystal field anisotropies across different magnetic sublattices. In this study, we introduce a novel approach to achieve altermagnetism in two-dimensional van der Waals materials by twisting bilayers. Furthermore, we explore the physical properties of altermagnets arising in these twisted bilayer structures. Our results lay the groundwork for exploring new possibilities in altermagnetic materials.

[1] L. Šmejkal, et al., Phys. Rev. X 12, 031042 (2022).