MA 16: Skyrmions I

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

MA 16.1 Tue 9:30 HSZ/0004

Charge Order, Spin textures, and Electronic Structure of Eu(Ga,Al)4 — Steven Gebel[1], Aleksandr Sukhanov[2], Artem Korshunov[3], Jaime Moya[4], Kevin Allen[5], Emilia Morosan[5], and •Marein Rahn[2] — [1]TU Dresden, Germany — [2]Universität Augsburg, Germany — [3]ESRF, Grenoble, France — [4]Princeton University, USA — [5]Rice University, USA

The tetragonal intermetallic series Eu(Ga,Al)$_4$, is known for a range of interesting phenomena, ranging from the nodal line semimetal EuGa4 to centrosymmetric skyrmion phases in EuAl$_4$. It would be of great interest to design the band topology of these materials and, in particular, to understand how it may couple to electronic correlations. To this end, one must clarify by what mechanisms the multifaceted spin- and charge-ordering instabilities of this series arise from the underlying electronic band structure. For instance, structural modifications and charge density waves exist throughout the series, but show a variable response to hydrostatic pressure – hinting at competing mechanisms. We provide an overview of the ordered phases in Eu(Ga,Al)$_4$ and then show how X-ray crystallography using diamond anvil pressure cells draws a clear line between different structural instabilities. Complementary measurements using inelastic X-ray scattering also provide evidence on the underlying electron-phonon coupling mechanisms. Our results provide a tentative x-P-T phase diagram of Eu(Ga$_{1-x}$Al$_x$)$_4$ and highlight interesting questions, e.g. regarding the origin of anomalous Hall effects in EuGa$_4$ and the nature of a new pressure-induced structural phase of EuAl$_4$.

MA 16.2 Tue 9:45 HSZ/0004

Topological pumping of skyrmionic textures in spiral multiferroics — •Luca Maranzana[1,2], Maxim Mostovoy[3], Naoto Nagaosa[4,5], and Sergey Artyukhin[1] — [1]Quantum Materials Theory, Italian Institute of Technology, Via Morego 30, Genoa, Italy — [2]Department of Physics, University of Genoa, Via Dodecaneso 33, Genoa, Italy — [3]Zernike Institute for Advanced Materials, University of Groningen, Nijenborgh 3, 9747 AG Groningen, Netherlands — [4]RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan — [5]Fundamental Quantum Science Program, TRIP Headquarters, RIKEN, Wako 351-0198, Japan

Precise positioning of topological defects is crucial for racetrack memories, where their positions along a magnetic nanotrack encode information. Conventional approaches rely on engineered pinning landscapes, which increase power consumption. Here, we show that spiral multiferroics serve as a natural ruler for electric-field-driven positioning of skyrmionic textures, extending the concepts introduced in [1]. An oscillating electric field, assisted by anisotropy or a static magnetic field, displaces the topological defect by exactly one spiral period per full oscillation of the field. Such adiabatic pumping, reminiscent of Thouless pumping, is topologically protected and remains robust against small perturbations. Our work proposes a route to electrically driven, topologically protected transport of spin textures and positions spiral multiferroics as a natural platform for skyrmion racetracks.

[1] L. Maranzana, M. Mostovoy, N. Nagaosa, and S. Artyukhin, arXiv:2502.13083 (2025).

MA 16.3 Tue 10:00 HSZ/0004

Statistical Signature of Chirality as a Probe of Skyrmion Topology and Collapse Dynamics — Shiyu Zhou[1], •Kai Litzius[2], Felix Büttner[2,3], and Lucas Caretta[1,4] — [1]Department of Physics, Brown University, Providence, Rhode Island 02912, USA — [2]Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany — [4]School of Engineering, Brown University, Providence, Rhode Island 02912, USA

Magnetic skyrmions are topological spin textures whose robustness has driven intense interest for spintronic applications, yet direct experimental evidence linking topology to stability has been limited. We introduce an accessible, material-agnostic method to probe skyrmion topology statistically by measuring annihilation field distributions using Kerr microscopy. By tuning in-plane magnetic fields, we drive transitions from topologically nontrivial to trivial skyrmion states and observe a clear shift in annihilation behavior: skyrmions show broad, thermally activated distributions, while trivial bubbles collapse deterministically with narrow distributions. Micromagnetic simulations corroborate this correlation between topology and collapse statistics. Our approach enables straightforward chirality detection and skyrmion state control without specialized imaging or transport probes. The ability to toggle between deterministic and stochastic collapse suggests new device concepts, including synchronized deletion for memory and topology-tunable randomness for probabilistic applications.

MA 16.4 Tue 10:15 HSZ/0004

observation of a distorted tilted conical spiral at the surface of Cu$_2$OSeO$_3$ — •Sina Mehboodi[1], Victor Ukleev[2], Chen Luo[2], Radu Abrudan[2], Florin Radu[2], Christian Back[1], and Aisha Aqeel[3] — [1]School of Natural Sciences, Technical University of Munich, Garching, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [3]Institute of Physics, University of Augsburg, Augsburg, Germany

Chiral magnets such as Cu$_2$OSeO$_3$ host a rich variety of noncollinear spin textures [1]. Using resonant elastic X-ray scattering (REXS), where the magnetic satellites are captured as scattered intensity on a CCD detector, we observed a well-ordered surface texture referred to as a distorted tilted conical (dTC) spiral phase. This phase displays strong anharmonicity, evidenced by pronounced higher-order magnetic satellites. Tilting the applied magnetic field causes a continuous reorientation of the dTC propagation vector and increases its modulation wavevector, revealing a high sensitivity of the surface spiral to field direction. Importantly, by combining REXS with rocking-curve analysis, we determine the full scattering vector of dTC, about 0.0718 nm^{-1}. This value is significantly smaller than the reported bulk TC wavevector ($\approx$ 0.095 nm^{-1}) [2], providing direct evidence that the surface spiral is intrinsically distorted and cannot be explained by a simple bulk-like conical modulation [3].

[1] A. Aqeel, et al., Phys. Rev. Lett. 126, 017202 (2021). [2] E. Marchiori et al., Commun. Mater. 5, 202 (2024). [3] S. Mehboodi et al. Sci. Technol. Adv. Mater. 26, 2532366 (2025).

MA 16.5 Tue 10:30 HSZ/0004

Optical manipulation of magnetic skyrmions and antiskyrmions — •Dola Chakrabartty[1], Andreas Wendeln[2,3], Manuel Zahn[1,4], Sascha Schäfer[2,3], and István Kézsmárki[1] — [1]Experimentalphysik V, Center for Electronic Correlations and Magnetism, Institute for Physics, University of Augsburg, Augsburg, D-86135, Germany — [2]Regensburg Center for Ultrafast Nanoscopy, University of Regensburg, Regensburg, 93040, Germany. — [3]Department of Physics, University of Regensburg, Regensburg, 93040, Germany. — [4]NTNU Trondheim, Trondheim, 7034, Norway

Topological magnetic textures like skyrmions and antiskyrmions, have potential applications in next-generation spintronic devices. Notably, skyrmions and antiskyrmions can be viewed as particle- and antiparticle-like entities, respectively, with opposite topological charges and the potential to annihilate each other or be created in pairs. The controlled and fast manipulation of these spin textures are crucial for their practical applications.

In this work, we utilized in-situ femtosecond optical pulses in Lorentz microscopy and investigated the possibility of manipulating skyrmions and antiskyrmions. Our preliminary results show that ultrafast laser excitation can induce a helicity switching of elliptical skyrmions as well as the transformation between different spin textures, such as skyrmions, antiskyrmions, non-topological bubbles and stripes. A statistical analysis of our observations provides insights into the energy landscape of these magnetic patterns. Our findings suggest that laser pulses can control topological magnetic states.

MA 16.6 Tue 10:45 HSZ/0004

Emergent reactance induced by the deformation of a current-drive skyrmion lattice — •Matthew Littlehales[1,2], Max Birch[3], Akiko Kikkawa[3], Yasujiro Taguchi[3], Diego Alba Venero[2], Peter Hatton[1], Naoto Nagaosa[3,4], Yoshinori Tokura[3,5,6], and Tomoyuki Yokouchi[3] — [1]Department of Physics, Durham University, South Road, Durham, DH1 3LE, UK — [2]ISIS Neutron and Muon Source, Rutherford Appleton Laboratory, Didcot, OX11 0QX, UK — [3]RIKEN Center for Emergent Matter Science (CEMS), Wako, Japan — [4]Fundamental Quantum Science Program

(FQSP), TRIP Headquarters, RIKEN, Wako, Japan — [5]Department of Applied Physics, University of Tokyo, Tokyo, Japan — [6]Tokyo College, University of Tokyo, Tokyo, Japan

Emergent electromagnetism offers an opportunity to develop novel applications by exploiting quantum mechanics. In condensed matter systems, the Berry phase acquired by conduction electrons acts as an emergent electromagnetic field, facilitating phenomena akin to classical electromagnetism. Magnetic skyrmions, spin vortices with nontrivial topology, offer a unique opportunity to investigate emergent electromagnetism. For example, non-trivial transport responses from magnetic skyrmions arise from the emergent Lorentz force and electromagnetic induction. Here, we present two new examples of emergent electric fields arising simultaneously from skyrmion lattice dynamics in MnSi. We find out-of-phase components in the electrical transport, reminiscent of a reactance, and attribute their existence to inertial, and deformative, current-driven skyrmion lattice dynamics.

15 min break

MA 16.7 Tue 11:15 HSZ/0004

***Ab inito* quantum transport for sub-10 nm skyrmions in 2D magnets** — •Moritz A. Goerzen, Salomé Trillot, and Dongzhe Li — CEMES, Université de Toulouse, CNRS, France

Topological spin textures, such as magnetic skyrmions, play a central role in modern magnetism and have attracted significant interest in both fundamental studies and spintronics applications. *Ab initio* theory can provide a direct connection to experiments, giving access to the material-dependent physics behind the observed effects. However, the high computational cost makes it difficult to model chiral skyrmions, which typically span several nanometers and arise from competing magnetic interactions. Here, we present a novel workflow capable of treating the electronic structure and transport properties of sub-10 nm skyrmions at the full *ab initio* level. We then apply this technique to investigate the electrical detection and chirality-induced orbitronics effects in 2D magnets. In particular, we demonstrate how non-collinear magnetoresistance, chirality-induced orbital moments, and orbital Hall effects evolve with skyrmion size, helicity, and spin-orbit coupling.

MA 16.8 Tue 11:30 HSZ/0004

Magnetic anisotropies resolved in the skyrmion-host GaV_4S_8 by high-field electron spin resonance spectroscopy — •Ignác Fejes[1], Titusz Fehér[1], Norbert Marcell Nemes[1], András Jánossy[2], Dávid Szaller[1,2,3], Sándor Bordács[3,5], Vladirmir Tsurkan[3], and István Kézsmárki[4] — [1]Department of Physics, Institute of Physics, Budapest University of Technology and Economics, Muegyetem rkp. 3., H-1111 Budapest, Hungary — [2]HUN-REN-BME Condensed Matter Physics Research Group, Budapest University of Technology and Economics, Muegyetem rkp. 3., H-1111 Budapest, Hungary — [3]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86135 Augsburg, Germany — [4]GFMC, Departamento de Fisica de Materiales Universidad Complutense de Madrid, 28040 — [5]Institute of Applied Physics, MD 2028, Chisinau, R. Moldova

Appearance of exotic types of magnetic ordering, such as skyrmions, strongly depends on the magnetic anisotropies present in a material, particularly in axially symmetric systems where second-order anisotropy in spin-orbit coupling is allowed. Here, we used high-field electron spin resonance spectroscopy (ESR) to study the field and orientation dependence of the spin excitation in the field-polarized state of GaV_4S_8. Below T_S = 44 K, the material transforms from a cubic phase to a polar rhombohedral phase, giving rise to multiple structural domains at low temperatures. We assigned the observed resonance modes to the corresponding polar domains and identified the relevant anisotropies - magnetocrystalline and g-factor - of GaV_4S_8.

MA 16.9 Tue 11:45 HSZ/0004

Isolated Magnetic Hopfions — Xiaowen Chen[1], •Nikolai S. Kiselev[2], Filipp N. Rybakov[3], Donghai Yang[1], and Fengshan Zheng[1] — [1]South China University of Technology, Guangzhou, China — [2]Forschungszentrum Jülich, Germany — [3]Uppsala University, Sweden

Hopfions are three-dimensional topological solitons formed by closed loops of vortex strings. In magnetic crystals, hopfions have so far been observed only in unusual configurations in which they are linked to skyrmion strings [1]. Although theory predicts the existence of stable, isolated hopfions in frustrated magnets [2] and chiral magnets [3], their experimental realization has remained elusive. Here we report laser-induced nucleation and direct TEM observation of isolated magnetic hopfions in the B20-type FeGe crystal [4]. We map out the nucleation conditions as a function of laser fluence and external magnetic field. Good agreement between experimental data and micromagnetic simulations unambiguously confirms the emergence of isolated hopfions and reveals their detailed structure. We derive the relevant topological invariant for hopfions embedded in helical or conical backgrounds and calculate its integer values for the observed objects. We demonstrate that these hopfions are stable without geometrical confinement and can coexist and interact with other topological spin textures. [1] F. Zheng, et al., Nature **623**, 718 (2023). [2] F. N. Rybakov et al., APL Mater. **10**, 111113 (2022). [3] J.-S. B. Tai & I. I. Smalyukh, Phys. Rev. Lett. **121**, 187201 (2018). [4] X. Chen, et al., preprint on Research Square https://doi.org/10.21203/rs.3.rs-7435743/v1

MA 16.10 Tue 12:00 HSZ/0004

Strain-controlled topological magnetic textures in anti-skyrmion hosting materials — •Somasree Bhattacharjee[1], István Kézsmárki[2], and Jan Masell[1] — [1]Institute of Theoretical Solid State Physics (TFP), Karlsruhe Institute of Technology (KIT), 76049 Karlsruhe, Germany — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86159 Augsburg, Germany

In non-centrosymmetric crystal structures with D_{2d} or S_4 symmetry, anisotropic Dzyaloshinskii-Moriya interaction (DMI) stabilizes anti-skyrmions which was recently confirmed experimentally [1,2]. In these materials, easy-axis anisotropy additionally stabilizes skyrmions and non-topological bubbles in certain ranges of external magnetic fields and lamella thicknesses. The competition between magnetic dipolar interaction and DMI renders skyrmions elliptical depending on their handedness. Also, dipolar interaction stabilizes skyrmion caps on top of antiskyrmions which renders them rectangular [3]. In this work, we investigate how external mechanical strain can be used as an additional tuning parameter for the stability of these topological magnetic textures. We show that strain breaks the degeneracy of distinct types of elongated skyrmions and antiskyrmions, which can be used to controllably switch the helicity of the textures. [1] A. Nayak et al. Nature 548, 561 (2017), [2] K. Karube et al. Nat. Mater. 20, 335 (2021), [3] F. S. Yasin, J. Masell, et al., Adv. Mater. 36 (16), 2311737 (2024)

MA 16.11 Tue 12:15 HSZ/0004

MULTISTABLE SKYRMIONS IN THIN NANODOTS — •Mateusz Zelent[1,2] and Maciej Krawczyk[2] — [1]FACHBEREICH PHYSIK AND LANDESFORSCHUNGSZENTRUM OPTIMAS, RHEINLAND-PFÄLZISCHE TECHNISCHE UNIVERSITÄT KAISERSLAUTERN-LANDAU, 67663 KAISERSLAUTERN, GERMANY — [2]Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznan, ul. Uniwersytetu Poznańskiego 2, Poznan, Poland

We present a new method for controlling and manipulating magnetic skyrmions in ultrathin multilayer structures by employing spatially tailored magnetostatic fields produced by ferromagnetic rings. Through a combination of analytical calculations and micromagnetic simulations, we demonstrate that the stray field generated by a Co/Pd ferromagnetic ring with perpendicular magnetic anisotropy can markedly increase the stability of skyrmions in an Ir/Co/Pt nanodot even when the Dzyaloshinskii Moriya interaction is entirely absent. Our analysis reveals a multistable behaviour, in which skyrmions can exist with two or even three distinct diameters, depending on the magnetization direction of the ring. The associated energy barriers separating these states are substantial, indicating possible applications in binary or multilevel magnetic data storage. We further show that transitions between these states can be triggered in a controlled and robust manner using short magnetic-field pulses. Overall, our approach offers a versatile strategy for engineering the magnetostatic energy landscape and designing skyrmion-based devices with customizable stability characteristics.

MA 16.12 Tue 12:30 HSZ/0004

First-Principles calculation of skyrmion collapse via the geodesic nudged elastic band approach — •Nihad Abuawwad[1], Daniel Wortmann[1], Gregor Michalicek[1], and Stefan Blügel[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Institute for Theoretical Physics, RWTH Aachen University, 52074 Aachen, Germany

Magnetic skyrmions are often investigated using spin models parameterized from first-principles calculations and achieving a fully *ab initio* description of skyrmion energetics and collapse mechanisms remains a significant challenge. In this work, we present a high-performance computing density functional theory (DFT) framework to compute both the skyrmion structure and its minimum-energy collapse pathway. Using the all-electron FLEUR code [1] within the AiiDA-FLEUR workflow environment [2], we construct an automated geodesic nudged elastic band (GNEB) workflow designed to determine the skyrmion collapse mechanism entirely from first principles. The method generates a sequence of intermediate magnetic states via geodesic interpolation between an initial skyrmion configuration and the final ferromagnetic state, and each image is evaluated under constrained magnetic moments to obtain accurate total energies and true magnetic forces. The resulting energy profile reveals the minimum energy path (MEP) and the associated barrier governing the topological skyrmion collapse. We compared these with the spin-model approach.

[1] D. Wortmann, et al. FLEUR, Zenodo (2023). [2] J. Broeder, et al., Proc. Extreme Data Workshop 40, 43*48 (2019).