MA 33: Non-Skyrmonic Magnetic Textures I

Time: Thursday 9:30–13:00 Location: H16

MA 33.1 Thu 9:30 H16

Anomalous quasielastic scattering in centrosymmetric helimagnets — N. D. Andriushin[1], J. Grumbach[1], A. A. Kulbakov[1], Y. V. Tymoshenko[2,1], Y. A. Onykiienko[1], R. Firouzmandi[3], E. Cheng[3], S. Granovsky[1], Y. Skourski[4], J. Ollivier[5], H. C. Walker[6], V. Kocsis[3], B. Büchner[3], M. Doerr[7], •D. S. Inosov[1], and D. C. Peets[1] — [1]IFMP, TU Dresden, Germany — [2]JCNS, FZ Jülich, Germany — [3]IFW Dresden, Germany — [4]HZDR, Dresden, Germany — [5]ILL, Grenoble, France — [6]ISIS, RAL, Didcot, UK — [7]MPI-FKF, Stuttgart, Germany

Centrosymmetric helimagnets which host spin helices or skyrmion-like topological spin structures comprise a distinct subclass of materials in which helical order is stabilized by bond frustration in contrast to the more common path of antisymmetric exchange interactions. Here we will present the spin-dynamical properties of the $SrFeO_3$ [1] and $Sr_3Fe_2O_7$ [2] perovskites. Inelastic neutron scattering reveals that with increasing temperature, high-energy magnons increasingly lose coherence, and the spin fluctuations become dominated by a distinct quasielastic component at low energies, concentrated at the ordering wave vectors. This quasielastic component likely originates from helical domain walls. We anticipate that this could be generic to all symmetric helimagnets in which the chiral symmetry is spontaneously broken by the magnetic order.

References:
[1] N. D. Andriushin *et al.*, arXiv:2409.10214 (2024).
[2] N. D. Andriushin *et al.*, npj Quant. Mater. **9**, 84 (2024).

MA 33.2 Thu 9:45 H16

Characterising 3D Topological Magnetic Textures using the Hopf index: Hopfions, Fractional Hopfions and Screw Dislocations — •Maria Azhar, Sandra Chulliparambil Shaju, Ross Knapman, Alessandro Pignedoli, and Karin Everschor-Sitte — Faculty of Physics and CENIDE, University of Duisburg-Essen.

In magnetic systems, twisted, knotted, linked, and braided vortex tubes manifest as Skyrmions, Hopfions, Fractional hopfions, or screw dislocations [1]. These complex textures are characterized by topologically non-trivial quantities, such as a Skyrmion number, a Hopf index H, a Burgers vector (quantified by an integer), and linking numbers.

We address the common challenges and pitfalls associated with numerically calculating H using the traditional Whitehead integral [2]. We present an alternative analytical method for determining H, introducing a new discrete geometric formulation [3]. This approach separates H into contributions from the self-linking and inter-linking of flux tubes of the emergent magnetic field.

Our analysis reveals the natural emergence of fractional Hopfions or textures with non-integer H, which we interpret as "mixed topology" states. These states can smoothly transform into one of several possible topological sectors with integer H. We establish a robust physical foundation for the Hopf index to assume integer, non-integer, or specific fractional values, depending on the system's underlying topology.
[1] M. Azhar, et al., PRL 128, 157204 (2022)
[2] R. Knapman, M. Azhar, et al., arxiv:2410.22058
[3] M. Azhar, et al., arXiv:2411.06929

MA 33.3 Thu 10:00 H16

Strain-induced spin spiral in Dy-doped Ferrite films — •Holger Meyerheim[1], Anupam Singh[1], Verena Ney[2], Andreas Ney[2], Arthur Ernst[2], Malleshwararao Tangi[1], Ilya Kostanovski[1], Manuel Valvidares[3], Pierluigi Gargiani[3], Jean-Marc Tonnerre[4], Stuart S. P. Parkin[1], and Katayoon Mohseni[1] — [1]MPI f. Mikrostrukturphysik, D-06120 Halle — [2]Johannes Kepler University, A-4040 Linz (Austria) — [3]ALBA Synchrotron, E-08290 Cerdanyola del Valles (Spain) — [4]Institut Neel, CNRS & Univ. J. Fourier, F-38042 Grenoble (France)

Ferrites are known as textbook ferrimagnets. Recent interest in oxides as low-dissipation materials in spintronics has also focused interest on the modification of the spin texture of oxides in general [1]. Here we present a combined experimental and theoretical study which shows that in 5-40 nm thick Dy-doped Ni-ferrite films the local structural strain and the resulting concomitant symmetry reduction induced by the large Dy^{3+} ions incorporated in the percent concentration range into the octahedral sites of the spinel-type structure leads to the emergence of the chiral Dzyaloshinskii-Moriya interaction (DMI). The DMI is responsible for the onset of a non-collinar spin texture. Using soft x-ray resonant magnetic reflectivity and x-ray magnetic circular dichroism experiments in the vicinity of the Fe- and Ni-$L_{2,3}$- and the Dy-$M_{4,5}$ edges we develop a model in which the Fe and Ni magnetic moments are aligned in a spiral-like spin texture with a q-vector almost parallel to [001]. This work is supported by the DFG under grant MO 4198/2-1. [1] L. Caretta, et al., Nat. Comm. 11, 1090 (2020)

MA 33.4 Thu 10:15 H16

Quantum Bloch points in magnetic systems — •Vladyslav Kuchkin, Štefan Liščák, Andreas Haller, Andreas Michels, and Thomas Schmidt — University of Luxembourg

A Bloch point represents a three-dimensional hedgehog singularity of a magnetic vector field in which the magnetization vanishes at the center. Experimentally, the appearance of such points is well-established; at the same time, the standard micromagnetic theory is only suitable for fixed-length continuous magnetization vector fields and is thus not applicable to such singularities. To approach this problem, we study a Bloch point in a quantum Heisenberg model for the case of spin-1/2 particles. Such a state can be stabilized by adding a Zeeman term that imposes a boundary condition. We obtain the ground state and the corresponding magnetization profile by performing an exact diagonalization and using density matrix renormalization group techniques. Our findings show a smooth change of the spin length in the quantum model, leading to zero magnetization at the Bloch point. This behavior is generic for different system sizes. Our results indicate the necessity of generalizing the classical micromagnetic model, relying on a magnetization vector field of constant length, by adding a third degree of freedom of the spin: the ability to change its length. We achieve this by introducing a regularized $\mathbb{S}^3$ model that describes a four-dimensional order parameter of unit length. In contrast to earlier attempts to describe magnetization profiles of varying lengths, our approach satisfies the quantum mechanical constraints on spin operators.

MA 33.5 Thu 10:30 H16

Magnetic solitons in hierarchical 3D magnetic nanoarchitectures of nanoflower shape — •Olha Bezsmertna[1], Rui Xu[1], Oleksandr Pylypovskyi[1], David Raftrey[2,3], Andrea Sorrentino[4], Jose A. Fernandez-Roldan[1], Ivan Soldatov[5], Daniel Wolf[5], Axel Lubk[5], Rudolf Schäfer[5], Peter Fischer[2,3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]University of California Santa Cruz, Santa Cruz CA, USA — [3]Lawrence Berkeley National Laboratory, Berkeley CA, USA — [4]Alba Light Source, Cerdanyola del Vallès 08290, Spain — [5]Leibniz Institute for Solid State and Materials Research, Dresden, Germany

Curvilinear magnetism is an emerging field that explores how magnetic properties and responses are modified in geometrically curved objects [1]. Here, we synthesize large-scale, highly-periodic 3D nanomembranes [2] of 50-nm-thick permalloy of a nanoflower shape interconnected by close-to-hemispherical indentations. Nanoflowers with a size of about 200 nm exhibit a variety of magnetic states, e.g. domain walls, flower, vortex and a state with two Bloch lines. The ground magnetic state is a vortex, which is shifted away from the geometric center of the nanoflower. Micromagnetic simulations show nonlocal symmetry breaking, which is specific to 3D curved geometries enabling interactions between surface and volume magnetostatic charges, responsible for the shift of the vortex [3]. [1] D. Makarov et al., Springer Nature, Vol. 146 (2022). [2] R. Xu et al., Nature Comm 2022. [3] O. Bezsmertna et al., Nano Lett., doi.org/10.1021/acs.nanolett.4c04584

MA 33.6 Thu 10:45 H16

Emergence of topological superconductivity in the presence of chiral magnetism in 2D $CrInTe_3$ — •Arnob Mukherjee[1], Fengyi Zhou[2], Soheil Ershadrad[1], Tanay Nag[3], Duo Wang[2], and Biplab Sanyal[1] — [1]Department of Physics and Astronomy, Uppsala University, Box-516, 75120 Uppsala, Sweden — [2]Faculty of Applied Sciences, Macao Polytechnic University, Macao SAR, 999078, China — [3]Department of Physics, BITS Pilani-Hyderabad Campus, Telangana 500078, India

We propose a framework for designing two-dimensional (2D) topological superconductors (TSCs) using a bilayer hybrid system of monolayer $CrInTe_3$ with noncoplanar magnetic textures coupled to a 2D s-wave superconductor. This hybrid system induces a topological superconducting phase, serving as a platform for realizing the 2D Kitaev model and supporting Majorana zero-energy modes via emergent p-wave pairing. Using Density functional theory calculations, we calculate the essential magnetic parameters, such as Heisenberg exchange and Dzyaloshinskii-Moriya interactions (DMI) using the LKAG approach. Large-scale Monte Carlo simulations reveal that the substantial DMI stabilizes a noncoplanar spiral magnetic state without external fields. In this phase, we observe a transition from dipolar to edge modes in the zero-energy local density of states as the chemical potential varies. Under finite magnetic fields, the system exhibits a mixed magnetic state with isolated skyrmions and spiral domain walls, leading to unique low-energy electronic states and insulating behavior.

MA 33.7 Thu 11:00 H16

Topological textures in antiferromagnetic thin-films stabilized by interfacial magnetostrictive destressing — •Lukas D Cavar[1], Julian Skolaut[2], Olena Gomonay[1], Simon J Sochiera[1], David Anthofer[1], Miela Gross[3], Evangelos Golias[4], Dirk Backes[5], Caroline A Ross[3], and Angela Wittmann[1] — [1]JGU, Mainz, DE — [2]IEAP, CAU, Kiel, DE — [3]MIT, Cambridge, USA — [4]MAX IV, Lund, SE — [5]DLS, Didcot, UK

Weakly-compensated antiferro- and ferrimagnets present us with ultrafast dynamics, along with a weak magnetization vector that is legible, accessible, and robust to external perturbations. This makes them ideal candidates for the next generation of computing materials, where information may be encoded in the form of topological magnetic textures. Conventional long-range interaction– namely, the stray field– is not sufficient to stabilize such textures on its own. Here we discuss the magnet-substrate interface, where a magnetostriction-dependent interfacial incompatibility gives rise to long-range destressing fields capable of stabilizing topological textures in easy-plane magnetic thin-films with nearly-compensating staggered spin ordering. We investigate two such materials– α-Fe_2O_3 (hematite) and dysprosium iron garnet (DyIG) near its compensation temperature– by x-ray magnetic linear dichroism microscopy and indeed observe a rich landscape of topological textures. Thereby we tread towards a rigorous understanding of the interfacial destressing field and begin to uncover a promising new source of topological mesostructure.

15 min. break

MA 33.8 Thu 11:30 H16

Towards stabilizing 360° domain walls in dysprosium iron garnet through magnetoelastic interactions — •Julian Skolaut[1,2], Lukas Cavar[1], Olena Gomonay[1], Miela Gross[3], Simon Sochiera[1], David Anthofer[1], Evangelos Golias[4], Dirk Backes[5], Caroline A. Ross[3], and Angela Wittmann[1] — [1]JGU, Mainz, DE — [2]present address: IEAP, CAU, Kiel, DE — [3]MIT, Cambridge, US — [4]MAX IV, Lund, SE — [5]DLS, Didcot, UK

Topologically protected magnetic textures, including 360° domain walls (DWs), are of considerable interest for next-generation data storage and computing technologies. Realizing such textures in ferri- and antiferromagnetic systems allows us to capitalize on these materials' intrinsic robustness to external perturbations and faster dynamics. However, well-established mechanisms, such as stray fields, cannot stabilize 360° DWs at zero magnetic field. Hence, we must turn to more exotic stabilization mechanisms. One promising candidate is magnetoelastic destressing mediated by the substrate/magnetic film interface. Here, we report the observation of 360° DWs in ferrimagnetic dysprosium iron garnet thin films. These topological DWs are present in applied magnetic fields from zero to above coercivity, suggesting topological protection, and can be manipulated using magnetic fields. Upon return to zero magnetic field, the initial state is not reproduced, indicating hysteresis. This hints toward stabilization via magnetoelastic interactions. Corroborating these results with insights from other materials and theory will further the understanding of exotic mechanisms, such as destressing fields, as a source of topological magnetic textures.

MA 33.9 Thu 11:45 H16

Computational studies of novel Dzyaloshinsky-Moriya interactions — •Samuel Holt[1,2], Martin Lang[1,2], Swapneel Pathak[1,2], and Hans Fangohr[1,2,3] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Center for Free-Electron Laser Science, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Faculty of Engineering and Physical Sciences, University of Southampton, Southampton SO17 1BJ, United Kingdom

The exploration of magnetic phases in chiral magnets has gathered significant interest due to the unique physics and potential applications of these materials. A key factor in these systems is the Dzyaloshinsky-Moriya interaction (DMI), which arises from the asymmetric environment of interacting magnetic spins and is linked to noncentrosymmetric crystallographic point groups. While a few point groups have had their DMI extensively studied, many remain unexplored.

In this talk, we systematically explore the multidimensional parameter space of these new DMI terms using micromagnetic simulations to identify and classify magnetic phases. Machine learning algorithms, such as clustering and autoencoders, are employed to automate this process, enabling the rapid identification and grouping of similar magnetic phases across extensive parameter spaces. Funded by EU Horizon 2020, grants 101152613 and 101135546.

MA 33.10 Thu 12:00 H16

Interplay between magnetic and charge order in an ultraclean van der Waals material — •Priya Baral[1], Sun Okumura[1], Moritz Hirschmann[2], Sebastian Esser[1], Rinsuke Yamada[1], Shun Akatsuka[1], Jonathan White[4], Samuel M. Moody[4], Stanislav Niktin[4], Nina-juliane Steinke[5], Shang Gao[6], Yoshichika Onuki[2], Taka-hisa Arima[2,7], Taro Nakajima[3], and Max Hirschberger[1,2] — [1]Department of Applied Physics, The University of Tokyo, Tokyo, JP — [2]RIKEN Center for Emergent Matter Science (CEMS), Saitama, JP — [3]Institute for Solid State Physics, University of Tokyo, Chiba, JP — [4]PSI Center for Neutron and Muon Sciences, Villigen PSI, CH — [5]Institut Laue-Langevin, 71 avenue des Martyrs, Grenoble, FR — [6]Department of Physics, University of Science and Technology of China, CHN — [7]Department of Advanced Materials Science, The University of Tokyo, JP

The interplay between charge-density wave order and magnetism has been a prominent area of research for decades, encompassing unconventional superconductors to more recent Kagome metals. The cooperative or competitive nature of these two phenomena has been a fundamental aspect of many-body physics. Recently, it has been demonstrated that RTe3 (R = rare earth) van der Waals materials exhibit helimagnetic textures coupled to an unconventional charge-density wave order. Here, we review recent developments in one of the ultra-clean members of the series, DyTe3. We reveal further evidence for the unconventional spin-charge coupling in this material by combining magnetic, transport and neutron scattering measurements.

MA 33.11 Thu 12:15 H16

Magnetic Ordering Temperature for Spin Spiral materials — •Varun Rajeev Pavizhakumari and Thomas Olsen — CAMD, Department of Physics, Technical University of Denmark, 2800 Kgs. Lyngby Denmark

Spin Spirals are the materials that show a helical arrangement of magnetic moments in the ground state. Thermal fluctuations from this state form collective excitations known as spin waves/magnons. As the thermal stability of a spin spiral is a decisive factor for its technological applications, there is considerable interest in the theoretical prediction of its critical temperature. This could be accomplished using two approaches - Holstein-Primakoff(HP) bosonization and the Green's function-Random Phase Approximation(RPA) where we can calculate the thermally renormalized magnon energies at each temperature. But these methods only exist for ferromagnetic and a few specific antiferromagnetic materials. In this work, we propose a single-Q spiral generalization of the HP bosonization and the Green's function-RPA to calculate the critical temperature. We benchmark these methods along with the classical Monte Carlo simulations and the Mean field theory, using their experimental exchange parameters for a diverse range of materials ; MnO and NiO(single site Neel state),MnF_2(altermagnetic),Cr_2O_3 and Fe_2O_3(two site Neel state) and $Ba_3NbFe_3Si_2O_{14}$(incommensurate). In all cases, we observe that the Green's function-RPA shows excellent agreement to the experiments and hence is as an ideal candidate to predict the critical temperature for any single-Q spirals.

MA 33.12 Thu 12:30 H16

Three-dimensional topological spin textures in curved chiral magnets — •Luke Turnbull[1,2], Max Birch[3], Marisel Di Pietro Martínez[1,2], Rikako Yamamoto[1,2], Jeffrey Neethirajan[1], Marina Raboni Ferreira[1,4], Rachid Belkhou[5], Simone Finizio[6], Dieter Suess[7], Geetha Balakrishnan[8], Claas Abert[7], Sebastian Wintz[9], and Claire Donnelly[3] — [1]MPI CPfS, Dresden, Germany — [2]WPI-SKCM2, Hiroshima, Japan — [3]RIKEN CEMS, Saitama, Japan — [4]Brazilian Synchrotron Light Laboratory, Sao Paulo, Brazil — [5]Synchrotron SOLEIL, Saint Aubin, France — [6]SLS, PSI, Villigen, Switzerland — [7]University of Vienna, Vienna, Austria — [8]Univeristy of Warwick, Coventry, UK — [9]HZB, Berlin, Germany

Nanoscale topologically non-trivial magnetization configurations generate significant interest due to both their fundamental properties, and their potential applications in ultra-efficient computing devices. While such textures have been widely studied in two dimensions, three dimensional (3D) ordering can yield more complex configurations, resulting in richer topologies and dynamic behaviours. However, reliably nucleating such 3D textures has proven challenging. Here, we achieve the controlled formation of a double helix ordering through the 3D nanopatterning of chiral single crystal helimagnets into nano-tori. We demonstrate that the interplay of intrinsic exchange interactions of the single crystal, with the extrinsic emergent effects of the patterned geometry, leads to the stabilisation of surface-localized topologically non-trivial double helices. Our approach has the potential to be applied to a wide range of quantum material systems.

MA 33.13 Thu 12:45 H16

Lifetime of toroidal Hopfions in bulk magnets with competing exchange interactions — •Moritz Sallermann[1,3], Hannes Jonsson[3], and Stefan Blügel[1,2] — [1]RWTH Aachen University, Germany — [2]PGI-1, Forschungszentrum Jülich, Germany — [3]University of Iceland, Iceland

Hopfions are three-dimensional topological solitons characterized by the Hopf invariant, which quantifies the pairwise linking number of constant magnetization pre-images. In simple models of bulk magnets with competing exchange interactions, Hopfions emerge as local energy minima in numerical simulations. However, to fully understand their stability against decay due to thermal fluctuations, merely identifying these local minima is insufficient. A more comprehensive understanding requires determining their expected average lifetimes. We employ the harmonic transition state theory framework, a computationally efficient yet approximate method, to estimate these lifetimes. This approach yields an Arrhenius-type expression comprising two key ingredients: the energy barrier and an entropic prefactor. The energy barrier represents the minimal energy needed to initiate decay, while the entropic prefactor measures the relative entropy of the energy bottleneck, compared to the configuration space volume of the local minimum. We present our findings on the lifetimes of Hopfions in these systems and discuss technical challenges encountered, such as the treatment of Goldstone modes and the computation of sparse positive-definite determinants.

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