Symposium Novel phases and dynamical properties of magnetic skyrmions (SYMS)

jointly organised by
the Low Temperature Physics Division (TT),
the Magnetism Division (MA),
the Surface Science Division (O), and
the Crystalline Solids and their Microstructure Division (KFM)

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The discovery of skyrmions in cubic chiral ferromagnets over a decade ago, featuring non-trivial topological winding and greatly enhanced sensitivity to spin transfer torques, stimulated intense research into the suitability of skyrmions for technical applications. The symposium focusses on the recent identification of symmetry-broken phases and new forms of driven dynamical states of skyrmions in ferromagnetic host materials vis a vis the discovery of skyrmionic order in geometrically frustrated and antiferromagnetic magnets and their dynamical properties. The symposium this way highlights the intimate relationship of non-trivial topology and exceptional spin dynamics in different skyrmion-hosting systems.

Overview of Invited Talks and Sessions

(Lecture hall Audimax 2)

Invited Talks

SYMS 1.1	Tue	10:00–10:30	Audimax 2	**Imaging skyrmions in synthetic antiferromagnets by single spin relaxometry** — •Aurore Finco
SYMS 1.2	Tue	10:30–11:00	Audimax 2	**Microwave spectroscopy of the skyrmionic states in a chiral magnetic insulator** — •Aisha Aqeel, Jan Sahliger, Takuya Taniguchi, Stefan Maendl, Denis Mettus, Helmuth Berger, Andreas Bauer, Markus Garst, Christian Pfleiderer, Christian H. Back
SYMS 1.3	Tue	11:15–11:45	Audimax 2	**Archimedean Screw in Driven Chiral Magnets** — •Nina del Ser
SYMS 1.4	Tue	11:45–12:15	Audimax 2	**Frustration-driven magnetic fluctuations as the origin of the low-temperature skyrmion phase in $Co_7Zn_7Mn_6$** — •Jonathan White, Victor Ukleev, Kosuke Karube, Peter Derlet, Chennan Wang, Hubertus Luetkens, Daisuke Morikawa, Akiko Kikkawa, Lucile Mangin-Thro, Andrew Wildes, Yuichi Yamasaki, Yuichi Yokoyama, Le Yu, Cinthia Piamonteze, Nicolas Jaouen, Yusuke Tokunaga, Henrik Rønnow, Taka-hisa Arima, Yoshinori Tokura, Jonathan White
SYMS 1.5	Tue	12:15–12:45	Audimax 2	**Magnetic Skyrmions as Topological Multi-Media Influencers** — •Sebastián A. Díaz

Sessions

SYMS 1.1–1.5	Tue	10:00–12:45	Audimax 2	**Novel phases and dynamical properties of magnetic skyrmions**

SYMS 1: Novel phases and dynamical properties of magnetic skyrmions

Time: Tuesday 10:00–12:45 Location: Audimax 2

Invited Talk SYMS 1.1 Tue 10:00 Audimax 2
Imaging skyrmions in synthetic antiferromagnets by single spin relaxometry — •Aurore Finco — Laboratoire Charles Coulomb, Université de Montpellier and CNRS, Montpellier, France

Antiferromagnets attract a great interest for spintronics owing to the robustness of the hosted magnetic textures and their fast dynamics. NV-center magnetometry has emerged in the last years as a powerful technique to investigate them. Here we introduce a new imaging mode of the NV magnetometer which relies on the detection of noise originating from spin waves interacting with the textures of interest.

We demonstrate this method on synthetic antiferromagnets (SAF). We first image domain walls and prove that we perform noise-based imaging by measuring spin relaxation times. Calculations of the spin wave dispersions as well as maps of simulated noise intensity enable us to conclude that we probe spin waves channelled in the domain walls. Going further, we tune the composition of the SAF stacks in order to stabilize spin spirals or skyrmions. In both cases, our relaxometry-based technique is able to image the non-collinear structures, demonstrating its efficiency and opening new avenues of exploration in the characterization of complex structures in magnetically-compensated materials.

This work was done in collaboration with the UMR CNRS/Thalès and the C2N in Palaiseau, France. This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 846597 and from the DARPA TEE Program.

Invited Talk SYMS 1.2 Tue 10:30 Audimax 2
Microwave spectroscopy of the skyrmionic states in a chiral magnetic insulator — •Aisha Aqeel[1], Jan Sahliger[1], Takuya Taniguchi[1], Stefan Maendl[1], Denis Mettus[1], Helmuth Berger[2], Andreas Bauer[1], Markus Garst[3], Christian Pfleiderer[1], and Christian H. Back[1,4] — [1]Technical University of Munich, Garching, Germany — [2]École polytechnique Federale de Lausanne, Lausanne, Switzerland — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

In the cubic chiral magnet Cu2OSeO3 a low-temperature skyrmion state (LTS) and a concomitant tilted conical state are observed for magnetic fields applied along specific crystallographic directions (<100>). In this work, we investigated the dynamic resonances of these novel magnetic states. We have used the broadband microwave spectroscopy to study these resonance modes. By comparing the results to linear spin-wave theory, we clearly identify the gyrational and breathing modes associated with the LTS, as well as the hybridization of the breathing mode with a dark octupole gyration mode mediated by the magnetocrystalline anisotropies. Interestingly, our findings suggest that under decreasing fields the hexagonal skyrmion lattice becomes unstable, resulting in the formation of elongated skyrmions.

15 min. break

Invited Talk SYMS 1.3 Tue 11:15 Audimax 2
Archimedean Screw in Driven Chiral Magnets — •Nina del Ser — Institute for Theoretial Physics, University of Cologne, Cologne, Germany

In chiral magnets a magnetic helix forms where the magnetization winds around a propagation vector $\mathbf{q}$. We show theoretically that a magnetic field $\mathbf{B}_\perp(t) \perp \mathbf{q}$, which is spatially homogeneous but oscillating in time, induces a net rotation of the texture around $\mathbf{q}$. This rotation is reminiscent of the motion of an Archimedean screw and is equivalent to a translation with velocity $\mathbf{v}_{\text{screw}}$ parallel to $\mathbf{q}$. Due to the coupling to a Goldstone mode, this non-linear effect arises for arbitrarily weak $\mathbf{B}_\perp(t)$ with $v_{\text{screw}} \propto B_\perp^2$ as long as pinning by disorder is absent. The effect is resonantly enhanced when internal modes of the helix are excited and the sign of $\mathbf{v}_{\text{screw}}$ can be controlled either by changing the frequency or the polarization of $\mathbf{B}_\perp(t)$. The Archimedean screw can be used to transport spin and charge and thus the screwing motion is predicted to induce a voltage parallel to $\mathbf{q}$. Using a combination of numerics and Floquet spin wave theory, we show that the helix becomes unstable upon increasing $\mathbf{B}_\perp$, forming a 'time quasicrystal' which oscillates in space and time for moderately strong drive.

Invited Talk SYMS 1.4 Tue 11:45 Audimax 2
Frustration-driven magnetic fluctuations as the origin of the low-temperature skyrmion phase in $Co_7Zn_7Mn_6$ — •Jonathan White[1], Victor Ukleev[1], Kosuke Karube[2], Peter Derlet[1], Chennan Wang[1], Hubertus Luetkens[1], Daisuke Morikawa[2], Akiko Kikkawa[2], Lucile Mangin-Thro[3], Andrew Wildes[3], Yuichi Yamasaki[4,5], Yuichi Yokoyama[4], Le Yu[1,6], Cinthia Piamonteze[1], Nicolas Jaouen[7], Yusuke Tokunaga[8], Henrik Rønnow[6], Taka-hisa Arima[2,8], Yoshinori Tokura[2,8], and Jonathan White[2] — [1]Paul Scherrer Institut, Switzerland — [2]RIKEN CEMS, Japan — [3]Institut Laue-Langevin, France — [4]NIMS, Japan — [5]PRESTO, Japan — [6]EPFL, Switzerland — [7]Synchrotron Soleil, France — [8]University of Tokyo, Japan

Magnetic skyrmion phases in noncentrosymmetric magnets are an established testbed for topological quantum matter research. In chiral cubic Co-Zn-Mn compounds, Bloch-type skyrmion phases are easily tuned according to composition, and display, amongst other phenomena, remarkable metastable skyrmion behaviour. Here we focus on $Co_7Zn_7Mn_6$, which we showed recently to host two thermodynamically distinct equilibrium skyrmion phases. In addition to a conventional A-phase stable near T_c, the second phase is instead stable at much lower temperature. From our most recent quantum beam experiments, we find the stability of the low temperature phase is uniquely derived from a novel cooperative interplay between chiral magnetism and magnetic frustration-induced spin fluctuations generated by a magnetic hyperkagome motif embedded in the crystal structure.

Invited Talk SYMS 1.5 Tue 12:15 Audimax 2
Magnetic Skyrmions as Topological Multi-Media Influencers — •Sebastián A. Díaz — University of Duisburg-Essen, Duisburg, Germany

Magnetic skyrmions are stable, particle-like spin configurations whose real-space topology affords them with fascinating properties. Soon after their experimental observation and motivated by the prospect of using them as information carriers, research focused on mastering their manipulation via their coupling to applied fields, electric currents, and temperature gradients. However, the spectrum of novel phenomena goes beyond these initial milestone discoveries. Recently, magnetic skyrmions have been shown to be fertile substrates for multiple topological media. This talk will focus on two of our latest theoretical proposals: topological magnon insulating phases supported by skyrmion crystals[1] and topological superconductivity induced by antiferromagnetic skyrmion chains[2]. The hallmarks of the former are robust magnonic states localized at the sample boundaries. These states are suitable for applications in magnonics, the harnessing of magnons as information carriers. Exploiting the mobility of antiferromagnetic skyrmions, our proposed topological superconductivity platform could provide the so far elusive smoking gun evidence of the non-Abelian exchange statistics of Majorana bound states localized at the ends of the chain.

[1] S. A. Díaz et al., PRL 122, 187203 (2019); S. A. Díaz et al., PRR 2, 013231 (2020); T. Hirosawa et al., PRL 125, 207204 (2020)

[2] S. A. Díaz et al., arXiv:2102.03423