MA 30: Focus Session: Topological Defects in Superconductors and Magnets (joint session TT/MA)

Vortices in superconductors and skyrmions in magnets are two examples of topological objects that can form a lattice and have particle-like properties. Their orientation and symmetry is determined by the magnetic field and the interaction within the material. The scientific and methodological approaches are similar*both can be studied using transport and magnetization and both can be observed using neutron scattering and scanning microscopies. Nanofabrication, often with the help of hybrid structures, allows controlling and manipulating them. The latter is believed to play a key role in applications involving current carrying and magnetic memory devices. The aim of the colloquium is to present most recent advances with a particular focus on the cross-fertilization of research on topological defects in superconductivity and magnetism.

Organization: Sebastian Mühlbauer, TU München; Hermann Suderow, Universidad Autonoma de Madrid; Javier Villegas, Thales, Paris; Markus Garst, TU Dresden

Time: Wednesday 15:00–17:45 Location: H 0104

Invited Talk MA 30.1 Wed 15:00 H 0104

Stability and Emergent Electrodynamics of Skyrmions — •Christian Pfleiderer — Physik-Department, Technische Universität München, D-85748 Garching, Germany

Skyrmions and related topological spin textures in chiral magnets attract great interest as a possible route towards novel spintronics devices. A series of studies is reported on the topological stability of skyrmions in chiral magnets for different temperature versus field histories. The character of magnetic textures, notably as observed in bulk compounds, at surfaces and in thin epitaxial films will be addressed. Further, the response of the different magnetic phases in chiral magnets to electric currents and the associated spin currents across the magnetic phase diagram of selected systems has been measured. Based on the combination of electrical resistivity, Hall effect, planar Hall effect, ac susceptibility and kinetic small angle neutron scattering the interplay of spin transfer torques with defects for the different magnetic phases and phase boundaries will be discussed.

Invited Talk MA 30.2 Wed 15:30 H 0104

Optical Manipulation of Single Flux Quanta — •Philippe Tamarat — LP2N, Université de Bordeaux, Institut d'Optique Graduate School and CNRS, France

The semiconductor electronics scaling road map will probably reach its physical fundamental limits within the next decade. Alternative technologies such as superconducting electronics are appealing due to higher operating frequencies together with fundamentally lower switching energies. In this context, a promising method requires the manipulation of individual flux quanta close to a Josephson junction. Yet, handling of individual vortices remains challenging and has been performed only with local probe scanning microscopies, slow techniques that are heavy to implement in a cryogenic environment.

We introduce the concept of laser manipulation of individual flux quanta, based on local heating of the superconductor with a focused laser beam to realize a fast, precise and non-invasive manipulation of an Abrikosov vortex, in the same way as with optical tweezers. This simple and far-field optical method provides a perfect basis for sculpting the magnetic flux profile in superconducting devices like a vortex lens or a vortex cleaner. Various regimes of vortex manipulation are achieved, from the precise and rapid positioning of individual vortices to the generation of tight vortex bunches. This method will fuel fundamental investigations of the vortex matter and open up new research directions in quantum computation based on Josephson junctions. I will also present our latest advances towards the creation of Abrikosov vortices with light.

Invited Talk MA 30.3 Wed 16:00 H 0104

Skyrmion Lattices in Random and Ordered Potential Landscapes — •Charles Reichhardt — Los Alamos National Laboratory, Los Alamos, USA

Since the initial discovery of skyrmion lattices in chiral magnets [1], there has been a tremendous growth in this field as an increasing number of compounds are found to have extended regions of stable skyrmion lattices [2] even close to room temperature [3]. These systems have significant promise for applications due to their size scale and the low currents or drives needed to move the skyrmions [4]. We examine the driven dynamics of skyrmions interacting with random and periodic substrate potentials using both continuum based modelling and particle based simulations. In clean systems we examine the range in which skyrmion motion can be explored as a function of the magnetic field and current and show that there can be a current-induced creation or destruction of skyrmions. In systems with random pinning we find that there is a finite depinning threshold and that the Hall angle shows a strong dependence on the disorder strength. We also show that features in the transport curves correlate with different types of skyrmion flow regimes including a skyrmion glass depinning/skyrmion plastic flow region as well as a transition to a dynamically reordered skyrmioncrystal at higher drives. We find that increasing the Magnus term produces a low depinning threshold which is due to a combination of skyrmions forming complex orbits within the pinning sites and skyrmion-skyrmion scattering effects.

15 min. break.

Invited Talk MA 30.4 Wed 16:45 H 0104

Hedgehog Spin-Vortex Crystal Magnetic Order in Superconducting $CaK(Fe_{1-x}M_x)_4As_4$ (M=Co, Ni) — •Anna Böhmer — Ames Laboratory, Iowa, USA — IFP, Karlsruhe Institute of Technology, Germany

Iron-based superconductors can support a number of antiferromagnetic phases, of which stripe-type antiferromagnetism is most common. It is found that Ni- and Co-doping in $CaKFe_4As_4$ suppresses superconductivity and stabilizes a new antiferromagnetic phase. This phase is studied using thermodynamic, transport, x-ray and neutron diffraction, as well as local magnetic measurements. A non-collinear antiferromagnetic structure preserving tetragonal symmetry is revealed. It is characterized by a superposition of the propagation vectors of the common stripe-type antiferromagnetism. This antiferromagnetic structure with a "hedgehog-type" moment motif is stabilized by the reduced symmetry of the $CaKFe_4As_4$ structure.

This work was performed in collaboration with W. R. Meier, Q.-P. Ding, A. Kreyssig, M. Xu, S. L. Bud'ko, A. Sapkota, K. Kothapalli, J. M. Wilde, W. Tian, V. Borisov, R. Valentí, C. D. Batista, P. P. Orth, R. M. Fernandes, R. J. McQueeney, A. I. Goldman, Y. Furukawa and P. C. Canfield and supported by the Gordon and Betty Moore Foundation's EPiQS Initiative through Grant GBMF4411 and the US DOE, Basic Energy Sciences under Contract No. DE-AC02-07CH11358.

[1] W. R. Meier et al., arXiv:1706.01067 (2017).

Invited Talk MA 30.5 Wed 17:15 H 0104

Geometric Frustration and Ratchet Effect of Vortices in an Artificial-Spin/Superconductor Hybrid — •Zhi-Li Xiao[1,2], Yong-Lei Wang[1,3], Xiaoyu Ma[3], Jing Xu[1,2], Boldizsar Janko[3], and Wai-Kwong Kwok[1] — [1]Materials Science Division, Argonne National Laboratory, Argonne, Illinois 60439, USA — [2]Department of Physics, Northern Illinois University, DeKalb, Illinois 60115, USA — [3]Department of Physics, University of Notre Dame, Notre Dame, Indiana 46556, USA

Geometric frustration emerges when local interaction energies cannot be simultaneously minimized, resulting in numerous degenerate states. It exists in a large variety of material systems, such as water ice and pyrochlore crystals (spin ice), as well as various artificial systems including artificial spin ice, vortex ice, magnetic colloidal ice, and buckled colloidal monolayers. However, it is difficult to achieve extensive degeneracy, especially in a two-dimensional (2D) system. Here, we report the realization of geometric frustration with massive degeneracy in a 2D system created in a superconducting thin film placed underneath an artificial-spin structure. The magnetic charges of the artificial-spins strongly interact with vortices in the superconductor, enabling the creation of controllable frustrated and crystallized vortex states by precise selection of the spin magnetic states. We reveal the various vortex states by molecular dynamic simulations and transport measurements. We demonstrate that a reprogrammable vortex ratchet effect can be achieved in this artificial-spin/superconductor heterostructure.