# TT 15: Focus Session: Skyrmionics: Future of Spintronics? (jointly with MA)

Major challenges faced by the spintronics community concern the stability and speed of processing information and the packing density of data stored. Present day limitations in spintronics may be traced to the use of conventional magnetic materials and how these materials are tailored to meet advanced technological requirements. The recent discovery of topological spin soliton lattices, frequently referred to as skyrmion lattices in recognition of seminal field-theoretical contributions of British nuclear physicist Toni Skyrme, as well as the possibility to generate isolated skyrmions as generic magnetic properties of bulk compounds, thin films, interfaces and surfaces has revealed several remarkable properties. These comprise of greatly enhanced stability due to their non-trivial topological winding, new capabilities to create and destroy magnetically encoded information, efficient coupling to spin currents generating spin transfer torques at dramatically reduced current densities, and last but not least, the capability to purpose-design broad-band spin dynamics devices.

This Focus Session aims to review critically the status of experimental and theoretical studies on skyrmions in non-centrosymmetric compounds and interface-driven spin-systems in the context of their potential for spintronics applications.

Organizers: Christian Back (Uni Regensburg) and Christian Pfleiderer (TU München)

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

**Invited Talk** TT 15.1 Mon 15:00 H 0104
**Skyrmion Dynamics** — •Yoshinori Tokura — RIKEN Center for Emergent Matter Science, Wako, Japan — University of Toyo, Tokyo, Japan

Dynamics of skyrmions have been investigated in terms of real-space observation by Lorentz transmission microscopy, topological transport phenomena, and micromagnetic simulations. Key functions toward 'skyrmionics' are discussed.

**Topical Talk** TT 15.2 Mon 15:30 H 0104
**Topological Transport Phenomena in Magnetic Skyrmion Matter** — •Markus Garst — Institut für Theoretische Physik, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany

Magnetic skyrmions are topological textures with a finite winding number – similar to the baryon number in nuclear matter – which is at the origin of various novel transport phenomena. It is directly reflected in a strong spin-Magnus force in their effective equation of motion resulting in a peculiar dynamics with skyrmions preferentially moving along equipotential lines akin to guiding centers of electrons in Landau levels. This not only allows for an efficient manipulation by spin currents but also enables skyrmions to avoid pinning centers giving rise to spintronic phenomena at ultralow threshold currents [1]. Moreover, the adiabatic motion of electrons in skyrmion textures results in an emergent electrodynamics revealed by a topological Hall effect and a skyrmion-flow Hall effect [2]. Interesting spin-thermal transport and skyrmion caloritronic phenomena are also to be expected in insulators. The topological winding number is manifest in the magnon-skyrmion scattering potential and, for example, leads to magnon skew scattering and a magnon Hall effect. In turn, the magnon pressure generated, e.g., by a thermal gradient induces, counterintuitively, a skyrmion motion towards the hot region, i.e., the magnon source [3].

[1] F. Jonietz *et al.*, Science **330**, 1648 (2010)
[2] T. Schulz *et al.*, Nat. Phys. **8**, 301 (2012)
[3] C. Schütte and M. Garst, Phys. Rev. B **90**, 094423 (2014)

**Invited Talk** TT 15.3 Mon 16:00 H 0104
**Interface Induced Individual Skyrmions in Thin Films and Multilayers** — K. Bouzehouane[1], V. Cros[1], C. Deranlot[1], •A. Fert[1], K. Garcia[1], C. Moreau-Luchaire[1], N. Reyren[1], J.-M. Sampaio[1,3], N. van Horne[1], M. Chshiev[2], Hongxin Yang[2], A. Thiaville[3], S. Rohart[4], C. Moutafis[4], C.A.F. Vaz[4], P. Warnicke[4], J. Raabe[4], and M. Weigand[5] — [1]Unité Mixte de Physique CNRS/Thales, 1 Av. Fresnel, 9767 Palaiseau, France — [2]Université de Grenoble, and SPINTEC (CNRS/CEA-INAC), 38054 Grenoble Cedex, France — [3]Laboratoire de Physique des Solides, Université Paris-Sud, CNRS-UMR 8502, 91405 Orsay Cedex, France — [4]Swiss Light Source, Paul Scherrer Institute, 5232 Villigen, Switzerland — [5]Max Planck Institute for Intelligent Systems, Heisenbergstraße 3, 70569 Stuttgart, Germany

This talk is on individual skyrmions induced by interface Dzyaloshinskii-Moriya Interactions (DMI) in thin magnetic films or multilayers. I will present:

(1) Ab-initio calculations clearing up characteristic features of interface DMI: extension of the DMI away from the interface spins and thickness dependence, influence of the existence of proximity-induced magnetism in the spin-orbit layer, influence of interface roughness.

(2) Micromagnetic simulations of the nucleation and current-induced motion of skyrmions.

(3) Preliminary experimental results on (Ir/Co/Pt)x10 multilayers.

**15 min. break.**

**Topical Talk** TT 15.4 Mon 16:45 H 0104
**Magnetic Skyrmions and Chiral Spin Structures in Ultra-Thin Films** — •Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Ultrathin magnetic films and heterostructures provide a fantastic playground for the stabilization, manipulation and usage of magnetic skyrmions – topological magnetization solitons – magnetic entities with particle like properties that may open a new vista for spintronics. A crucial quantity for the skyrmion formation is the Dzyaloshinskii-Moriya interaction (DMI), whose presence in thin films could be established in a concerted effort of first-principles theory and spin-polarized scanning tunneling microscopy [1]. It could be shown that the spin-orbit interaction and the structure inversion-asymmetry in these systems result in a DMI that is strong enough to give rise to one-dimensional and two-dimensional lattices [2] of chiral spin-textures as well as chiral domain walls. Even single skyrmions [3] could be induced. In retrospect, it is surprising how little is known about the DMI in these metallic systems. In this talk I give some insight into the DMI, the relation to the transport properties of electrons such as the THE and AHE in connection to the spin texture of a skyrmion, and discuss possibilities to manipulate the magnetic interaction to enlarge the materials base to stabilize single skyrmions.

[1] M. Bode *et al.*, Nature **447**, 190 (2007)
[2] S. Heinze *et al.*, Nature Phys. **7**, 713 (2011)
[3] N. Romming *et al.*, Science **341**, 636 (2013)

**Invited Talk** TT 15.5 Mon 17:15 H 0104
**Racetrack Memory: Highly Efficient Current Induced Domain Wall Motion in Synthetic Antiferromagnetic Racetracks** — •Stuart Parkin — Max Planck Institute for Microstructure Physics, Halle, Germany — IBM Research - Almaden, San Jose, California, USA

Memory-storage devices based on the current controlled motion of domain walls in magnetic racetracks promise performance and reliability beyond that of conventional magnetic disk drives and solid state storage devices. Racetracks that are formed from atomically thin, perpendicularly magnetized nano-wires, interfaced with adjacent metal layers with high spin-orbit coupling, give rise to domain walls possessing a chiral Néel structure. These domain walls can be moved very efficiently with current. However, high capacity racetrack memory requires closely-packed domain walls whose density is limited by dipolar coupling from their fringing magnetic fields. These fields can be eliminated using a spin-engineered synthetic antiferromagnetic (SAF) structure composed of two magnetic sub-layers, exchange-coupled via an ultrathin antiferromagnetic-coupling spacer layer. We show that nano-second long current pulses can move domain walls in SAF racetracks that have nearly no net magnetization. Surprisingly, we find that the domain walls can be moved even more efficiently and at much higher speeds of up to $\sim$ 750 m/sec compared to similar racetracks in which the sub-layers are coupled ferromagnetically. The origin of these giant current induced domain wall velocities is discussed.