MA 35.1 Wed 15:00 EB 301

**Skyrmion drag effects**

- **ADEL ABBOUT**¹, JOSEPH WESTON², XAVIER WINTIL², and AURÉLIEN MACHON¹ — ¹King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia — ²CEA Grenoble, France.

In this study, we work on the motion of skyrmionic magnetic textures and analyze the current induced by this motion using time-dependent nonequilibrium Green’s function formalism implemented on a real-space tight-binding model. We focus on the time dependent distribution of the nonequilibrium charge and spin densities and discuss the corresponding topological Hall effect. The perturbation induced by this motion applies a torque on the whole texture. The influence of the generated current on the whole texture is discussed and its signature is unveiled in the renormalization of the damping parameter. A cooperative effect due to the collective motion of skyrmions is proposed in order to enhance the skyrmion’s velocity. The stationary regime is analyzed as a function of the different parameters of the system and explained using the formalism of electronic pumping. A simple formula for the current is proposed.

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**MA 35.2 Wed 15:15 EB 301**

**Theory of tunneling vector spin transport on a magnetic skyrmion** — **KRZYSTOŻ PALOTA**¹, LEVENTE RÓZSA³, and LÁSZLÓ SZUNYOCH⁴ — ¹Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — ²University of Szeged, Szeged, Hungary — ³University of Hamburg, Hamburg, Germany — ⁴Budapest University of Technology and Economics, Budapest, Hungary

Spin-polarized scanning tunneling microscopy (SP-STM) demonstrated the creation and annihilation of individual magnetic skyrmions [1] that are promising for future technological use. The detailed microscopic mechanisms for these processes are, however, unknown. In the present work the tunneling spin transport of a magnetic skyrmion is theoretically investigated in SP-STM. The spin-polarized charge current [2] and tunneling spin transport vector quantities, the longitudinal spin current and the spin transfer torque are calculated in high spatial resolution within a simple electron tunneling theory for the first time. Beside the vector spin transport characteristics, the connections between conventional charge current SP-STM images and the magnitudes of the spin transport quantities are analyzed.


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**MA 35.3 Wed 15:30 EB 301**

**Quantum dynamics of skyrmions in chiral magnets** — **CHRISTINA PRAGODAKI** — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

We study the quantum propagation of a skyrmion in chiral magnetic insulators by generalizing the microscopic equations of motion to a finite temperature path integral formalism, using field theoretic tools. Promoting the center of the skyrmion to a dynamic quantity, the fluctuations around the skyrmionic configuration give rise to a time-dependent damping of the skyrmion motion. From the frequency dependence of the damping kernel, we are able to identify the skyrmion mass, thus providing a microscopic description of the kinematic properties of skyrmions. When defects are present or a magnetic trap is applied, the skyrmion mass acquires a finite value proportional to the effective spin, even at vanishingly small temperature. We demonstrate that a skyrmion in a confined geometry provided by a magnetic trap behaves as a massive particle owing to its quasi-one dimensional confinement. An additional quantum mass term is predicted, independent of the effective spin. With an explicit temperature dependence which remains finite even at zero temperature.

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**MA 35.4 Wed 15:45 EB 301**

**Optimizing the size of long-lived magnetic skyrmions**

- **ANASTASIA VARENTSOVA**¹, STEPHAN W. MALOTTI², STEPHEN W. HEINZE³, and PAVEL F. BESSARAB⁴ — ¹IITMO University, St. Petersburg, Russia — ²University of Kiel, Kiel, Germany — ³University of Iceland, Reykjavik, Iceland

Available experimental data on magnetic skyrmions in various materials demonstrate inverse correlation between the skyrmion size and skyrmion stability: small skyrmions tend to be less stable compared to large ones [1,2]. The question arises how fundamental this trend is and whether it is possible to obtain long-lived magnetic skyrmions at ambient conditions while keeping their size at the nanoscale.

Here, we demonstrate by means of transition state theory [3] and minimum energy path calulations [4] that the skyrmion lifetime at a given temperature is not a unique function of the skyrmion size and that it is possible to systematically tune material parameters so as to minimize the size of skyrmions while keeping their stability at a desired level. Based on this work we identify the most promising materials for the use as storage media based on magnetic skyrmions.


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**MA 35.5 Wed 16:00 EB 301**

**Critical Phenomena in Confined Skyrmion Systems** — **JONATHON WATER**¹, TIMOTHY SLUCKIN², DENIS KRAMER², HANS FANGOHRR², and ONDREJ HOVRICKÁ³ — ¹University of Southampton, Southampton, UK — ²European XFEL, Germany

There have been extensive studies which establish the magnetic phases and the thermal phase transition behaviour in bulk helimagnetic materials. However, many proposed device applications, which will utilise the skyrmion phase of these materials, are expected to assume operation in confined geometries and, therefore, it is critical to access the role of the confinement and finite size effects on the stability of skyrmion phases. So far, there have been few studies aimed at understanding the finite system size effects on the thermal phase transition behaviour in these systems. This presentation will discuss our recent developments of systematic analysis of these fundamental effects.

We present large-scale Monte-Carlo simulations of cubic nanoparticles, modelled by a general Heisenberg model with Dzyaloshinskii-Moriya interaction (DMI), and establish phase diagrams for different combinations of exchange and DMI strengths. We apply several different annealing protocols when generating the phase diagram in order to establish the role of metastability and hysteresis in the phase behaviour of these systems. Finally we discuss the results of a finite system size scaling analysis and establish the dependence of critical phase transition temperature on the particle size.

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**MA 35.6 Wed 16:15 EB 301**

**Magnetic skyrmion dynamics in thin cylindrical nanodots** — **KONSTANTIN GUSLIEVSKII**¹, ZUKHRA GAREEVA², and YURIY GUSLIEVSKII² — ¹Depto. Física de Materiales, Universidad del País Vasco, UPV/EHU, 48080 San Sebastián, Spain — ²IKERBASQUE, the Basque Foundation for Science, 48013 Bilbao, Spain — ³Institute of Molecule and Crystal Physics, Russian Academy of Sciences, 450075 Ufa, Russia

Magnetic skyrmions, robust particle-like nanosize objects, attracts considerable attention due to promising applications in spintronics and information technologies. Being a kind of magnetic topological solitons in 2D spin systems, skyrmions exhibit a wide variety of unusual properties related to their topology. In this talk we focus on the low and high frequency dynamics of magnetic skyrmions in the systems of restricted geometry: isolated cylindrical nanodots. We consider Bloch- and Neel skyrmions as the ground magnetic state of thin circular nanodots stabilized due to an interplay of the isotropic and Dzyaloshinskii-Moriya exchange interactions, perpendicular magnetic anisotropy and magnetostriiction. We calculate phase transition behaviour of spin excitations over the skyrmion background and classify the eigenmodes according to their spatial symmetry. We show that only one gyrotropic mode (rotation of the skyrmion center position with the frequency about of 1 GHz) exists for the skyrmion of definite polarity and the other low frequency modes that are observed in the skyrmion spectra correspond to spin waves. We found an asymmetry between azimuthal spin waves propagating in the clockwise and counter-clockwise directions that is closely related to the skyrmion topology.

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**MA 35.7 Wed 16:30 EB 301**

**Internal structure and stability of skyrmions in ferromagnet/heavy-metal multilayers** — **KERESZA CHICHAY**¹, JOSEPH BARKER², and OLEG TRETIAKOV³,² — ¹Center for Functionalized Magnetic Materials (FunMagMa), Emmanuel Kant Baltic
Frustration of the Dzyaloshinskii–Moriya interaction in ultrathin Co films — **Sebastian Meyer¹, Stephan Von Malottki¹, Bertrand Dupé², and Stefan Heine⁵** — 1Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Leibnizstr. 15, 24098 Kiel — 2Institute of Physics, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz

Non-collinear spin structures such as chiral domain walls and skyrmions are being intensively studied since they are promising for spintronic applications [1, 2]. The Dzyaloshinskii-Moriya interaction (DMI) is crucial for stabilizing these non-trivial magnetic states favoring a unique rotational sense. Here, we show frustration of the DMI in ultrathin Co films using density functional theory (DFT) as implemented in the FLEUR code [3]. We study Co monolayers and Pt/Co bilayers on the Ir(111) surface and calculate the energy dispersion of homogeneous flat spin spirals including spin-orbit coupling. Clockwise rotating spin spirals are preferred for large periods close to the ferromagnetic state while below a certain spin spiral period an anticyclonic sense is obtained. This effect arises due to competing DMI interactions with different neighbors that are of opposite sign. With our results from DFT, we parametrize an atomistic spin model and simulate domain wall properties using spin-dynamics simulations.

Skyrmion-Lattice Collapse and Defect-Induced Melting in Chiral Magnetic Films — •Leonardo Pierobon¹, Christoforos Moutafis², Michalis Charilaou¹, and Jörg Löffler¹ — ¹Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich, Switzerland — ²School of Computer Science, University of Manchester, Manchester, UK

Complex spin textures arise in nanostructured magnets due to competing interactions, primarily the Heisenberg exchange and the Dzyaloshinskii-Moriya interaction (DMI), which promote spin collinearity and canting, respectively. Upon rotational-symmetry breaking, particle-like objects with non-trivial spin configurations, i.e., skyrmions, can be created. The winding of skyrmions bestows a topological protection on the system, and the transition to the topologically trivial ferromagnetic state requires a phase transition. Here, we systematically compare isotropic and anisotropic DMI systems by means of high-resolution numerical simulations. We show that in perfect systems skyrmion lattices can be inverted in a field-induced first-order phase transition, whereas the existence of even a single defect replaces the inversion with a second-order phase transition following a defect-induced lattice melting process. This radical qualitative change signifies the importance of employing such an analysis for all realistic systems in order to correctly interpret experimental data. Our results shed light on fundamental processes behind magnetic phase transitions, and pave the way for their experimental realization in technologically relevant multilayer materials.

Reservoir Computing with Random Skyrmion Fabrics — •Daniele Pinna¹, George Bourianoff², and Karin Everschor-Sitte¹ — ¹Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany — ²Intel Labs, Intel Corp, Austin, TX

Thanks to their many nanoscale properties, skyrmions are promising in applications ranging from non-volatile memory [1] and spintronic logic devices [2], to enabling the implementation of unconventional computational standards [3, 4]. In this talk we will discuss how a random skyrmion “fabric” composed of skyrmion clusters embedded in a magnetic substrate can be effectively employed to implement a functional reservoir computer. This is achieved by leveraging the nonlinear resistive response of the individual skyrmions arising from their current dependent AMR [5]. Complex time-varying current signals injected via contacts into the magnetic substrate are shown to be modulated non-linearly by the fabric’s AMR due to the current distribution following paths of least resistance as it traverses the geometry. By tracking resistances across multiple input and output contacts, we show how the instantaneous current distribution, reminiscent of Atomic Switch Networks, effectively carries temporally correlated information about the injected signal. This in turn allows us to numerically demonstrate simple pattern recognition.