MA 11: FS: Topological Defects in Electronic Systems (with TT)

Time: Tuesday 9:30–13:45 Location: H20

Invited Talk MA 11.1 Tue 9:30 H20

Skyrmions in Chiral Magnets — •Ulrich K. Rössler, Andrei A. Leonov, Anna B. Butenko, and Alexei N. Bogdanov — IFW Dresden

In non-centrosymmetric magnets the chiral Dzyaloshinskii-Moriya (DM) exchange stabilizes tubular baby-Skyrmions. These are topologically non-trivial localized, but smooth and static textures of a spin system. Chiral Skyrmionic states may exist in various magnetic systems as the chiral DM-couplings stem from the leading spin-orbit effect, if they are allowed by crystal symmetry. Extended Skyrmionic textures are determined by the stability of the localized solitonic Skyrmion cores and their geometrical incompatibility, which frustrates a homogeneous space-filling. Two-dimensional models for these inhomogeneous magnetic states bear strong similarity with Abrikosov-lattices. Just as cylindrical vortices arrange into regular arrays in type-II superconductors, Skyrmions may form ordered arrays in chiral magnets. Basic phenomenological continuum theory suggests that a cornucopia of unexpected effects can be found in these chiral magnets. The isolated particle-like Skyrmion excitations may undergo confinement near the magnetic transition, and these molecular units may finally condense into extended mesophases. This magnetic 'Skyrmionic matter' strongly resembles chiral nematic liquid crystal textures. The underlying theoretical ideas shed new light on more fundamental question about the appearance of countable units in a continuum, and mechanisms for the formation of self-generated amorphous states.

Invited Talk MA 11.2 Tue 10:00 H20

Dirac Strings and Magnetic Monopoles in the Spin Ice, $Dy_2Ti_2O_7$ — •David Jonathan Pryce Morris[1], Alan Tennant[1,2], Santiago Grigera[3], Bastian Klemke[1,2], Claudio Castelnovo[4], Roderich Moessner[5], Clemens Czternasty[1], Michael Meissner[1], Kirrily Rule[1], Jens-Uwe Hoffmann[1], Klaus Kiefer[1], Damien Slobinsky[6], and Robin Perry[7] — [1]Helmholtz Center Berlin for Materials and Energy, Berlin, Germany — [2]Technische Universität Berlin, Germany — [3]Instituto de Fisica de Liquidos y Sistemas Biologicos, La Plata, Argentina — [4]University of Oxford, United Kingdom — [5]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [6]St. Andrews University, United Kingdom — [7]University of Edinburgh, Scotland

Recent proposals in condensed matter physics that magnetic monopoles can appear as emergent quasiparticles have attracted wide levels of interest. Dirac's original picture of magnetic monopoles had them connected to strings through which magnetic flux flowed. Here we report studies into a system called Spin Ice, where spins obey "ice rules" of 2 spins into and 2 spins out of their tetrahedron. In these materials it has been predicted that strings of spins form via a 3D Kasteleyn transition [1]. The geometry of spin-ice allows for net magnetic charge (magnetic monopoles) to form where "ice rules" are broken at the tips of the strings [2]. Here we present three experimental pieces of evidence for these strings and magnetic monopoles [3].

[1] Phys Rev. Lett. 100, 067207 (2008)
[2] Nature 451, 42 (2008)
[3] Science 326, 411 (2009)

Topical Talk MA 11.3 Tue 10:30 H20

Manifestations of monopole physics in spin ice materials — •Claudio Castelnovo[1], Roderich Moessner[2], and Shivaji Sondhi[3] — [1]University of Oxford, Oxford, UK — [2]MPI-PKS, Dresden, Germany — [3]Princeton University, Princeton, USA

Spin ice materials such as $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ provide a rare instance of fractionalisation in three dimensions: their elementary excitations carry a fraction of the magnetic moment of the microscopic spin degrees of freedom, and they can be thought of as magnetic monopoles.

The peculiar nature of these excitations leads to unique signatures in the equilibrium and response properties. These include unusual neutron scattering structure factors, dynamical arrest and long lived non-equilibrium metastable states, as well as a response to external magnetic fields that promotes spin ice as a magnetic analogue of an electrolyte. In this talk, we review several of these striking phenomena.

The formulation of the low-temperature phase in terms of an emergent gauge field permits an unusual degree of analytical progress in the modelling of these materials.

Invited Talk MA 11.4 Tue 11:00 H20

Skyrmion Lattices in Pure Metals and Strongly Doped Semiconductors — •Christian Pfleiderer — Physik Department E21, Technische Universität München, D-85748 Garching, Germany

For a long time it was anticipated theoretically, that chiral magnets may support topological defects with the characteristics of skyrmions. We used neutron scattering and measurements of the Hall effect to identify the formation of two-dimensional lattices of skyrmion lines, a new form of magnetic order, in metallic and semiconducting B20 compounds, namely MnSi [1,2], $Mn_{1-x}Co_xSi$, $Mn_{1-x}Fe_xSi$ and $Fe_{1-x}Co_xSi$ [3]. The skyrmion lattices share remarkable similarities with vortex lattices in type II superconductors. For instance, they may exhibit domain formation and complex morphologies as seen, e.g., in ultrapure Nb [4]. Moreover, the pinning of the skyrmion lattices to the crystal lattice is extremely weak. In fact, they may be viewed as a spin crystal that is essentially disconnected from the atomic lattice. Our study establishes magnetic materials lacking inversion symmetry as an arena for new forms of order composed of topologically stable spin configurations.

[1] S. Mühlbauer, et al. , Science **323**, 915 (2009).
[2] A. Neubauer, et al., Phys. Rev. Lett. **102**, 186602 (2009).
[3] W. Münzer, et al., arXiv/0902.2587.
[4] S. Mühlbauer, et al., Phys. Rev. Lett. **102**, 136409 (2009).

15 min. break

Topical Talk MA 11.5 Tue 11:45 H20

Skyrmion lattice in MnSi — •Achim Rosch — Institute of Theoretical Physics, University of Cologne, 50937 Cologne, Germany

A magnetic skyrmion is a topologically stable vortex-like spin configuration. Similarly to a vortex lattice of a superconductor, a lattice of skyrmion lines is found [1] in the metallic magnet MnSi in a small magnetic field for a small range of temperatures. This state of matter is stabilized by weak spin-orbit interactions and thermal fluctuations. The topological winding number of the skyrmions implies that moving electrons pick up a Berry phase which leads to a characteristic contribution to the Hall constant [2] and an efficient coupling of currents to the magnetic structure. We therefore also investigate how spin-torque effects can lead to modifications of the magnetic structure when electric currents are applied.

[1] S. Mühlbauer, B. Binz, F. Jonietz, C. Pfleiderer, A. Rosch, A. Neubauer, R. Georgii, P. Böni, Science **323**, 915 (2009).

[2] A. Neubauer, C. Pfleiderer, B. Binz, A. Rosch, R. Ritz, P. G. Niklowitz, P. Böni , Phys. Rev. Lett. **102**, 186602 (2009).

Invited Talk MA 11.6 Tue 12:15 H20

Topological Insulators in Applied Fields: Magnetoelectric Effects and Exciton Condensation — •Joel Moore — University of California, Berkeley CA USA

"Topological insulators" are insulating in bulk but have protected metallic surface states as a result of topological properties of the electron wavefunctions. Several examples have been discovered recently in ARPES experiments that directly probe the surface state, including its spin structure. One way to characterize the topological insulator is through its magnetoelectric response in a weak applied field: it generates an electrical polarization in response to an applied magnetic field, and a magnetization in response to an applied electrical field. This talk first reviews the origin of this response and its generalization to other insulators and topological states. A strong applied electrical field can combine with Coulomb interactions to generate an unusual "exciton condensate" involving both surfaces of a thin film of topological insulator. This exciton condensate has several topological features that distinguish it from an ordinary superfluid; the most significant is that vortices support midgap localized states ("zero modes" in the particle-hole symmetric case) with effective fractional charge $\pm e/2$.

Topical Talk MA 11.7 Tue 12:45 H20

Probing non-Abelian statistics with quasiparticle interferometry — •Kirill Shtengel — University of California, Riverside, USA

States of matter are conventionally classified according to broken symmetries. Topologically ordered phases fall outside of this paradigm: with no local order parameter, they nevertheless have many peculiar properties setting them apart from disordered phases. In 2D, such phases may support anyons - quasiparticles that are neither bosons nor fermions. Moreover, anyons with non-Abelian statistics can occur, particularly in the fractional quantum Hall regime.

In this talk, I will focus on solid state interferometers designed to detect such exotic statistics. I will discuss Recent experiments in the the quantum Hall regime at 5/2 filling where the evidence for the existence of non-Abelian anyons may have in fact been observed for the first time. I will also mention potential applications of such interferometeric schemes for topological quantum computation.

Topical Talk MA 11.8 Tue 13:15 H20

Spin Hall effects in HgTe Quantum Well Structures — •Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Recently, it was pointed out that inverted HgTe structures are topologically non-trivial insulators, in which the quantum spin Hall insulator state should occur. In this novel quantum state of matter, a pair of spin polarized helical edge channels develops when the bulk of the material is insulating, leading to a quantized conductance. I will present transport data provide very direct evidence for the existence of this third quantum Hall effect: when the bulk of the material is insulating, we observe a quantized electrical conductance. Further experiments, using non-local transport measurements, show that the charge transport occurs through helical edge channels. The spin polarization of the edge channels can be demonstrated in split gate devices that are partially in the insulting and partly in the metallic regime, making use of the occurrence of the non-quantized metallic spin Hall effect to convert the magnetic spin signal into an electrical one.