MA 17: Skyrmions (jointly with MA, O) (joint session TT/MA)

Time: Monday 16:15–18:15 Location: HSZ 304

MA 17.1 Mon 16:15 HSZ 304

Quantum skyrmions in a triangular frustrated ferromagnet — •Vivek Lohani[1], Ciarán Hickey[1], Jan Masell[1,2], and Achim Rosch[1,3] — [1]Institute for Theoretical Physics, University of Cologne, Germany — [2]RIKEN Center for Emergent Matter Science, Japan — [3]Department of Physics, Harvard University, USA

Classically, skyrmions are described as tiny whirls of magnetization possessing a topological winding number. Their dynamics is similar to that of a charge, proportional to the winding number, that is coupled to an effective magnetic field. However, in the limit of small skyrmion size, quantum effects become important. Frustration stabilized skyrmion models – which exhibit degeneracy between classical skyrmions and antiskyrmions, and an additional zero mode, the *helicity* – provide a natural playground to study these quantum effects.

This begs the question – what is a quantum skyrmion? We argue that, in the quantum sector, a skyrmion is defined through the stable bound states of the Hamiltonian. By performing a numerical study, via exact diagonalization, we first demonstrate the existence of quantum skyrmions and identify the associated quantum selection rules. Furthermore, we explore their dynamics through a low energy, phenomenological Hamiltonian spanned by the translational and the helicity modes, wherein the coupling between translations and helicity leads to a rich dynamics. Most interestingly, we incorporate quantum tunneling, and how it breaks the degeneracy in the classical model and allows effective skyrmion charge to flip, thereby leading to a non-trivial bandstructure that is quite sensitive to the spin quantum number.

MA 17.2 Mon 16:30 HSZ 304

Quantum skyrmion state — •Evgeny A. Stepanov[1], Mikhail I. Katsnelson[2], and Vladimir V. Mazurenko[3] — [1]Institute of Theoretical Physics, University of Hamburg, Germany — [2]Radboud University, Institute for Molecules and Materials, Nijmegen, Netherlands — [3]Theoretical Physics and Applied Mathematics Department, Ural Federal University, Ekaterinburg, Russia

Skyrmions in physics of magnetism appear as classical spin structures that are formed in the systems as the result of a competition between different magnetic interactions. Such nontrivial magnetic textures can be observed in materials with the use of a spin-polarized scanning tunneling and Lorenz microscopy, or in X-ray and neutron scattering experiments. Theoretically, a skyrmion state can be described by solving a classical spin lattice problem or a corresponding continuous micromagnetic model. Here, we find that the classical skyrmion can be considered as a particular projection of a more general quantum skyrmion state. To perform a complete characterization of this novel state, we introduce a quantum analog for a classical skyrmion number that can be calculated as a scalar triple product of spin operators. We show that this quantity allows for a clear distinction of the quantum skyrmion state, which is characterized by a nontrivial correlation of spins in all three space directions, from other more simple spin orderings. On a basis of an exact numerical solution for supercells with up to 25 spins we demonstrate that the quantum skyrmion state can be obtained for a much broader range of magnetic fields than the corresponding classical skyrmion solution of the problem.

MA 17.3 Mon 16:45 HSZ 304

Vortex-Phase in Non-Centrosymetric Antiferromagnets — •Benjamin Wolba[1], Sebastian Mühlbauer[2], and Markus Garst[1] — [1]Institut für Theoretische Festkörperphysik (TFP), Karlsruhe Institut für Technologie (KIT), 76131 Karlsruhe — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, 85748 Garching, Germany

In this work we consider two-dimensional, non-centrosymmetric antiferromagnets, for which the competition between exchange and Dyzaloshinskii-Moriya interaction leads to the formation of spatially modulated phases of the staggered order parameter. Within the framework of Ginzburg-Landau theory we show that by applying a magnetic field parallel to the c-axis, which thus induces easy-plane anisotropy, one can stabilize a square lattice of vortices close to Neel temperature. Upon decreasing temperature, this vortex phase undergoes spontaneous symmetry breaking into a rectangular phase, which was not anticipated before. We discuss the relevance of our results for the chiral antiferromagnet $Ba_2CuGe_2O_7$.

MA 17.4 Mon 17:00 HSZ 304

Weak Crystallization of Fluctuating Skyrmion Textures in MnSi — Jonas Kindervater[1], Ioannis Stasinopoulos[1], Andreas Bauer[1], •Franz Xaver Haslbeck[1], Felix Rucker[1], Alfonso Chacon[1], Sebastian Mühlbauer[1], Christian Franz[1], Markus Garst[2,3], Dirk Grundler[1,4], and Christian Pfleiderer[1] — [1]TU München, Garching, Germany — [2]TU Dresden, Dresden, Germany — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany — [4]Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland

We report an experimental study of the emergence of nontrivial topological winding and long-range order across the paramagnetic to skyrmion lattice (SkL) transition in the transition metal helimagnet MnSi. Combining measurements of the susceptibility with small-angle neutron scattering, neutron-resonance spin-echo spectroscopy, and all-electrical microwave spectroscopy, we find evidence of skyrmion textures in the paramagnetic state exceeding 10^3 Å with lifetimes above several 10^{-9} s. Our experimental findings establish that the paramagnetic to SkL transition in MnSi is well described by the Landau soft-mode mechanism of weak crystallization, originally proposed in the context of the liquid-to-crystal transition. As a key aspect of this theoretical model, the modulation vectors of periodic small-amplitude components of the magnetization form triangles that add to zero. In excellent agreement with our experimental findings, these triangles of the modulation vectors entail the presence of the nontrivial topological winding of skyrmions already in the paramagnetic state of MnSi when approaching the SkL transition.

MA 17.5 Mon 17:15 HSZ 304

Tuning of the critical temperature of a superconducting thin film in proximity of a chiral magnet — •Julius Grefe, Marvin Sach, Bastian Rubrecht, Jannis Willwater, Stefan Süllow, and Dirk Menzel — Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

Theory has suggested a possibility to control the critical temperature T_C of a superconductor via the proximity effect with a magnetic system exhibiting a non-collinear spin structure [1]. MnSi being an archetype of the B20 structure shows helimagnetic behavior below $T_N = 29.5$ K and $B_{C1} = 100$ mT. The related pseudobinary compound $Fe_{1-x}Co_xSi$ with a tunable Néel-temperature from 0 K to 55 K even expands the accessible temperature range.

Superconducting Nb thin films have been deposited by molecular beam epitaxy on substrates prepared from Triarc-Czochralski grown single crystals. We investigate a shift of T_C in the Nb film upon reorientation of the spin helices in the substrate.

This proximity effect is suggested for usage in superconducting spin valves consisting only of a single magnetic layer and a thin superconducting film promising more simple and compact devices.

[1] N. G. Pugach et al., Appl. Phys. Lett. **111**, 162601 (2017).

MA 17.6 Mon 17:30 HSZ 304

Distribution of energy barriers associated with magnetic skyrmion decay in $Fe_{0.5}Co_{0.5}Si$ — •Alfonso Chacon[1], Marco Halder[1], Jonas Kindervater[1], Andreas Bauer[1], Sebastian Mühlbauer[2], Achim Rosch[3], and Christian Pfleiderer[1] — [1]Physik Department, Technische Universität München, Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [3]Institut für Theoretische Physik, Universität zu Köln, Köln, Germany

We report comprehensive measurements of the magnetization and small-angle neutron scattering of the time-dependence of the decay of metastable skyrmion lattice order in $Fe_{0.5}Co_{0.5}Si$ after field cooling. Comparison of the SANS intensity pattern with the magnetization allows to identify contributions in the magnetization that are due to skyrmions only. Combining first-order reversal behaviour with the time dependence under carefully selected conditions, justifies the application of time versus temperature superposition and infer the distribution of energy barriers associated with the decay of magnetic skyrmions. The resulting distribution of energy barriers allows to discriminate between contributions due to the non-trivial topology and defect- and disorder-related pinning.

MA 17.7 Mon 17:45 HSZ 304

Helix reorientation at the transition between helical and conical phases of the chiral magnet Cu_2OSeO_3 — •Laura Köhler[1,4], Peter Milde[1], Erik Neuber[1], Philipp Ritzinger[1], Andreas Bauer[2], Christian Pfleiderer[2], Helmuth Berger[3], and Markus Garst[4] — [1]Technische Universität Dresden, 01062 Dresden, Germany — [2]Technische Universität München, 85748 Garching, Germany — [3]École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [4]Karlsruher Institut für Technologie, 76131 Karlsruhe, Germany

In chiral magnets, the Dzyaloshinskii-Moriya interaction stabilizes a magnetic helix which is a one-dimensional periodic magnetic texture. The exact orientation of this helical texture is determined by the competition between crystalline anisotropies and the applied magnetic field. We study the reorientation process of the helix as a function of field in the insulating chiral magnet Cu_2OSeO_3 using magnetic force microscopy. As a function of field, we determine the wavelength projected onto the sample surface as well as the electric polarization induced by the magnetoelectric coupling. Our experimental observations are well described by an effective Landau theory for the helix orientation as previously applied to MnSi [1].

[1] A. Bauer, A. Chacon, M. Wagner, M. Halder, R. Georgii, A. Rosch, C. Pfleiderer, M. Garst, PR B 95, 024429 (2017).

MA 17.8 Mon 18:00 HSZ 304

Skyrmion Lattice Magnet Gd_2PdSi_3 Studied by High-Resolution Dilatometry — •Sven Spachmann[1], Matthias Frontzek[2], Chongde Cao[3], Wolfgang Löser[4], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Oak Ridge National Laboratory, Oak Ridge, USA — [3]Northwestern Polytechnical University, Xi'an, China — [4]Leibniz Institute for Solid State and Materials Research (IFW), Dresden, Germany

A Bloch-type skyrmion state emerging in low magnetic fields has recently been reported for the frustrated centrosymmetric triangular-lattice magnet Gd_2PdSi_3 [1]. Here, we present high-resolution thermal expansion and magnetostriction measurements on single crystals of this material in order to study the phase diagram and in particular the transitions to the skyrmion phase. In zero magnetic field, a single peak in the thermal expansion coefficient indicates the onset of long-range antiferromagnetic order at $T_N = 19.7$ K, which exhibits uniaxial pressure dependencies of opposite sign along the a- and c-axis, respectively. Up to $B = 4$ T, four known phases are confirmed, including the skyrmion phase for $B||c$ which appears in a discontinuous transition. In addition, a previously non-reported phase is observed. The anomalies in thermal expansion and magnetostriction at the different phase boundaries as well as the respective uniaxial pressure dependencies imply significant changes in the spin-lattice coupling for different fields.

[1] T. Kurumaji et al., Science 10.1126/science.aau0968 (2019)