Experimental report

06/10/2018

Proposal: **5-42-477**

Council: 4/2018

Title: Dynamic studies of skyrmion stability

Research area: Physics

This proposal is a new proposal

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Samples: MnSi

Instrument	Requested days	Allocated days	From	To
D11	4	0		
D22	4	0		
D33	4	3	01/06/2018	04/06/2018

Abstract:

Magnetic skyrmions show promise as a future data storage technique due to their topological protection and the existence of skyrmion lattices (SkL) at a wide range of temperatures and magnetic fields in different materials. Metastable skyrmion lattices have been produced and observed using SANS outside of the A phase by rapidly cooling through the phase boundary. The metastable SkL could be progressively driven to the equilibrium (non-skyrmion) phase by changing the applied field, and even undergo a structural transition to a square symmetry in the process.
To date most SANS studies of the SkL have focused on static properties. We propose to explore the dynamics associated with the SkL stability in the vicinity of the equilibrium phase boundaries in MnSi. We will use a bespoke AC coil to raise or lower the magnetic field outside the A-phase and observe the SkL as a function of time. Given that thermal quenching is able to produce metastable SkL phase, we expect that time scales associated with the "unwinding" of the skyrmions will be relatively slow and compatible with the AC field technique.

Dynamic Studies of Skyrmion Stability

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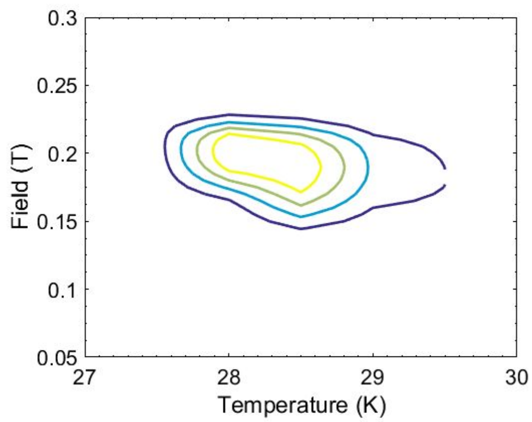
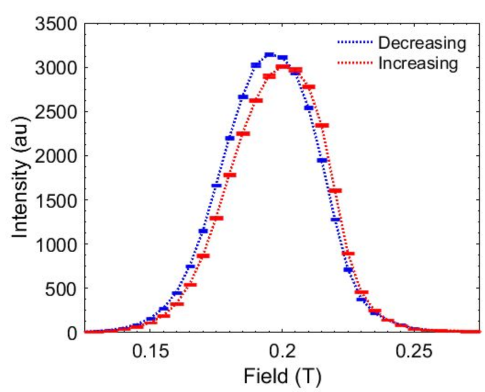
6/1/18 - 6/4/18

Observations:

We began by scanning sht and trs in order to locate the sample, and then aligned our SkL by rocking in both san and phi. Rocking curve width ~ 2.2 degrees. We then began mapping our phase space by taking a temperature sweep from 26 K to 32 K at 0.2 T. The peak was found around 28 K, and so we started taking field cuts at a range of temperatures around 28 K.

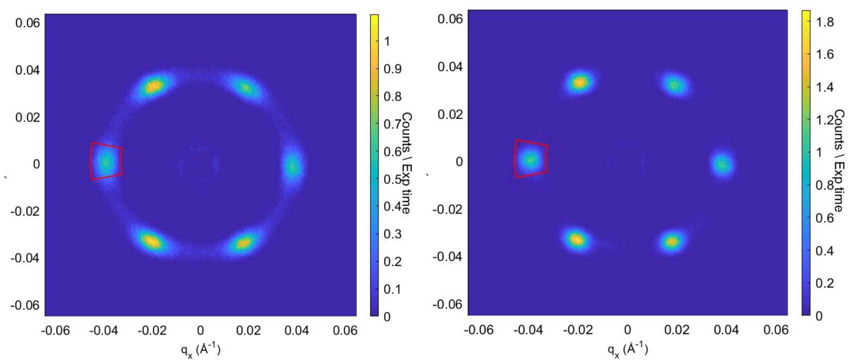


For comparison, we tried sweeps of the field in both direction, and found that the phase lags a bit in the direction that the field is changing (increasing (red) or decreasing (blue)).



We also tried taking data points that were further apart (thus increasing the speed we were moving through phase space), but found no change in the phase.

In the process of wiring up the AC power supply, we accidentally sent a large noise signal through our coil (we measured this later and found it to be ~250 mA at 3.5 kHz). This pulse effectively annealed our skyrmion lattice and decreased our azimuthal width from 16 degrees to 10 degrees (RC width was unaffected at 1.7 degrees). We increased our collimation to 10.3 m to increase our resolution.



We tried reproducing this effect with a wide range of frequencies and amplitudes to no avail. We were eventually successful when we reproduced the noise signal with 300 mA at 500 Hz. We took a field sweep RC at 28 K to see if periodically zapping changes our phase diagram. No major change in the phase shape was observed. Towards the end of this series of measurements, one of the tubes in the detector got broken and shut down the whole detector. To continue our measurements, we brought the panel detectors in so that our peaks would lie on them.

After getting our peak centered, we continued exploring the effect of the AC field on the SkL. We tried one quick “ratchet” measurement (with a sawtooth AC signal), but only saw the intensity decrease. Next, we tried wiggling the field half way along the SkL conical transition. We saw the intensity decline, but then gradually rise again after the oscillation was stopped. This caused us to realize that the AC field was causing heating in our sample. We verified this by zapping the sample and then watching the RO peak as function of time. We also took a temperature sweep through field cooling and verified that this produced clean peaks.

To mitigate the heating effect, we increased the exchange gas to increase our cooling power. Next, we went to the top of the temperature sweep and tested various oscillations to try and measure how much we could apply without measurably changing the SkL. Based on our observations, we suspect that there was both an inductive and conductive component to the heating, the second being from the resistive heating of the coil itself.

We set out and found an empirical formula that seemed to keep us below the cooling power of the cryostat, and then used these constraints to continue trying boundary wiggle measurements. After not seeing much with the sine wave, we switched to the square wave. This seemed to have an impact on the RC peak, so we set up a scan that measured the effect of a range of amplitudes all at 5 Hz.

We observed an increase in scattered intensity of approximately 10% as the amplitude of the AC field was increased from 0 to 35 Gauss (square wave, 5 Hz).