Scaling behaviour of the Skyrmion phases of Cu_2OSeO_3 from neutron scattering

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Motivation

Skyrmions are topologically protected particle-like magnetic textures consisting of spin rotations with a diameter of ~50 nm, typically forming 2D hexagonal structures perpendicular to applied magnetic fields (see fig. 1). This ordering can be induced in chiral magnets due to the interplay of Dzyaloshinskii-Moriya and ferromagnetic exchange interactions.

The dynamics of skyrmions resembles superconducting flux vortices and can be controlled by external electric fields. This opens avenues for applications in low-energy electronics. [1-5].

Figure 1: Illustration of the Magnetic texture of skyrmions [6].

Previous works

Small Angle Neutron Scattering is ideal to study magnetic skyrmions since their lattice distance is within 20-100 nm. This is confirmed on various skyrmion systems [1,7] (see figs. 2, 5-7).

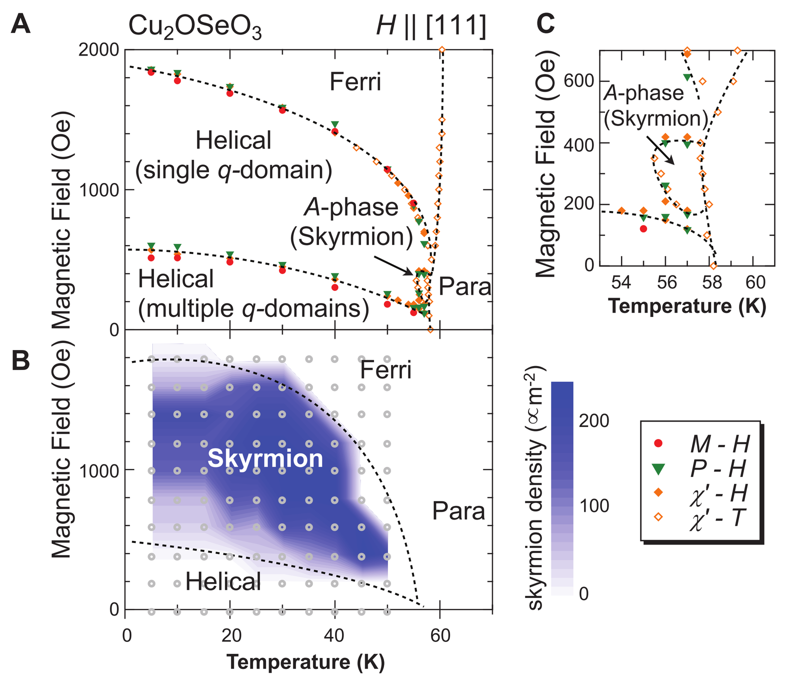

Figure 2: Phase diagram of a) bulk and b) thin films of Cu_2OSeO_3 [2].

Small Angle Neutron Scattering (SANS) at QUOKKA, ANSTO

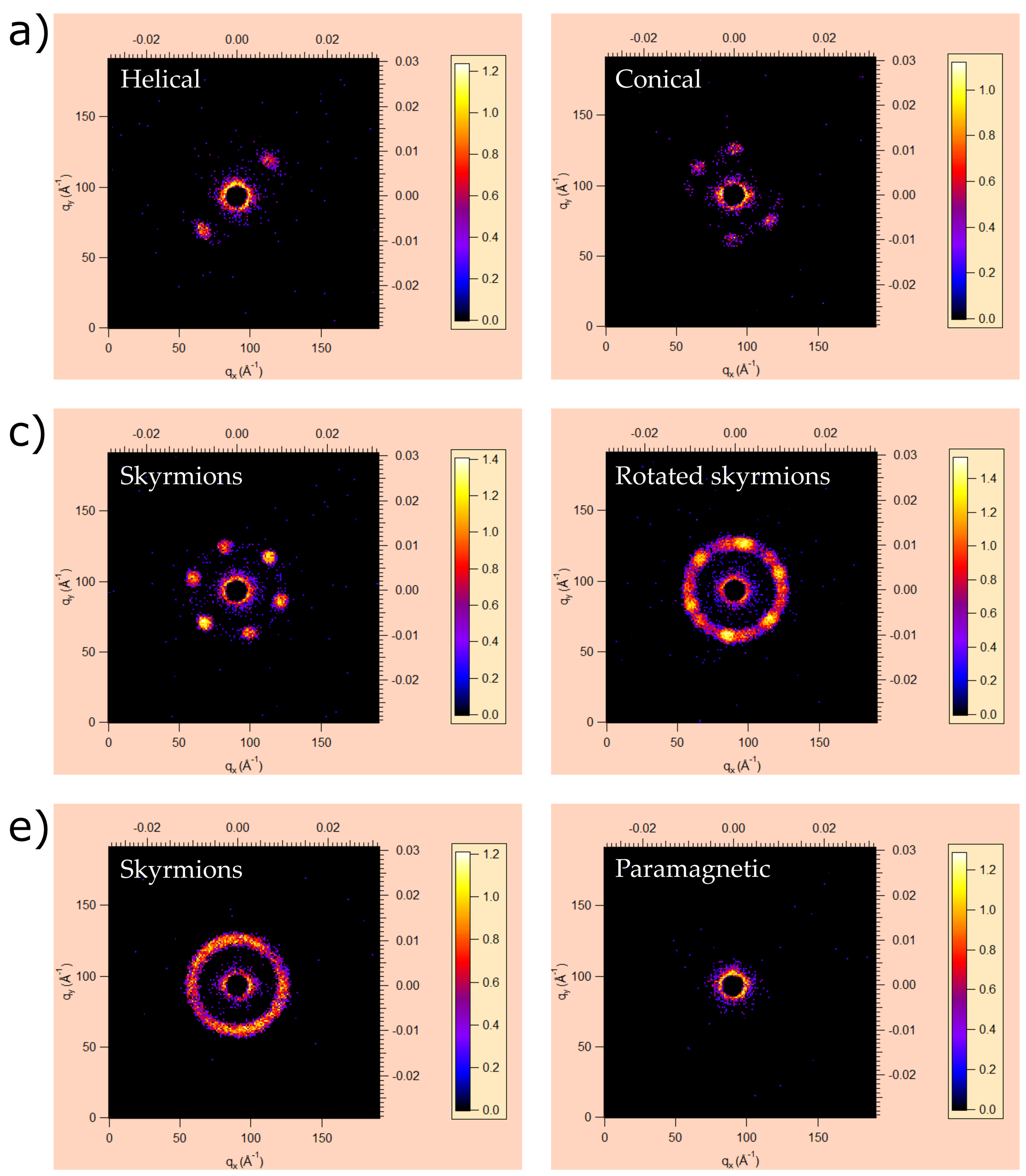

Figure 5 (left): Selected SANS patterns of pure and Tellurium - doped Cu_2OSeO_3 samples along different magnetic phases, (see panel labels) including scattering rings associated with skyrmions [9].

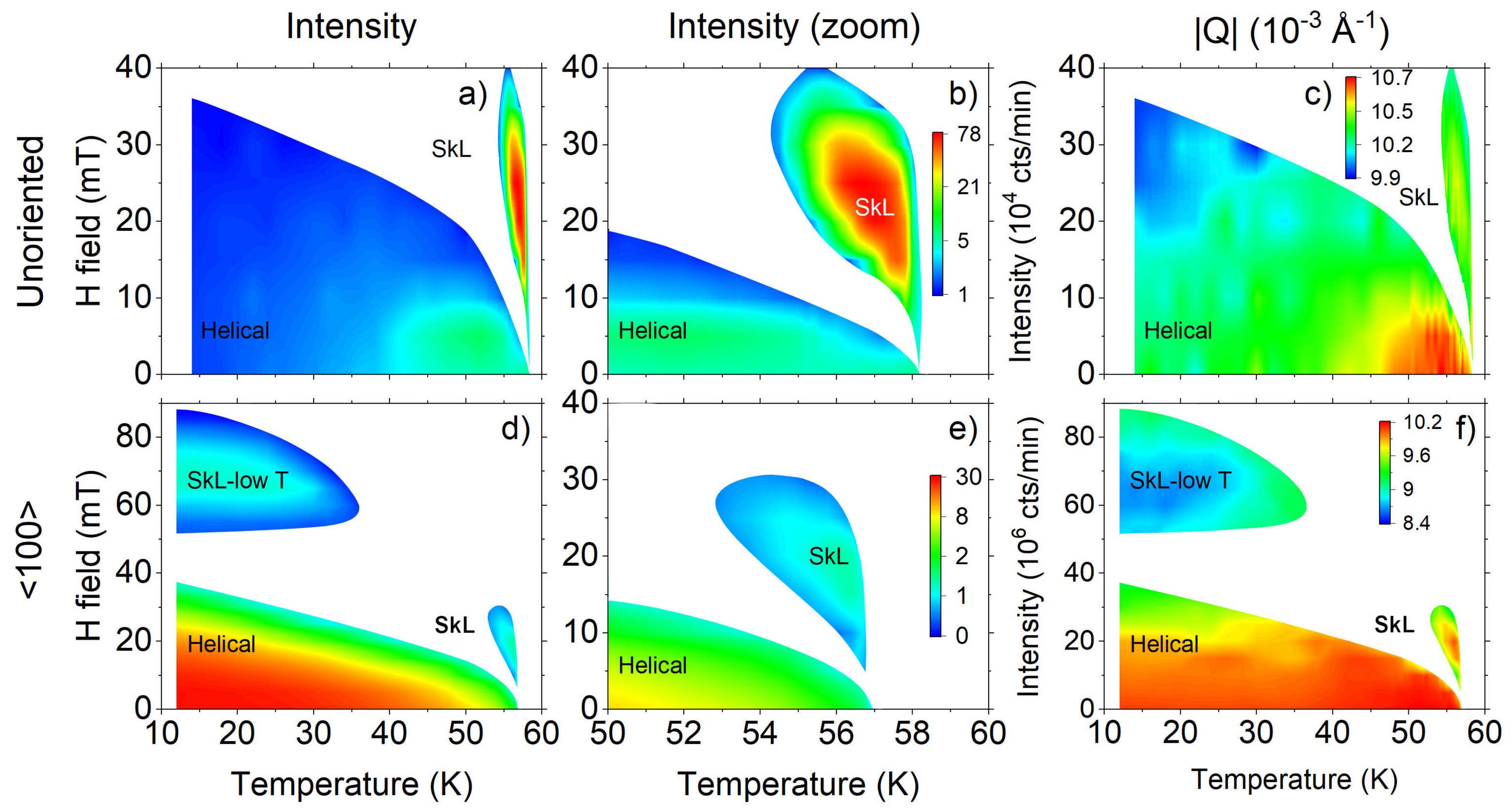

Figure 6: Neutron phase diagrams from neutron scattering intensity across a, d) the full temperature range reveal low- and high-temperature skyrmion lattices, the later is zoomed in panels b, e). Panels c, f) show variations of the scattering vector.

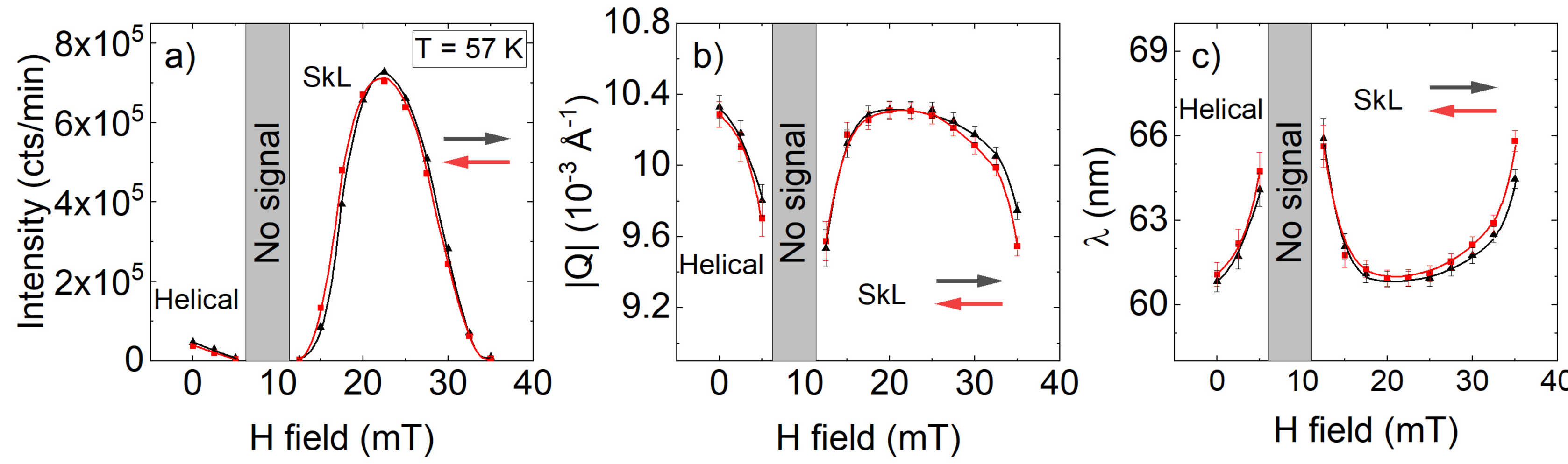

Figure 7: Zero Field Cooling (ZFC) magnetic field sweeps of unoriented Cu_2SeO_3 reveal changes in a) the scattering intensity, b) the magnitude of the scattering vector, |Q|, and c) the magnetic lattice parameter, which is inversely proportional to |Q| (paper in preparation).

Our samples

Pure and doped single crystals of Cu_2OSeO_3 can be grown using chemical vapour transport. We used samples provi-ded by colleagues at the School of Chemical Sciences of the U. of Auckland (see fig. 3)

Figure 3: as grown image of a Cu_2OSeO_3 crystal

Lorentz TEM

Skyrmions were confirmed by our colleagues at Brookhaven National Labs, NY, USA, via Lorentz TEM (see fig. 4) [8].

Magnetic field dependence at 26 K

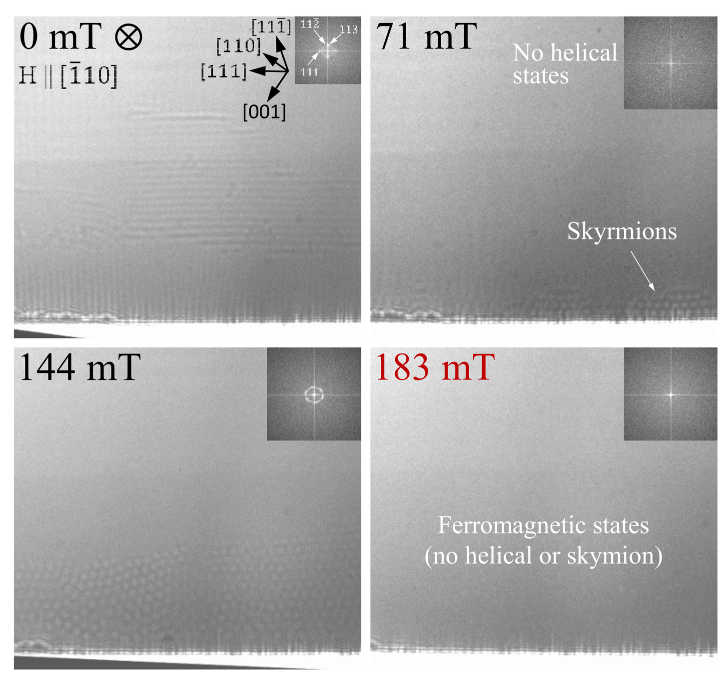

Figure 4: Lorentz TEM images taken from our Cu_2OSeO_3 samples in different magnetic phases [8].

Conclusion

Small Neutron Scattering on Cu_2OSeO_3 single crystals reveals the temperature and field dependence of the skyrmions and helical observed patterns (see figs. 5, 6). The magnitude of the scattering vector can be used as a phase transition parameter to gain in depth information of the stabilisation of these magnetic states. We are preparing a theory to model our observations.

References

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