Presenter: Paul Neves

Mentors: Nicholas Butch & Juscelino Leão

NIST Center for Neutron Research

Summer Undergraduate Research Fellowship

NIST Center for Neutron Research

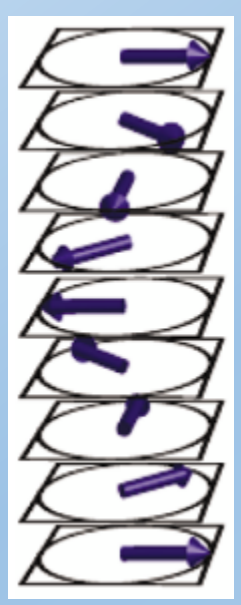
CHRNS
CENTER FOR HIGH RESOLUTION NEUTRON SCATTERING
NIST

Outline

- Magnetic Behavior of Cu_2OSeO_3 (Background)
- Sample Synthesis/Characterization
- SANS Measurements
- Conclusions/Future Work

Magnetic Structures

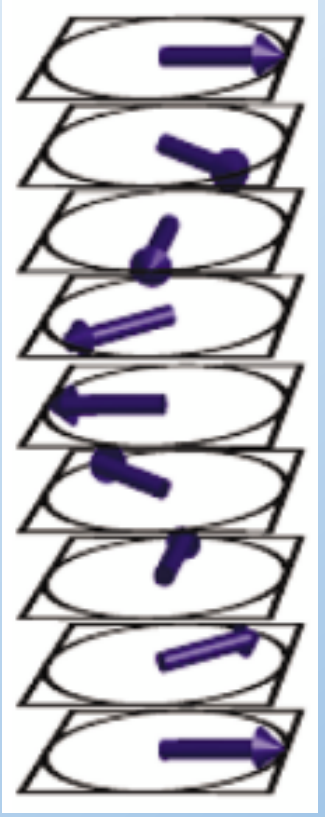
Ferromagnetic Structure

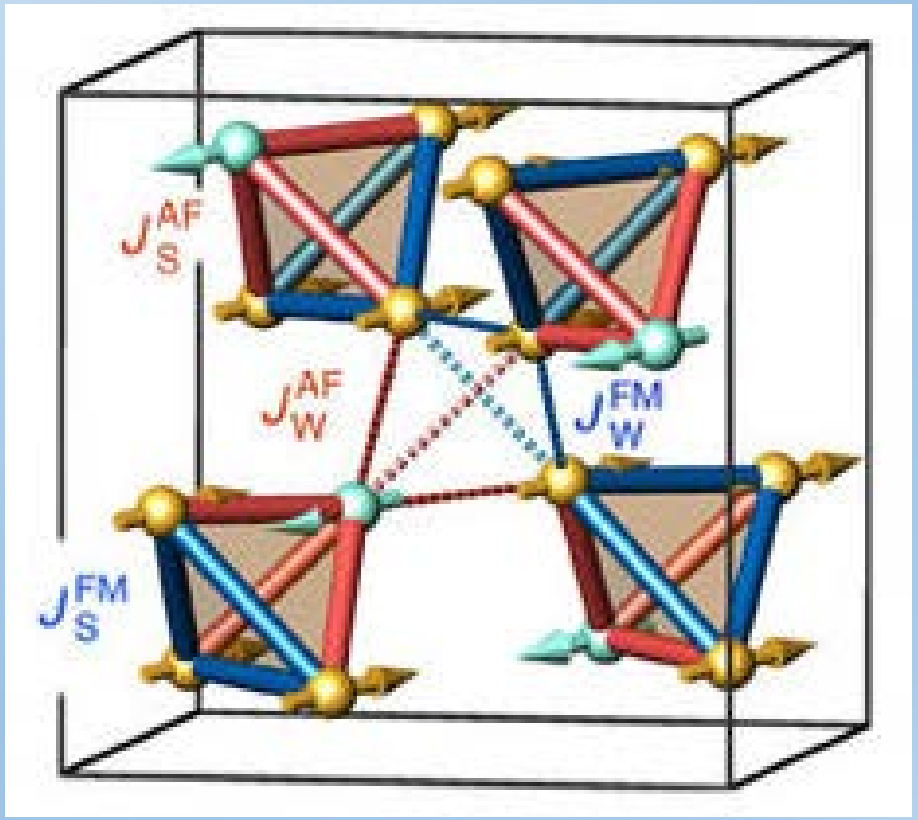


Helical Structure

Higgins, Jeremy M. *et al.* Signature of Helimagnetic Ordering in Single-Crystal MnSi Nanowires. *Nano Letters* **10,** 1605-1610 (2010)

An Interesting Material: Cu_2OSeO_3





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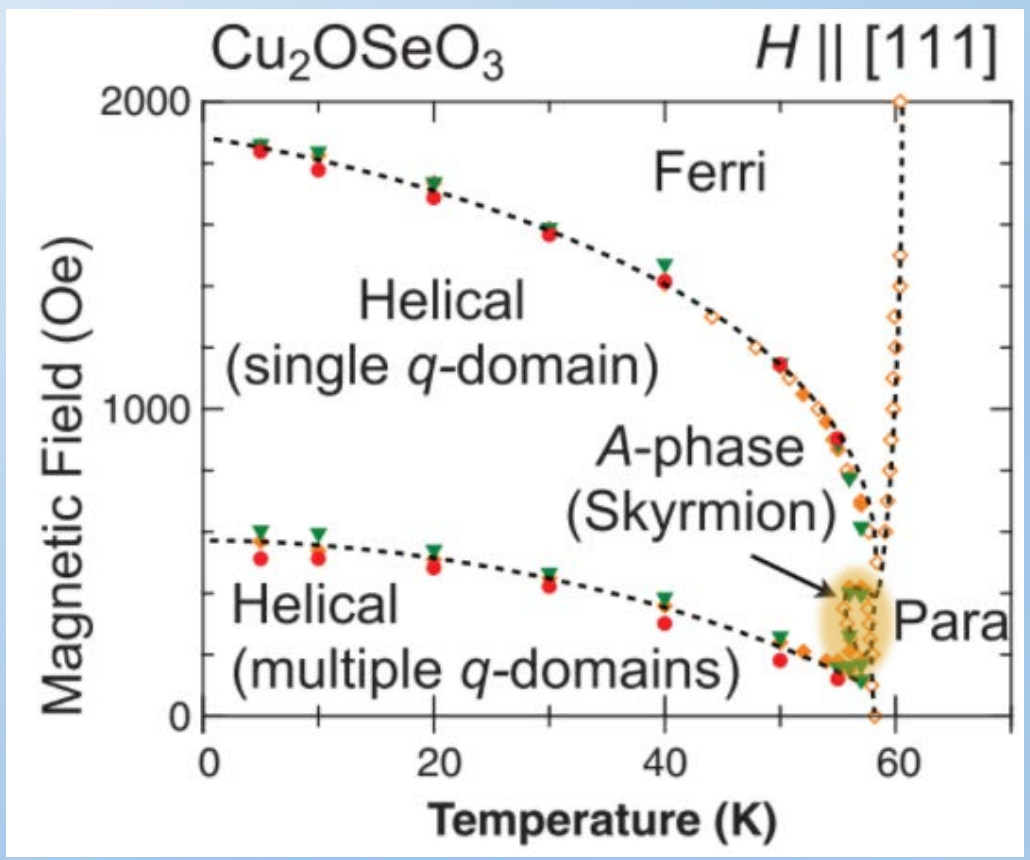
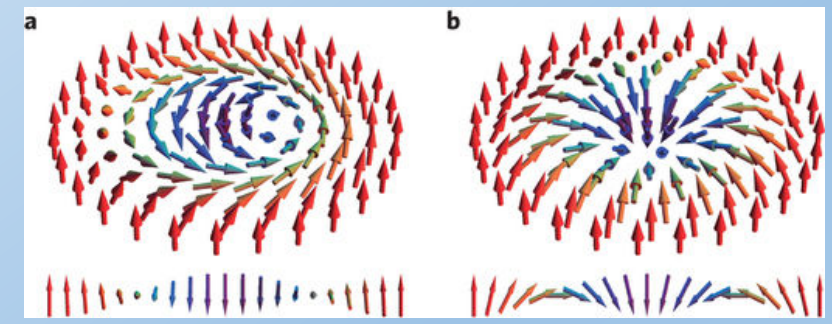


(10 Oe = 1 mT)

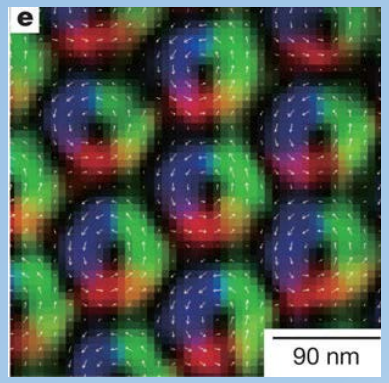
Seki, S. *et al.* Observation of Skyrmions in a Multiferroic Material. *Science* **336,** 198-201 (2012)

Magnetic Skyrmions

- Topological structure
  - Potential data storage applications
  - Robust (stable)
- Result from competing interactions
  - Limited field and temperature range



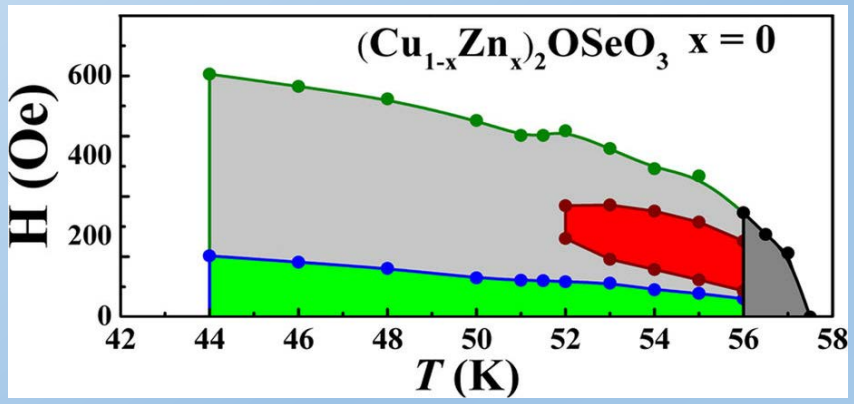
Kézsmárki, I. *et al.* Neel-type Skyrmion Lattice with Confined Orientation in the Polar Magnetic Semiconductor GaV_4S_8. *Nature Materials* **14,** 1116-1122 (2015)

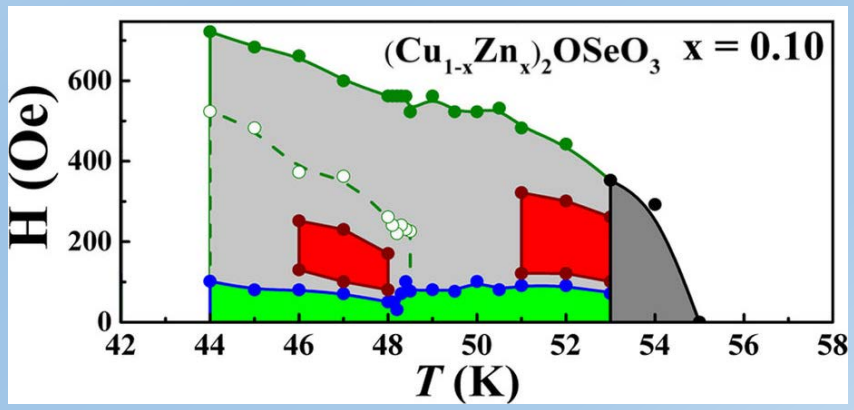


Yu, X. Z. *et al.* Real-space observation of a two-dimensional skyrmion crystal. *Nature* **465,** 901-904 (2010)

What Are *We* Studying?

- Chemical substitution affects the skyrmion phase
- Substitute Zn for Cu
  - Magnetization only
  - Structure not directly confirmed





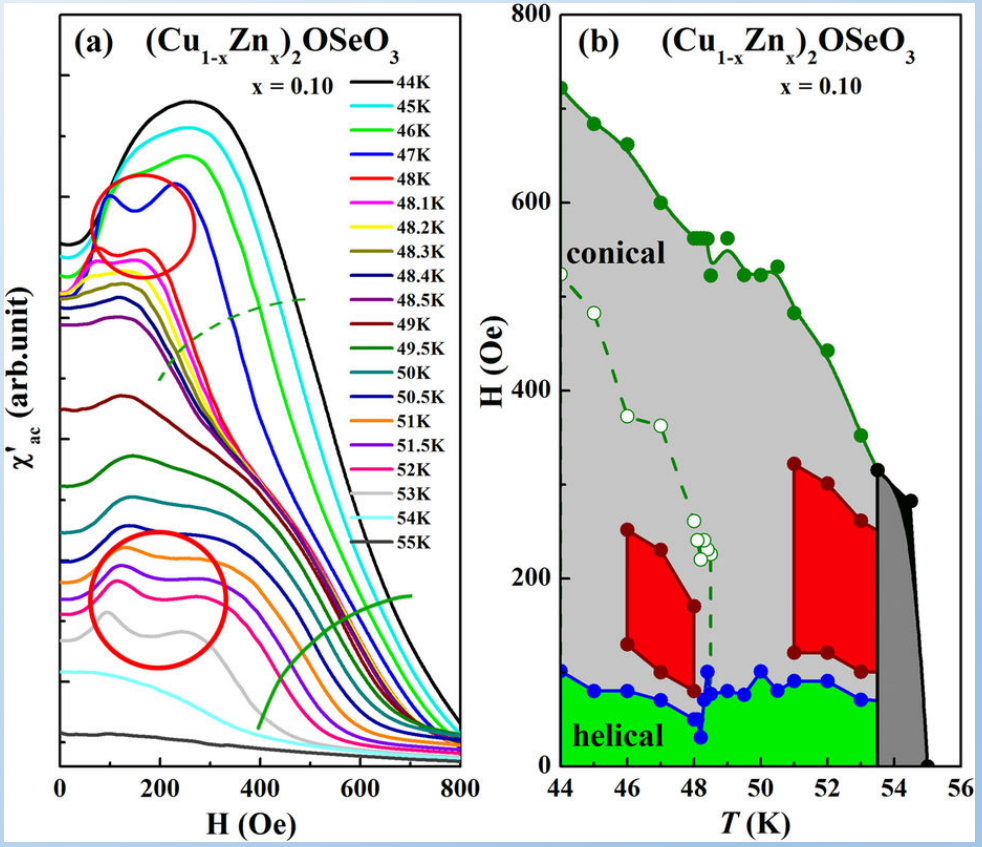
(10 Oe = 1 mT)

Wu, H. C. *et al.* Unexpected Observation of Splitting of Skyrmion Phase in Zn Doped Cu_2OSeO_3. *Science Reports* **5,** (2015)

Growing Powders

- Mix/grind CuO and SeO_2
- Seal in evacuated quartz tube
- Ba
- Pr
- La

DC Susceptibility: Zn Doping



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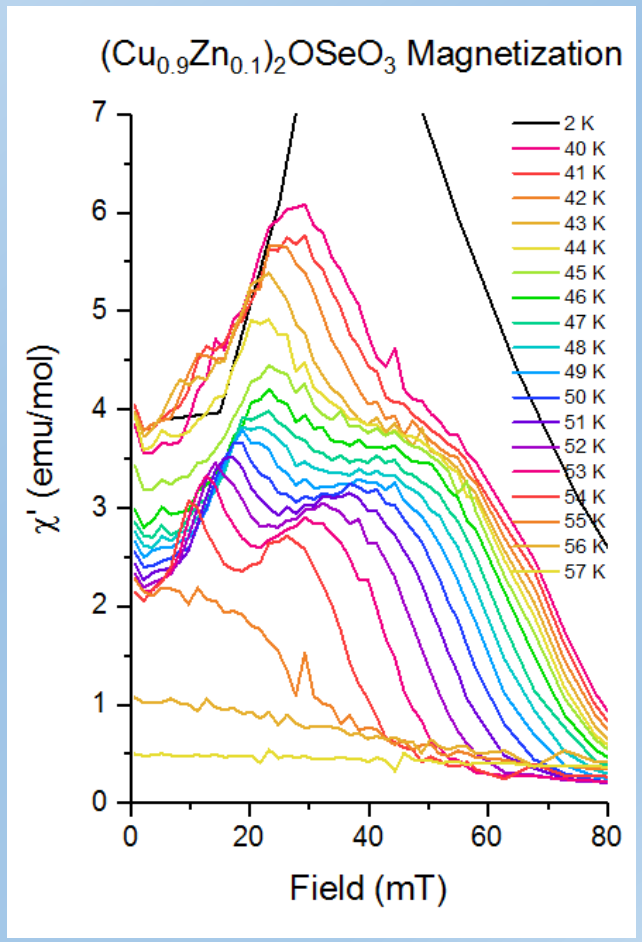
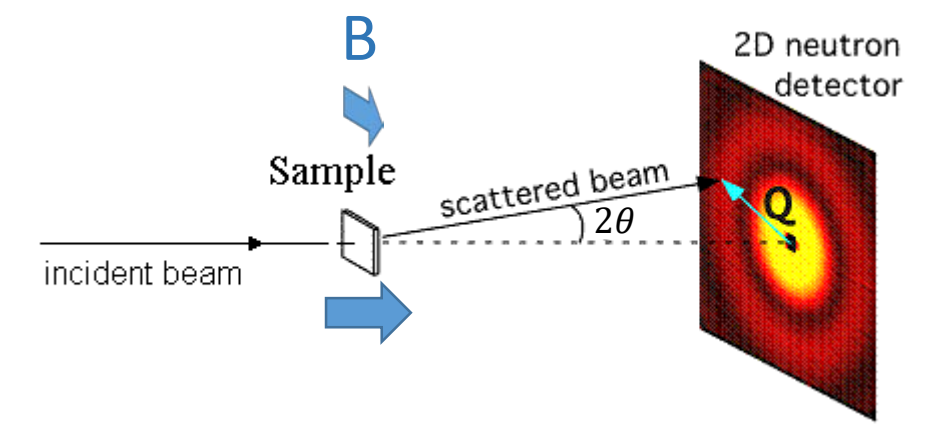


(10 Oe = 1 mT)

Small Angle Neutron Scattering

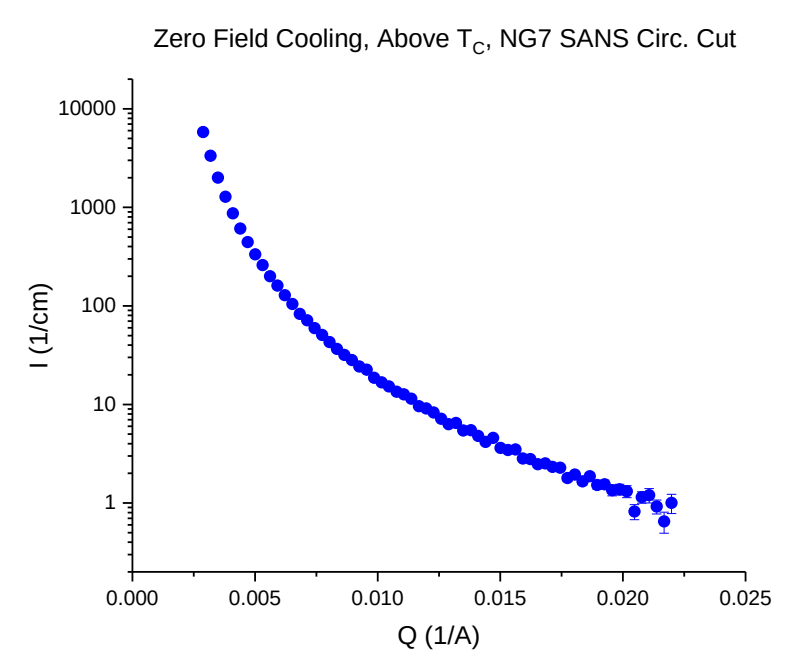
- Powders
  - Cu_2OSeO_3
  - $(Cu_{0.9}Zn_{0.1})_2OSeO_3$
- ~0-70 mT Field
  - On axis
  - Transverse axis
- 12-53 K

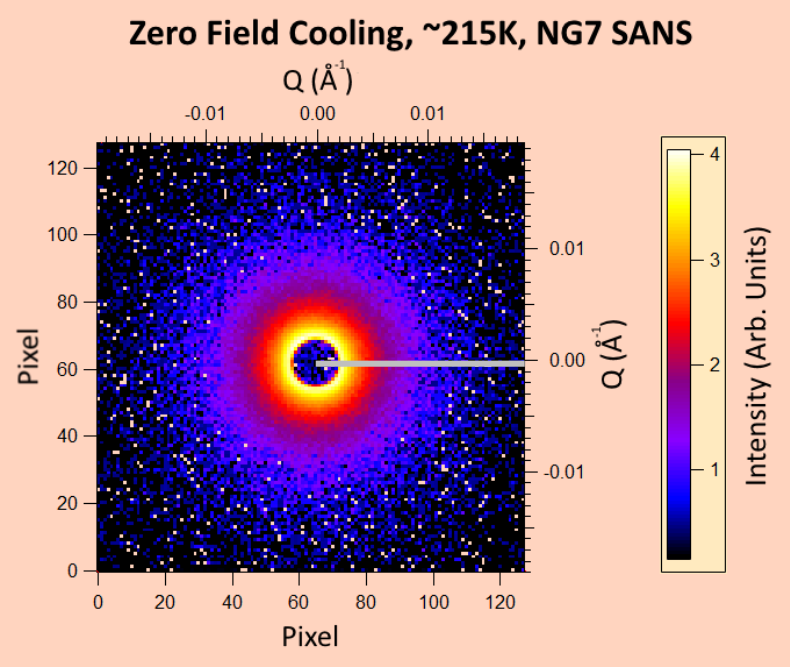


https://www.ncnr.nist.gov/programs/sans/index.html

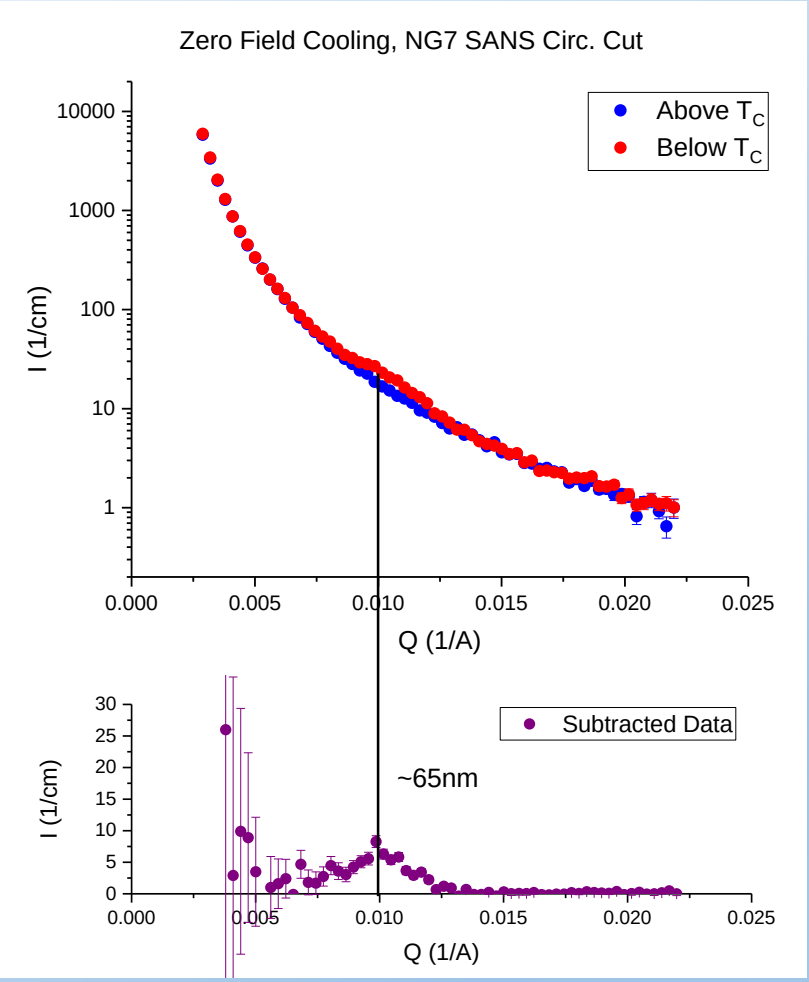
$$Q = \frac{2\pi}{d} = \frac{4\pi}{n\lambda}\sin\theta$$

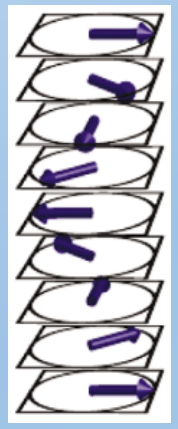
Structural Scattering





SANS: Zn Doped, H On Axis





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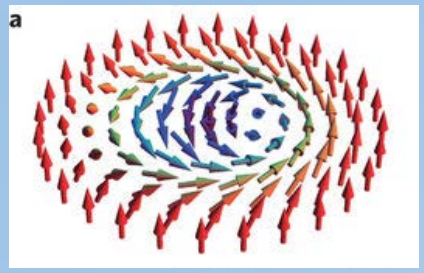

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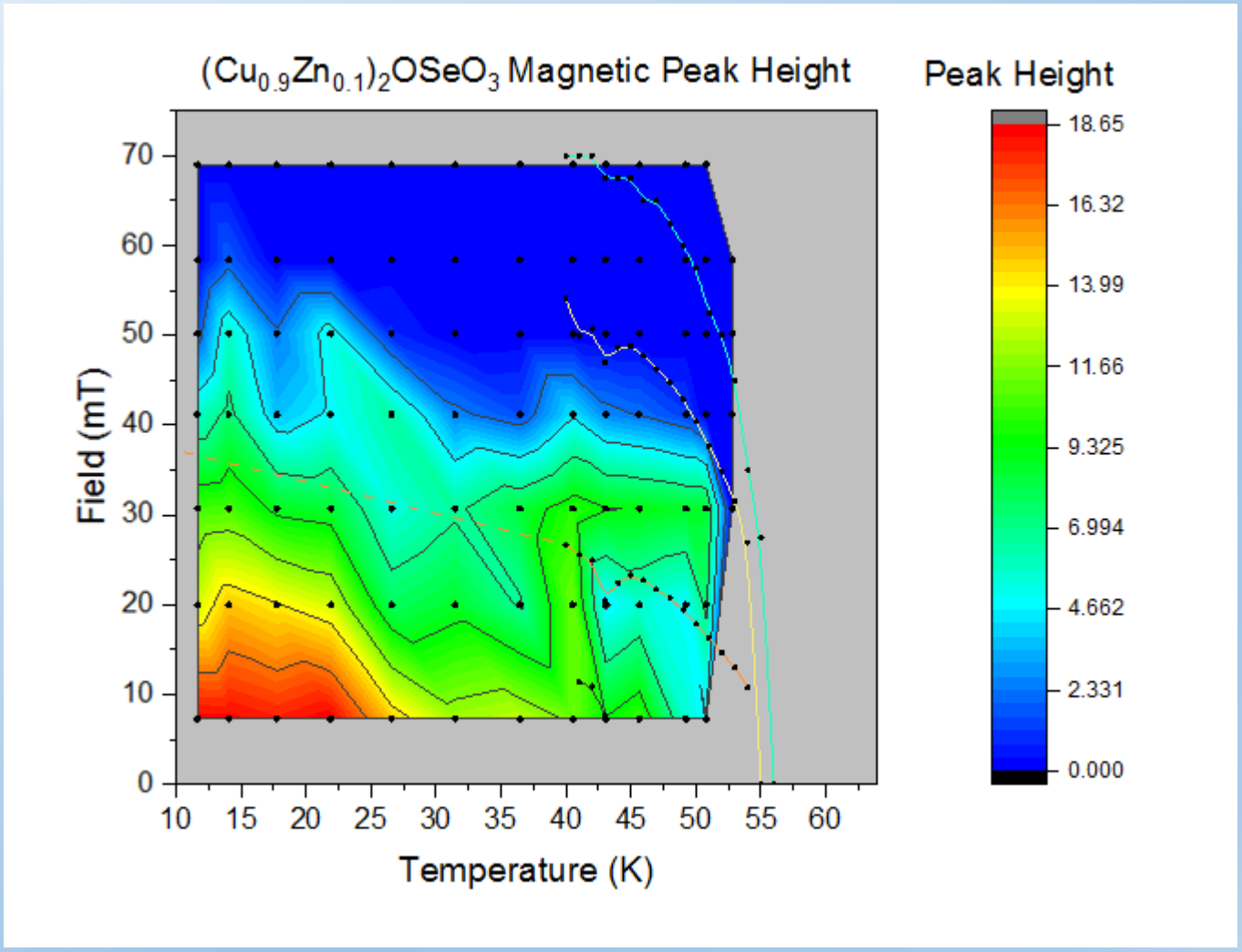
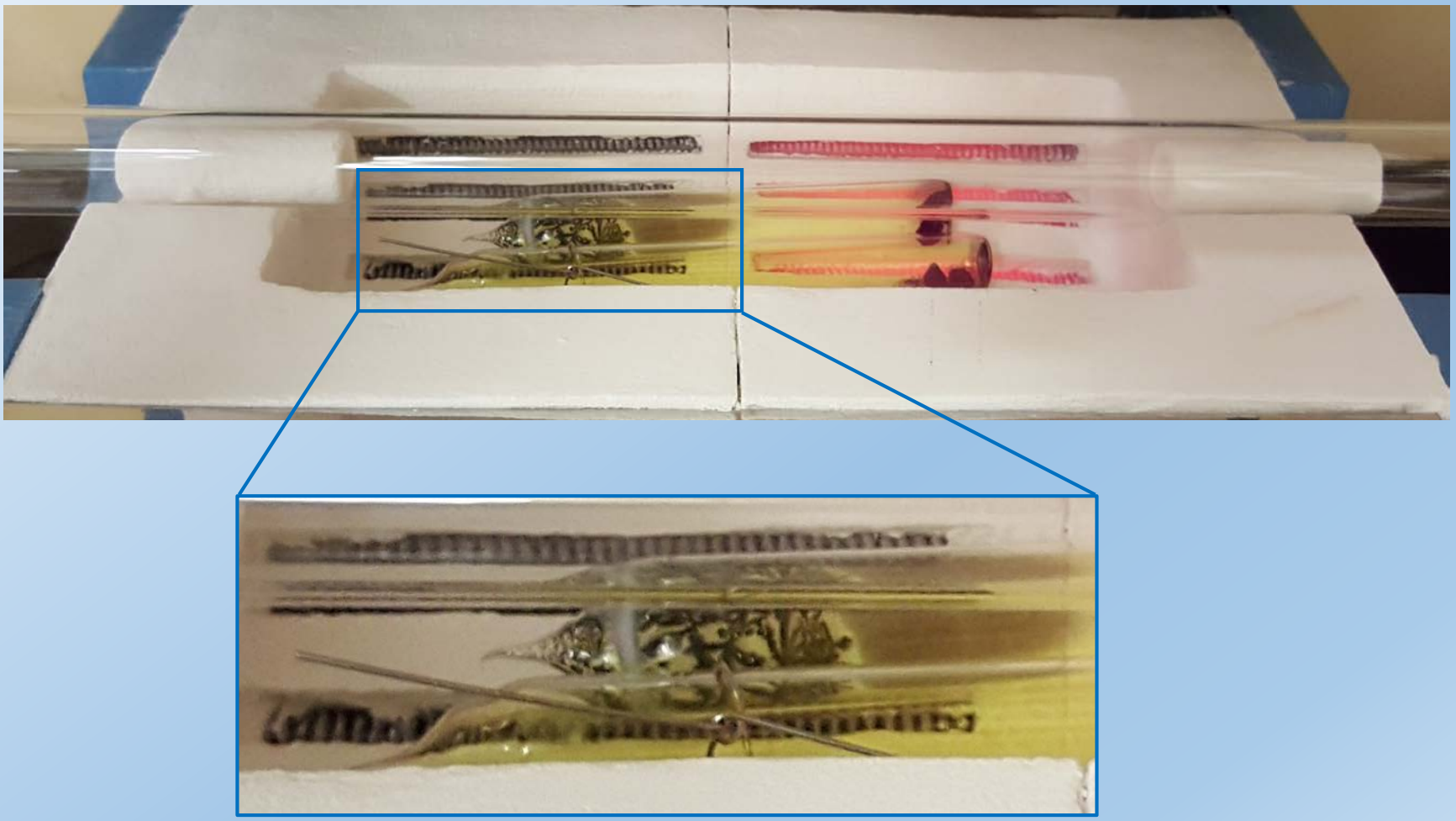


Future: Single Crystals?!?!



Summary

- Interesting results
  - Expanded phase diagram
  - Possible co-existence of skyrmion and helical phases near published phase boundaries
  - Published phase diagram is too discrete
- Ongoing work

Acknowledgements

- Nick Butch, Juscelino Leão
- NIST and the SURF program
- The NCNR and CHRNS
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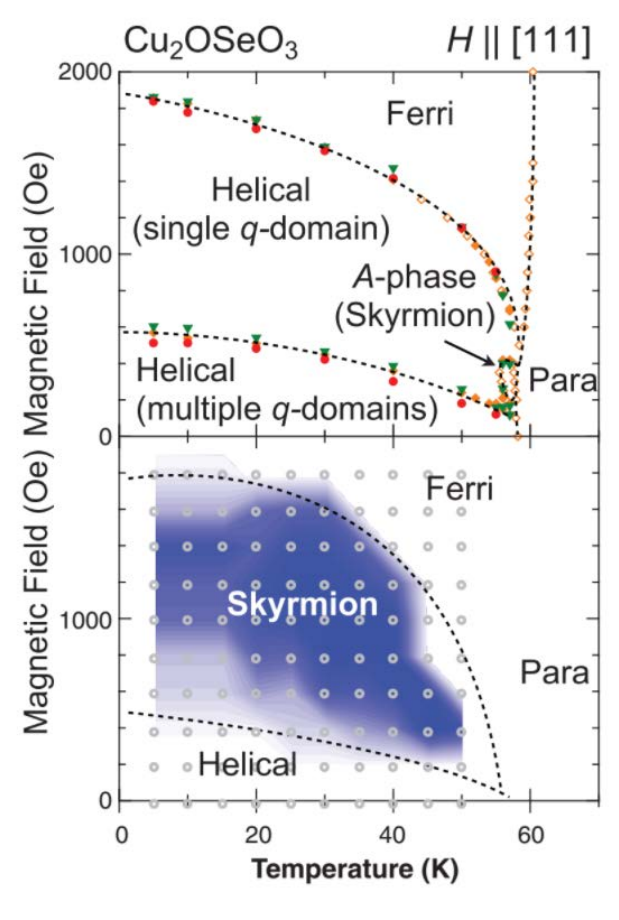
- Dan Neumann
- Dustin Gilbert, Jeffrey Krzywon, Tanya Dax, Kefeng Wang, I-Lin Liu, Shanta Saha, Mary Ann FitzGerald
- Doug Johnson, Patrick Connelly, Scott Slifer, Colin Wrenn, Andrew Malone

An Interesting Material: Cu_2OSeO_3



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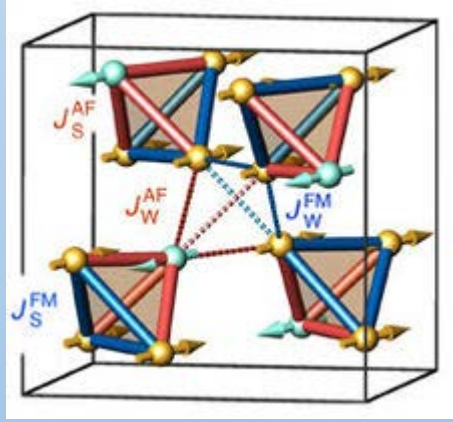

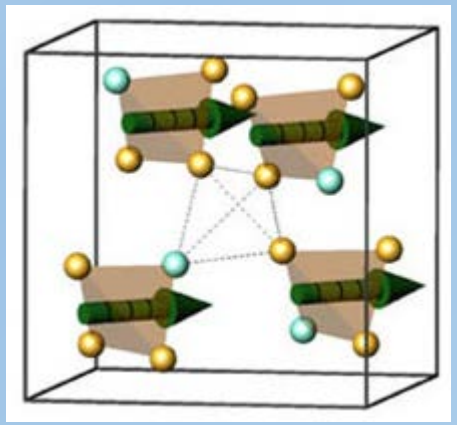

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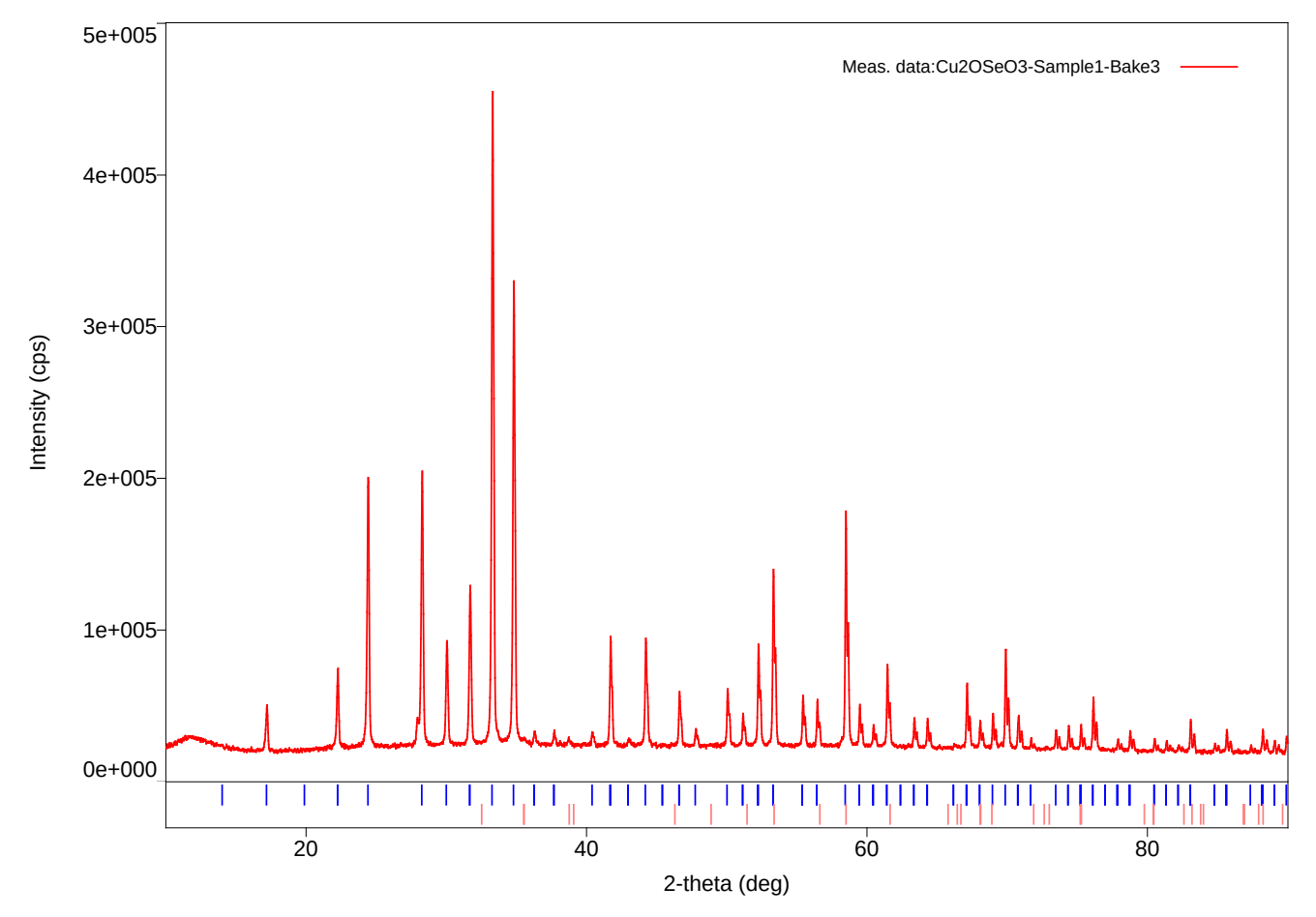
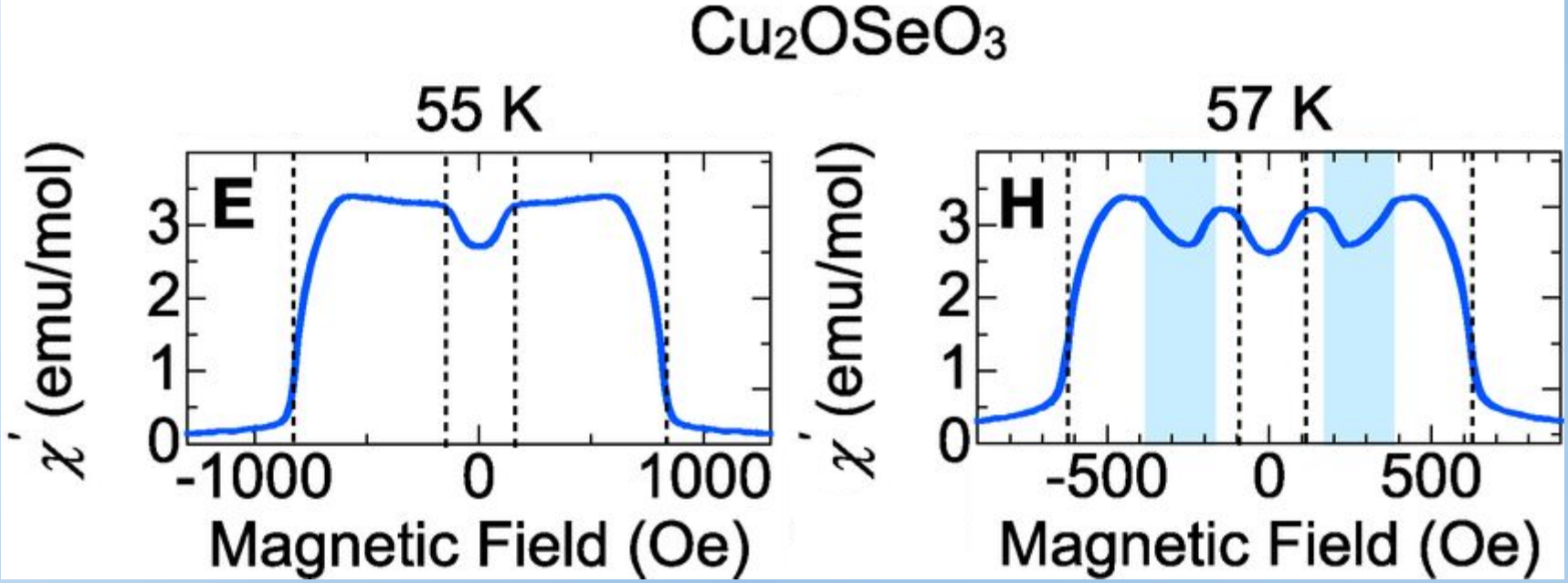
X-Ray Powder Diffraction



Magnetization: Parent



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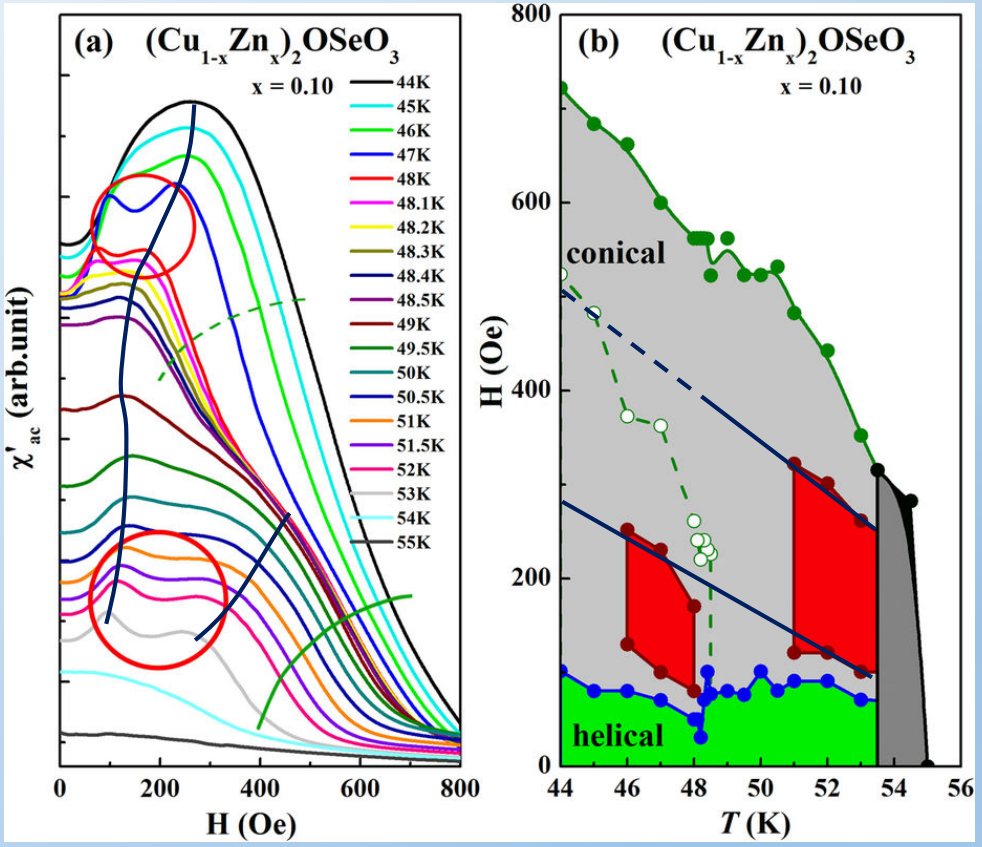
Magnetization: Zn Doped



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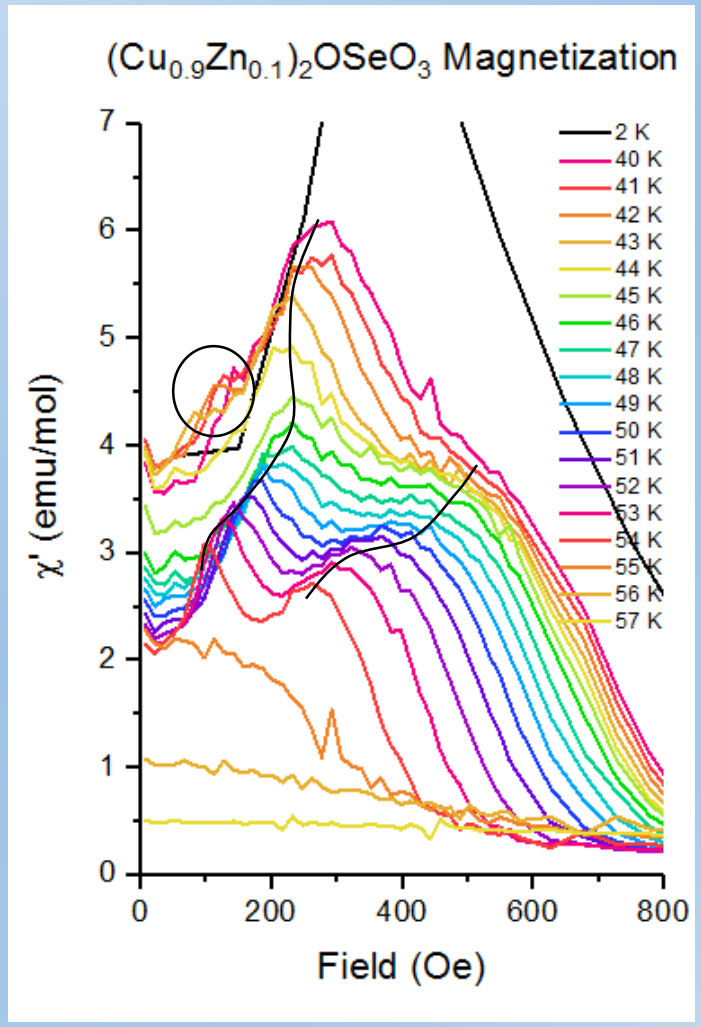
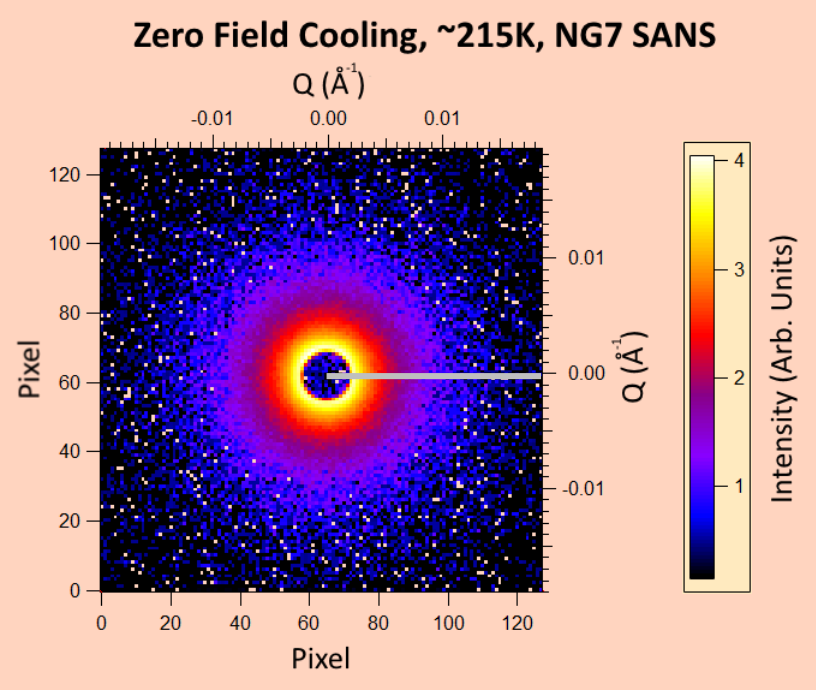
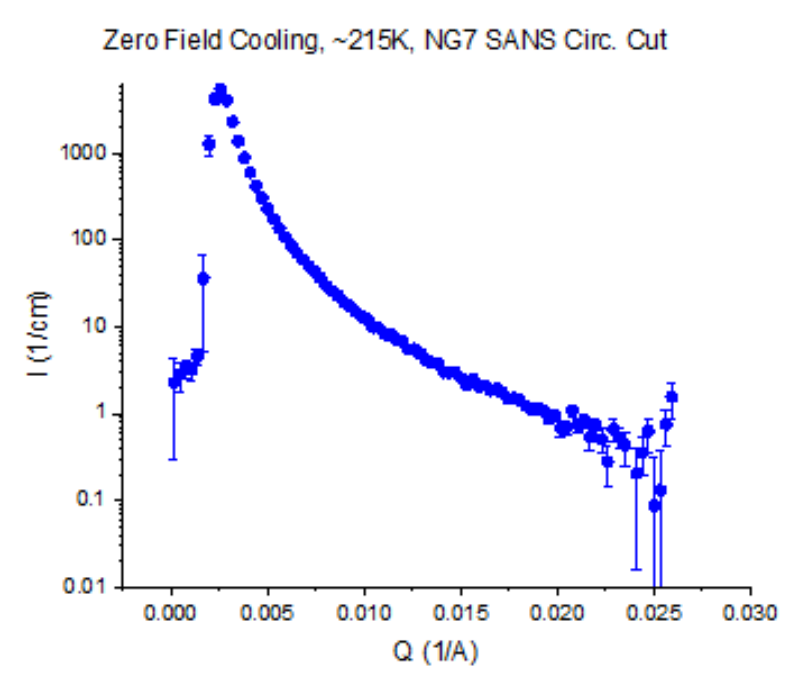


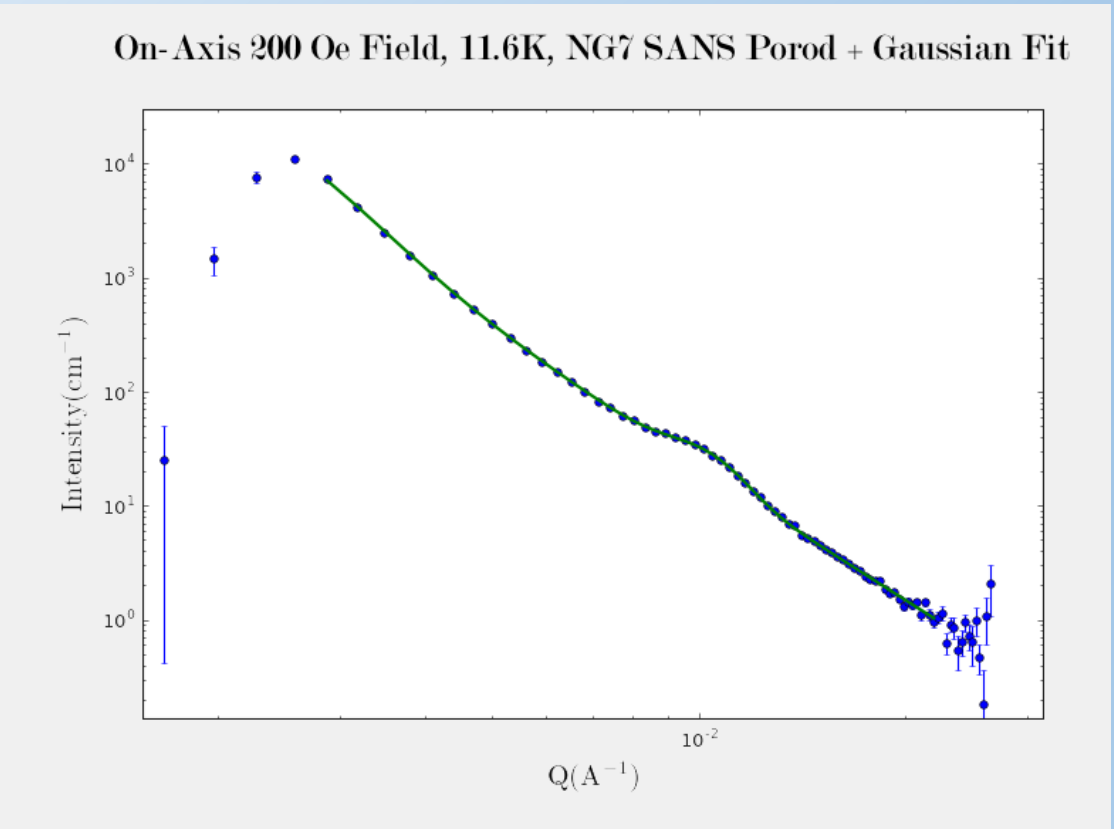
Structural Scattering



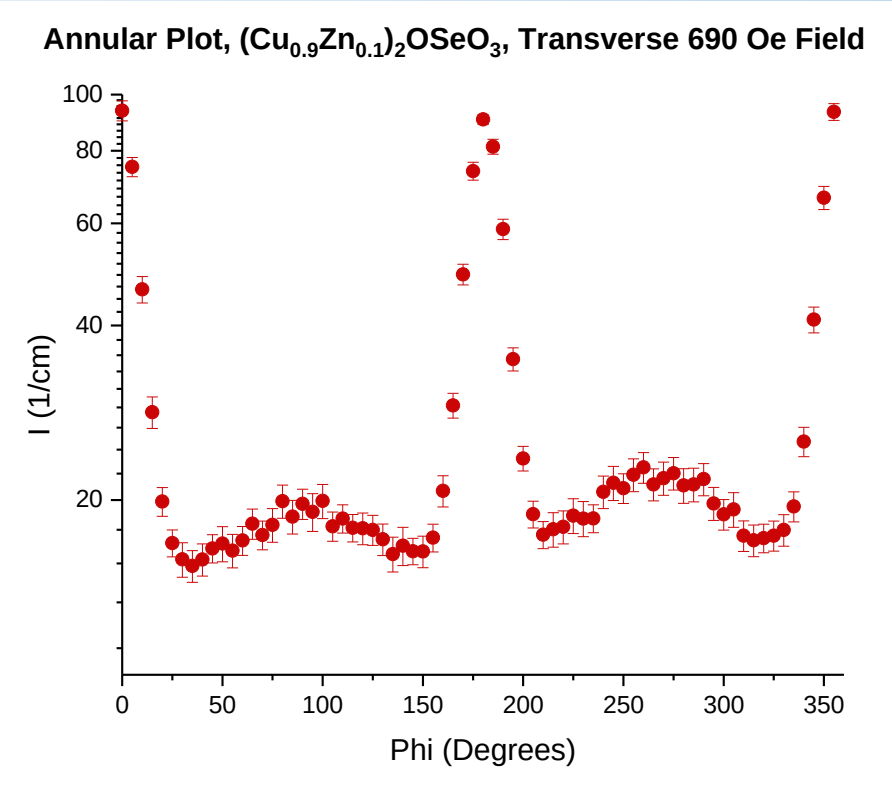


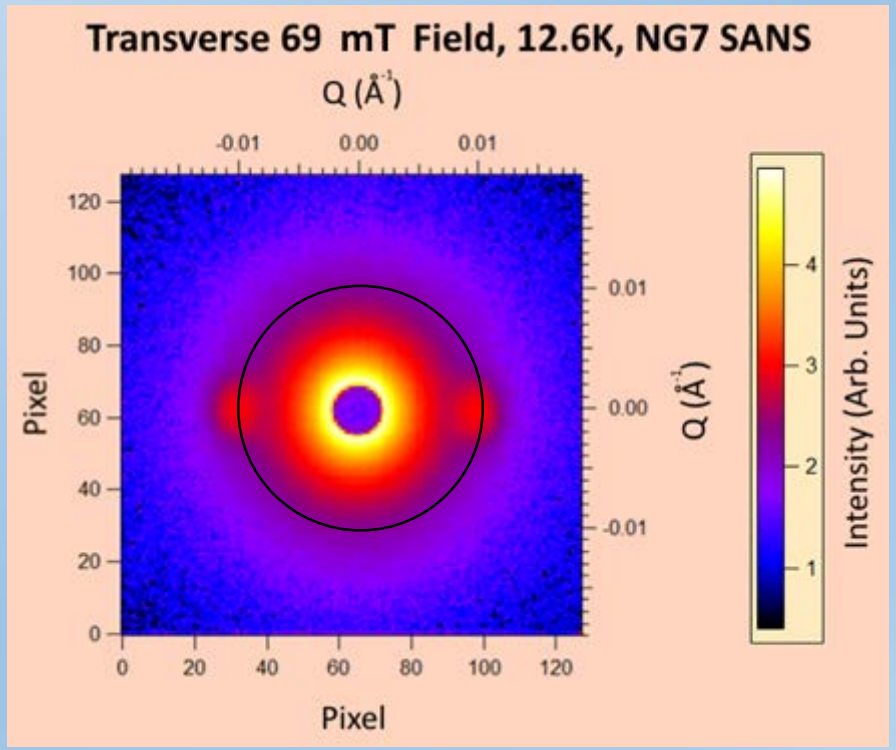
$$q = \frac{2\pi}{d}$$

SANS: Zn Doped, H On Axis



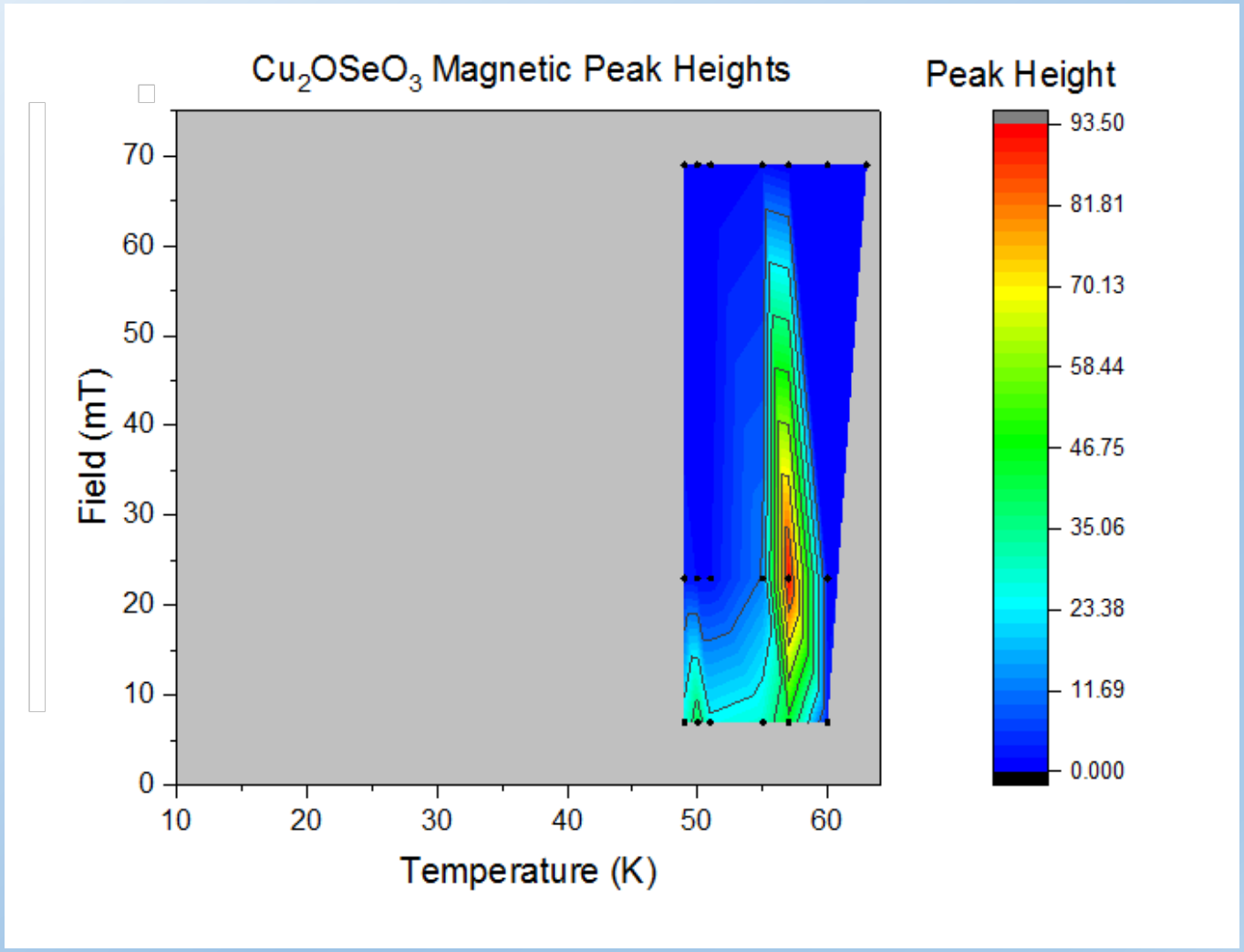
SANS: Zn Doped, Transverse H



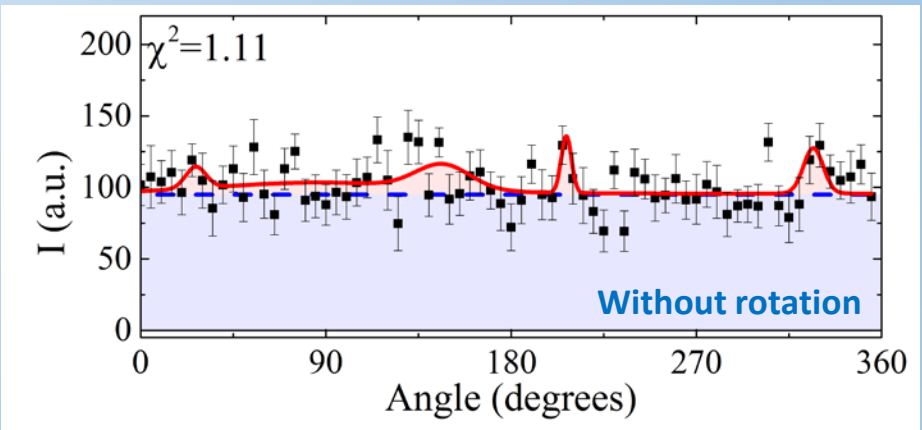


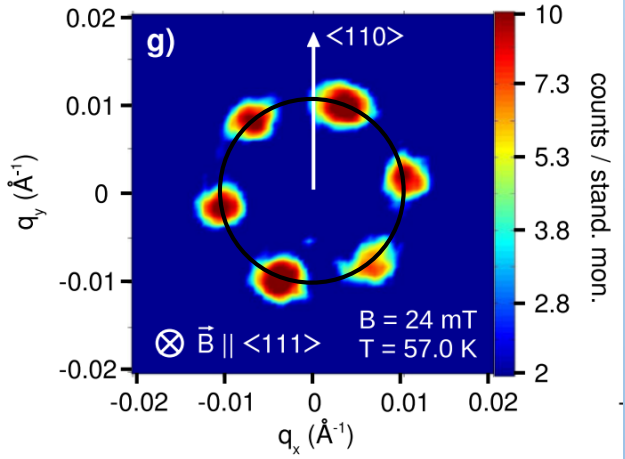
B

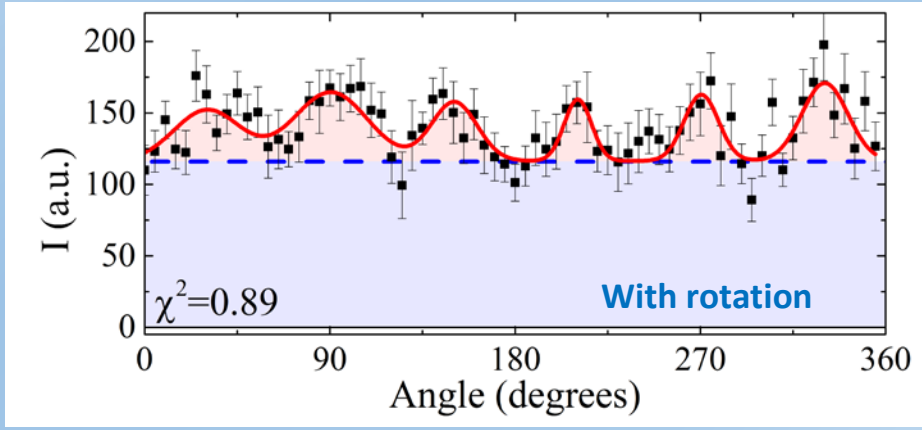
SANS: Zn Doped, H On Axis



SANS: Parent, H On Axis, Rotated







Adams, T. *et al.* Long-Wavelength Helimagnetic Order and Skyrmion Lattice Phase in Cu_2OSeO_3. Physical Review Letters 108, (2012)

Future: Single Crystals?!?!