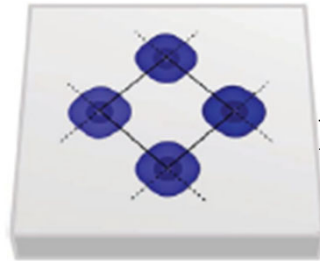


Strain tunability of multipolar Berry curvature in altermagnet MnTe

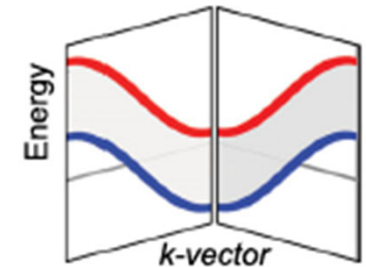
Na Hyun Jo
Norman M. Leff Assistant Professor
University of Michigan, Ann Arbor

Magnetic Ordering

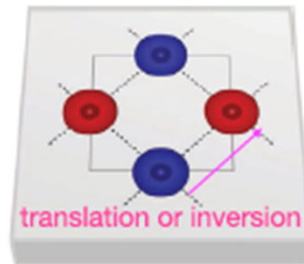
Ferromagnetism (FM):



No symmetries connect up and down

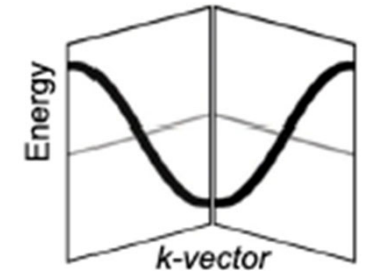


Antiferromagnetism (AFM):

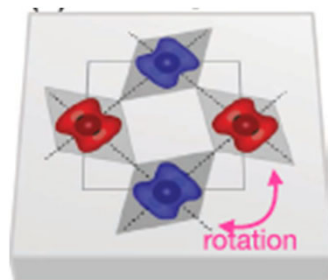


$$E_{\uparrow,k} = [C_2 || t] E_{\uparrow,k} = E_{\downarrow,k}$$

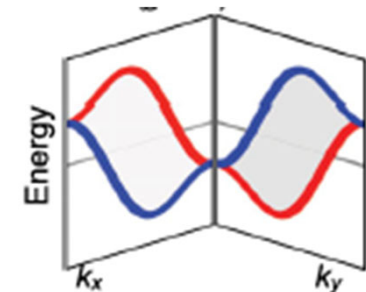
$$E_{\uparrow,k} = [C_2 || \bar{E}] E_{\uparrow,k} = E_{\downarrow,-k} = E_{\uparrow,-k}$$



Altermagnetism (AM):

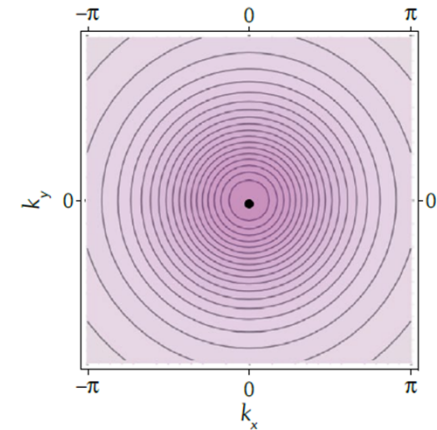
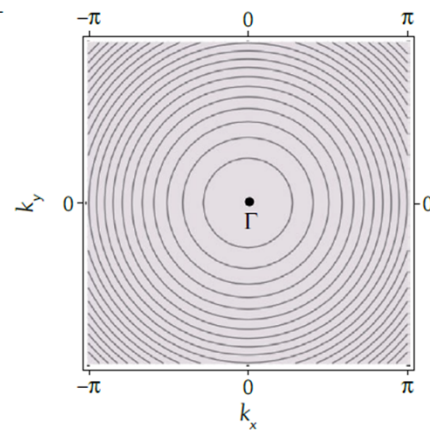
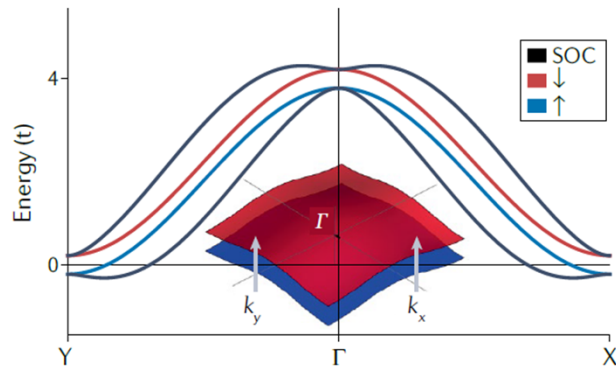


$$E_{\uparrow,k} = [C_2 || C] E_{\uparrow,k} = E_{\downarrow,k'} \neq E_{\uparrow,k'}$$

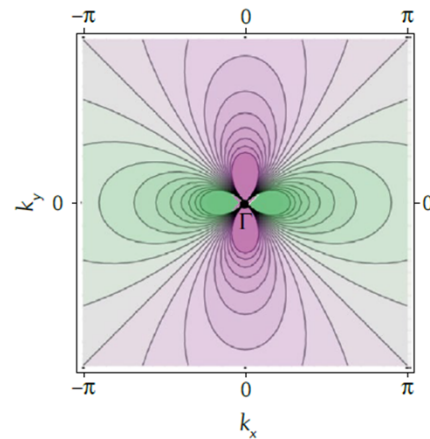
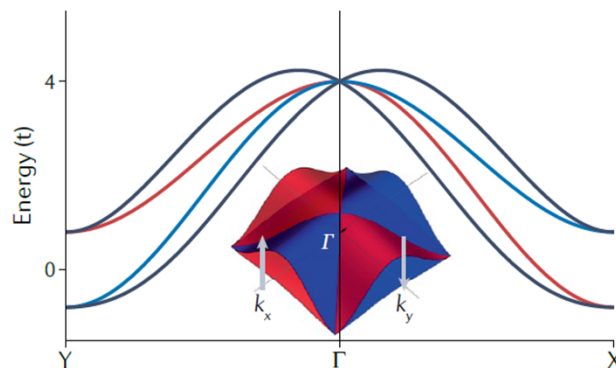


Multipolar Berry curvature

FM



AM

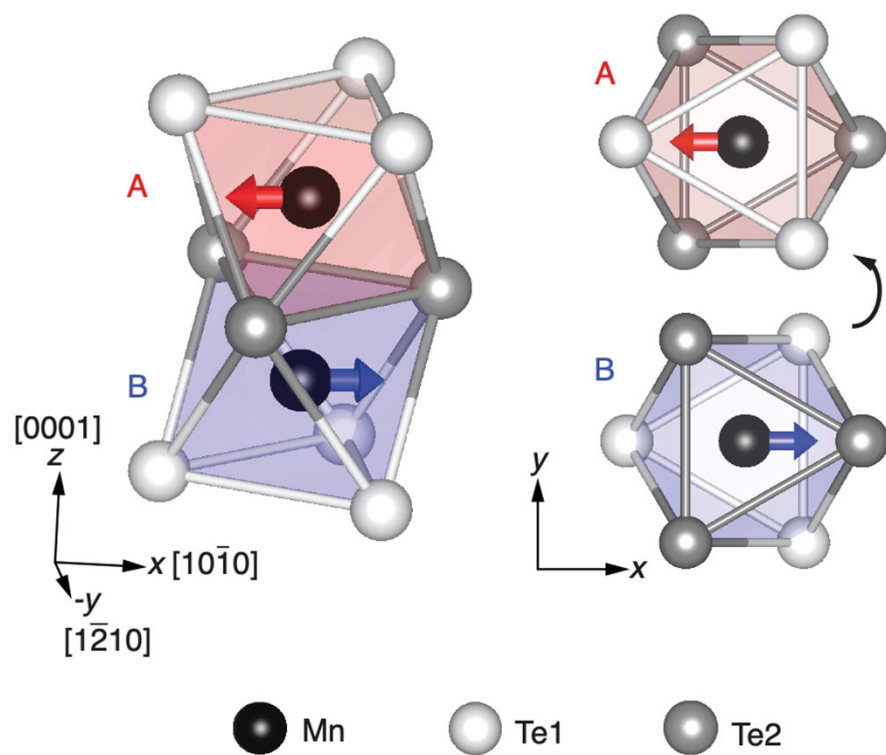


Small Perturbation

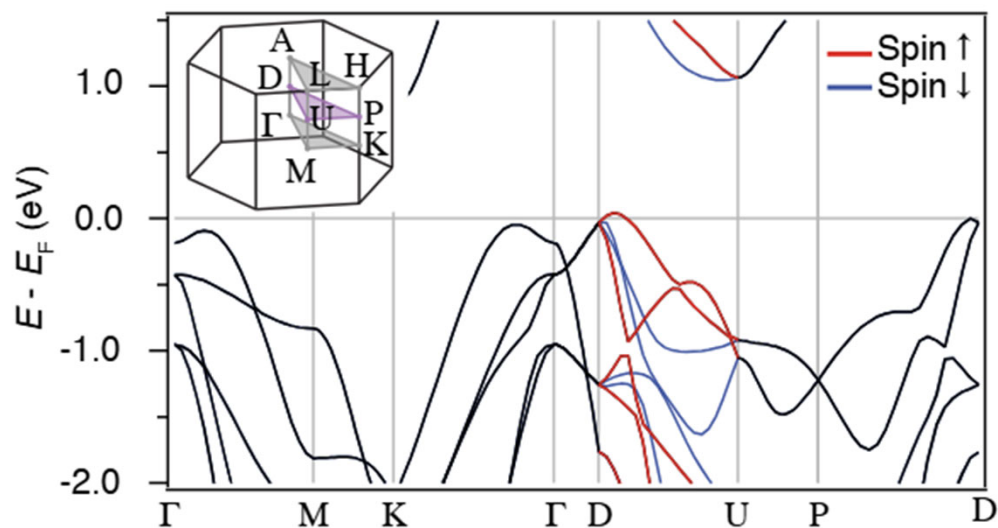
Anisotropic strain!

MnTe

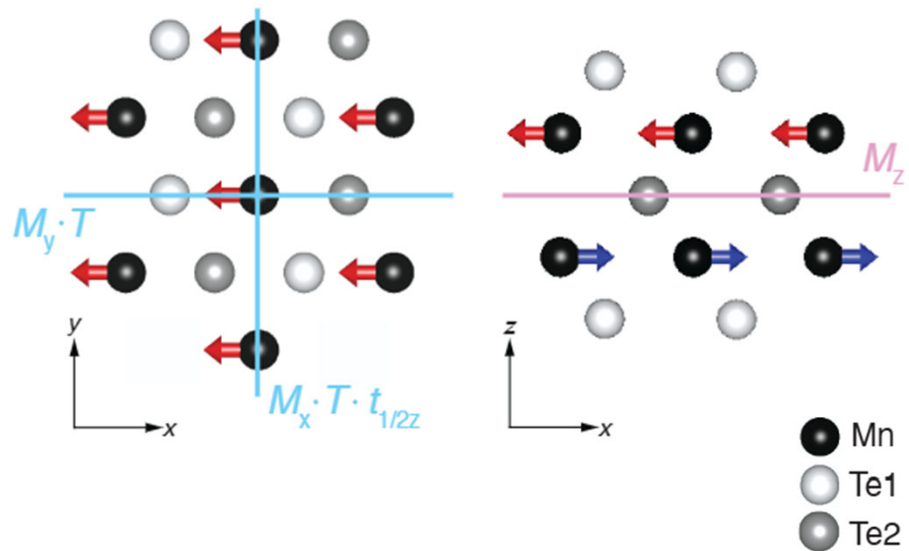
Real space



Momentum space



Anomalous Hall Effect in MnTe



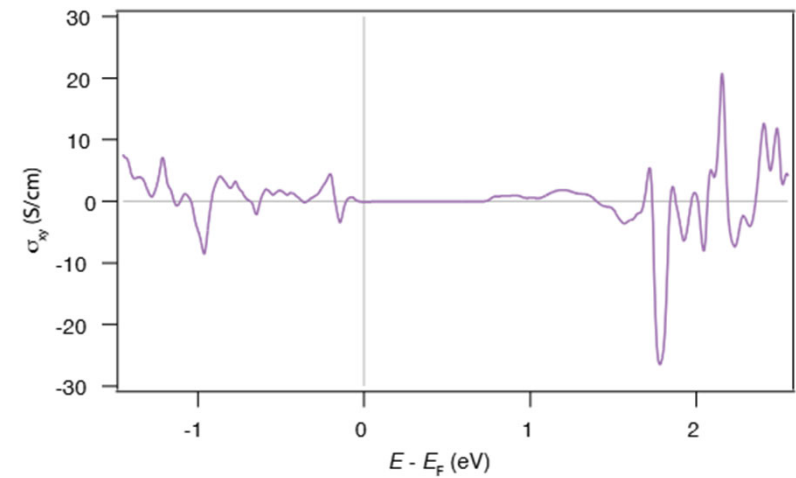
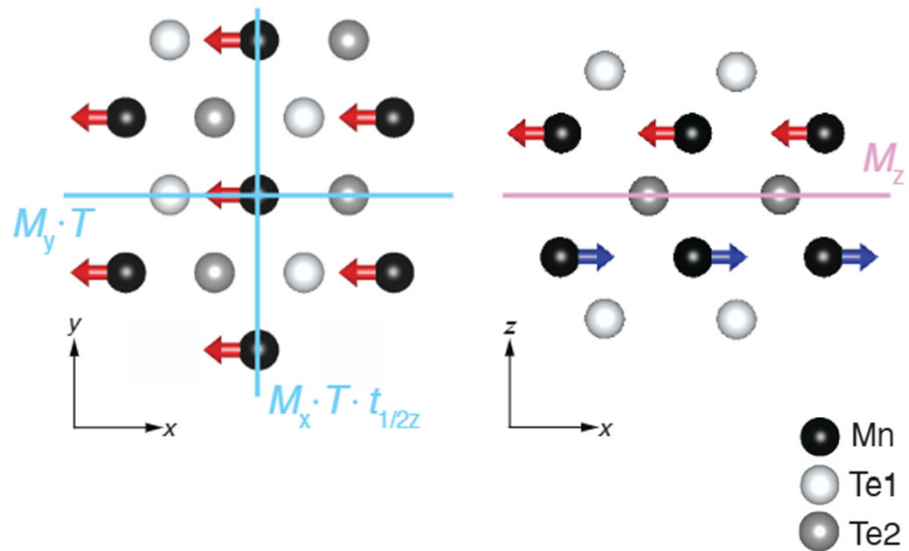
$$M_z \cdot t_{1/2} \longrightarrow \vec{h} \parallel z$$

$$M_y \cdot T \longrightarrow \vec{h} \perp y$$

$$M_x \cdot t_{1/2} \cdot T \longrightarrow \vec{h} \perp x$$

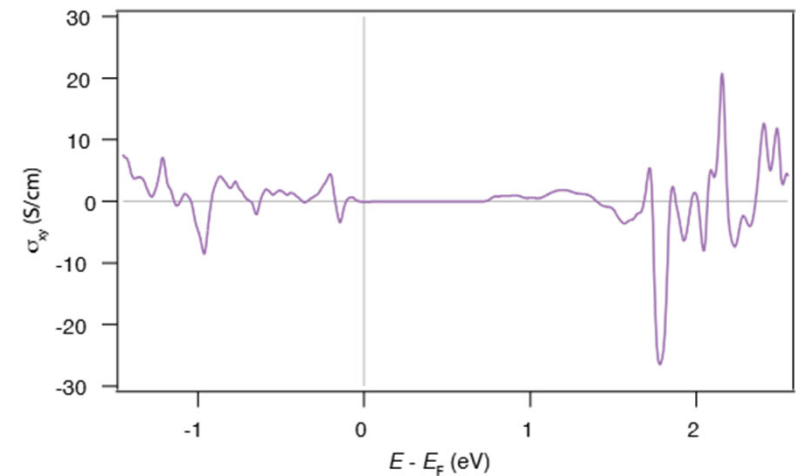
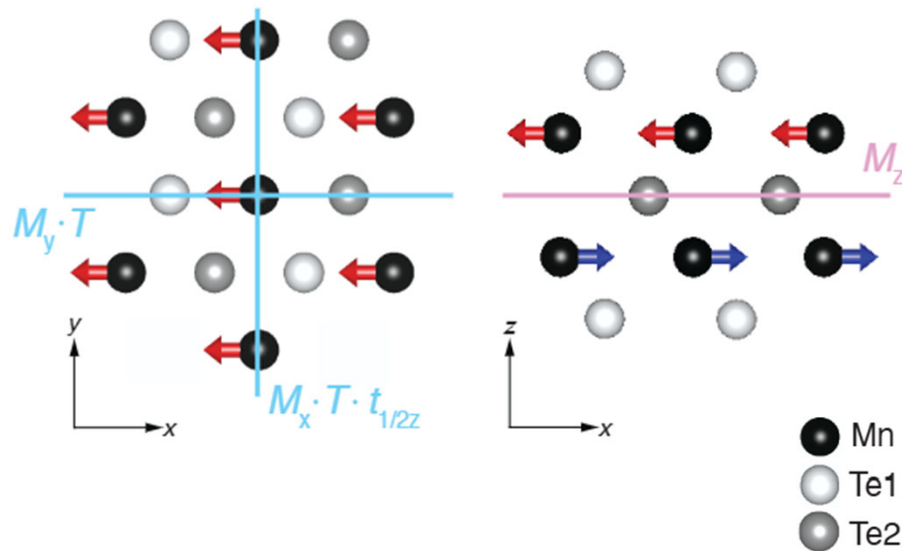
$$\begin{aligned} \therefore \vec{h} &\parallel z \\ \therefore \vec{j}_H &= \vec{h} \times \vec{E} \perp z \end{aligned}$$

Anomalous Hall Effect in MnTe



$$\begin{aligned} \therefore \vec{h} &\parallel z \\ \therefore \vec{j}_H &= \vec{h} \times \vec{E} \perp z \end{aligned}$$

Anomalous Hall Effect in MnTe



$$\begin{aligned} \therefore \vec{h} &\parallel z \\ \therefore \vec{j}_H &= \vec{h} \times \vec{E} \perp z \end{aligned}$$

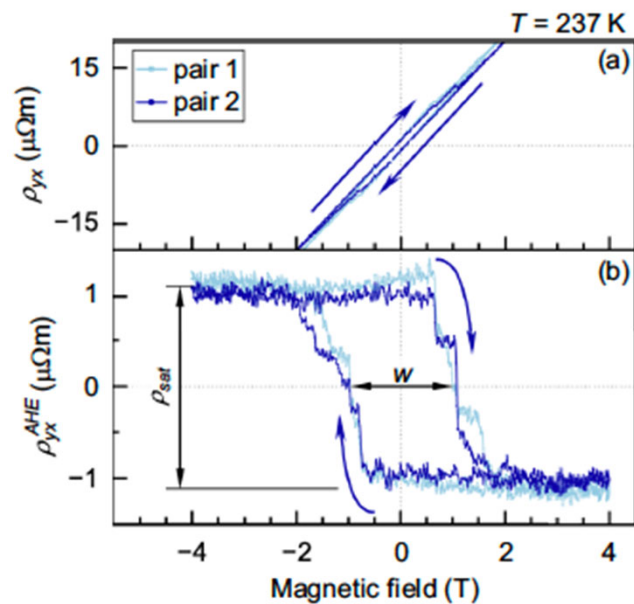
The same symmetry also allows weak ferromagnetism

S.Smolenski, ... , N. H. Jo, arXiv:2509.21481

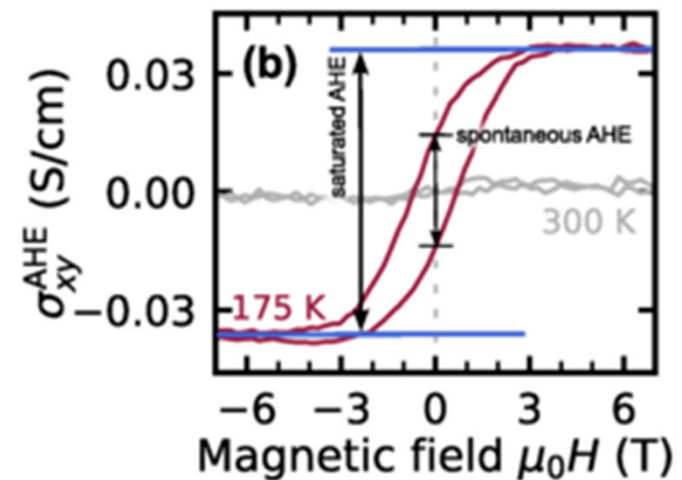
7

Anomalous Hall Effect in MnTe

Single Crystal



Thin Film



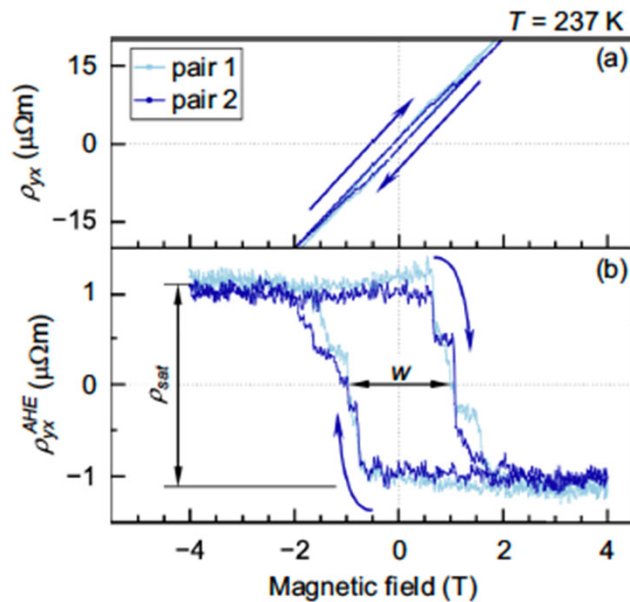
K. P. Kluczyk *et al.* PRB **110**, 155201 (2024).

R. D. Gonzalez Betancourt *et al.* PRL **130**, 036702 (2023).

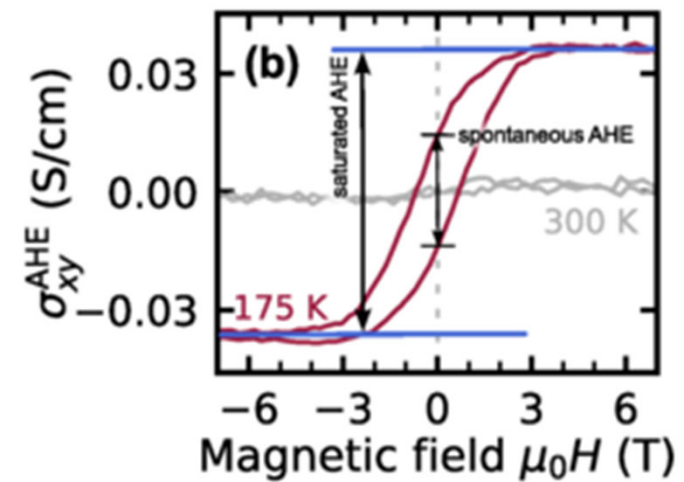
Anomalous Hall Effect in MnTe

Single Crystal

Thin Film



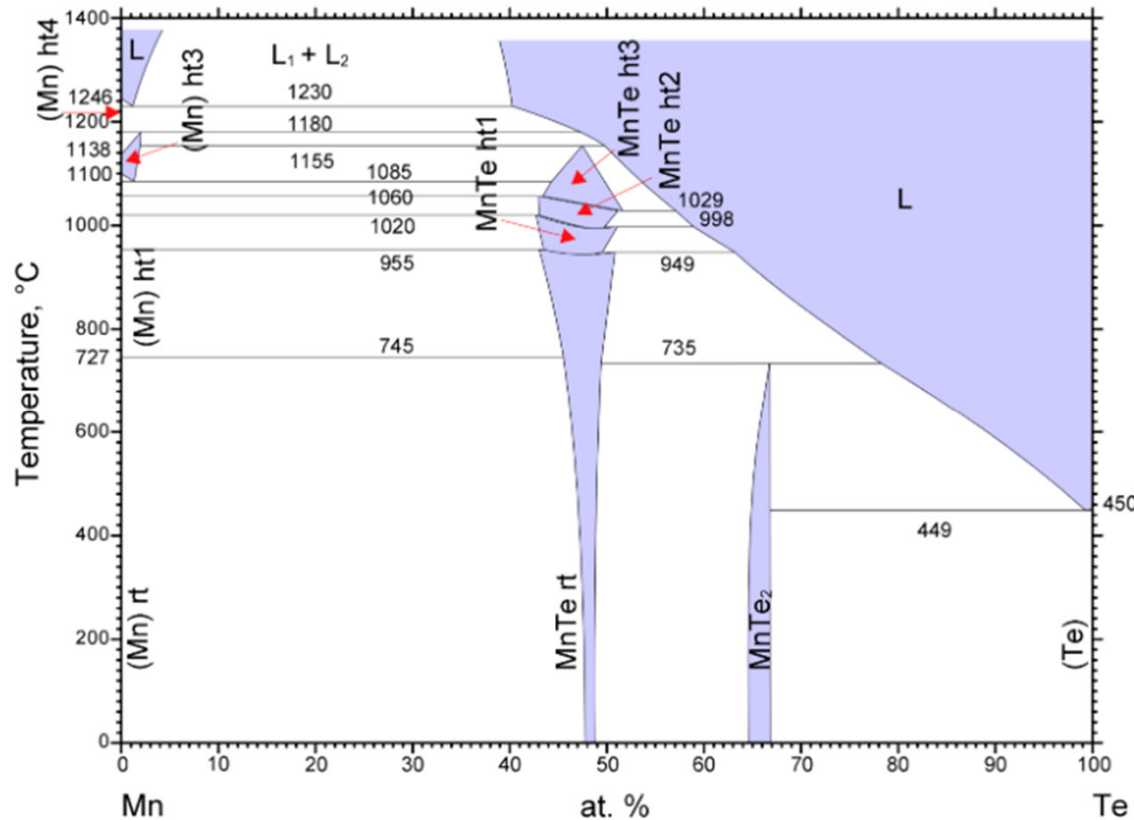
Strain?



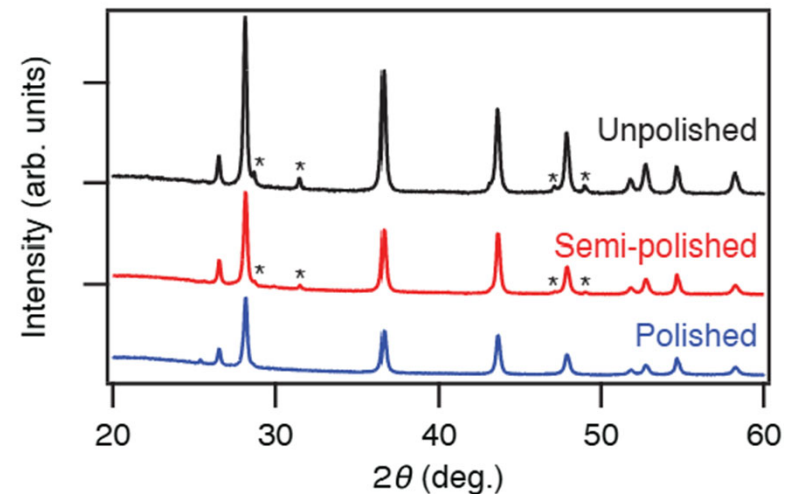
K. P. Kluczyk *et al.* PRB **110**, 155201 (2024).

R. D. Gonzalez Betancourt *et al.* PRL **130**, 036702 (2023).

Single crystal growth

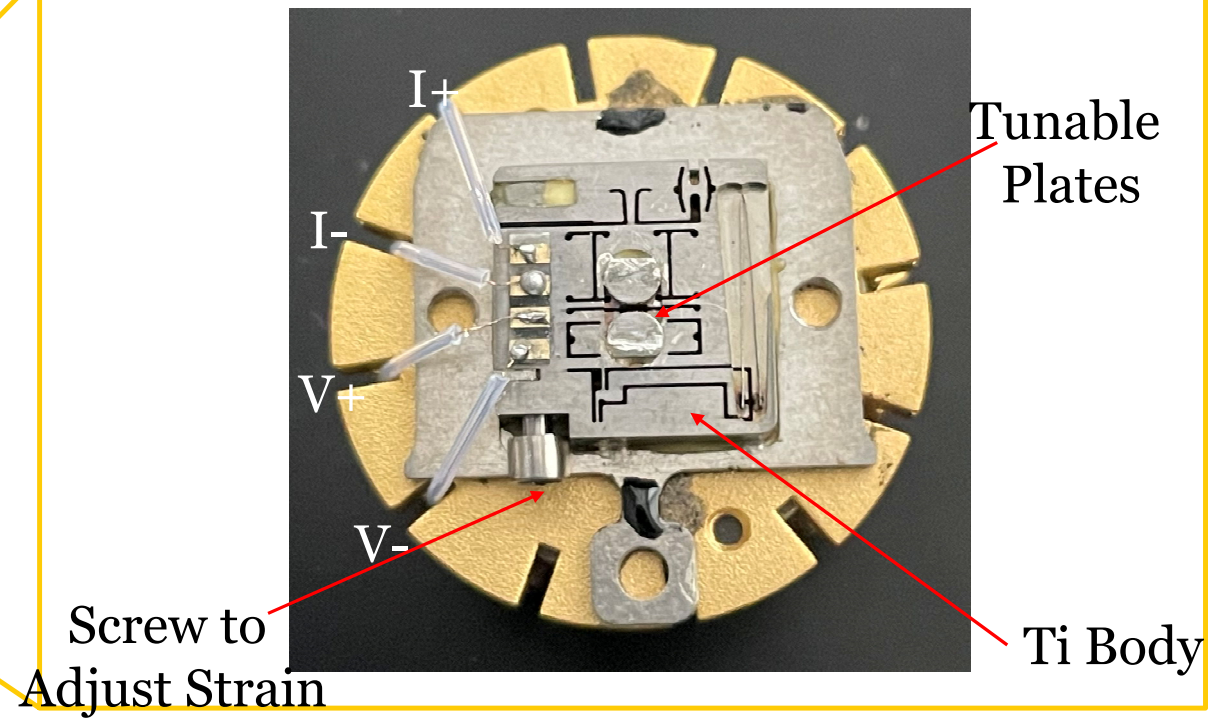
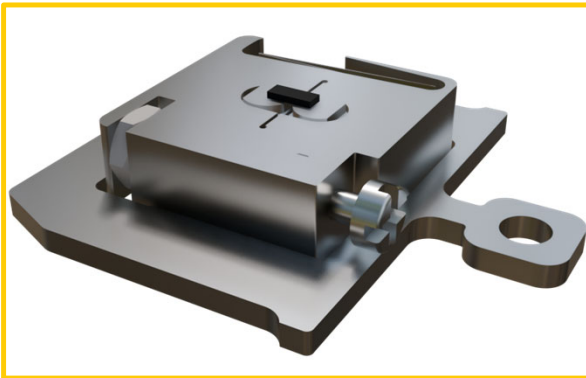


Self - flux

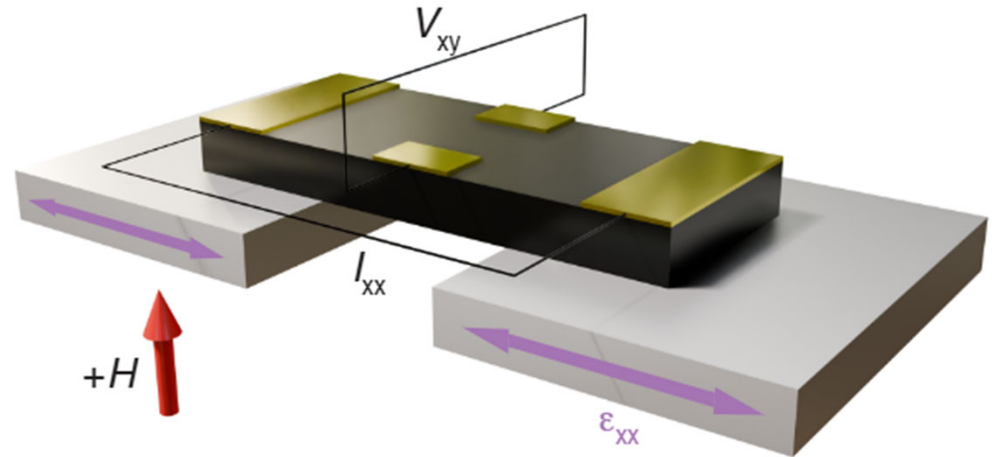
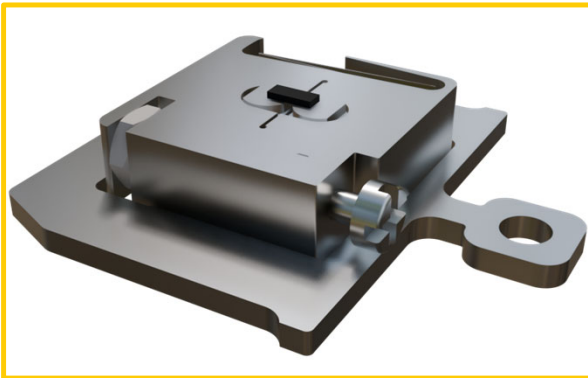


- Crystallographic orientation: single crystal XRD & diffraction contrast tomograph
- All the measurements were performed > 100 K

Strain cell

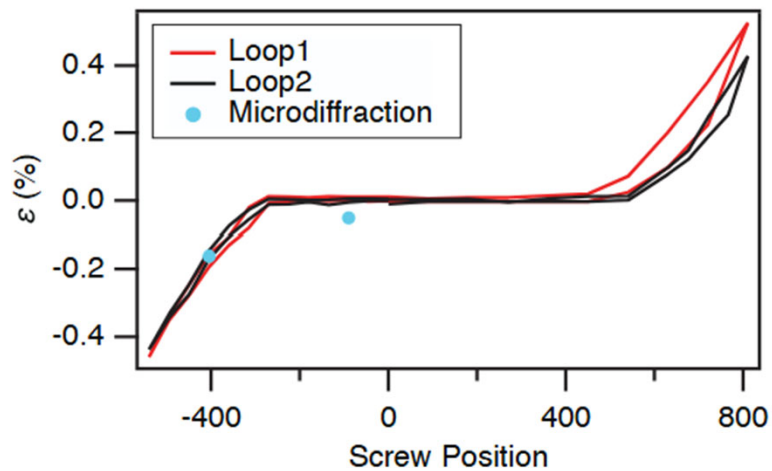


Strain cell

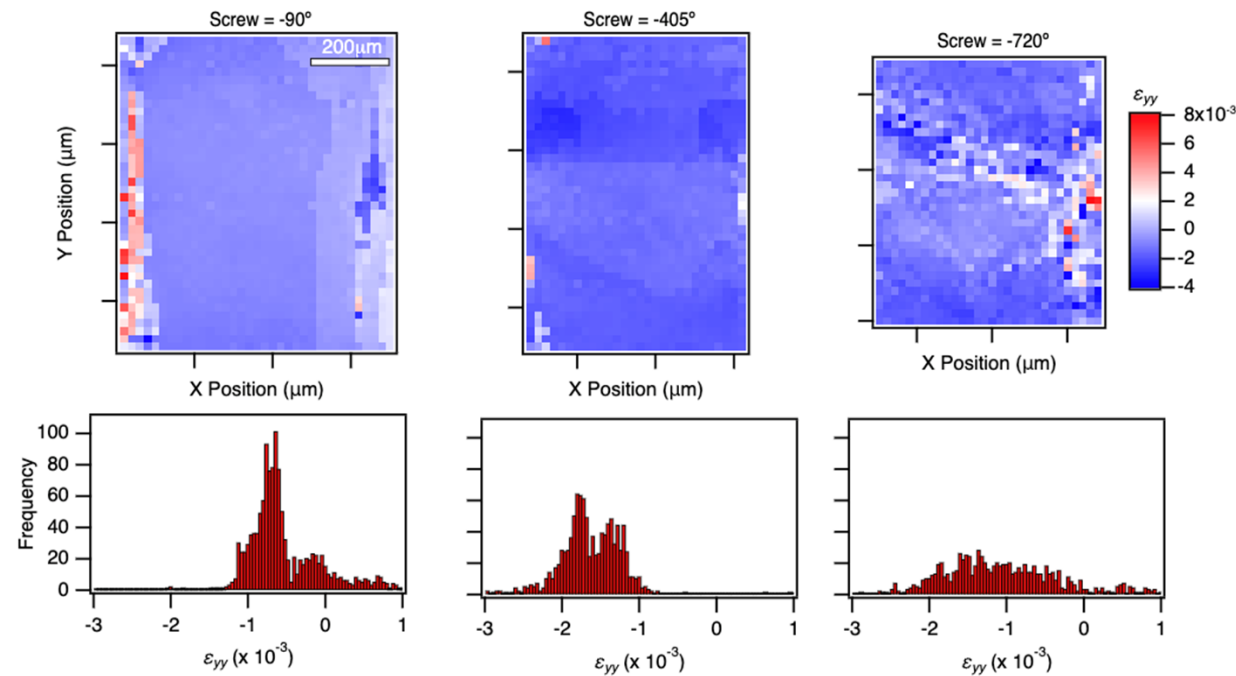


Applied strain

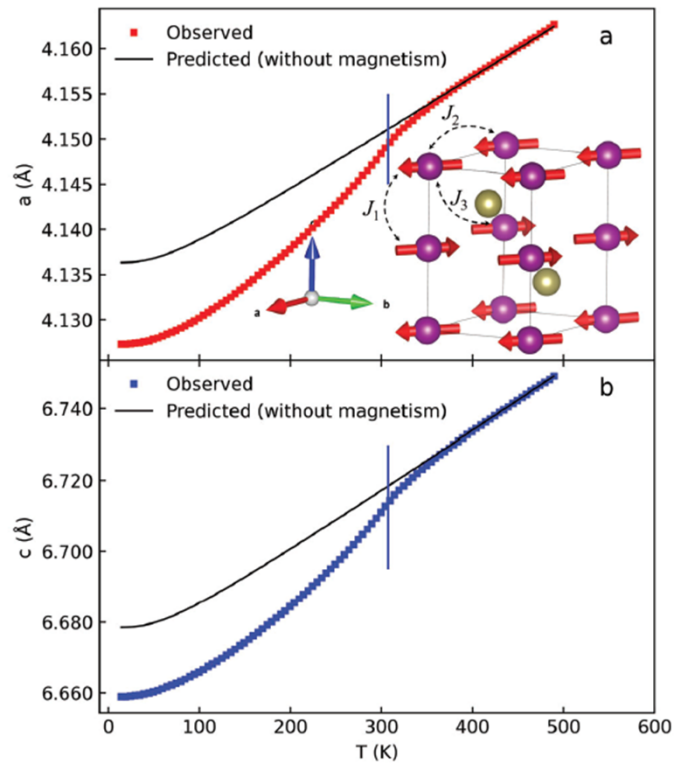
Strain gauge



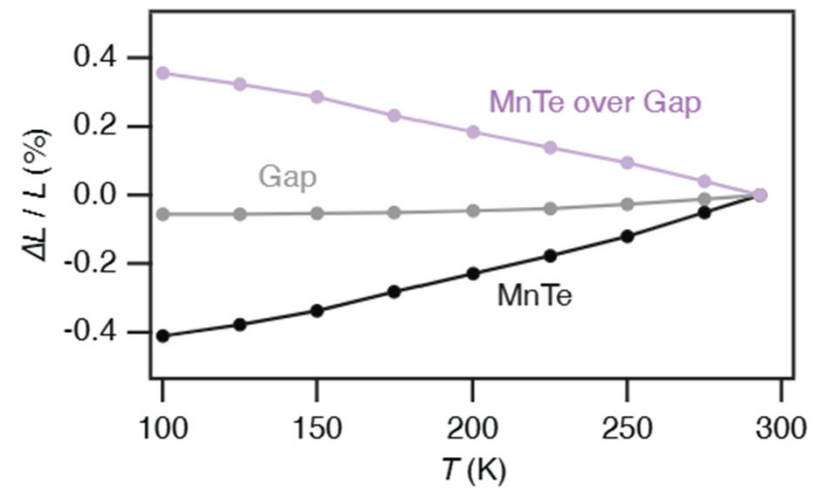
Microdiffraction



Applied strain

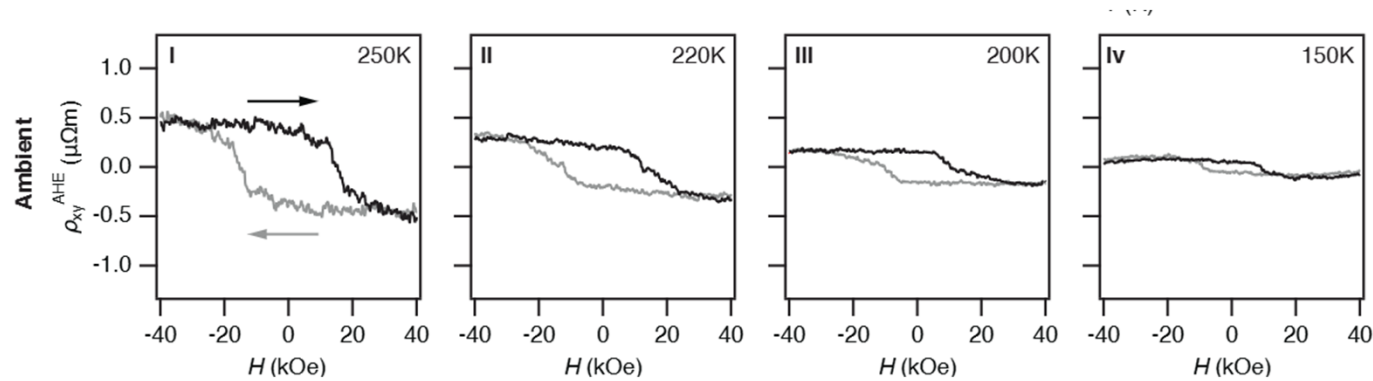


R. Baral *et al.* Adv. Func. Mater. **33**, 2305247 (2023).

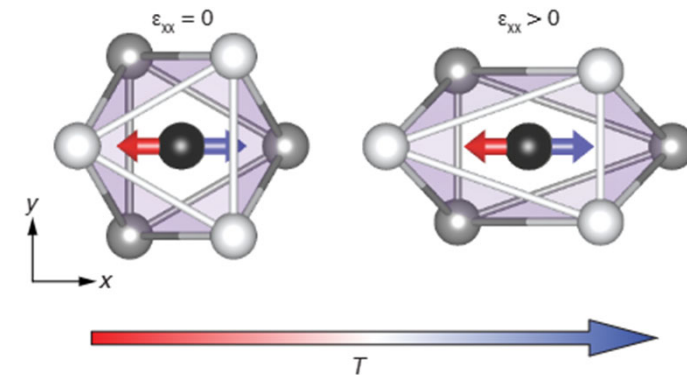
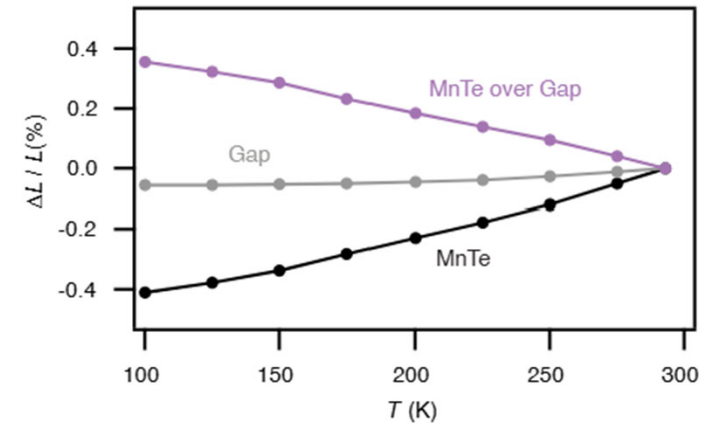
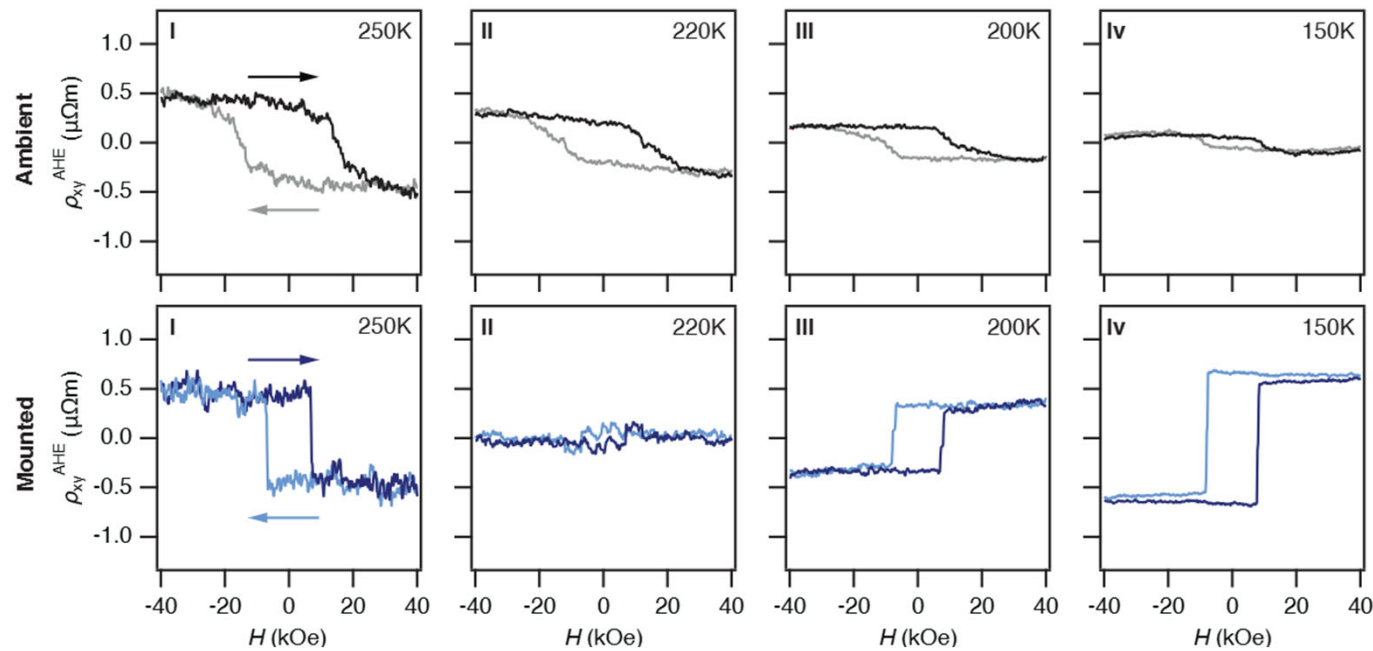


S.Smolenski, ... , N. H. Jo, arXiv:2509.21481

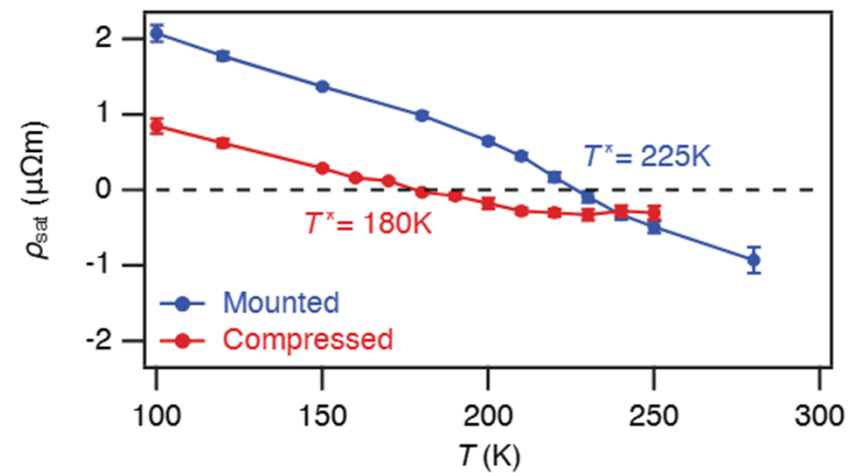
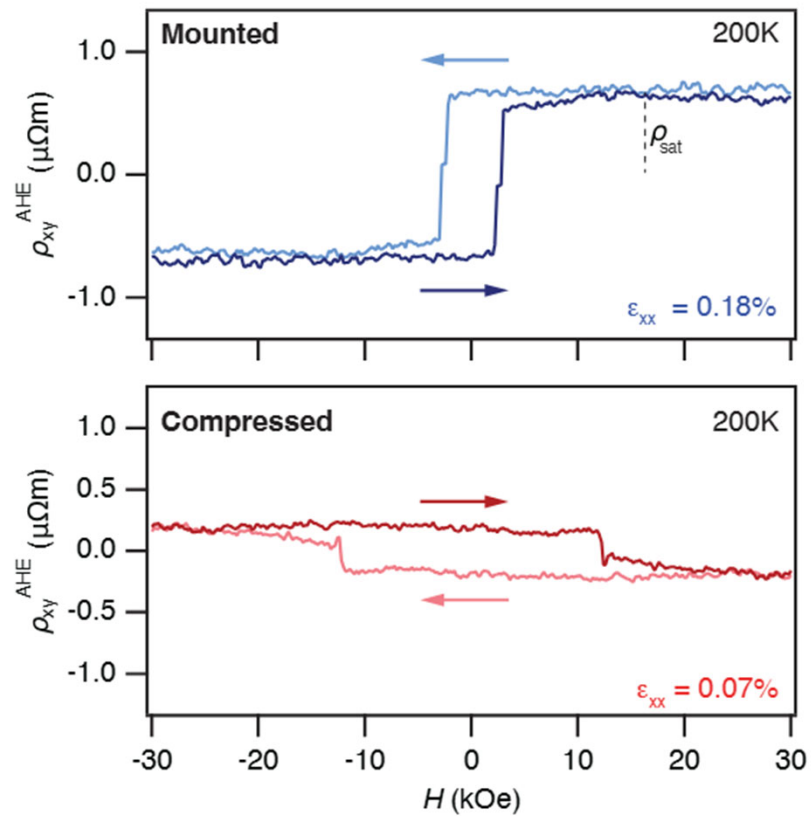
Applied strain



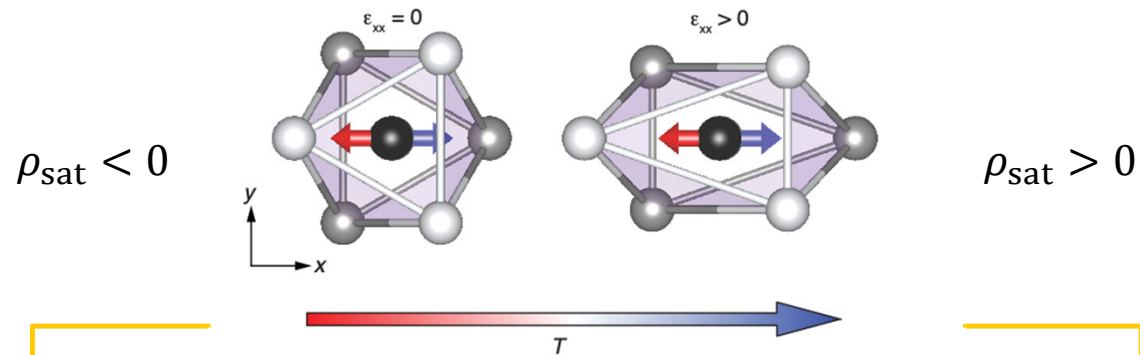
Applied strain



Applied strain



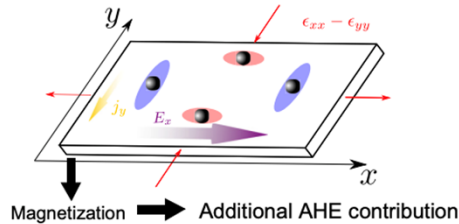
Why sign changes?



Takahashi, K., *et al.* Phys. Rev. B **111**, 184408 (2025).

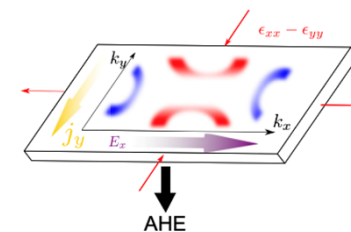
Piezomagnetism

$$M_{\mu} = M_{\mu}(\epsilon = 0) + \Lambda_{\mu\gamma\delta}\epsilon_{\gamma\delta}$$



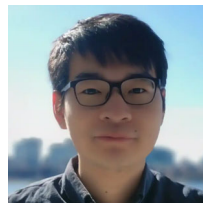
Strain-Dependent Berry Curvature

$$\sigma_{\alpha\beta} = \sigma_{\alpha\beta}(\epsilon = 0) + v_{\alpha\beta\gamma\delta}\epsilon_{\gamma\delta}$$

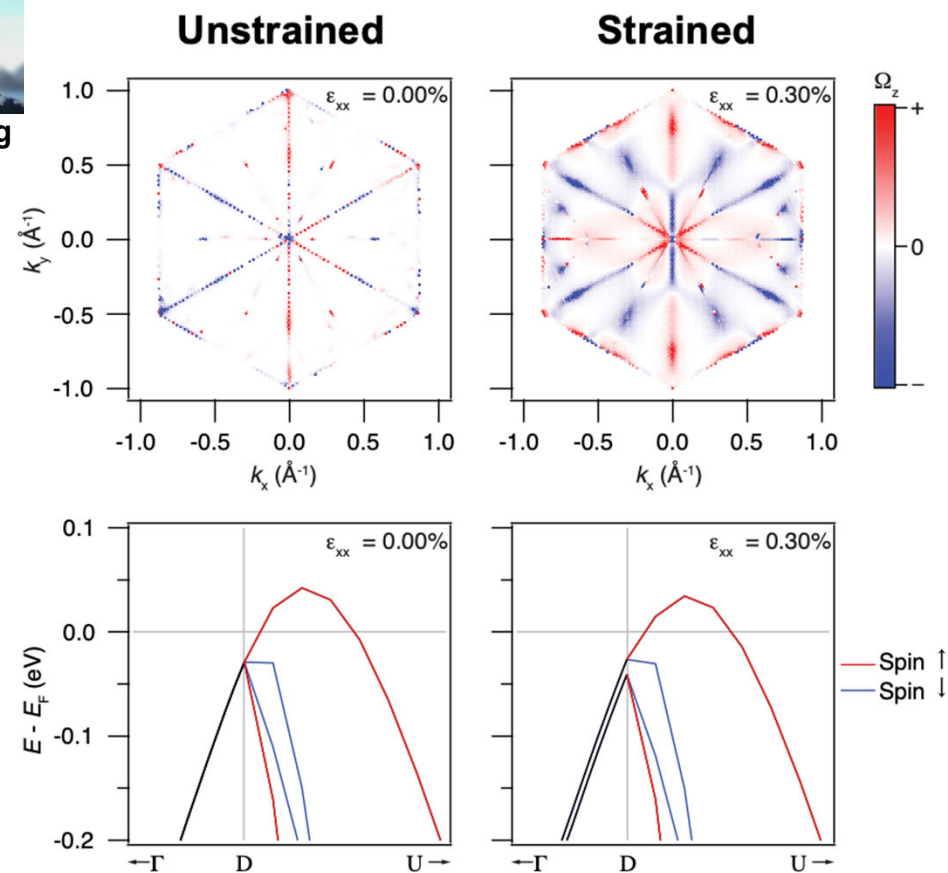
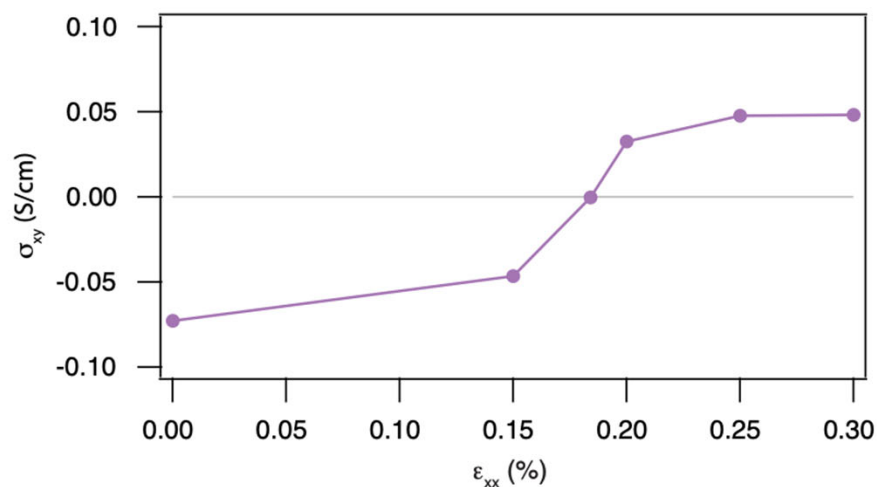


S.Smolenski, ... , N. H. Jo, arXiv:2509.21481

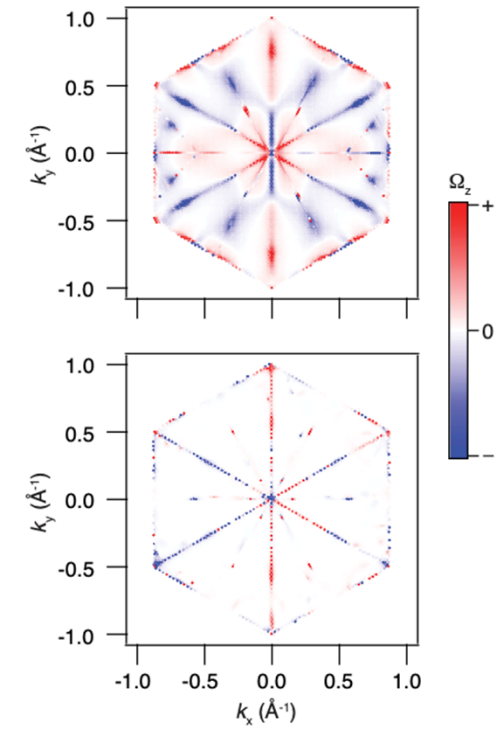
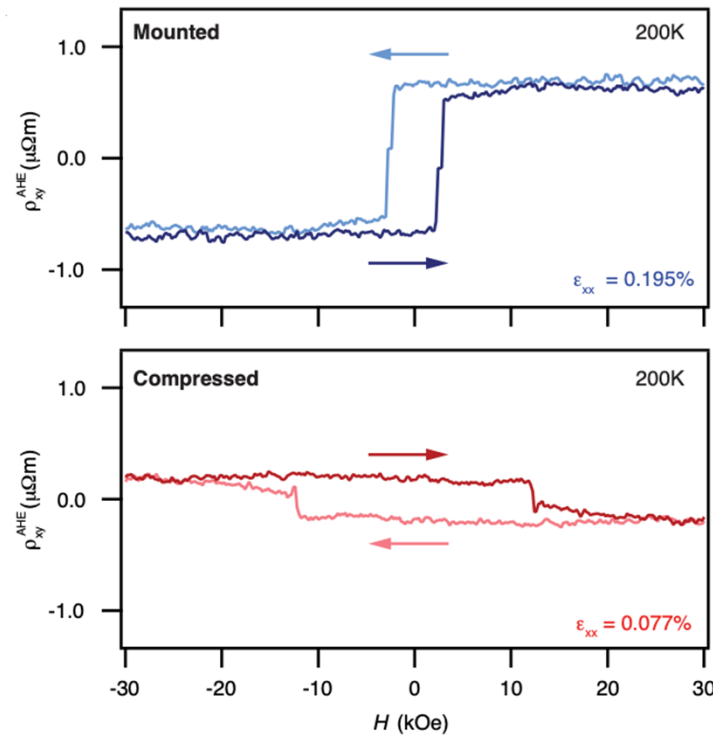
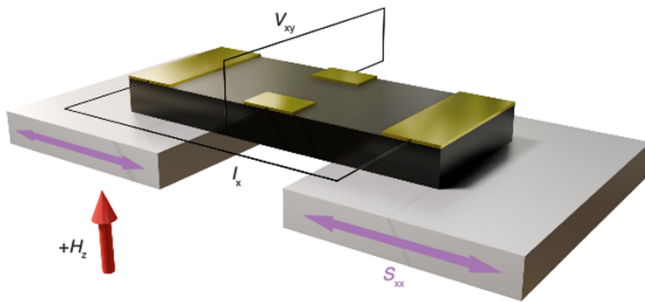
DFT calculations



Yang Zhang
Ning Mao



Summary



- Strain-tunable AHE described via modifications to anomalous Berry curvature

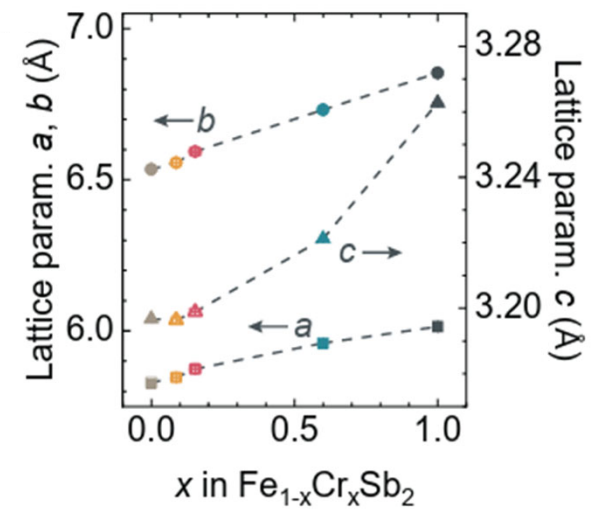
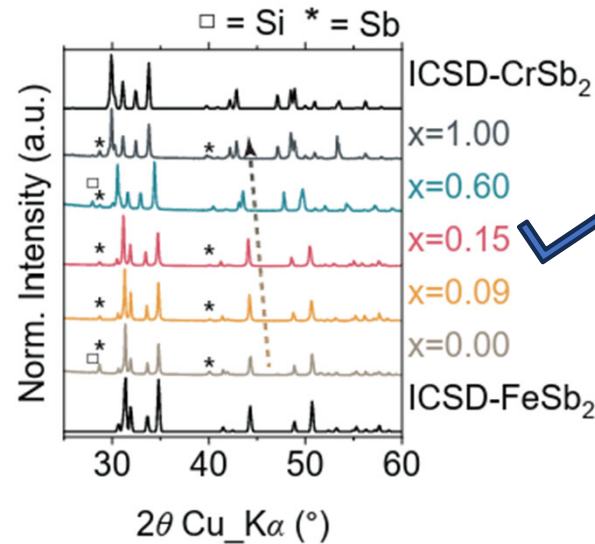
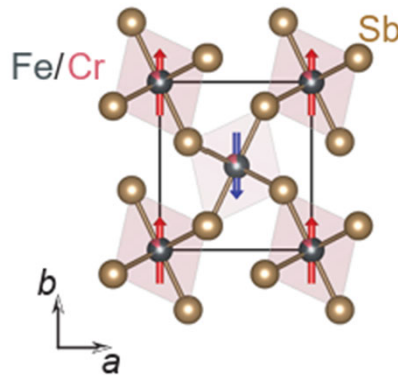
Strain vs doping



Doping introduces disorder

Strain vs doping

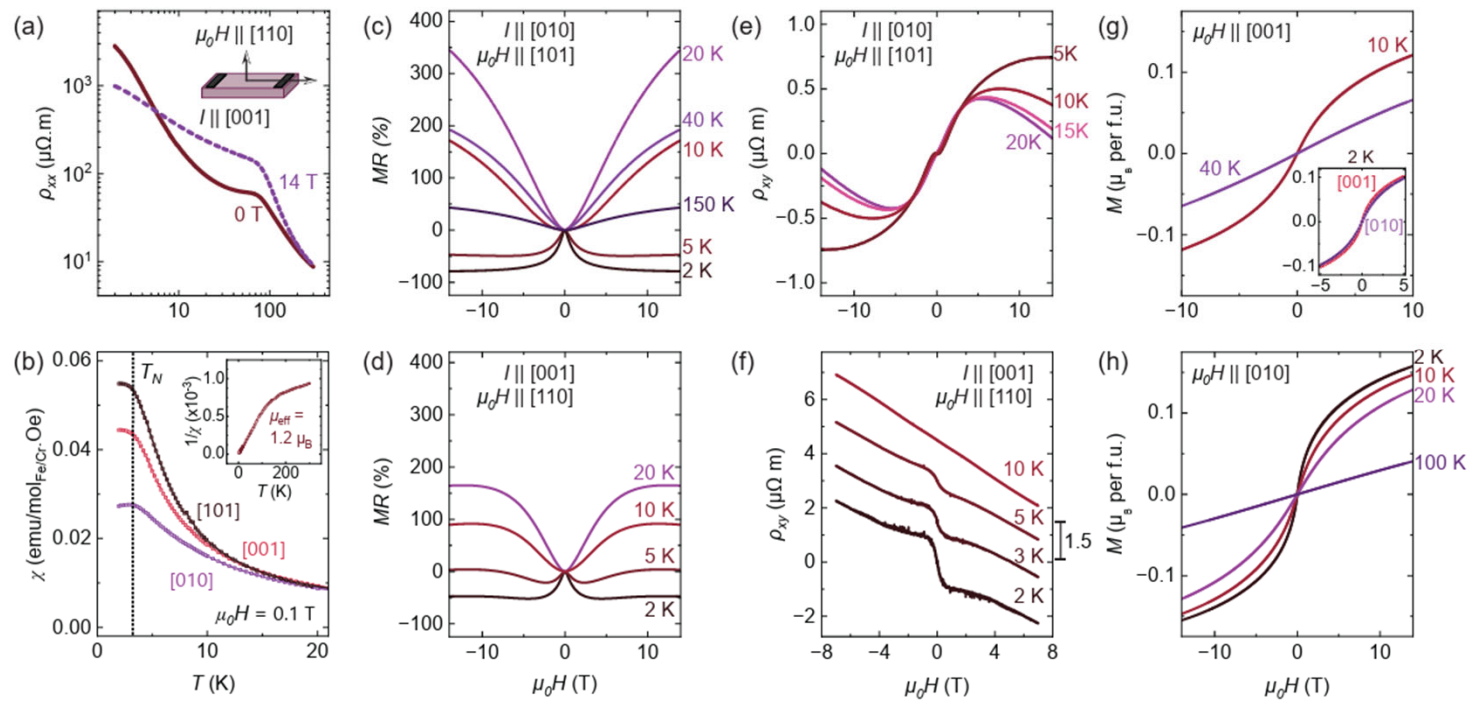
Cr doped FeSb₂



Strain vs doping



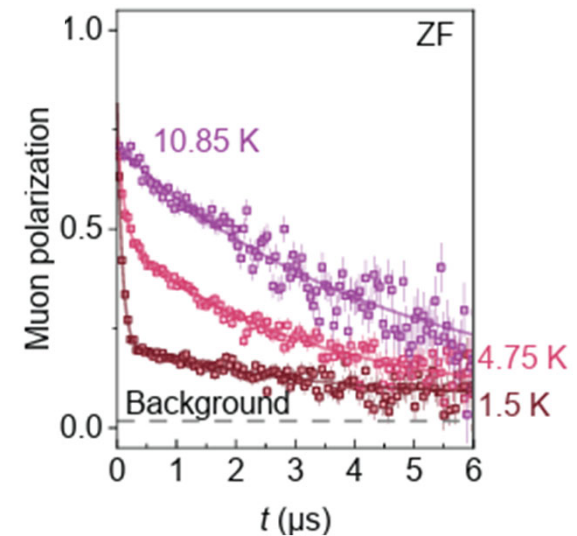
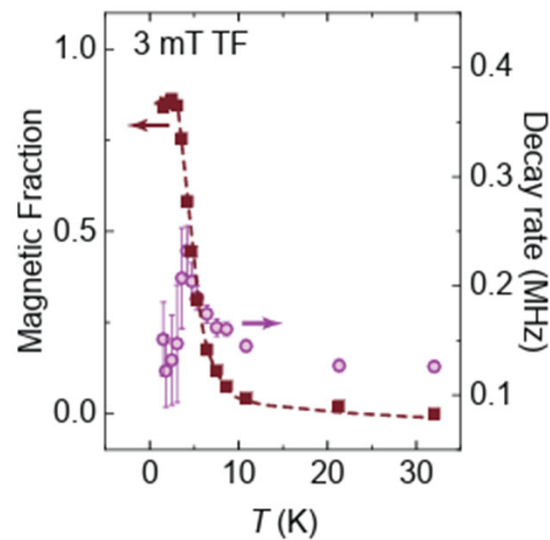
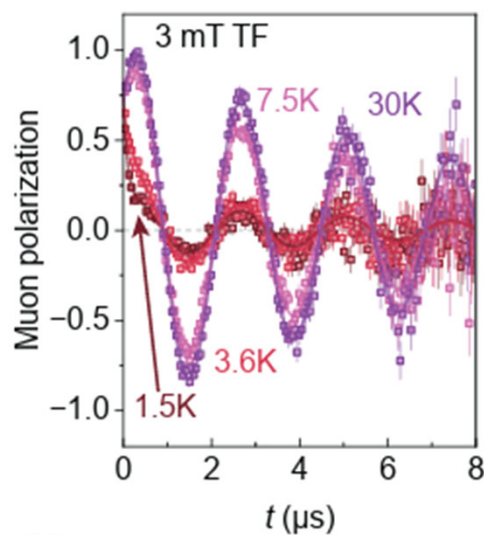
Cr doped FeSb₂



Strain vs doping



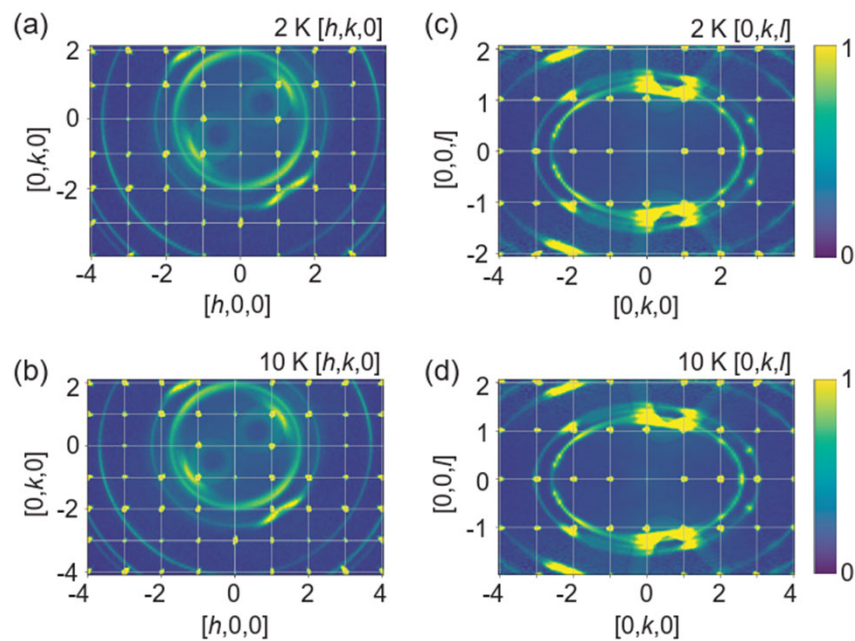
Cr doped FeSb₂



Strain vs doping



Cr doped FeSb₂



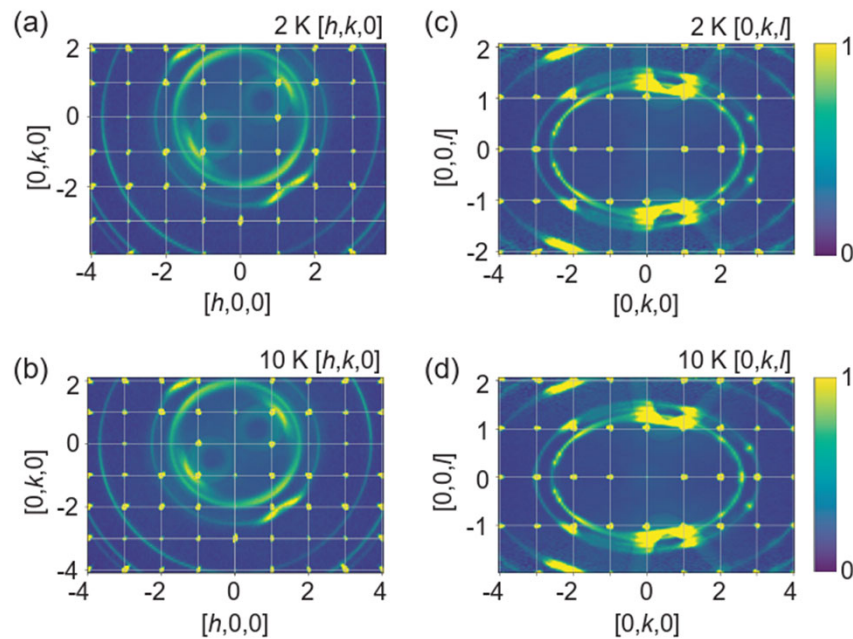
No additional magnetic Bragg Peak

- 1) Altermagnet
- 2) Ferromagnet

Strain vs doping

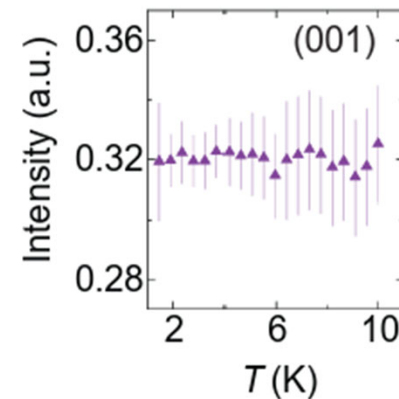


Cr doped FeSb₂



No additional magnetic Bragg Peak

- 1) Altermagnet
- 2) Ferromagnet
- 3) **Non-magnetic!!!**



Acknowledgements



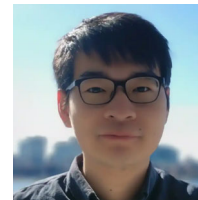
Career DMR-2337535



Lu Li
Dechen Zhang



Kai Sun



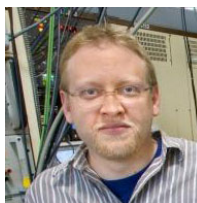
Yang Zhang
Ning Mao



Weiwei Xie
Mingyu Xu



ADVANCED LIGHT SOURCE



Aaron Bostwick



Chris Jozwiak



Eli Rotenberg



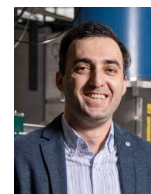
Nobu Tamura



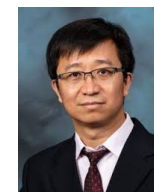
Ming Yi
Yucheng Guo



Elena Gati
Rafael Lopes Sabainsk



Zurab Guguchia
Thomas J. Hicken



Huibo Cao
Si Athena Chen
Tatenda Kanyowa