REACTOR INSTITUTE DELFT

Kinetic-arrest induced phase coexistence and metastability in $(Mn,Fe)_2(P,Si)$

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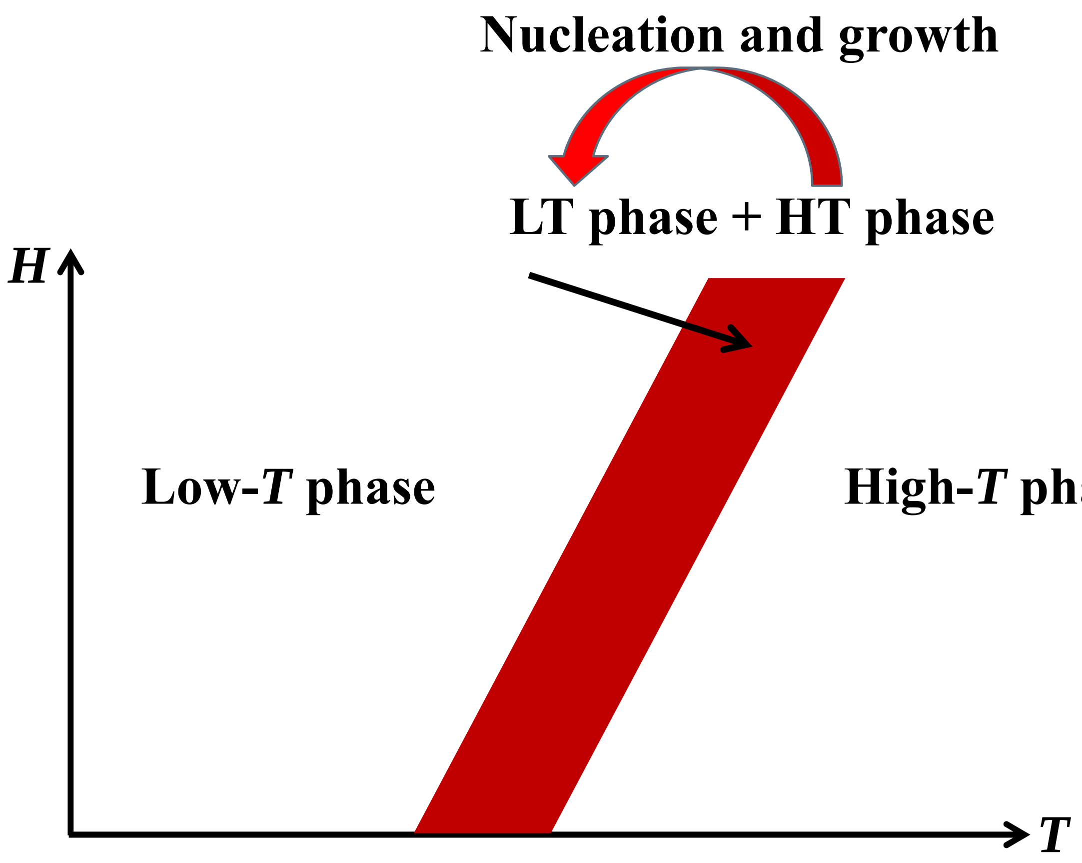
Outline

- Background
- Neutron diffraction
- In-field x-ray diffraction
- Magnetic relaxation measurements

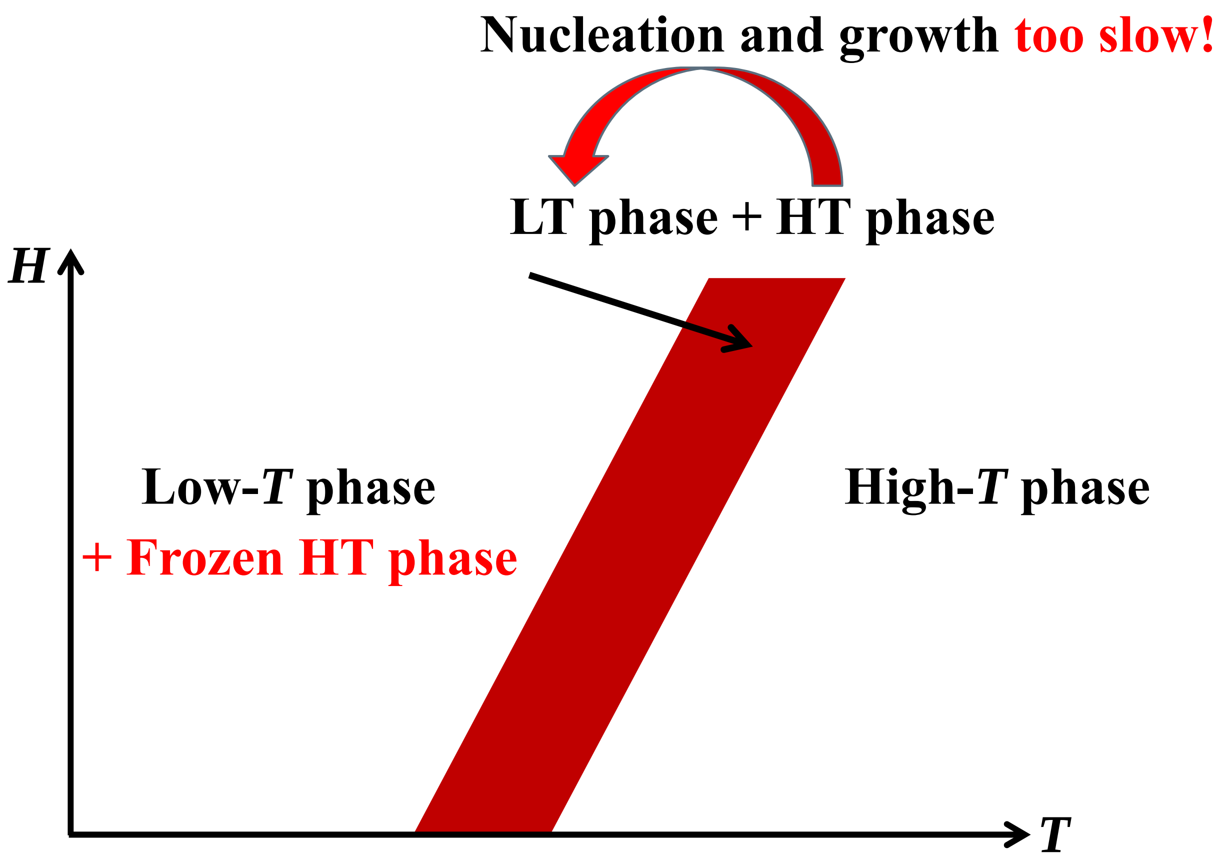
Background

Phase coexistence in first-order phase transition



Background

Kinetic arrest



Examples of kinetic arrest

Kinetic arrest in a variety of magnetic materials:

$Ce(Fe_{0.96}Ru_{0.04})_2$,[1] Ni-Mn-X Heuslers,[2]

Gd_5Ge_4,[3] $Fe_{49}(Rh_{0.93}Pd_{0.07})_{51}$,[4] manganites,[5] *etc*.

Reference: [1] Manekar M.A. *et al.*, *Phys. Rev. B* 64, 104416(2001).

[2] Sharma V.K. *et al.*, *Phys. Rev. B* 76, 140401(2007).

[3] Roy S.B. *et al.*, *Phys. Rev. B* 74, 012403(2006).

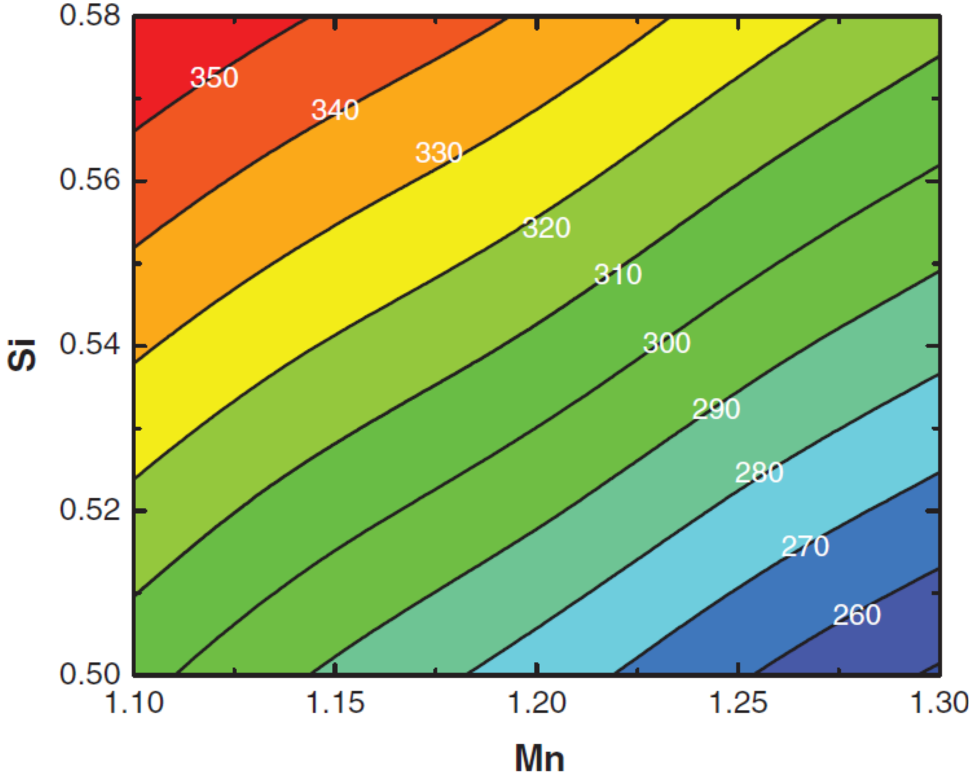
[4] Kushwaha P. *et al.*, *Phys. Rev. B* 80, 174413 (2009).

[5] Kuwahara H. *et al.*, *Science* 270, 961(1995).

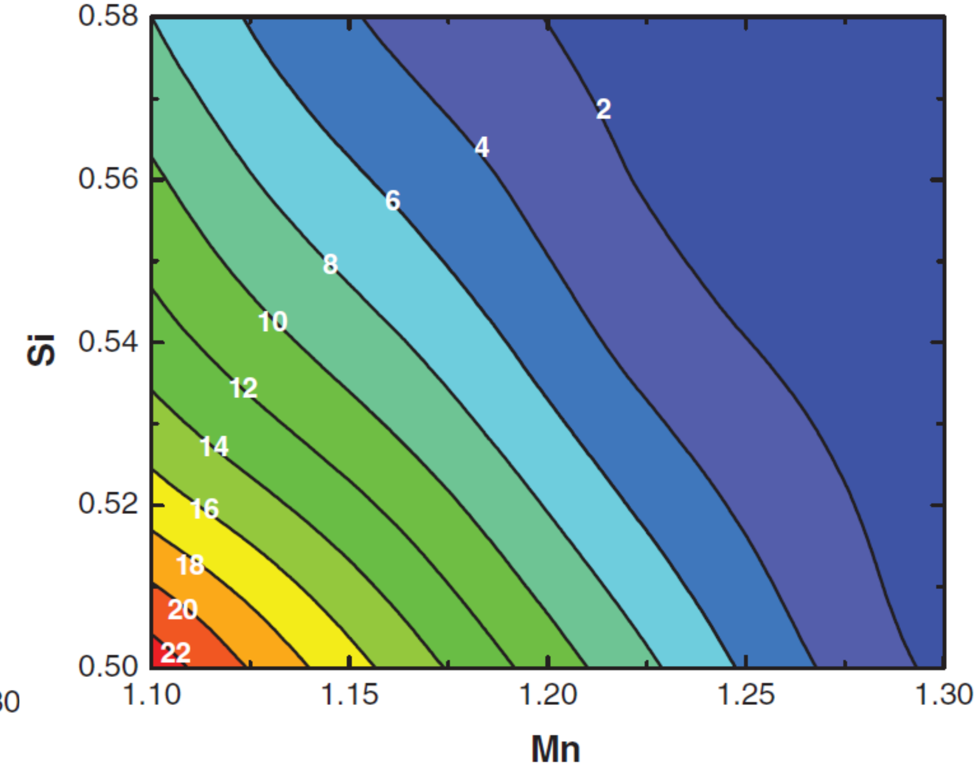
Hexagonal $(Mn,Fe)_2(P,Si)$

First-order transition

T_C

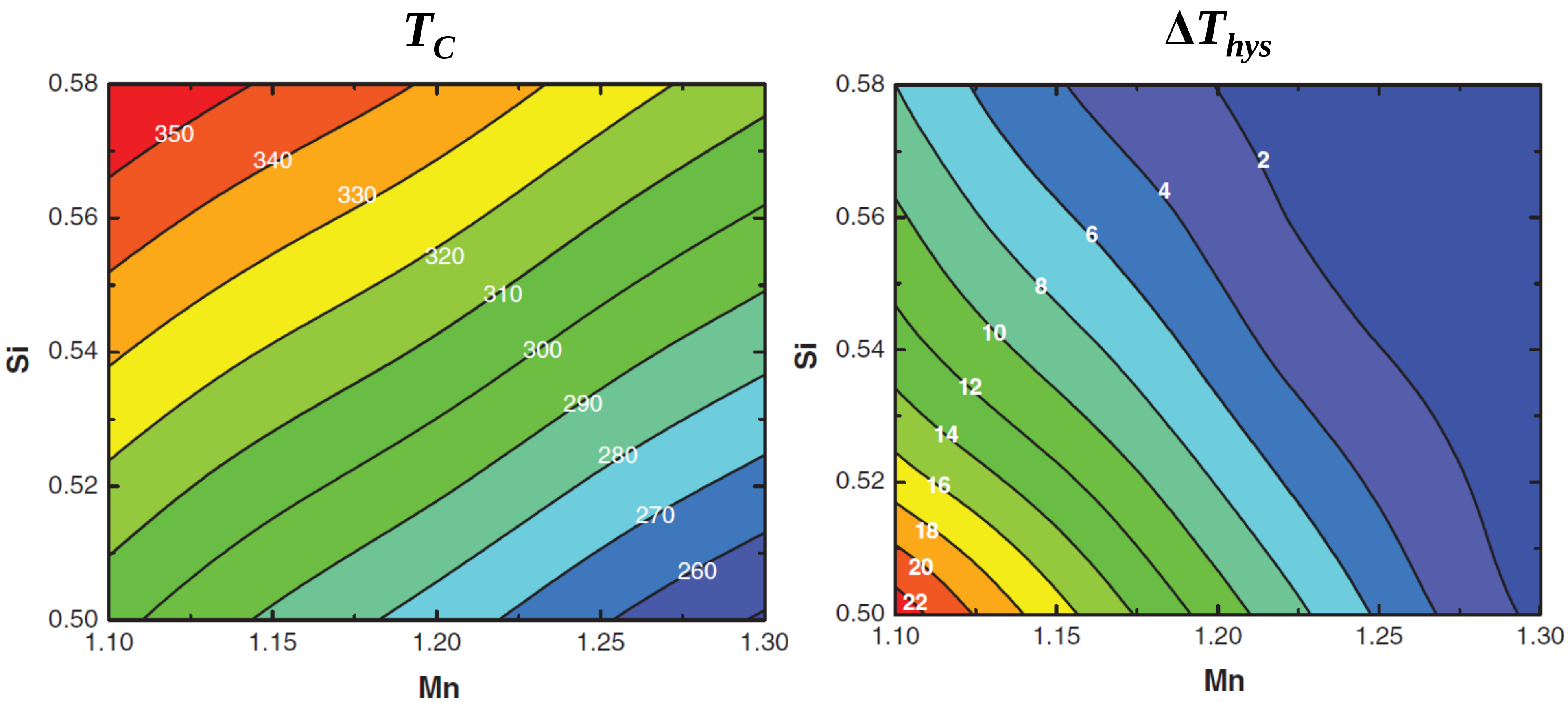


ΔT_{hys}



Dung N.H. *et al.*, *Adv. Energy Mater*. 1, 1215(2011)

$Mn_{1.30}Fe_{0.65}P_{0.67}Si_{0.33}$



Dung N.H. ***et al.*****,** ***Adv. Energy Mater*****. 1, 1215(2011)**

$Mn_{1.30}Fe_{0.65}P_{0.67}Si_{0.33}$ ★

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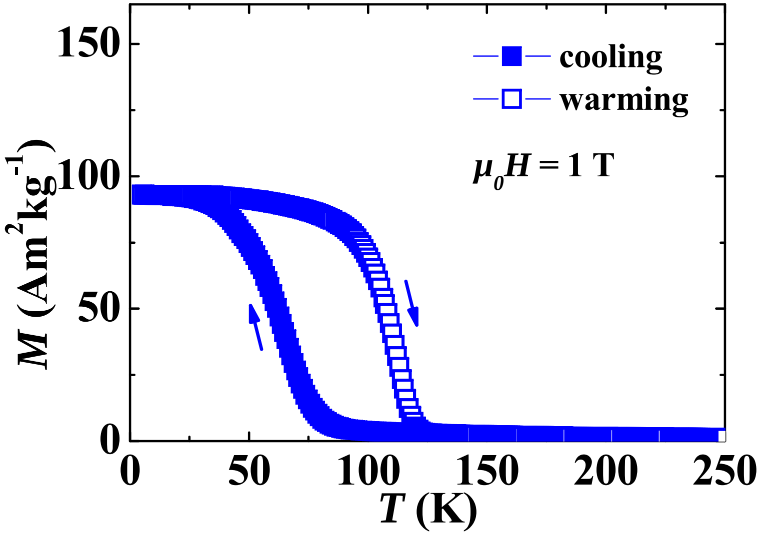
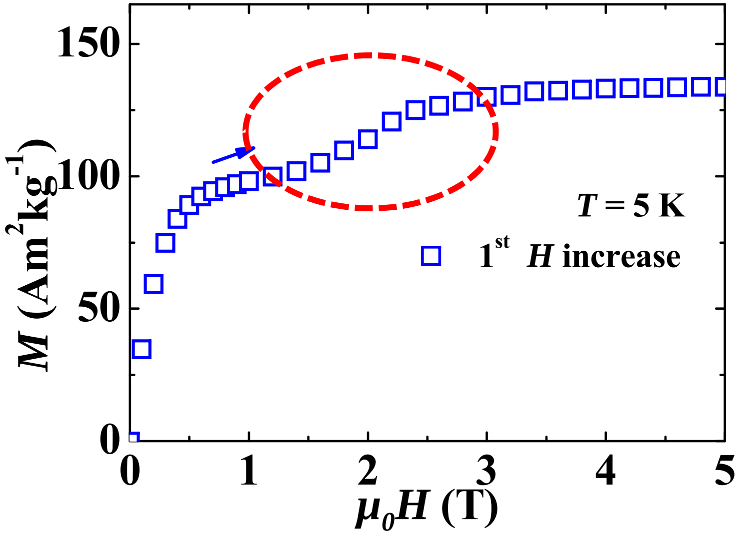
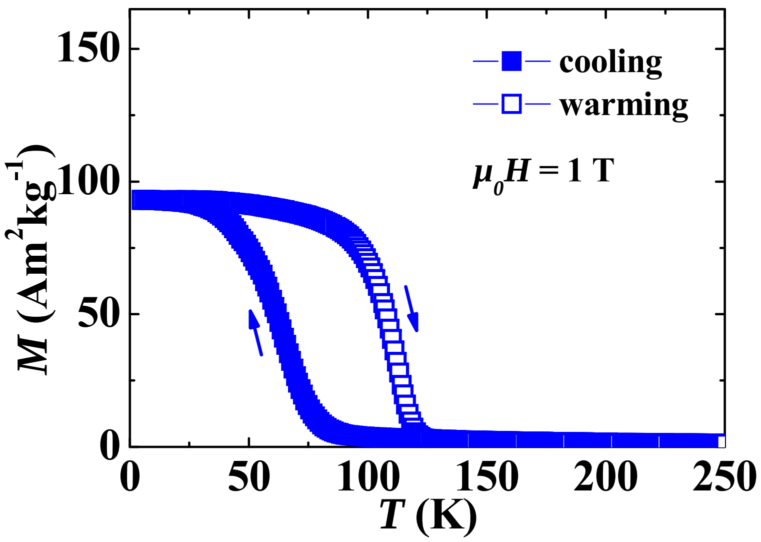
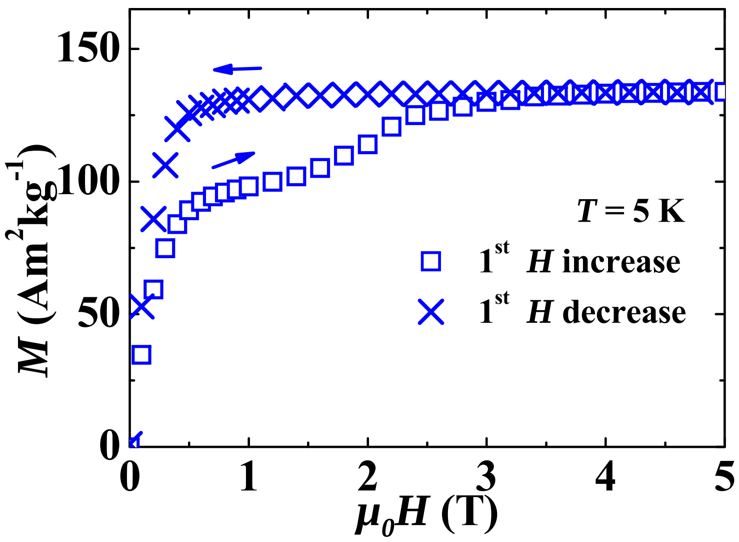




$Mn_{1.30}Fe_{0.65}P_{0.67}Si_{0.33}$





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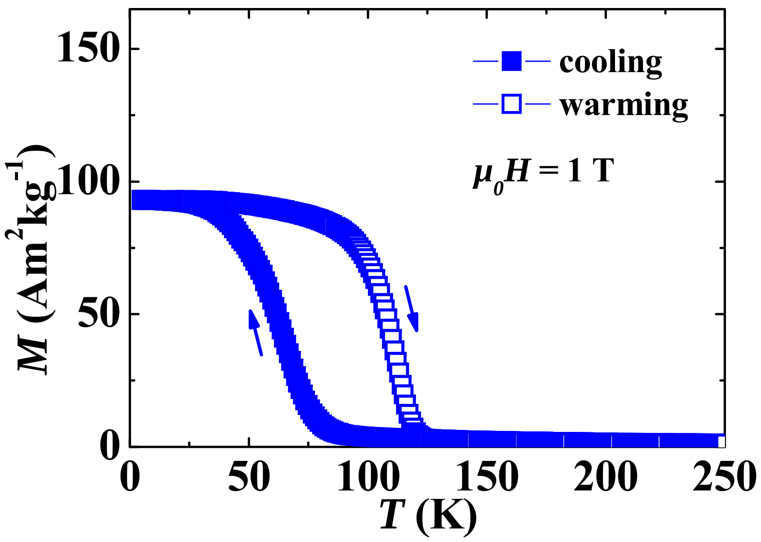
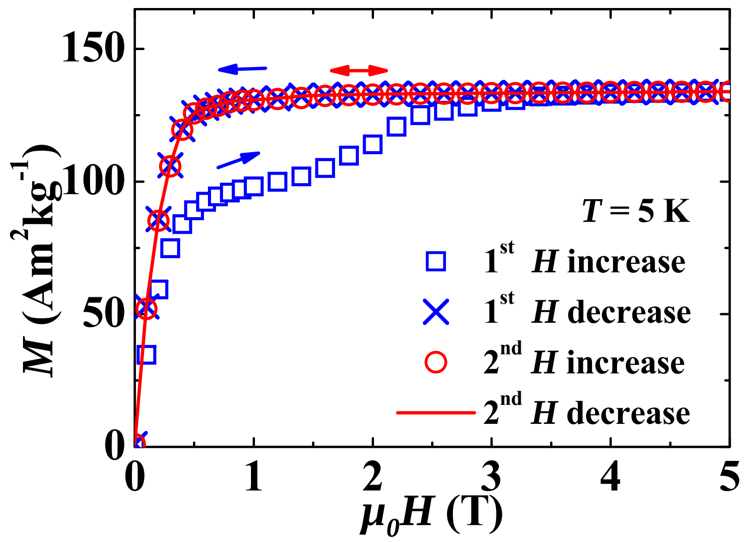
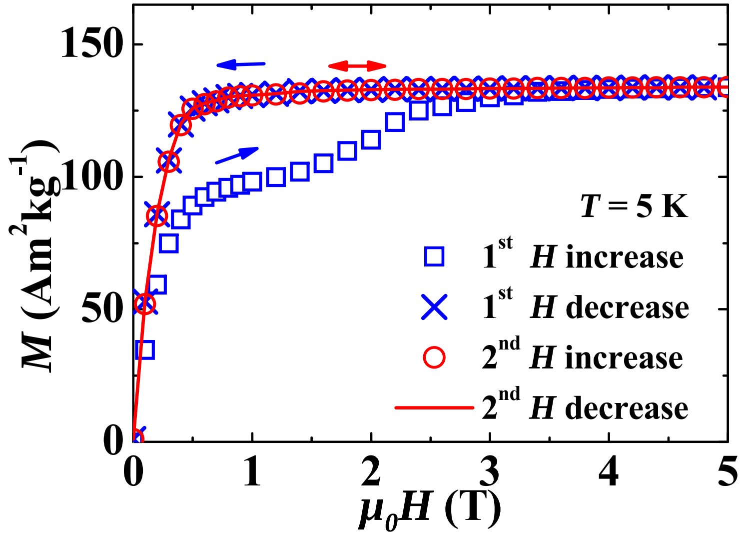




Possible reasons:



(1) At low-*T*, ferrimagnetic or other magnetic structure with low magnetization;

(2) At low-*T*, FM + frozen PM (kinetic arrest).

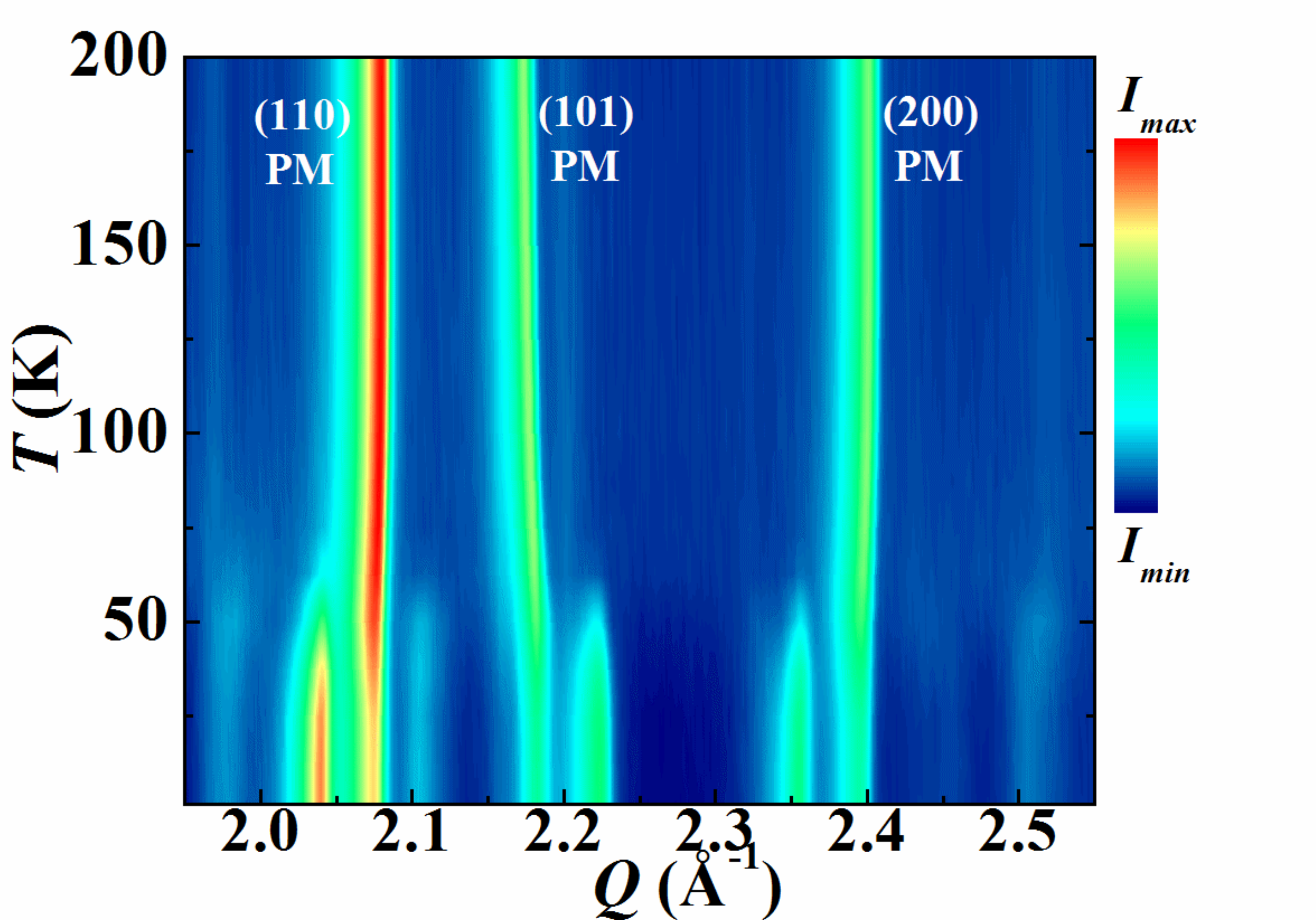
Neutron diffraction

- **Sample: $Mn_{1.30}Fe_{0.65}P_{0.67}Si_{0.33}$**

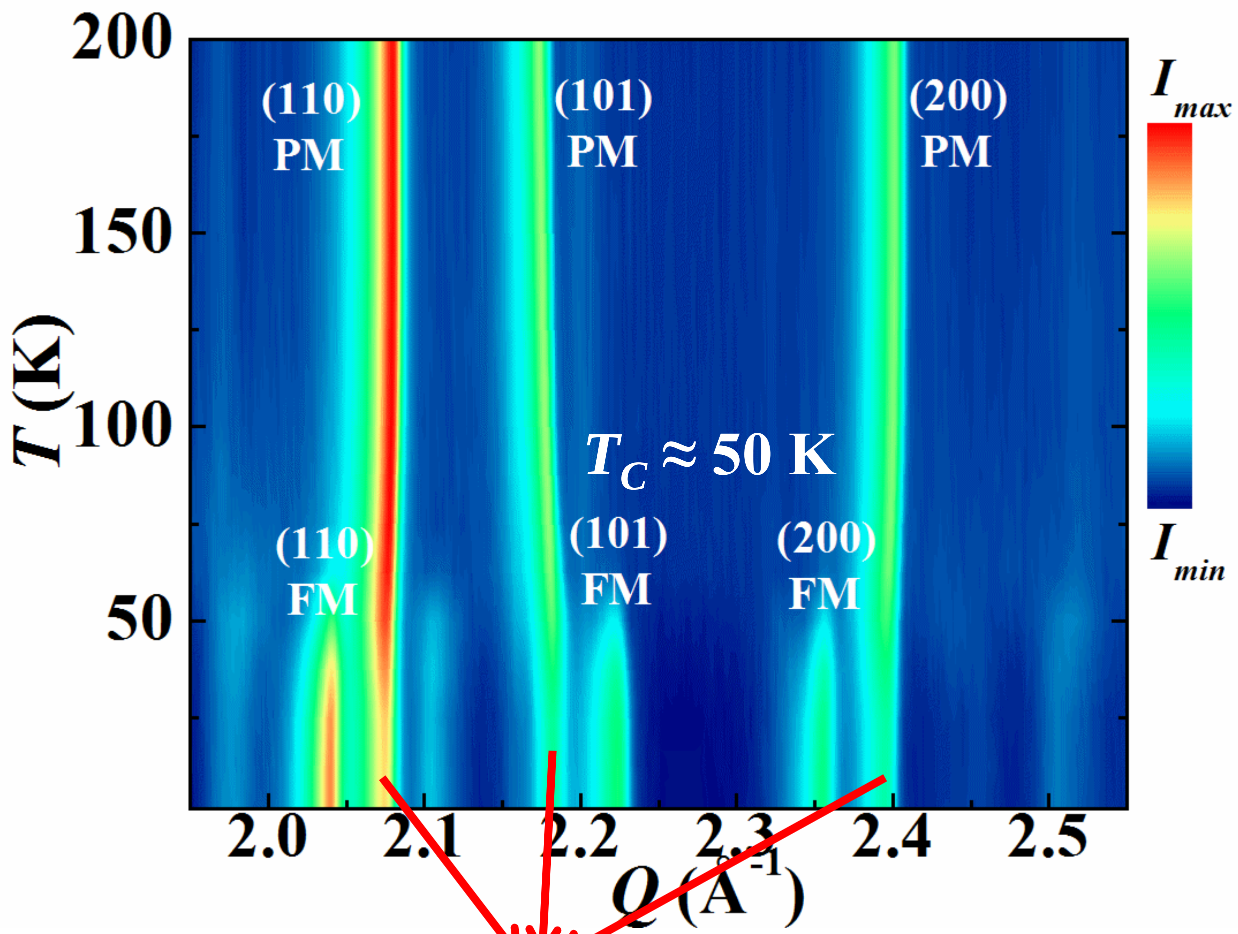
- **Diffractometer: WISH, at ISIS facility, UK**

- **Measurement: Data collected on cooling from 200 K to 1.5 K**

T-dependent neutron diffraction pattern

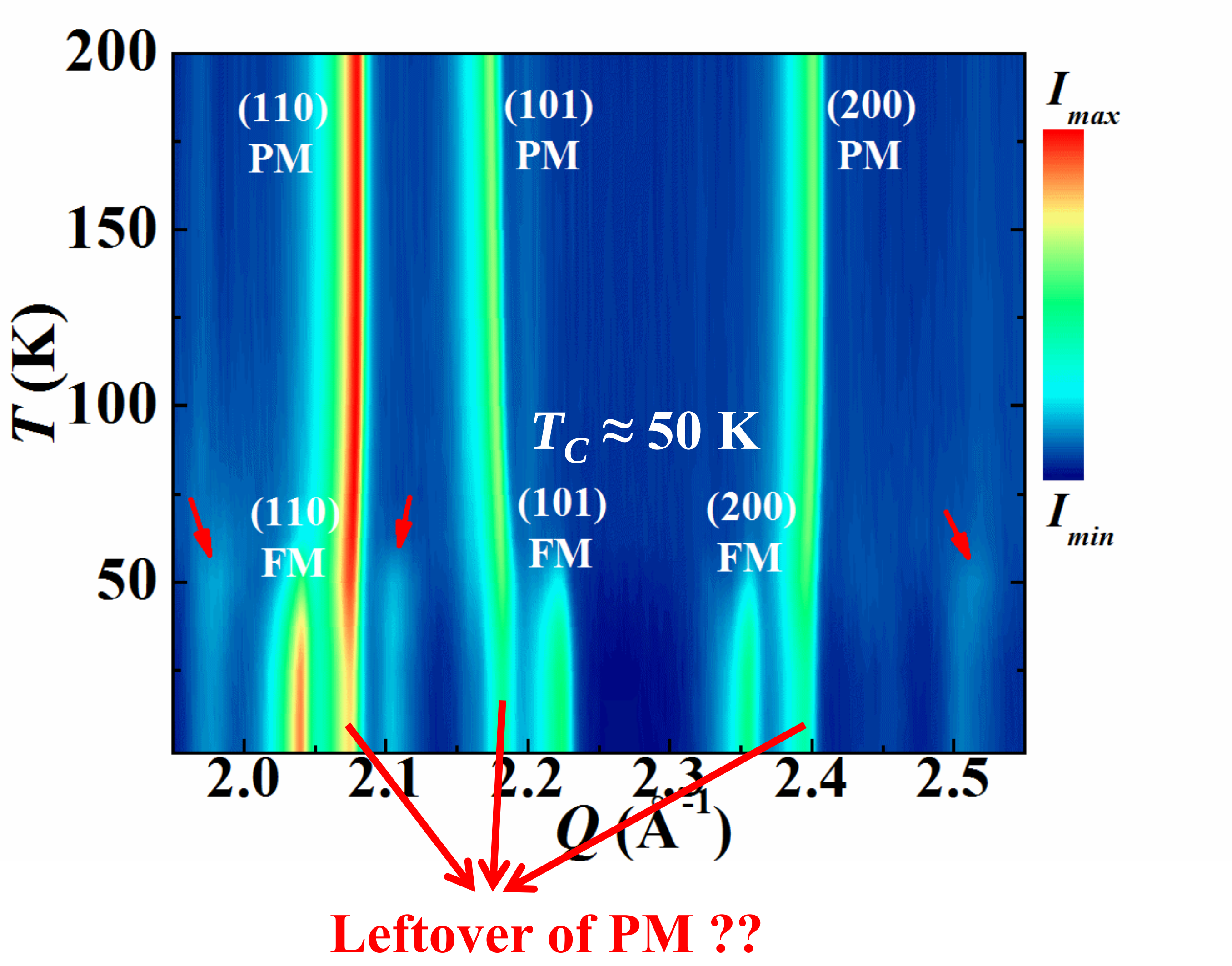


T-dependent neutron diffraction pattern

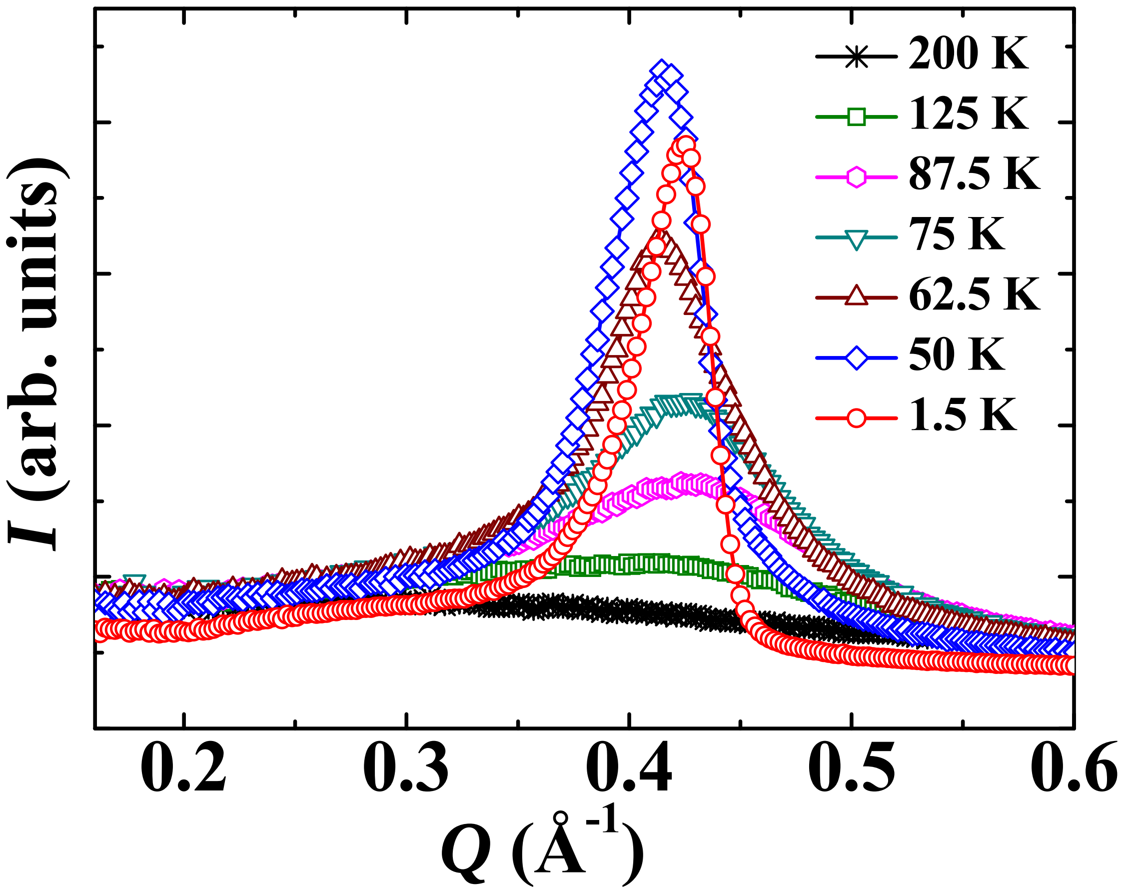


Leftover of PM ??

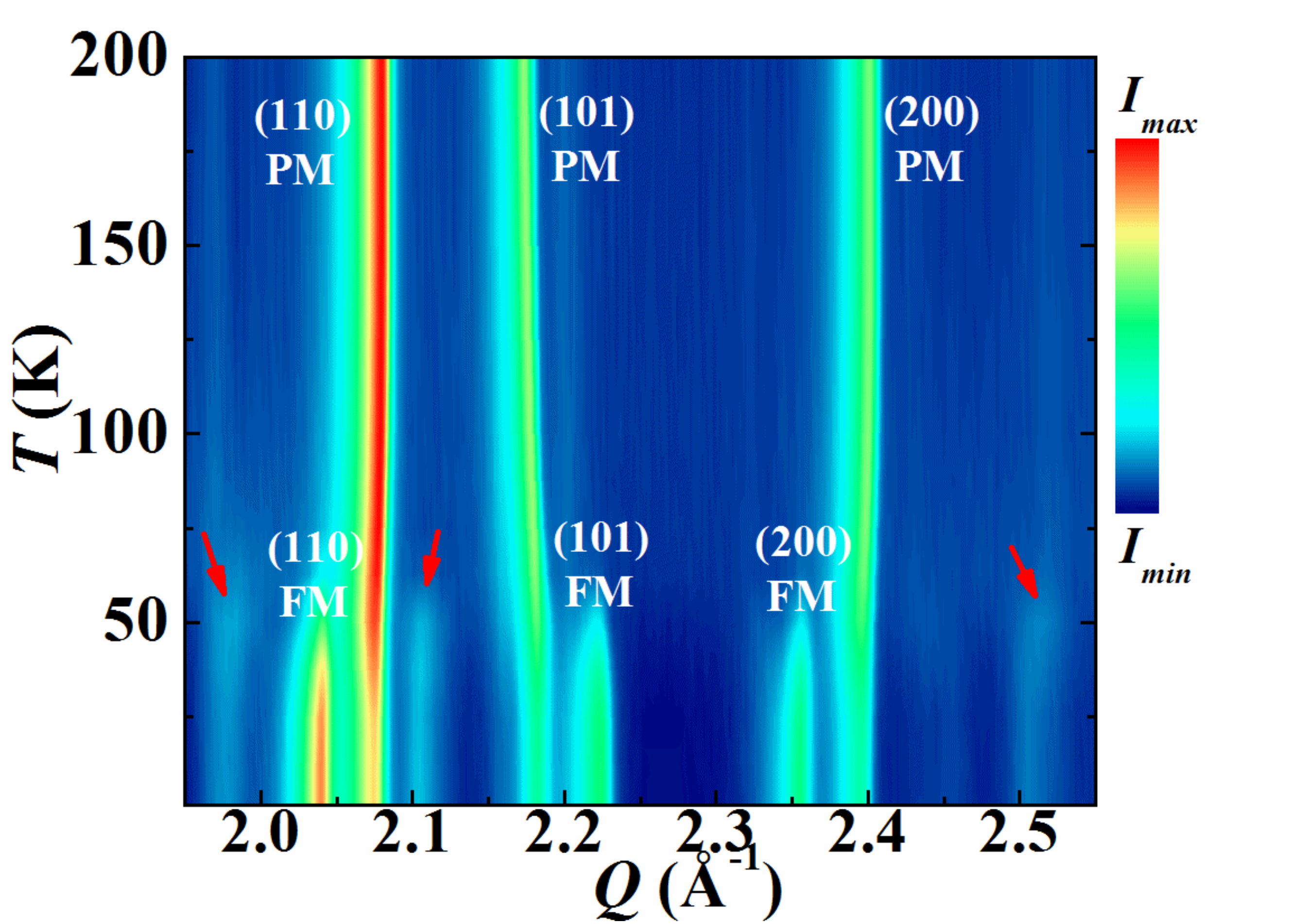
Satellites show up at low *T*



Magnetic reflection at low *Q*



Incommensurate spin-density wave with $\vec{q}$ = 0.36•(1, 0, 0)



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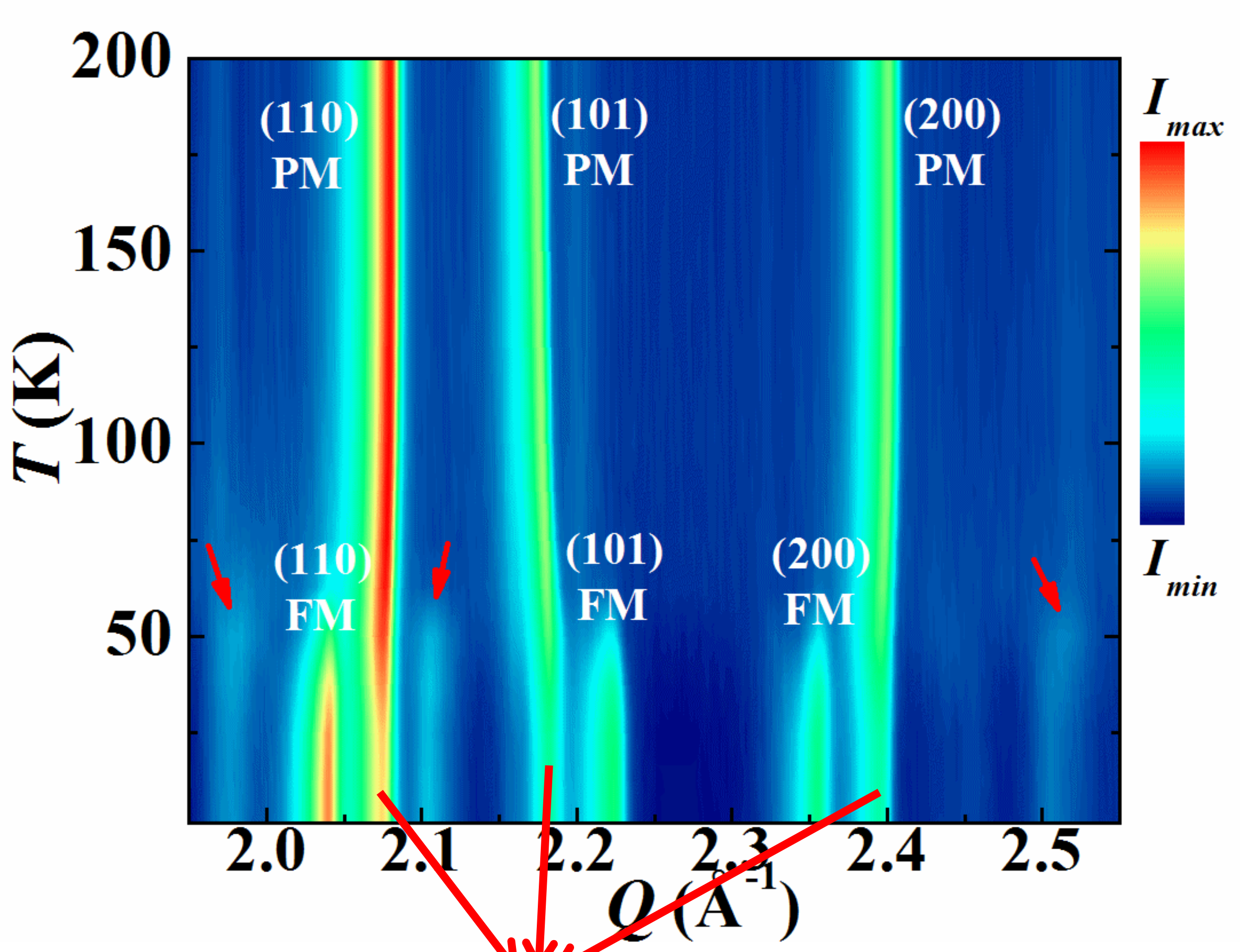
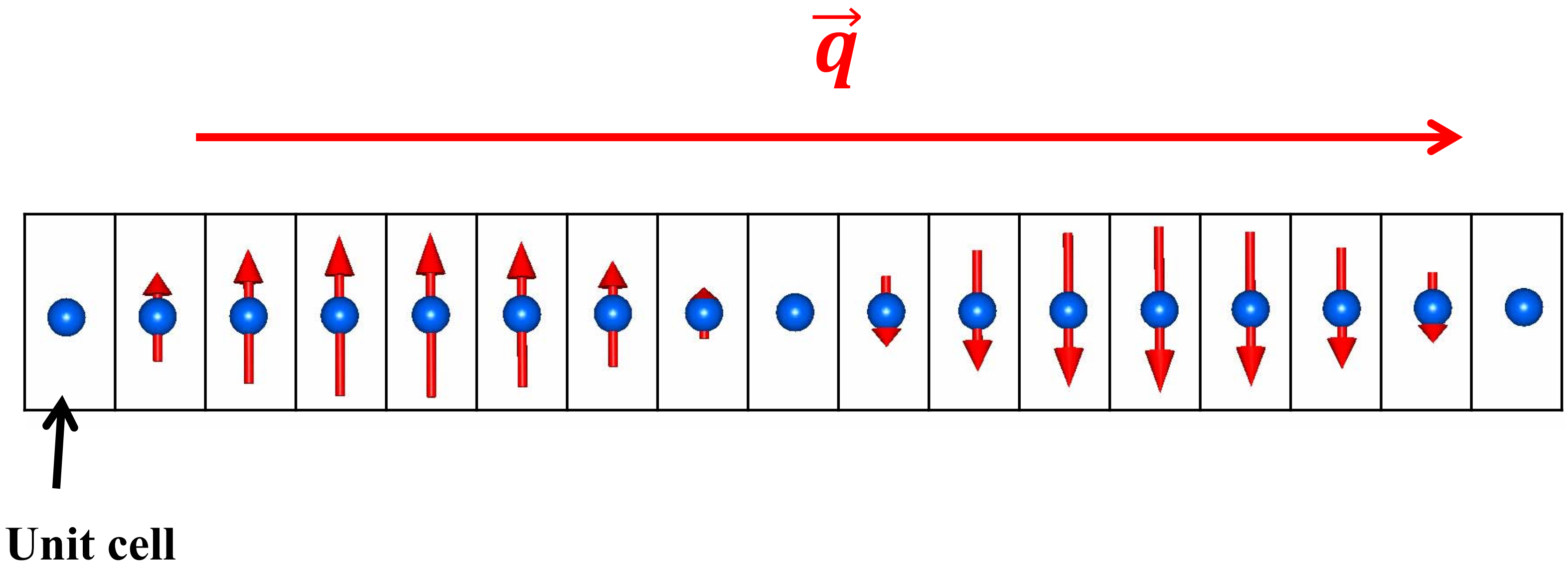
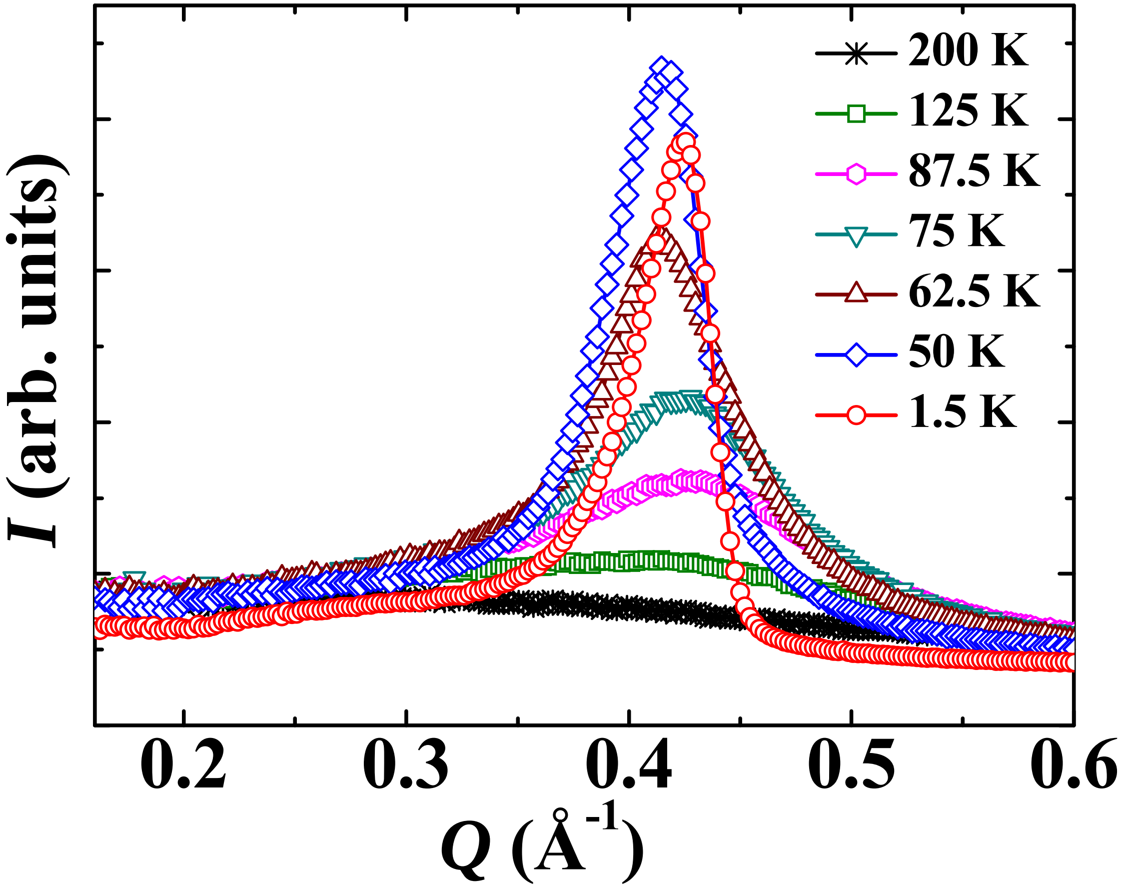


Nuclear scattering of the SDW

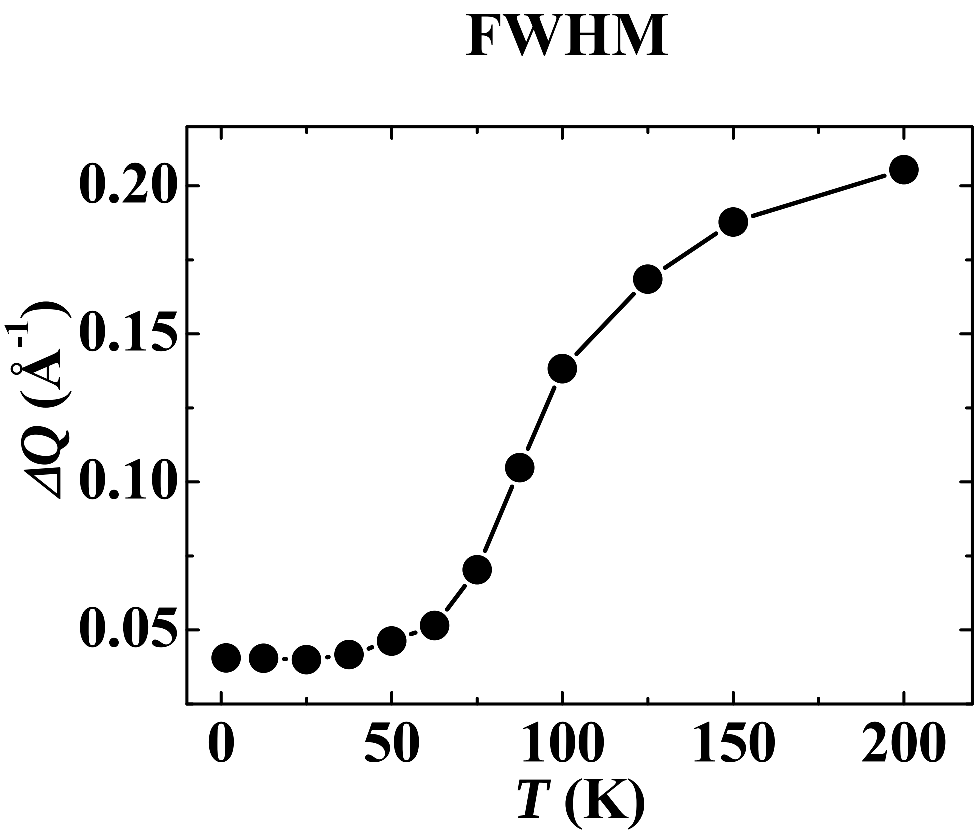
Incommensurate spin-density wave (SDW)



Analysis on the peak at low *Q*



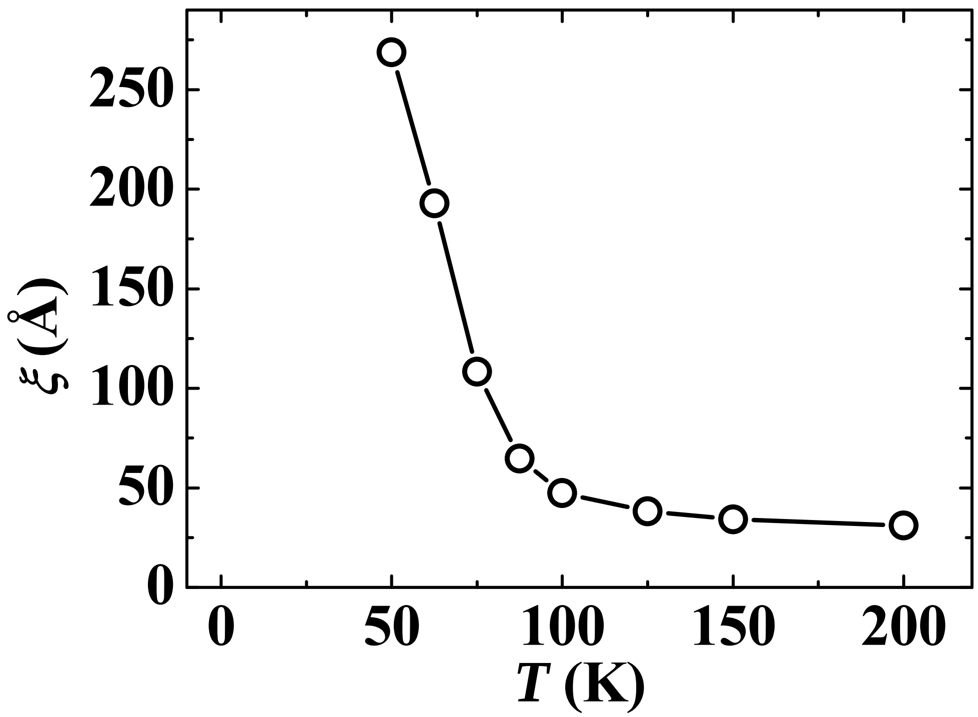
Analysis on the peak at low Q



Analysis on the peak at low *Q*

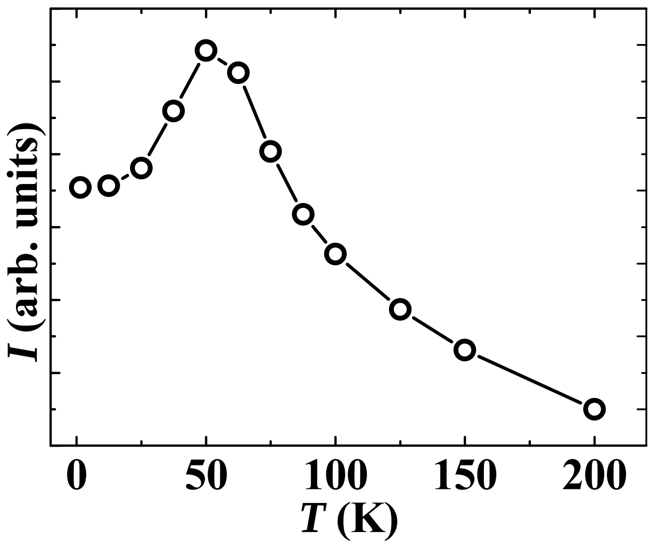
Short-range magnetic correlation

Correlation length of SDW



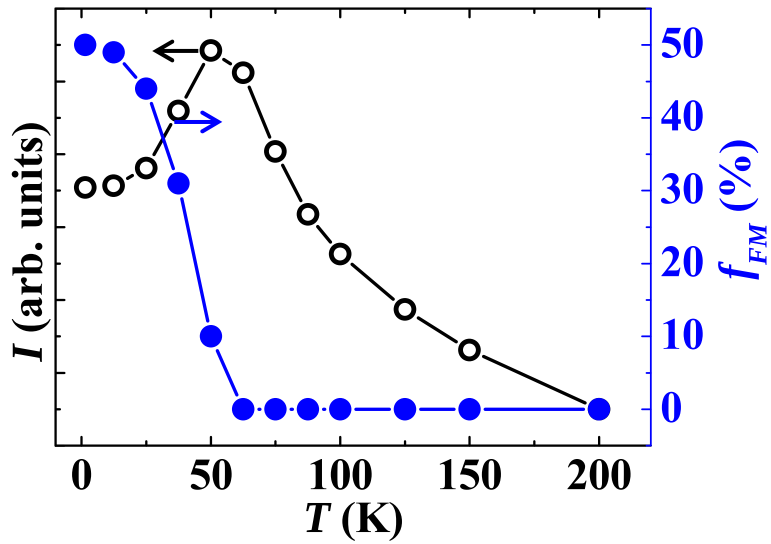
Analysis on the peak at low *Q*

Integrated intensity

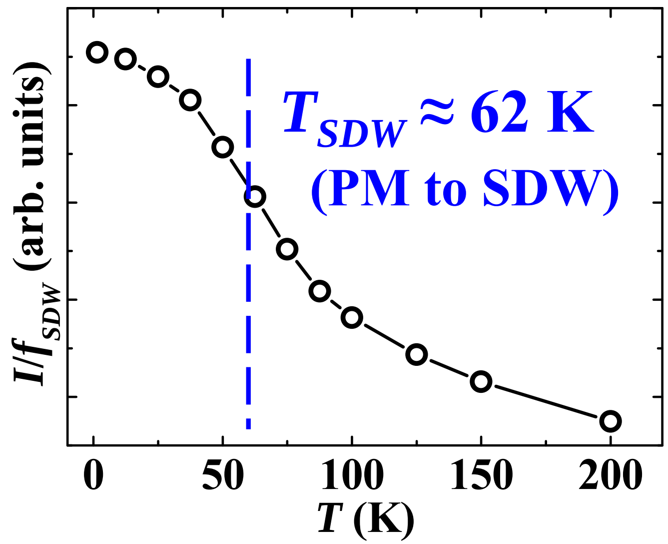


Analysis on the peak at low *Q*

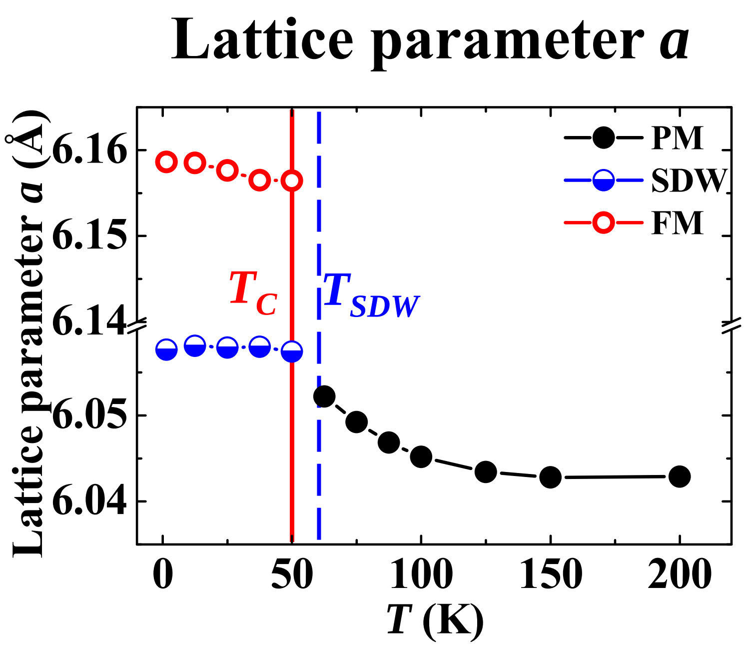
Integrated intensity

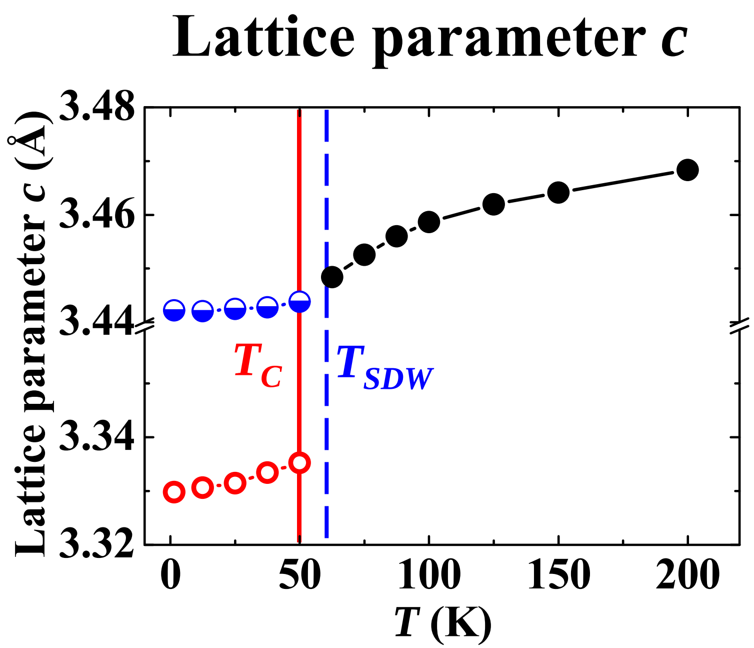


Normalized intensity



Lattice parameters





- ❖ **PM → SDW transition, $T_{SDW} \approx 62$ K, is a second-order transition;**
- ❖ **SDW→ FM transition, $T_C \approx 50$ K, is a first-order transition;**

Metastability of the SDW phase

- In-field x-ray diffraction

- Magnetic relaxation measurements

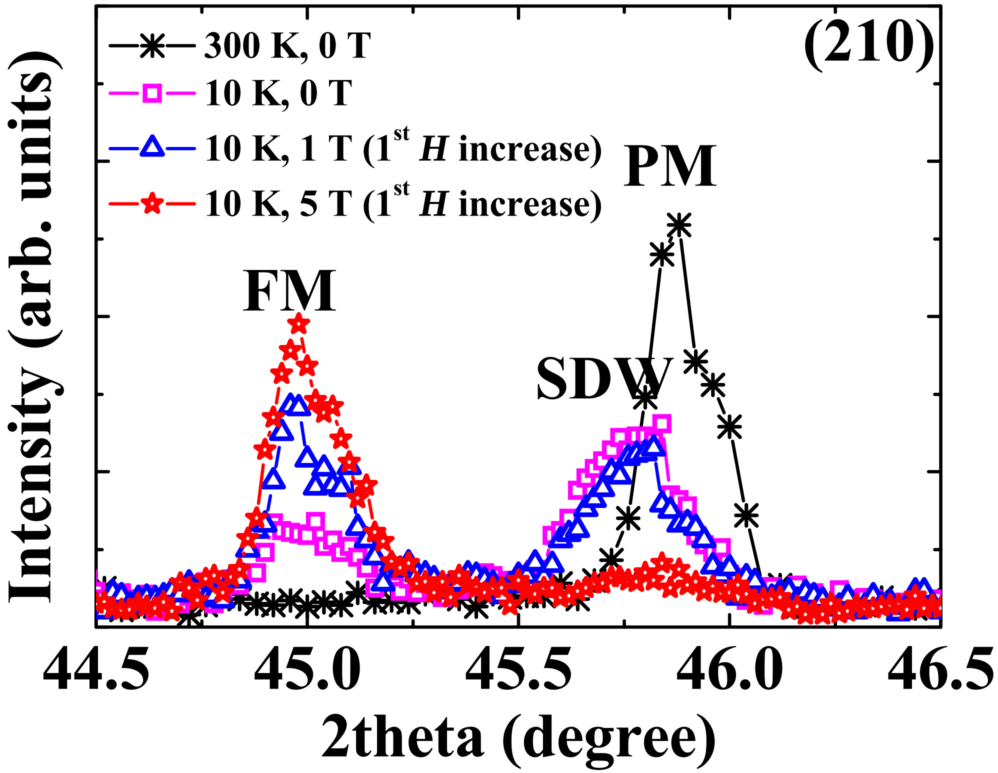
In-field x-ray diffraction

- Sample: $Mn_{1.30}Fe_{0.65}P_{0.67}Si_{0.33}$

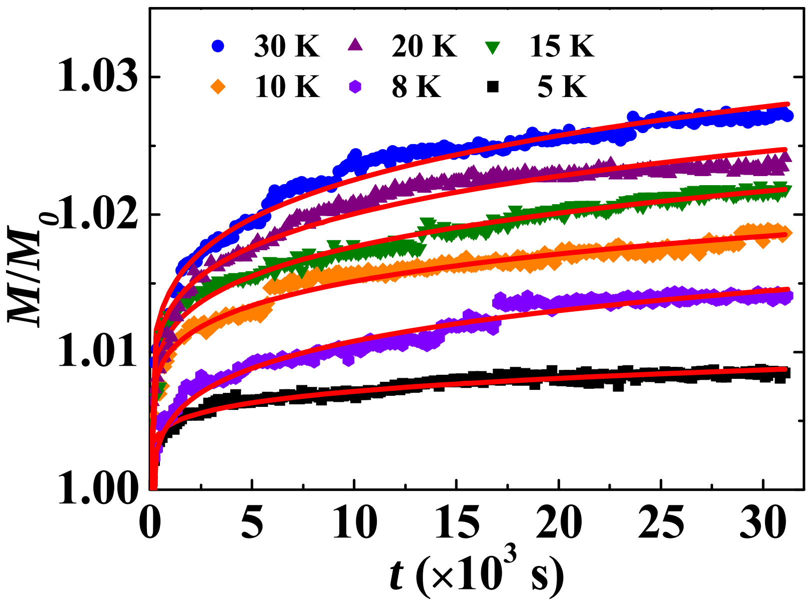
- Measurement: at 300 K and 10 K in magnetic field 0 – 5 T

In-field x-ray diffraction

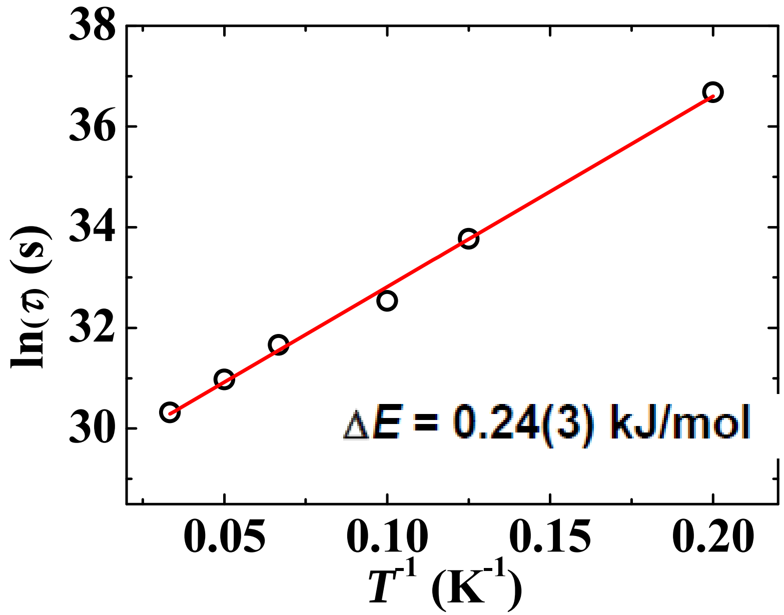
Two phases at low-*T* (SDW→ stable FM)



Magnetic relaxation measurement



$$M/M_0 \propto \exp[-(t/\tau)^\beta]$$



$$\tau \propto exp(\frac{\Delta E}{RT})$$

Summary

PM

↓

PM with short-range magnetic ordering

↓ $T_{SDW} \approx$ **62 K, 2nd order**

SDW

↓ $T_C \approx$ **50 K, 1st order**

FM

❖ **Due to small thermal energy at low *T*, the SDW-FM transition is kinetically arrested and phase coexistence is observed. The SDW phase is metastable.**

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P. Manuel

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K. Takahashia

Thank you for your attention!