PHD DAYS PRESENTATION

Probing the crystal and magnetic structure evolution from Perovskite to Brownmillerite In $La_{0.7}Sr_{0.3}MnO_{3-\delta}$

15.02.2024 JCNS-2 FORSCHUNGSZENTRUM JÜLICH

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OUTLINE

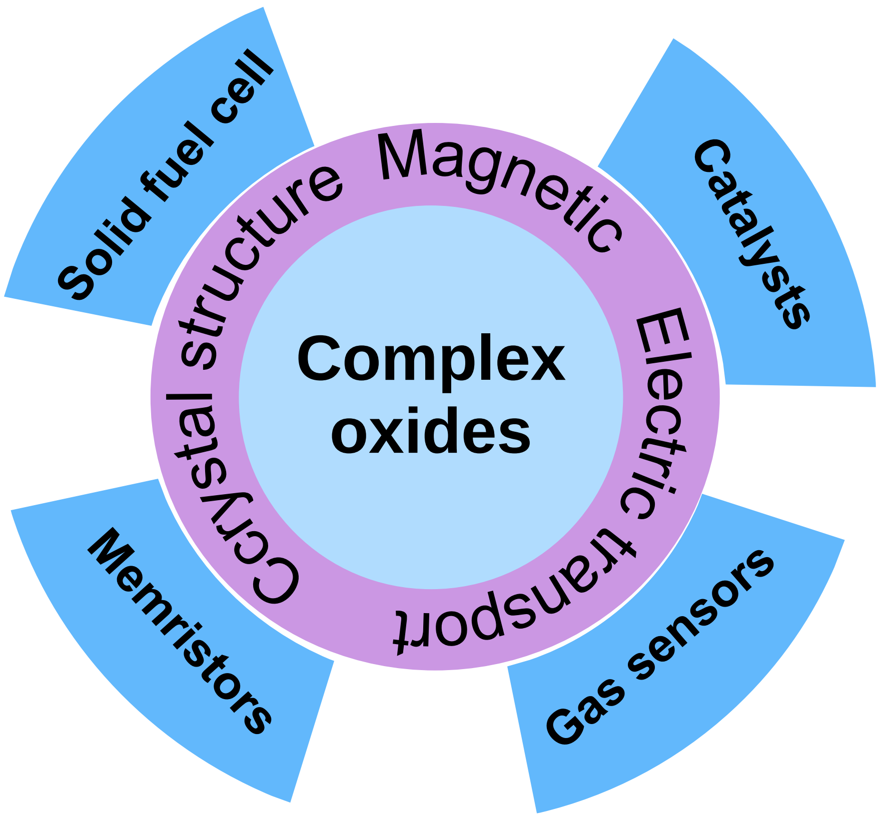
1. Introduction, motivation and project focus

2. Probing the crystal and magnetic structure evolution from PV to BM at the micro-, meso- and macroscopic length scale

3. Conclusions and outlook

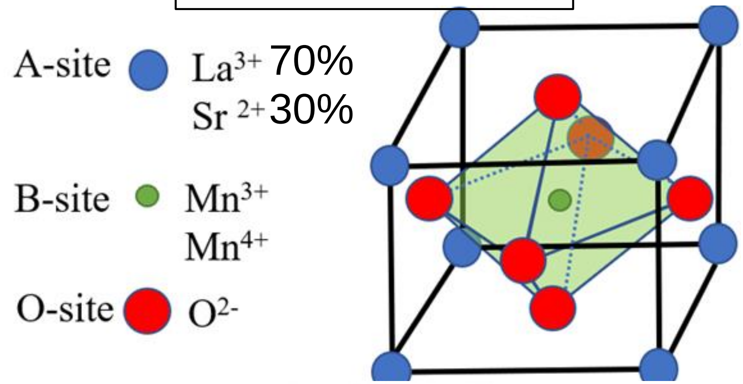
1. INTRODUCTION, MOTIVATION AND PROJECT FOCUS

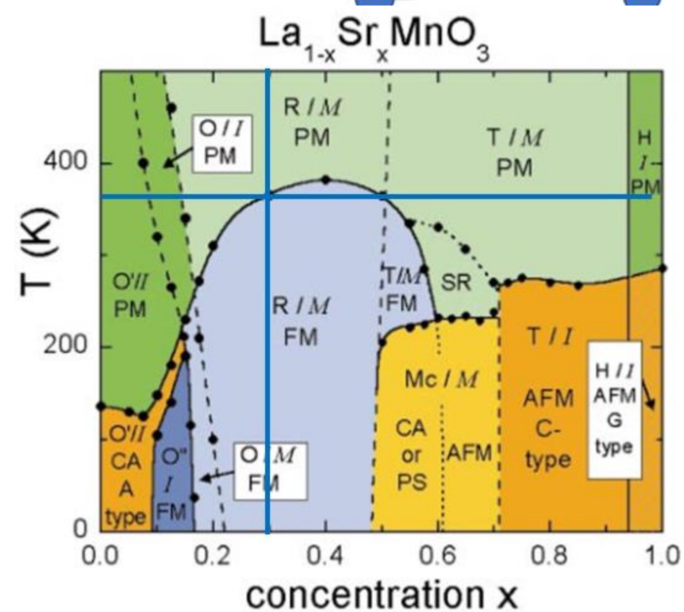
Complex oxides



Various applications of complex oxides

$La_{0.7}Sr_{0.3}MnO_{3-\delta}$





Hemberger, J., et al., Physical Review B, 2002.66(9): p.1-8

1. INTRODUCTION, MOTIVATION AND PROJECT FOCUS

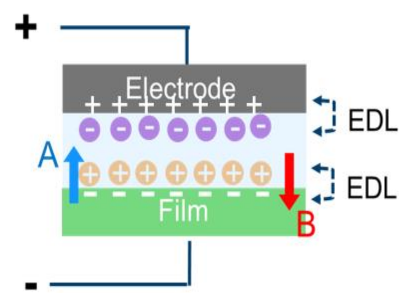
Deoxygenation

During master thesis

Perovskite
R -3 c H

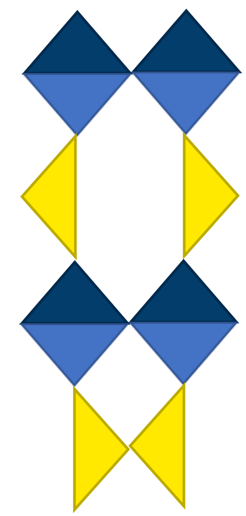
- **Thermal annealing**

- **Al-assisted thermal annealing**
- **Ionic liquid gating**



- **Structure and magnetic properties of PV and BM**

Brownmillerite
C2/c



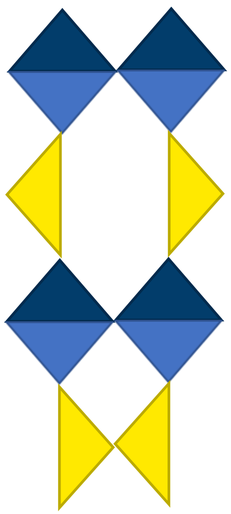
Deoxygenation

PhD thesis focus

Perovskite
R -3 c H

Step by step evolution process

Brownmillerite
C2/c



Muti-length

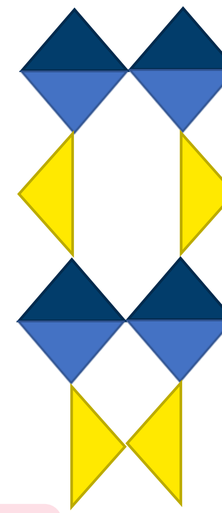
- **Microscopic**
- **Mesoscopic**
- **Macroscopic**

Detailed understanding of topotactic phase transition

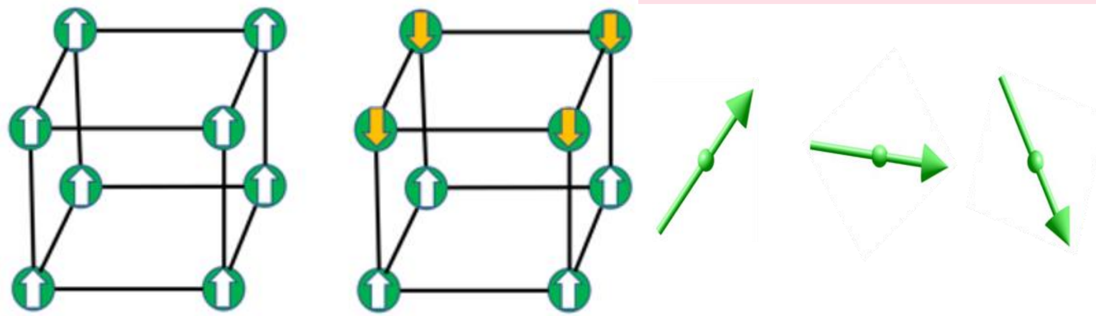
1. INTRODUCTION, MOTIVATION AND PROJECT FOCUS

Perovskite
R -3 c H

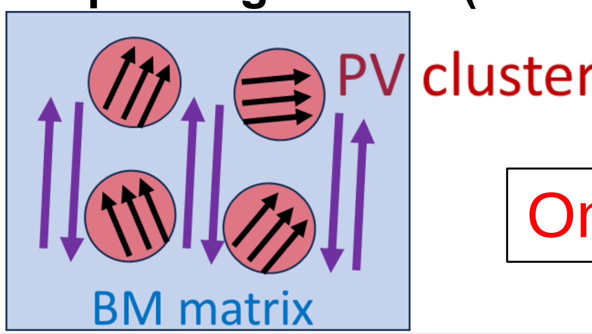
Brownmillerite
C2/c



☑ ◆ Microscopic length scale (neutron powder diffraction…)

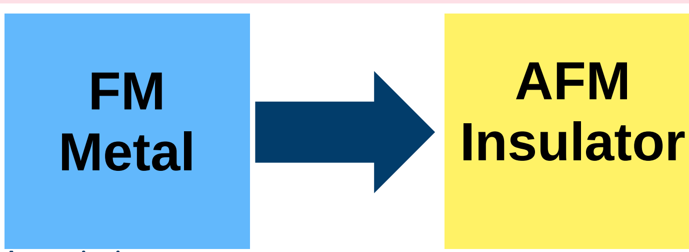


☐ ◆ Mesoscopic length scale (GISANS,SANS,PEEM…)



On going project!

☑ ◆ Macroscopic length scale (SQUID-magnetometry…)

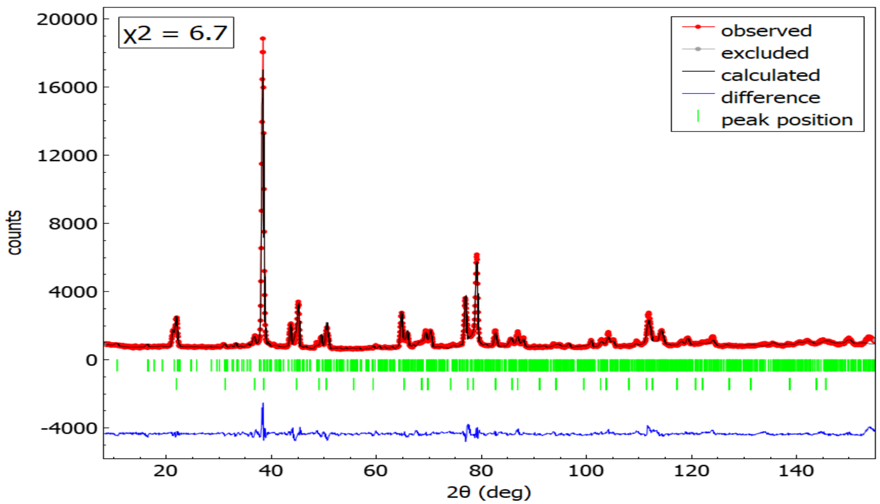


2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

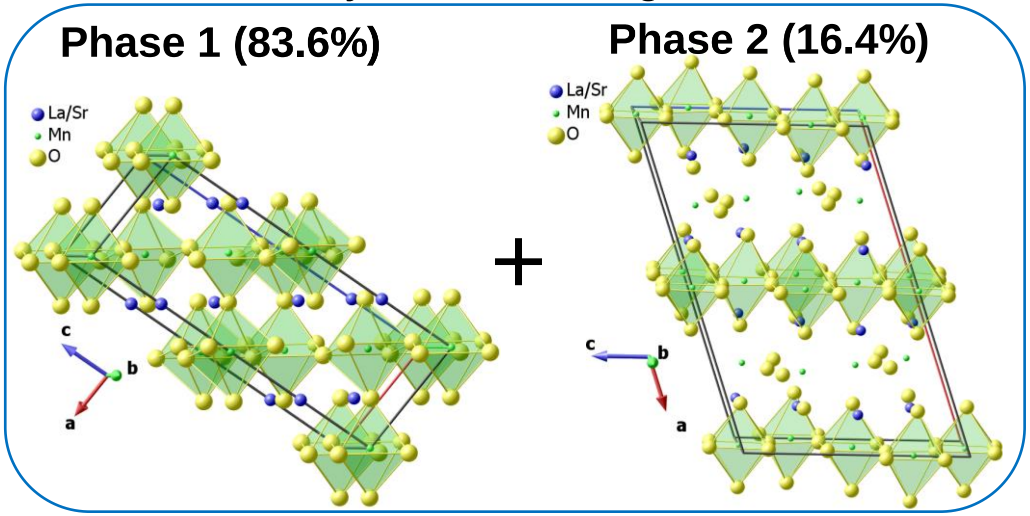
LSMO powder, INTER. 1, neutron powder diffraction at PSI, HRPT

PAUL SCHERRER INSTITUT

High T 400K



crystal clustering?



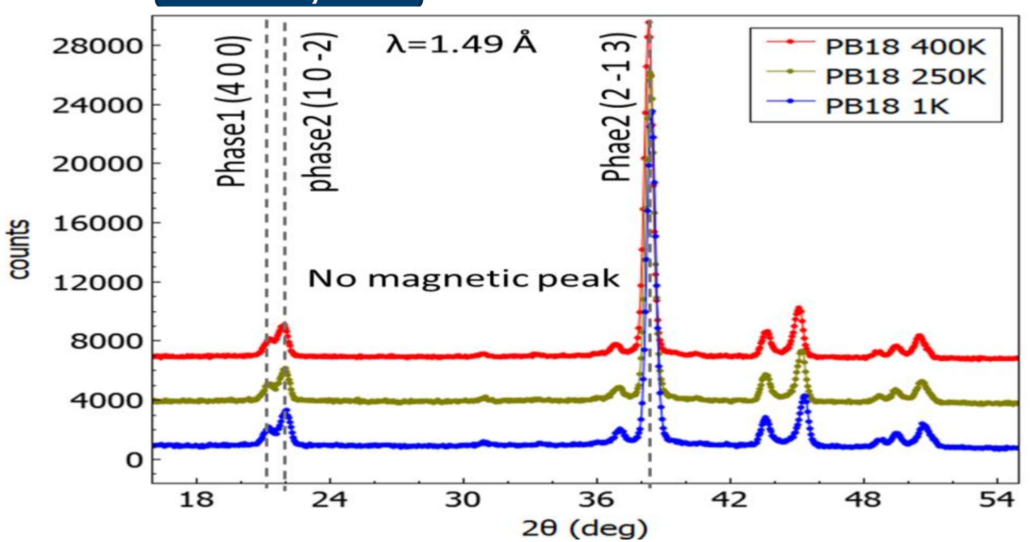
Phase 1: **Perovskite (R3-c)167**

a=5.525Å	b=5.525Å	c=13.537Å
α=90° β=90°	γ=120°	V= 357.9$Å^3$

Phase 2: **(C2/c) 15**

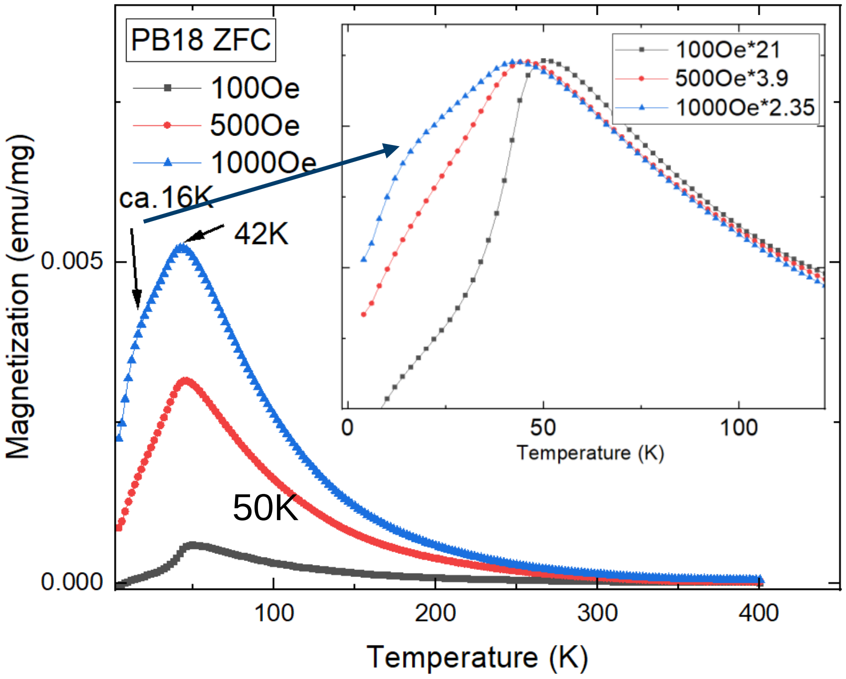
a=16.814Å	b=5.458Å	c=10.901Å
α=90°	β=108.707° γ=90°	V= 947.8$Å^3$

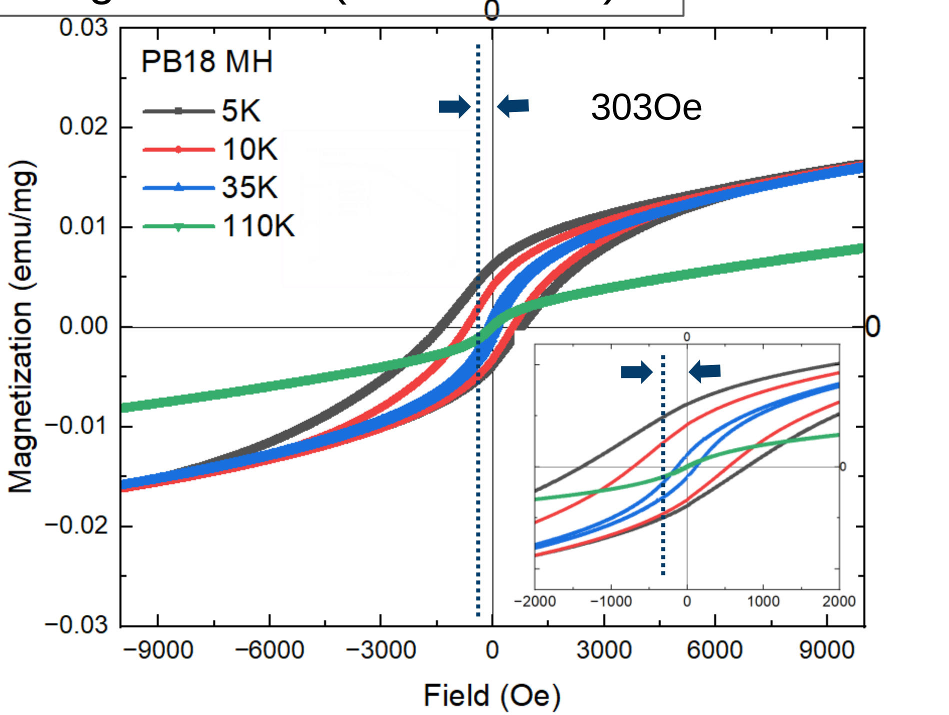
Low T, 1K



2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

LSMO powder, INTER. 1, Vibrating Sample Magnetometer(PPMS-VSM)



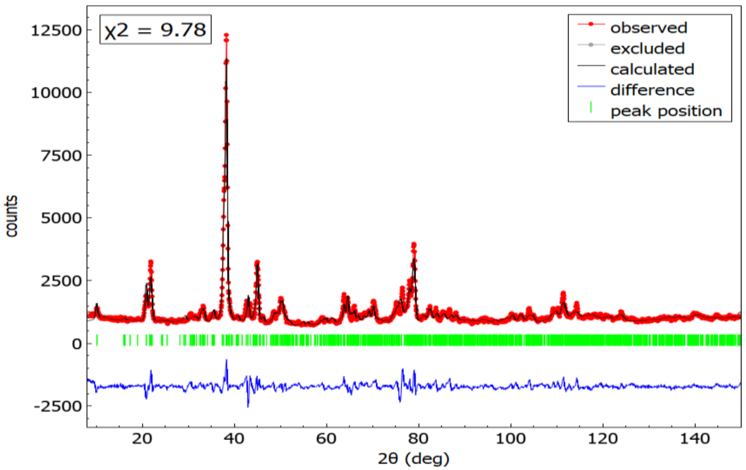


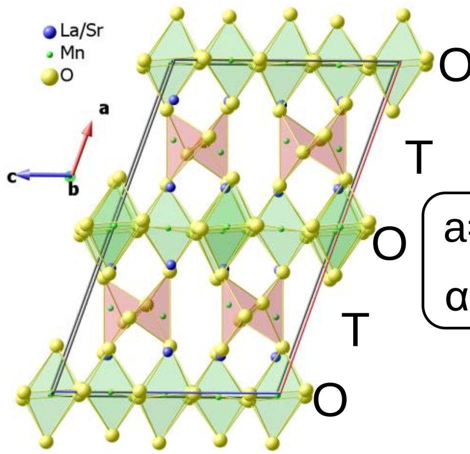
- Peak at 16K and at 42K indicates spin glass state and superparamagnetic state. (need AC-susceptibility)
- Exchange bias of 303Oe of at 5K implies the interaction between different magnetic states. e.g. between FM cluster and AFM cluster.

2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

LSMO powder, INTER. 2 (more $V_{\ddot{O}}$), neutron powder diffraction at PSI, HRPT

High T 400K



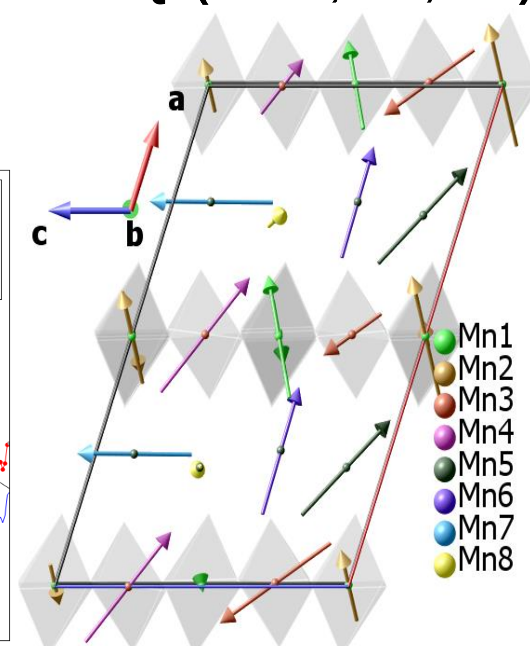


Near-Brownmillerite (C2/c)15

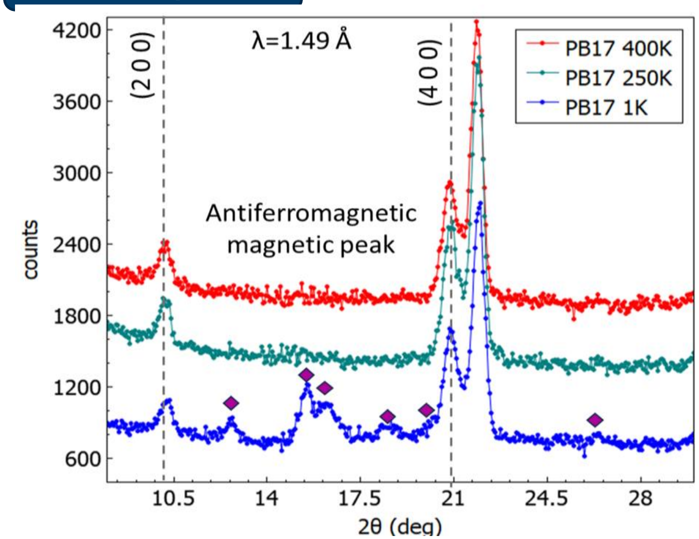
a=17.109Å b=5.437Å c=10.965Å

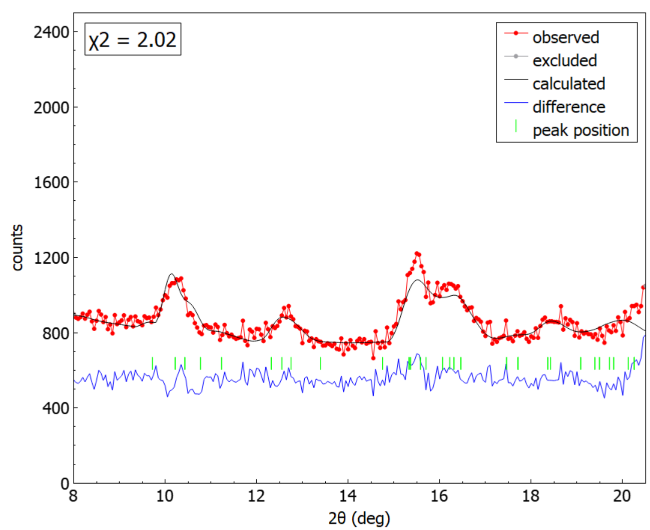
α=90° β=109.627° γ=90° V= 961Å^3

Q=(-0.125,0.25,0.15)



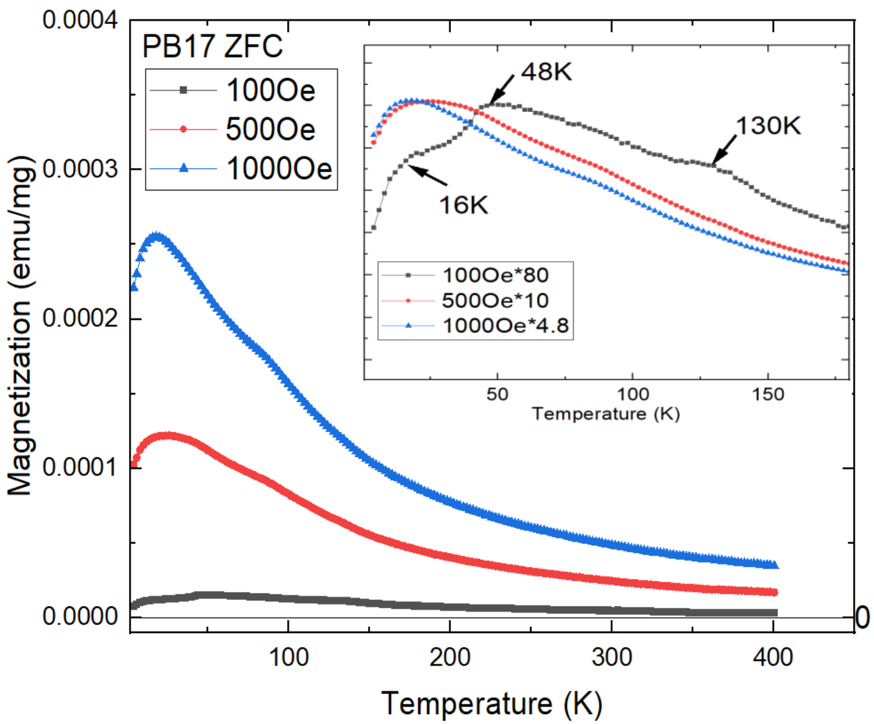
Low T, 1K

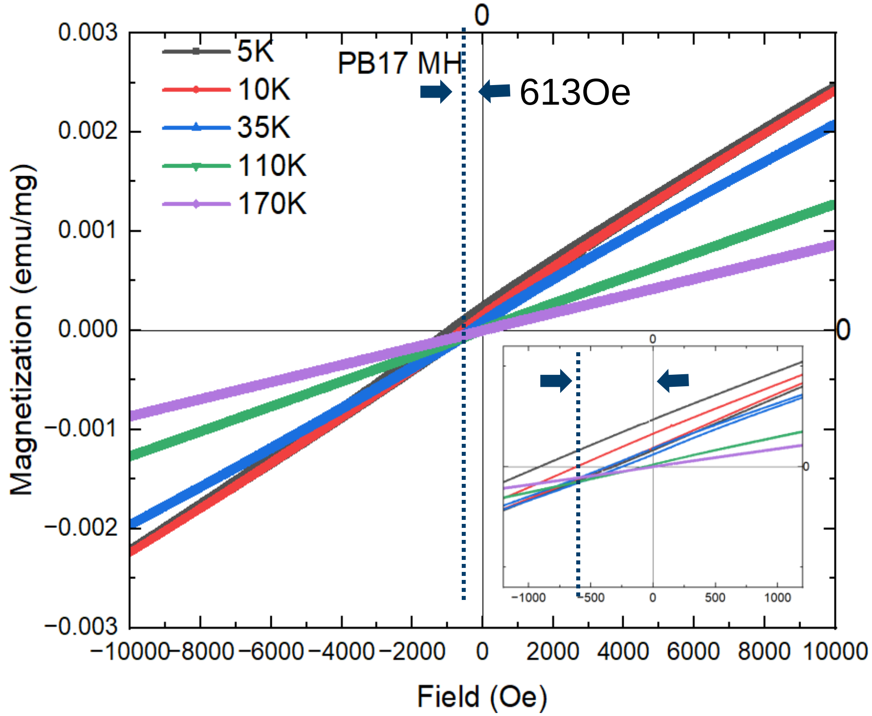




2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

LSMO powder, INTER. 2 (more $V_{\ddot{O}}$), Vibrating Sample Magnetometer(PPMS-VSM)



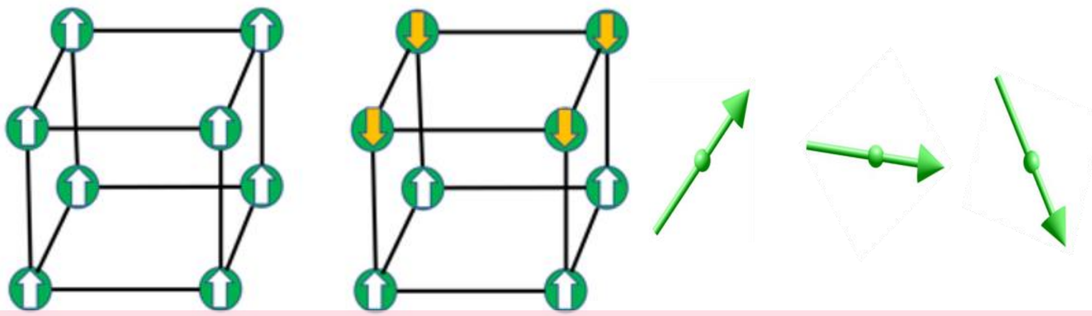


- 3 Peaks at 16K and at 48K and 130K.
- Peaks due to AFM at different T? (need neutron thermodiffraction) Or due to AFM+SP+SG? (need AC-susceptibility)
- Exchange bias of 613Oe of at 5K. ➡ Strong interaction.

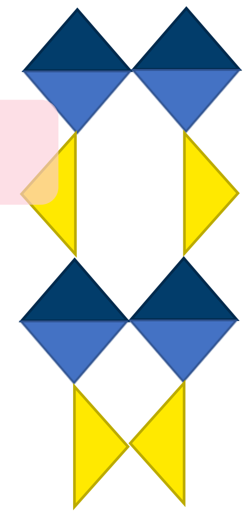
1. INTRODUCTION, MOTIVATION AND PROJECT FOCUS

☑ ◆ **Microscopic length scale (neutron powder diffraction…)**

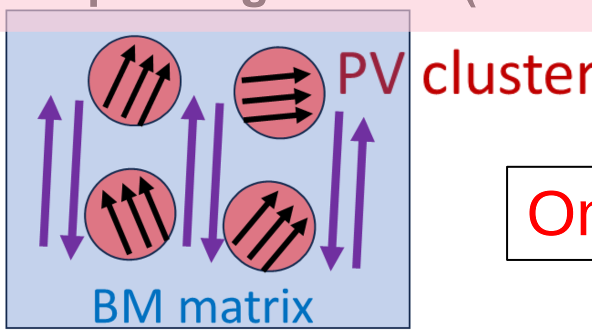
Perovskite
R -3 c H



Brownmillerite
C2/c



☐ ◆ Mesoscopic length scale (GISANS,SANS,PEEM…)



On going project!

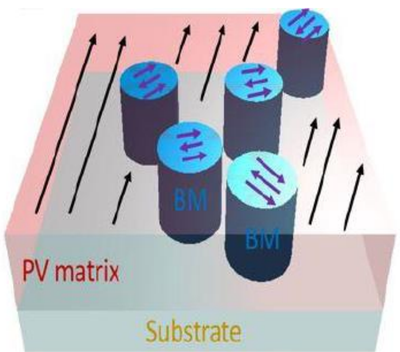
☑ ◆ **Macroscopic length scale (SQUID-magnetometry…)**

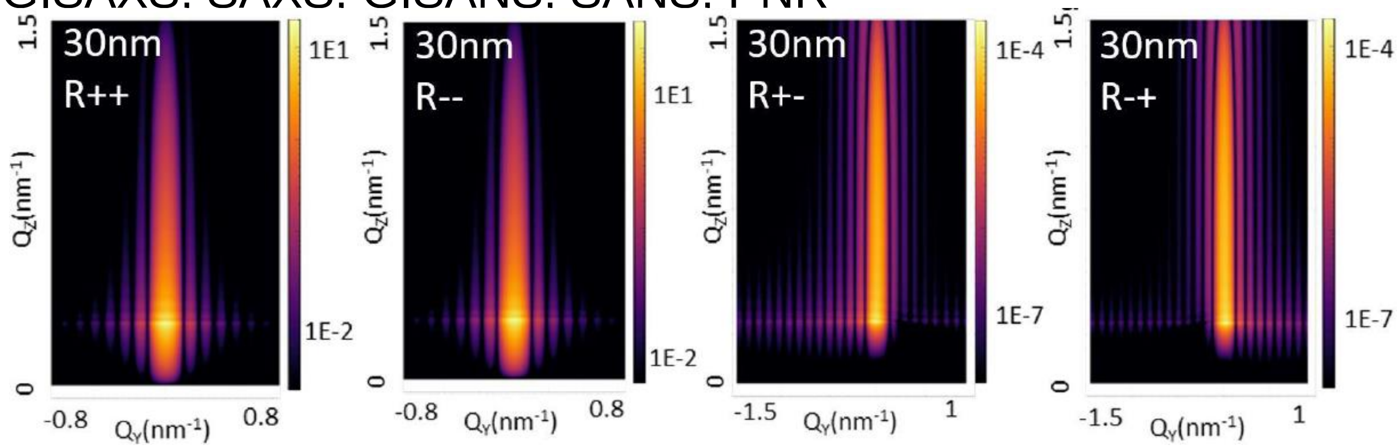
FM Metal → **AFM Insulator**

2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

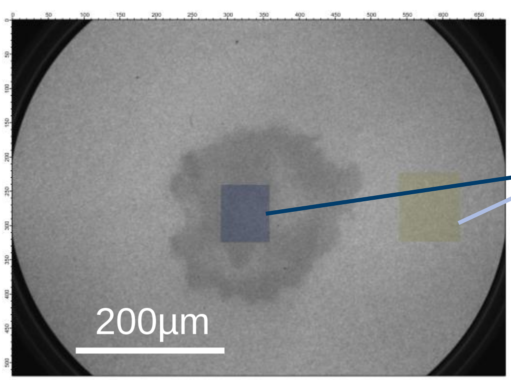
Experimental methods for probing mesoscopic information

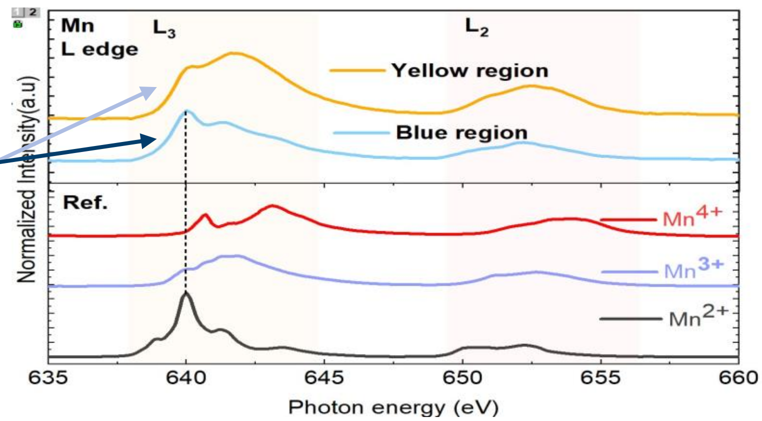
1. Scattering method: GISAXS. SAXS. GISANS. SANS. PNR





2.Imaging method: PEEM, STXM, STEM

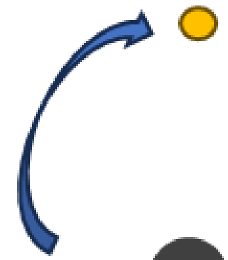




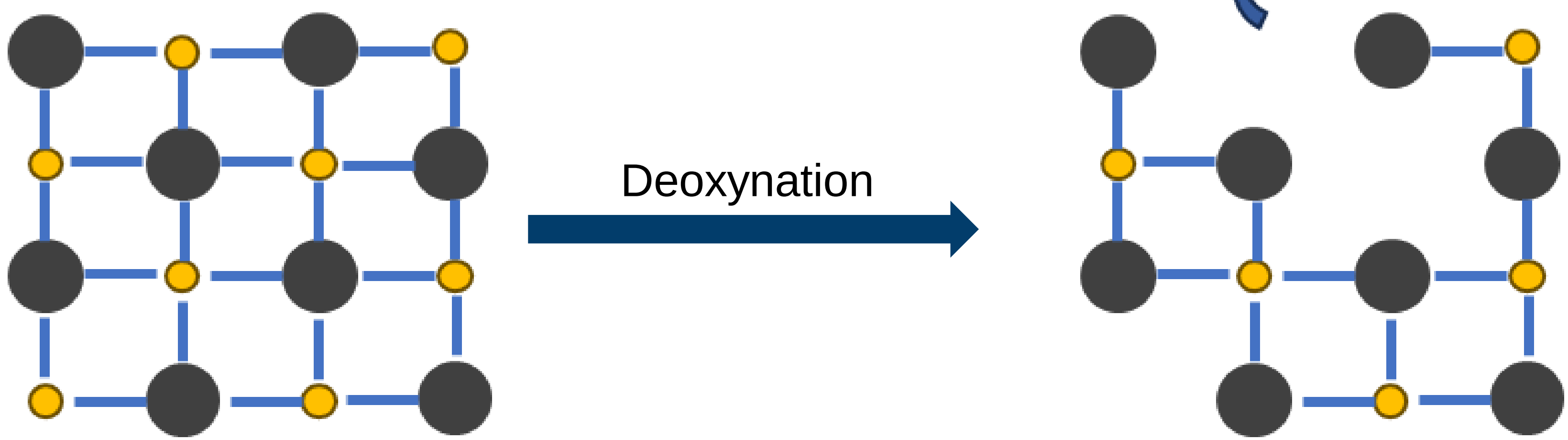
Done by Lei Cao

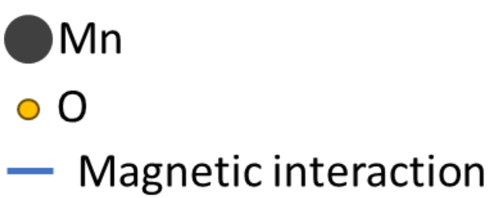
2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

Simulation



Magnetic and electric transport property via simulation?

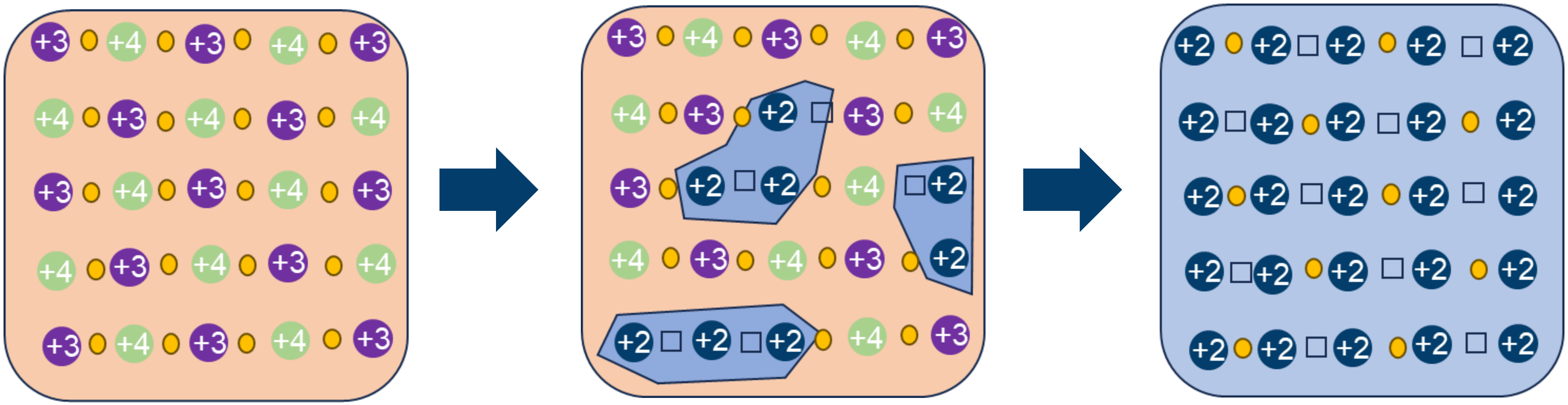




Percolation theory!

2. THE CRYSTAL AND MAGNETIC STRUCTURE EVOLUTION

Percolation simulation via Monte Carlo method



Double exchange Ferromagnetic

Percolation gradual breakdown

Super exchange Antiferromagnetic

Plan:

Stage 1: Simple percolation using a 2D matrix (later 3D matrix). ← **Current**

Stage 2: Mn oxidation state change induced by oxygen vacancy and the breakdown of double exchange.

Stage 3: Oxygen diffusion.

3. CONCLUSIONS AND OUTLOOK

Conclusions

- The evolution of the crystal and magnetic structure of LSMO powder from PV to BM has been probed in micro- and macroscopic length scales. The results indicate a potential crystal and magnetic clustering process in mesoscopic length scale.

Outlook

- Mesoscopic: the crystal and magnetic clustering process will be continued on the LSMO powder via **SAXS SANS** and on the thin film using **PEEM, STXM, STEM**, **GISAXS, GISANS, PNR** + **percolation simulation**.

THANKS FOR YOUR ATTENTION!

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