

*Probing magnetic and orbital correlations in
doped manganites with soft x-ray resonant
scattering*

Jessica Thomas



Outline

I: Soft x-ray resonant diffraction in manganites

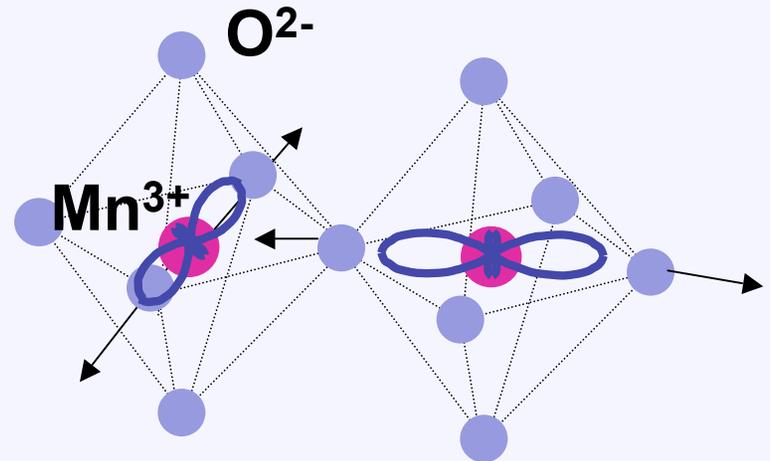
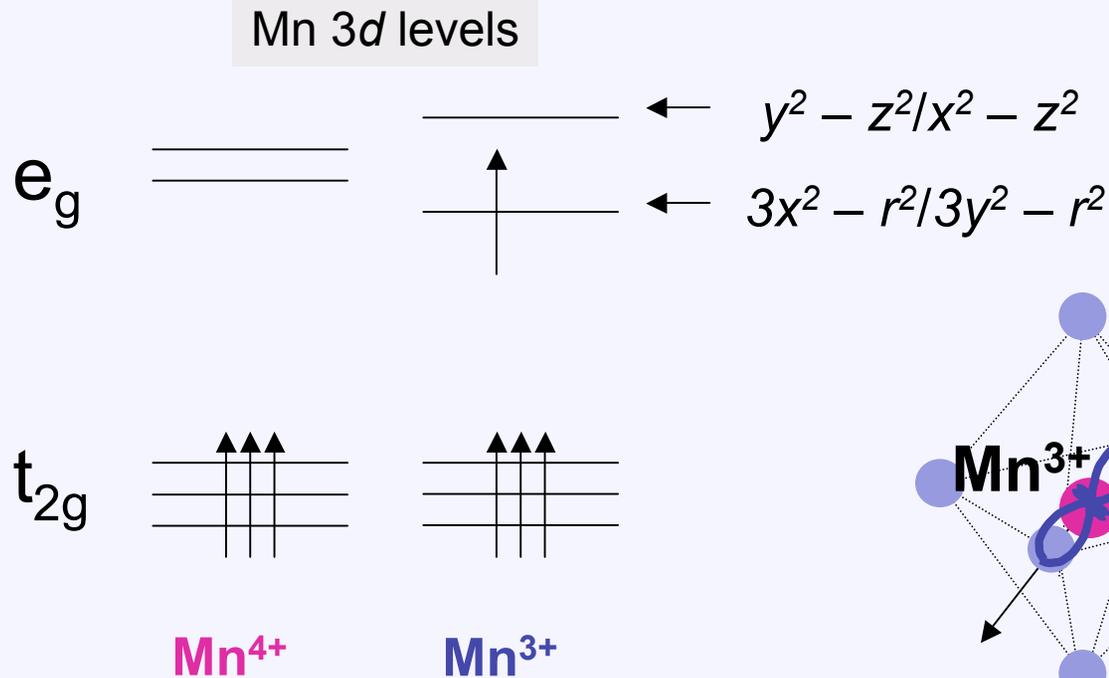
- Why are we interested in orbital physics?
- How soft XRD probes both orbital and spin correlations
- Experimental results and modeling the ground state

II: Ferro-electrically doped manganite thin films

- X-ray magnetic resonant scattering studies
- Projects on the horizon

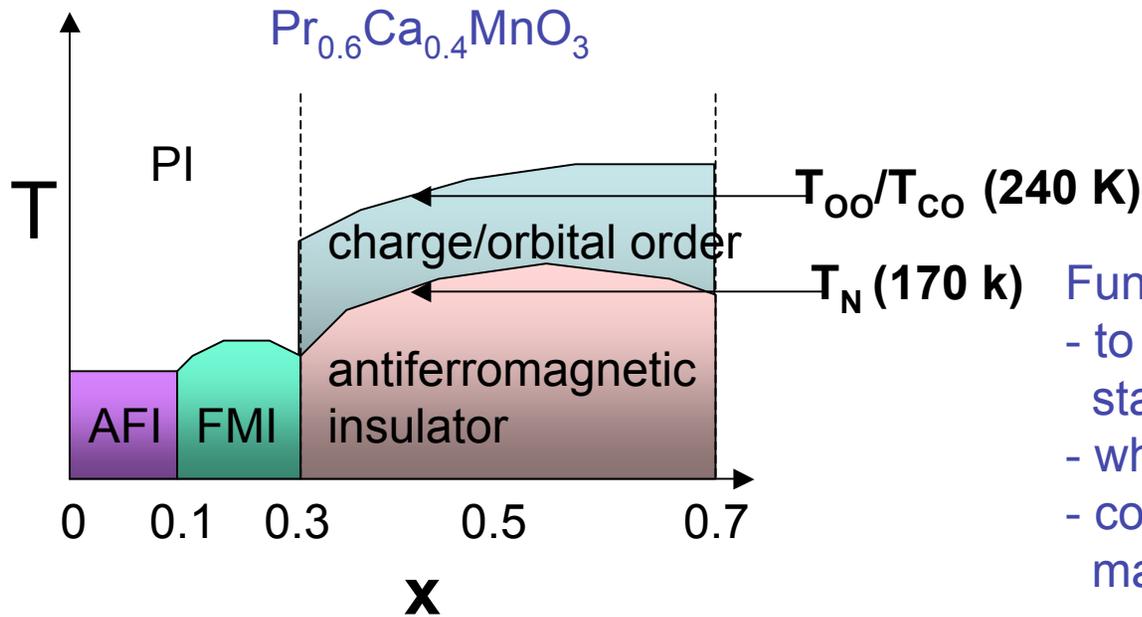
Why study orbital physics?

1. Active degree of freedom in manganites and correlated electron materials
 - How do orbital correlations drive magnetism?
 - Role in magneto-resistance?



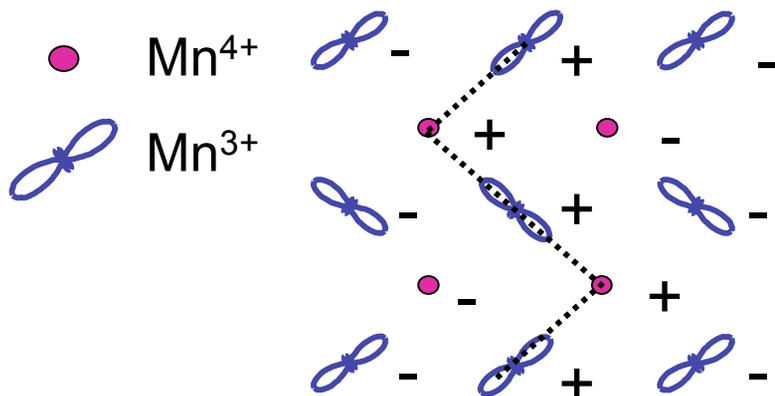
2. New solid state physics?
 - orbitons?
 - orbital liquids?

CE type charge, orbital and magnetic order in half-doped manganites

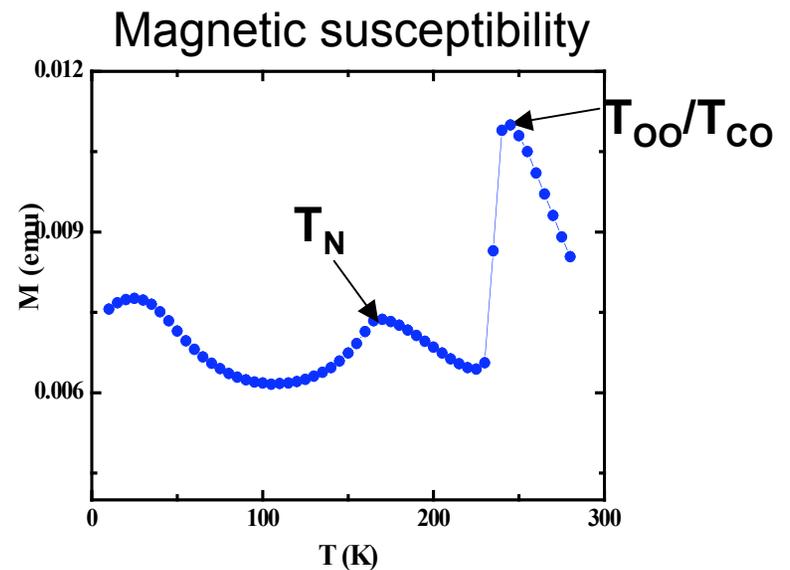


Fundamental questions:

- to what extent is the ground state charge ordered?
- what drives charge/orbital order?
- connection between orbital and magnetic correlations



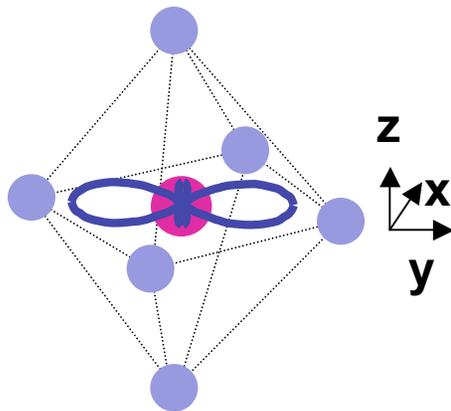
Goodenough (1955)



How do you “see” orbital order with x-ray diffraction?

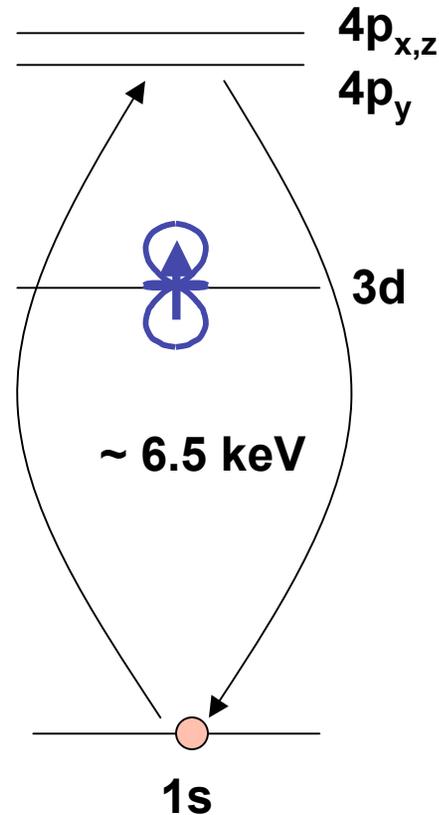
Non-resonant diffraction

Structural distortions

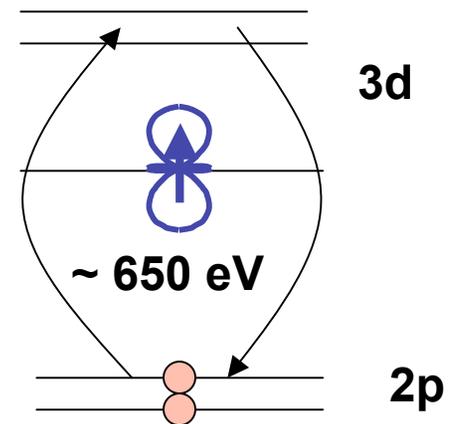


Resonant diffraction at a Mn absorption edge

K-edge: sensitive to oxygen distortions

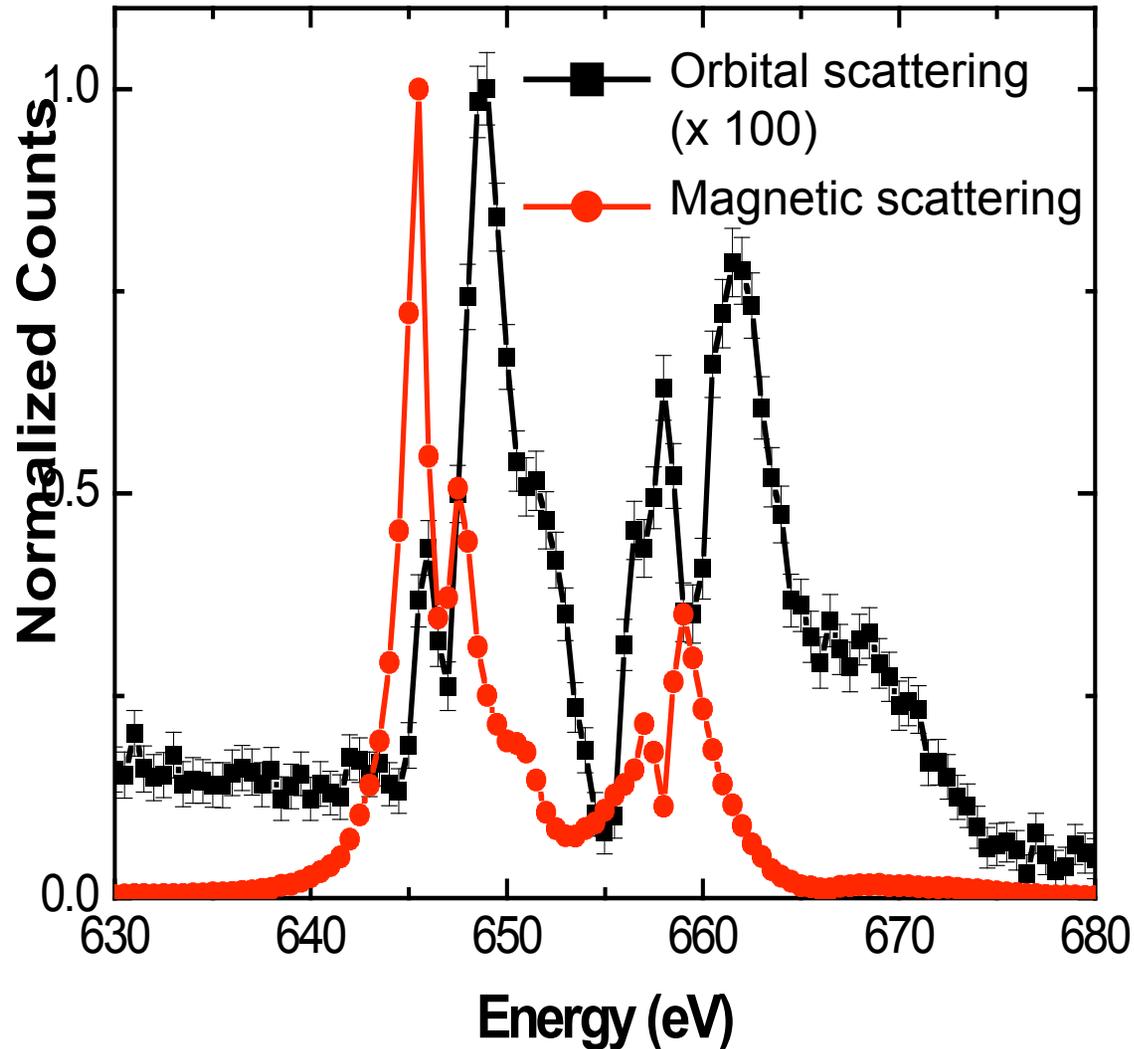


L-edge: sensitive to 3d orbital and spin structure

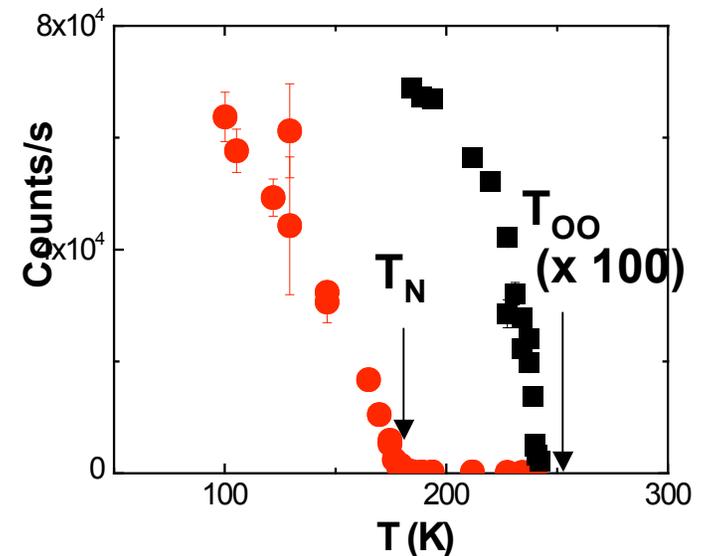


Magnetic and orbital resonant line shapes: NSLS X1B

Diffacted intensity at $Q = (\frac{1}{2}, 0, 0)/(0, \frac{1}{2}, 0)$

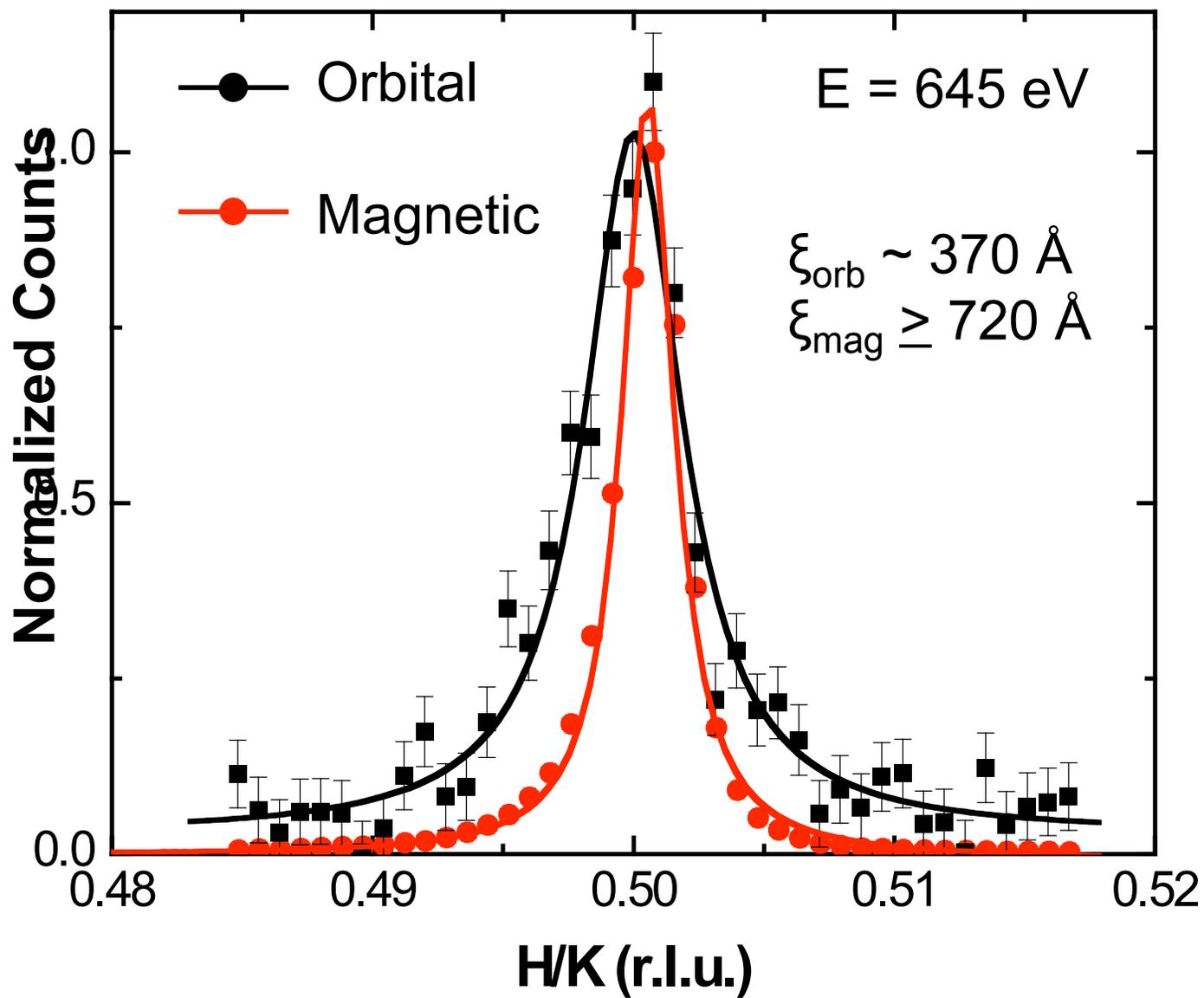


3 eV shift in spectral weight between the magnetic and orbital spectra

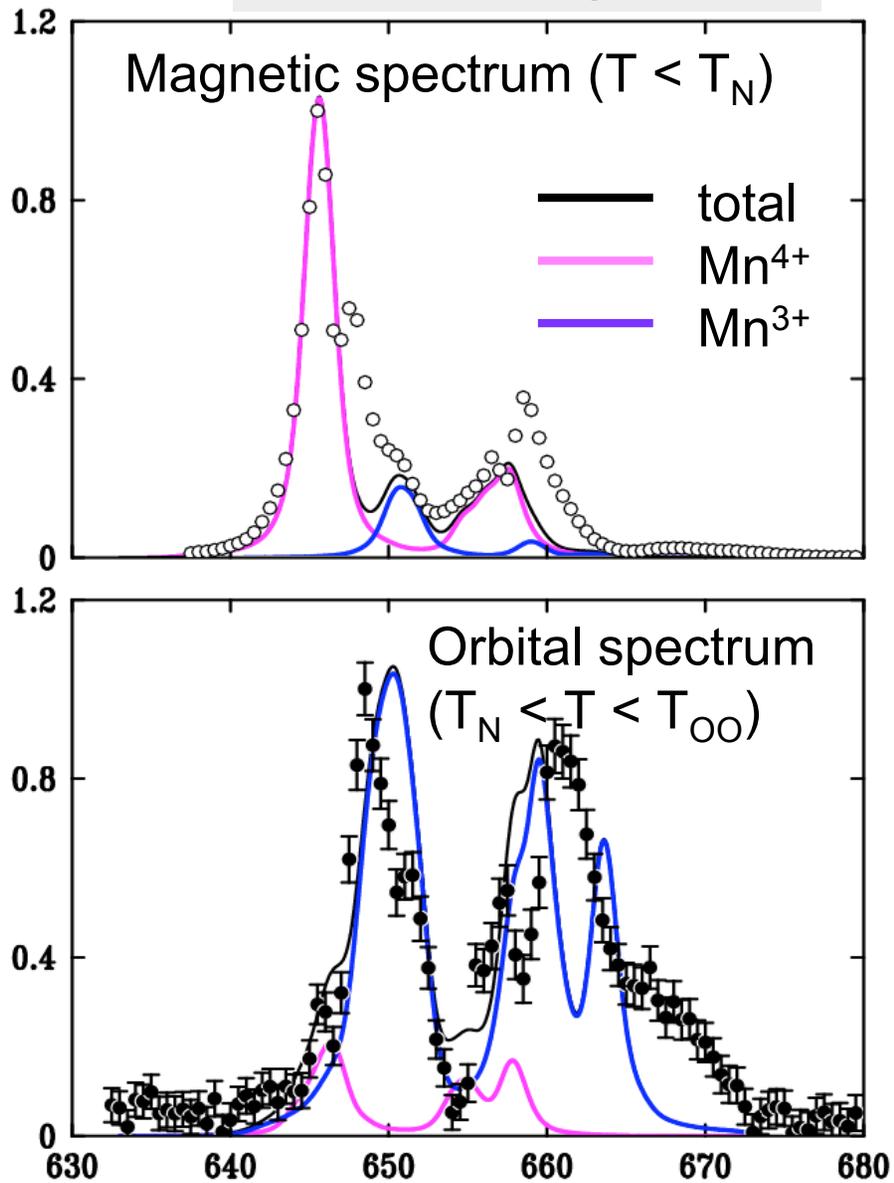


J. Thomas, J. Hill, S. Grenier, P. Abbamonte, M. v. Veenendaal, G. Sawatzky et al.
PRL 92, 237204 (2004)

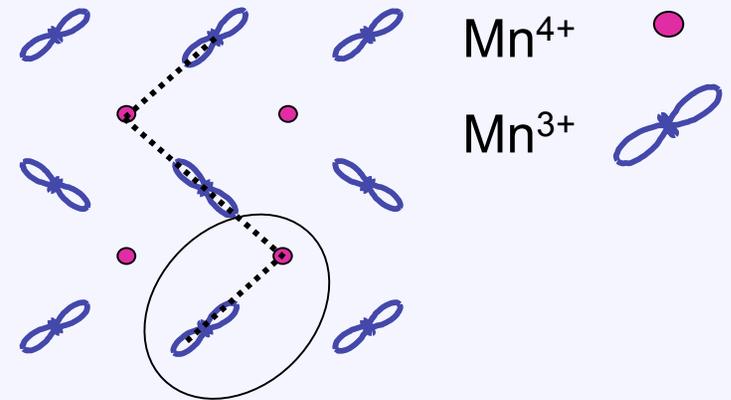
Longitudinal scans:
Orbital correlations are shorter ranged than magnetic correlations



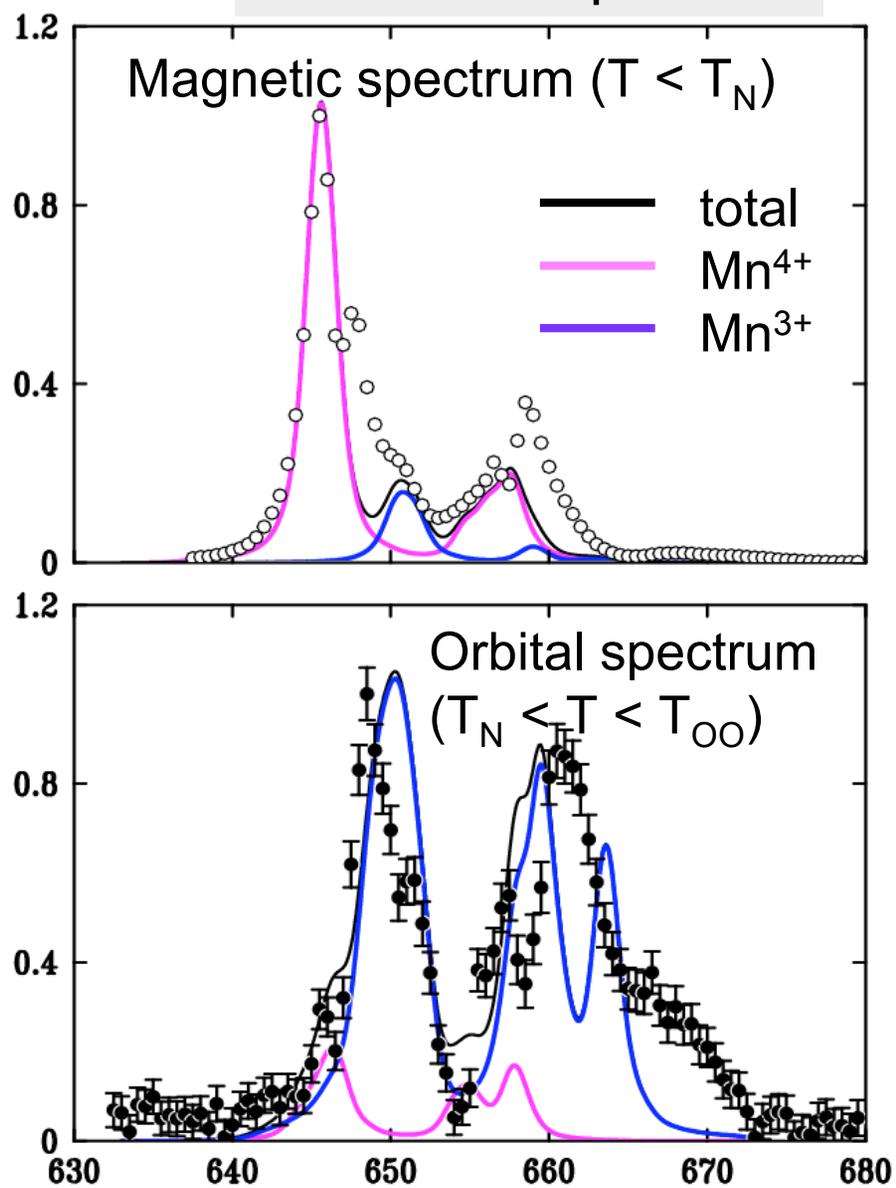
Calculated spectra



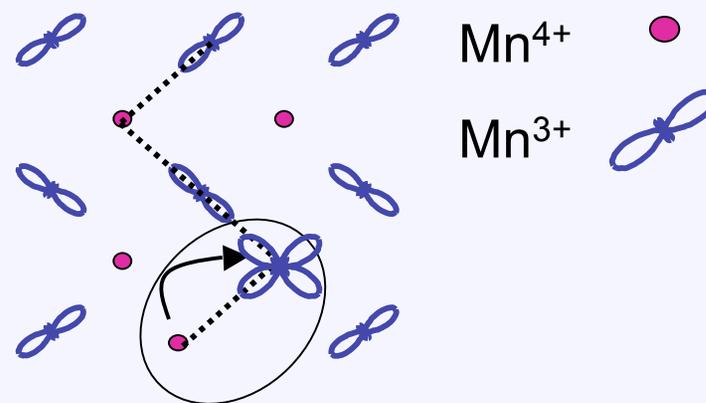
Relaxed charge-order model



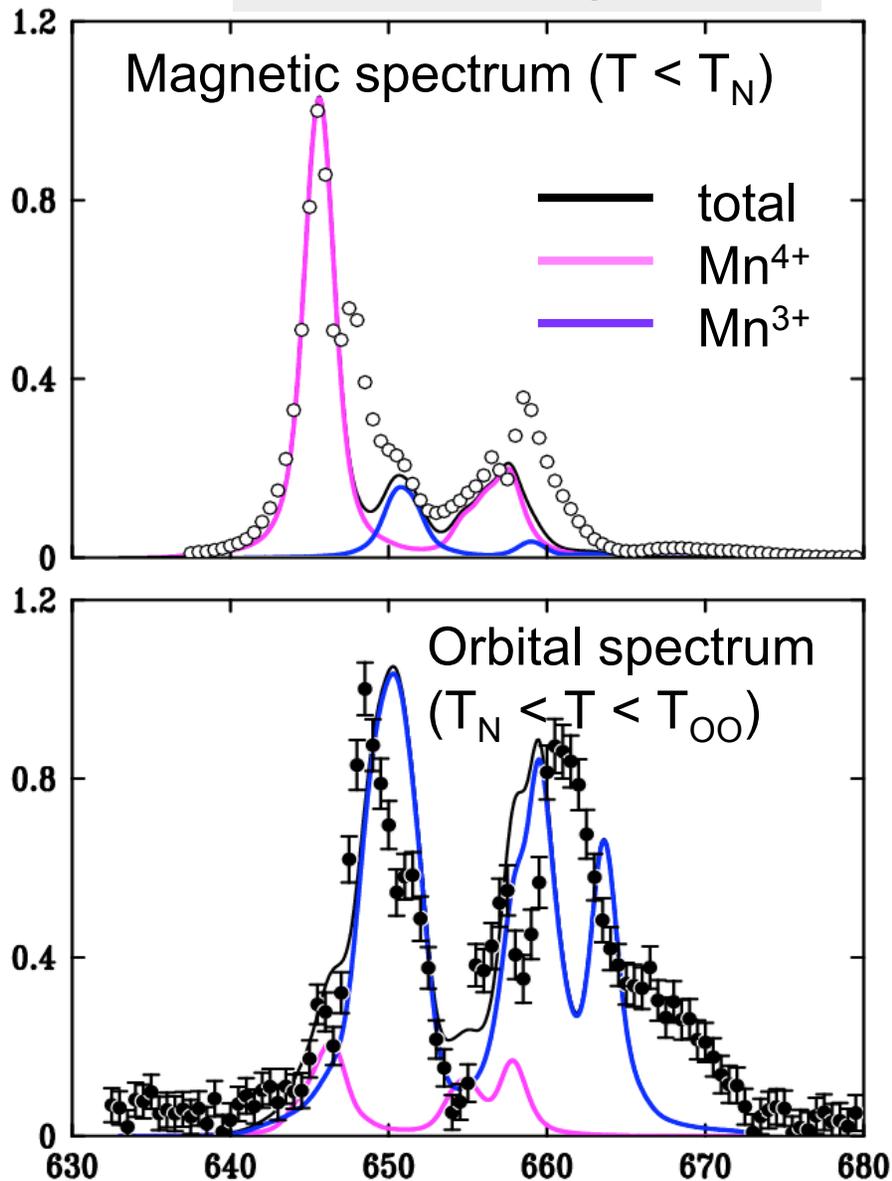
Calculated spectra



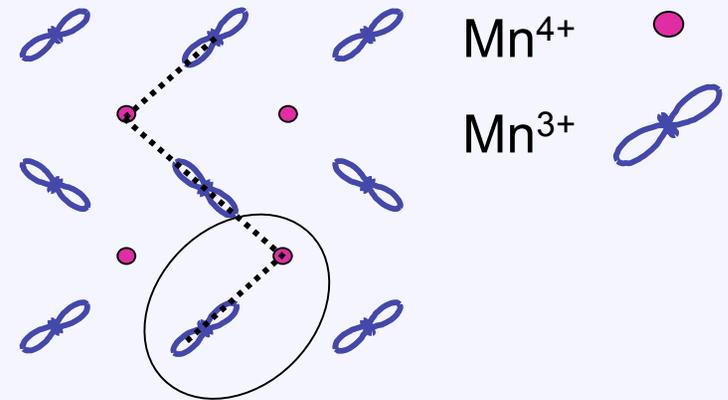
Relaxed charge-order model



Calculated spectra

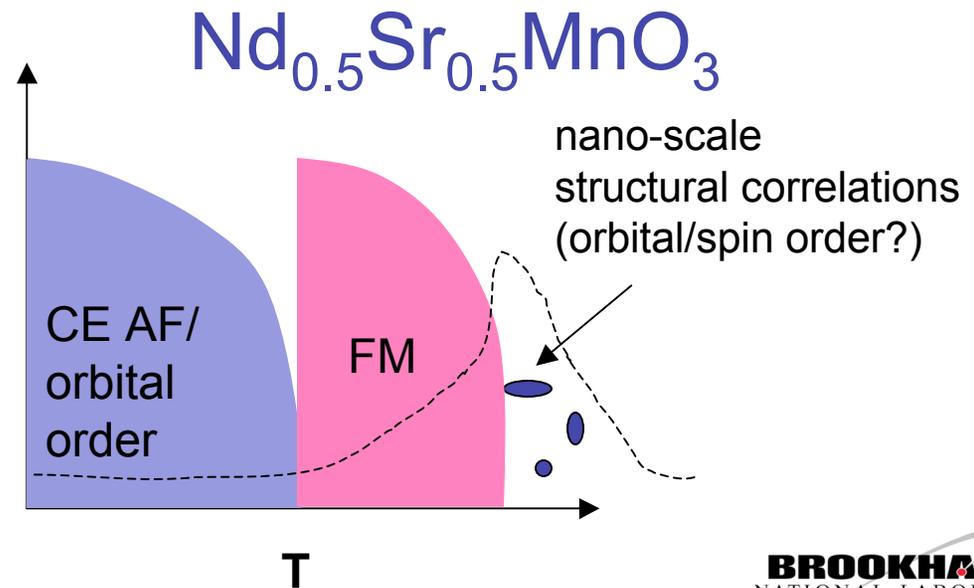
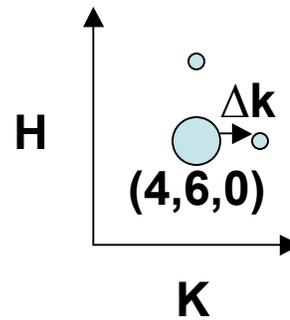
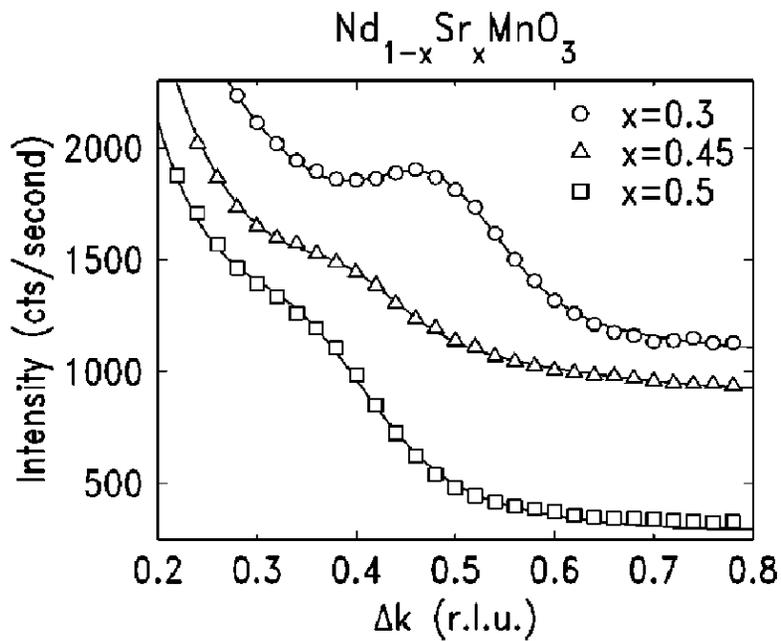


Relaxed charge-order model



- 3 eV spectral weight shift between orbital and magnetic resonant diffraction spectra
- Difference in intensity

Future Experiment: Looking for nanoscale structural correlations in a half doped manganite

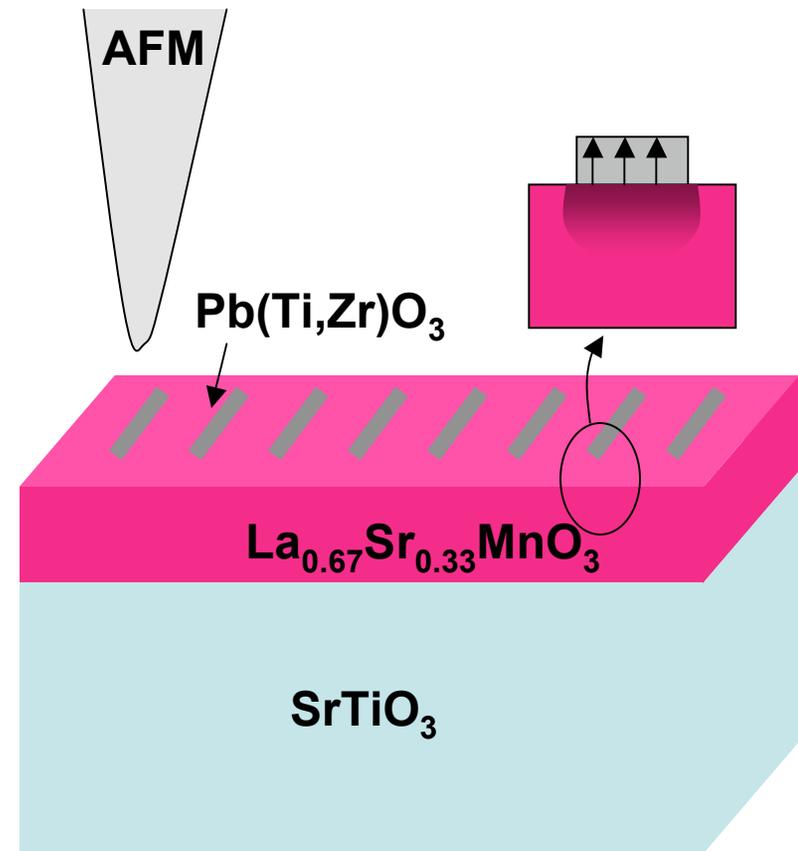
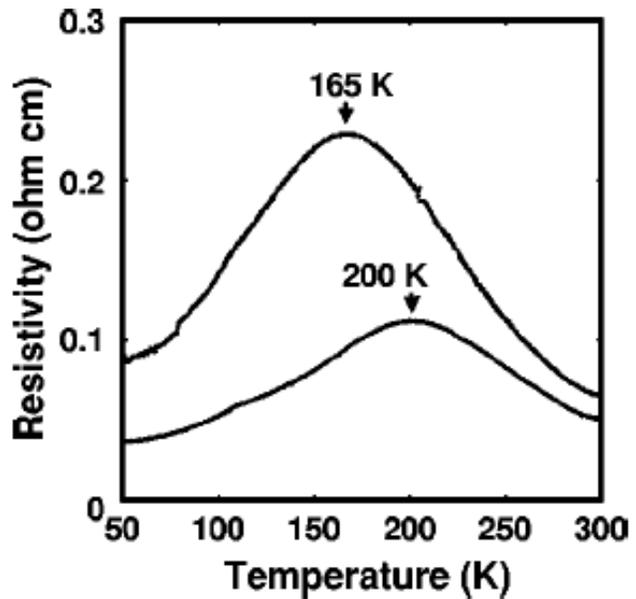
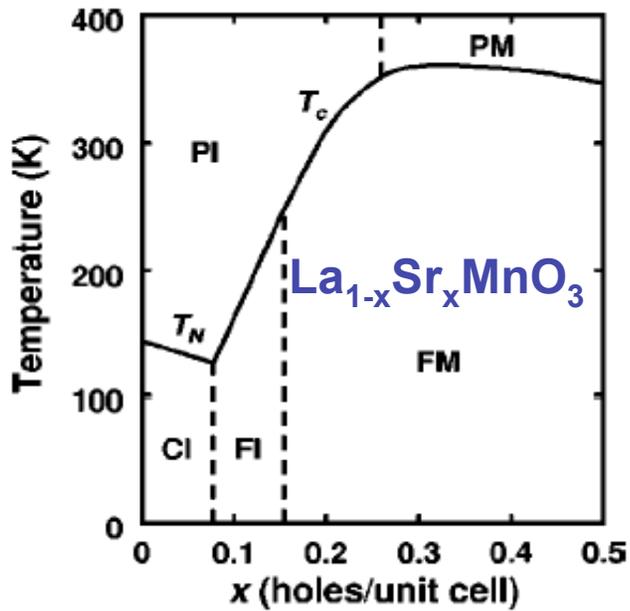




Ferroelectric doping of manganite thin films

Ferro-electric doping of ferromagnetic manganite films

(Collaboration with Charles Ahn, Yale University)



X. Hong *et al* Phys. Rev. B **68** (2003)

Preliminary questions

How does the ferroelectric doping modulate the magnetism?

To what extent does the doping penetrate the LSMO film?

Comparison between structural and magnetic roughness.

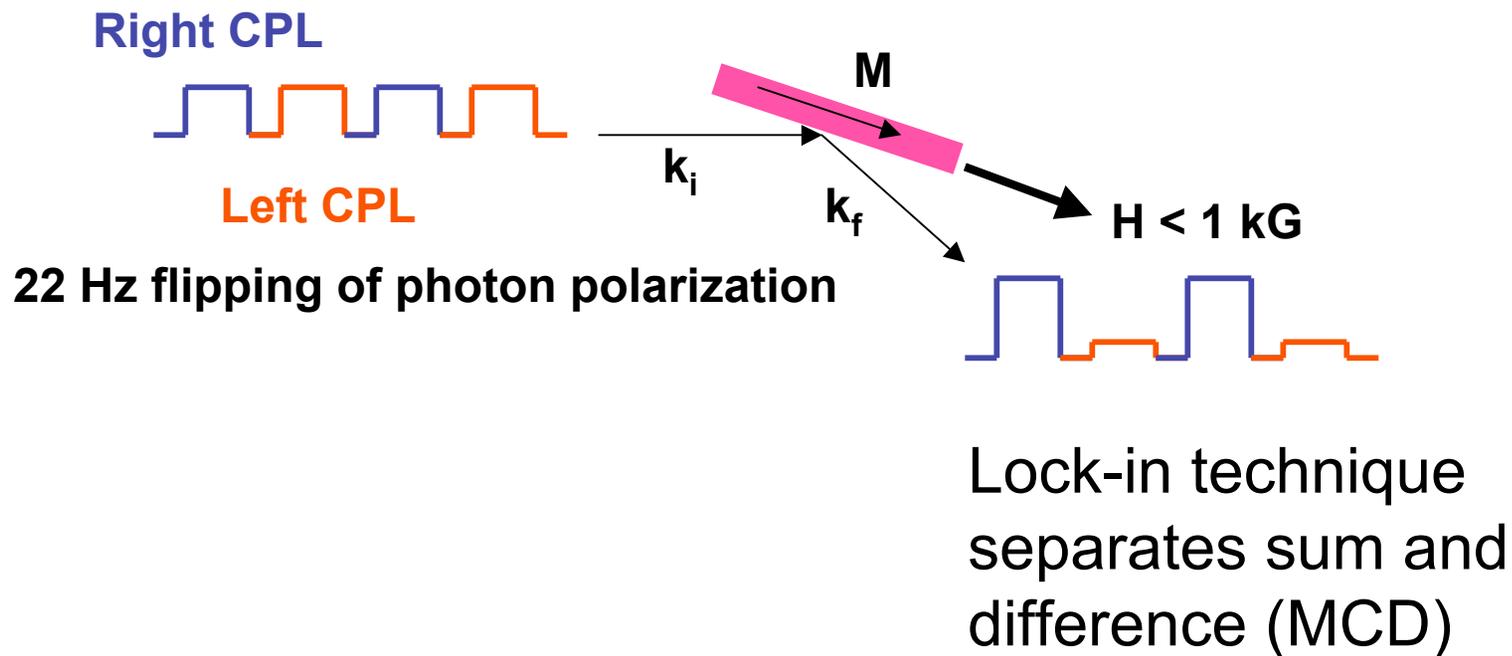
Mechanism for T_c shift?



How do magnetic correlations in the manganite evolve with PZT geometry and spacing?

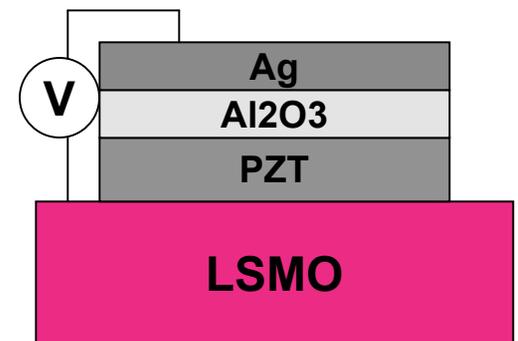
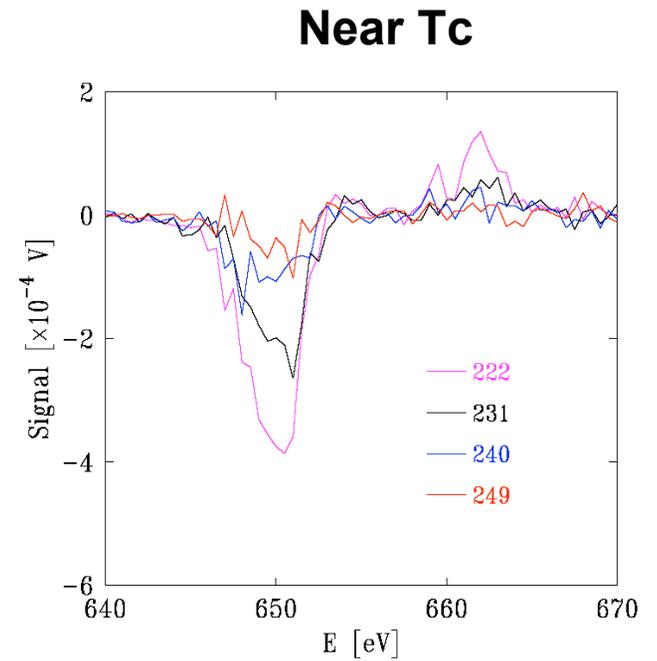
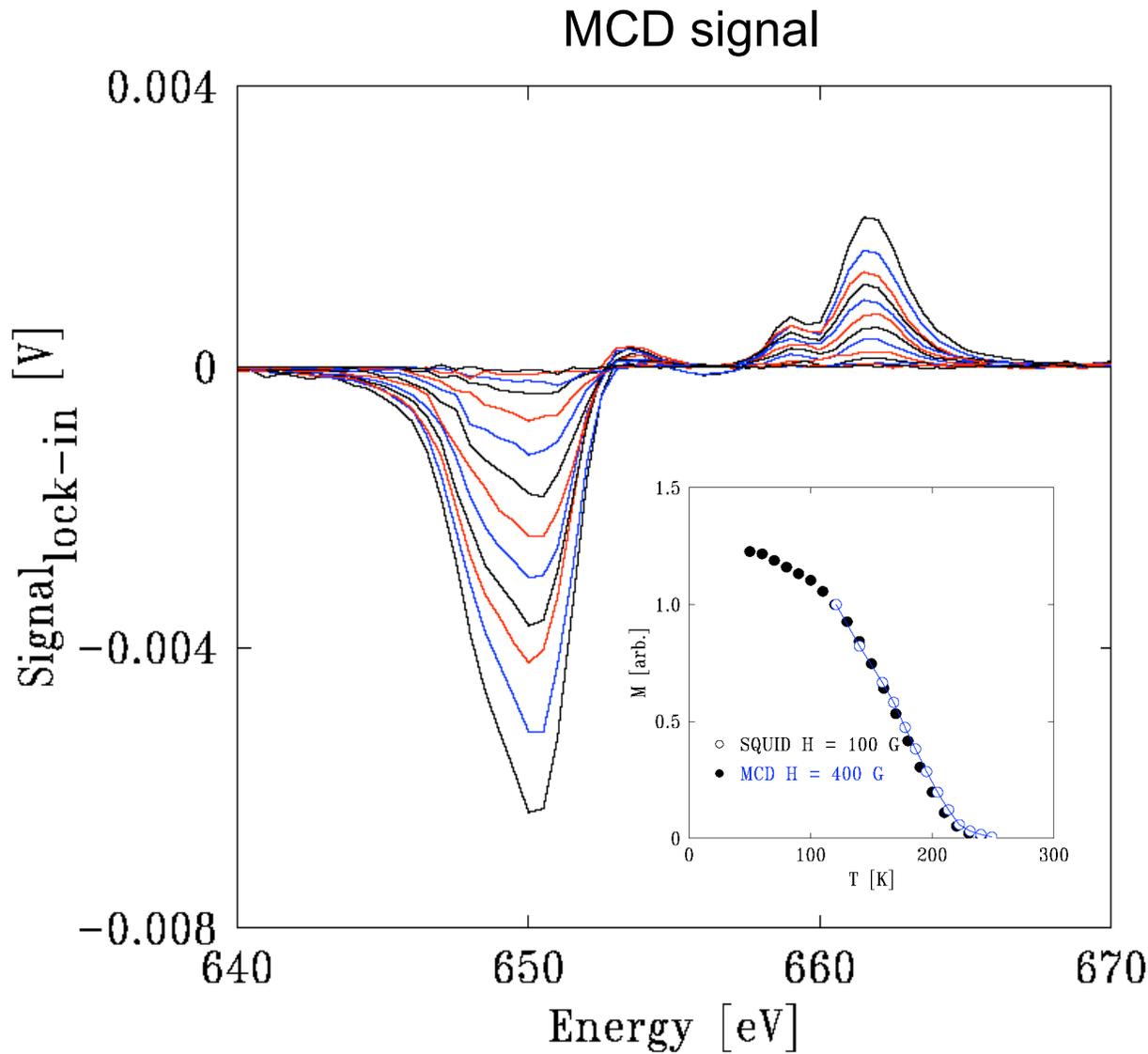
Probing ferromagnetism with Magnetic Circular Dichroism (MCD) at the Mn $L_{II,III}$ -edges

MCD measured in reflectivity mode: Wiggler beamline X13-A NSLS

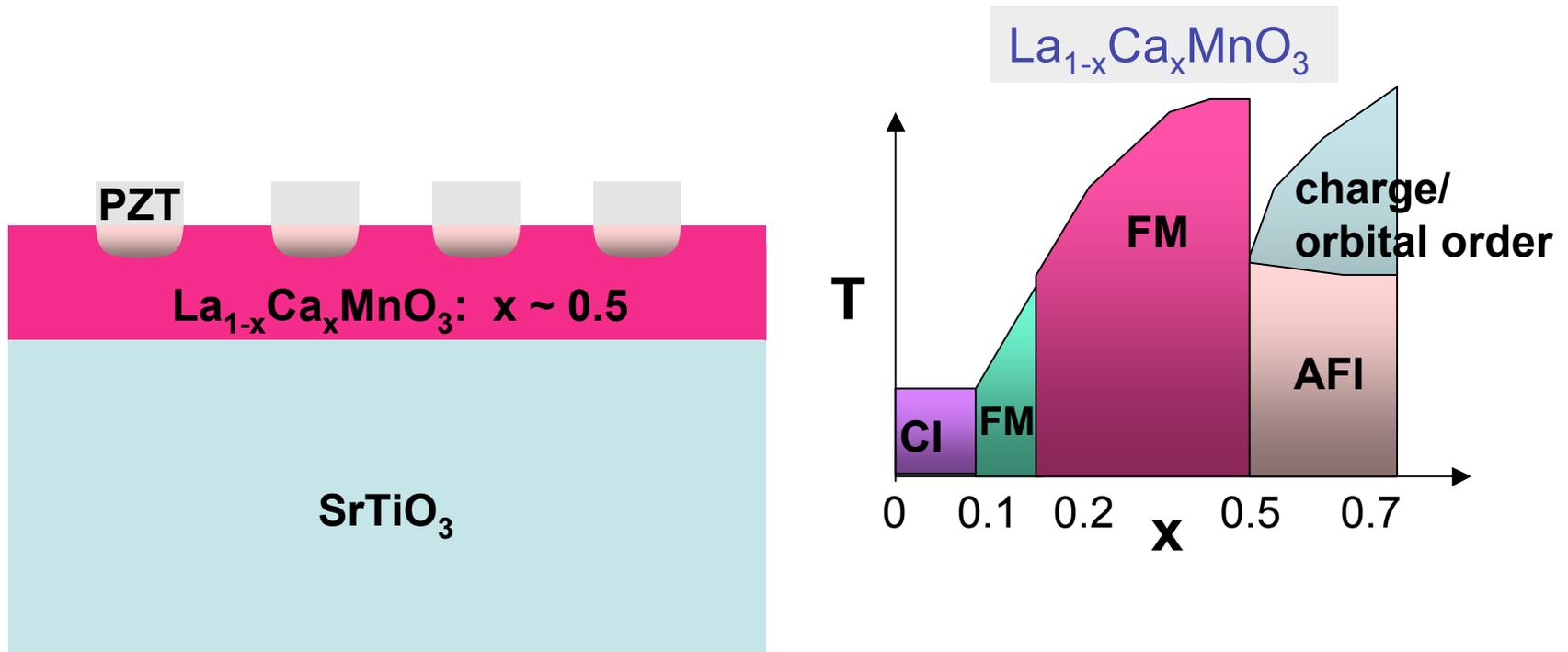


$$\text{Intensity}_{\text{MCD}} \sim M_{\text{FM}}$$

MCD detection of ferromagnetism in **bare** 3 nm LSMO films



Looking into the future: manipulating magnetic inhomogeneity



- Effects of “doping” on formation of the ferromagnetic phase (MCD)
- Correlations between the doped regions (Diffraction)

Summary

Soft x-ray resonant diffraction

- Direct probe of magnetic and orbital correlations.
- Spectroscopy of 3d states + calculations can lead to new statements about the ground state.

Beam lines permitting rapid sample transfer and change of parameters, including:

Low temperatures, polarization analysis, azimuthal rotations

Combine absorption (electron yield) and diffraction measurements

Surface preparation?

Soft x-ray magnetic resonant scattering from a buried interface

Needs

- High flux, sensitivity, stability
- Electronics?

Collaborators

John Hill *Physics. Dept, Brookhaven National Laboratory*
Stephane Grenier *Physics. Dept, Brookhaven National Laboratory*
Peter Abbamonte *NSLS, Brookhaven National Laboratory*
Andrivo Rusydi *NSLS, Brookhaven National Laboratory*
Young-June Kim *Physics. Dept, Brookhaven National Laboratory*

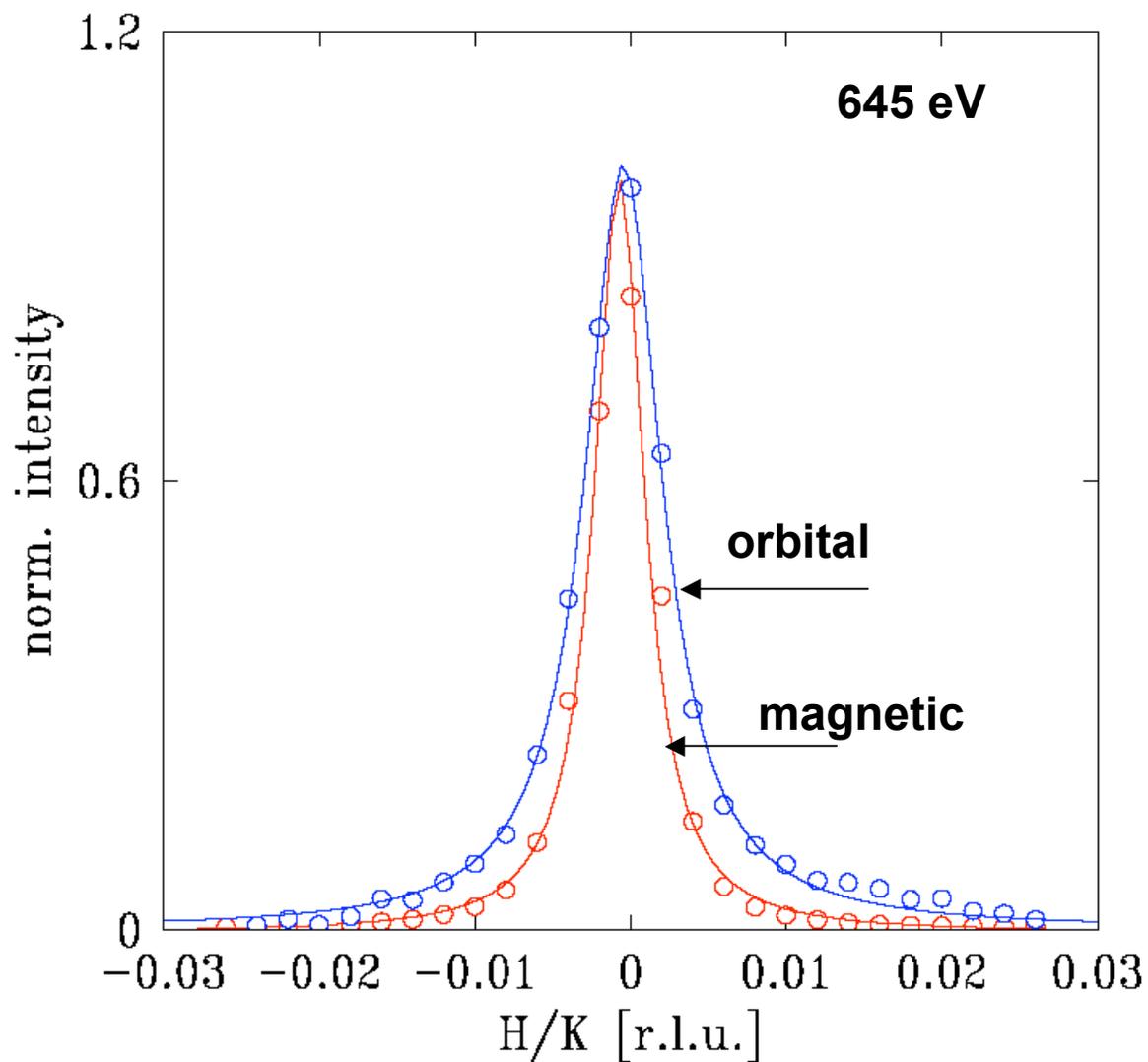
Y. Tokura *University of Tokyo, Japan*
Y. Tomioka *AIST, Japan*

Des McMorrow *University College, London*

Michel van Veenendaal *N. Illinois Univ./Argonne National Lab*
George Sawatzky *University of British Columbia*

Charles Ahn *Yale University*
Xia Hong *Yale University*

Transverse scans:
Orbital correlations are shorter ranged than magnetic correlations



PCMO (x=0.4 and 0.5)

