“Exploiting Symmetry Mismatch to Control Magnetism in a Ferroelastic Heterostructure”

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Xu Group Meeting

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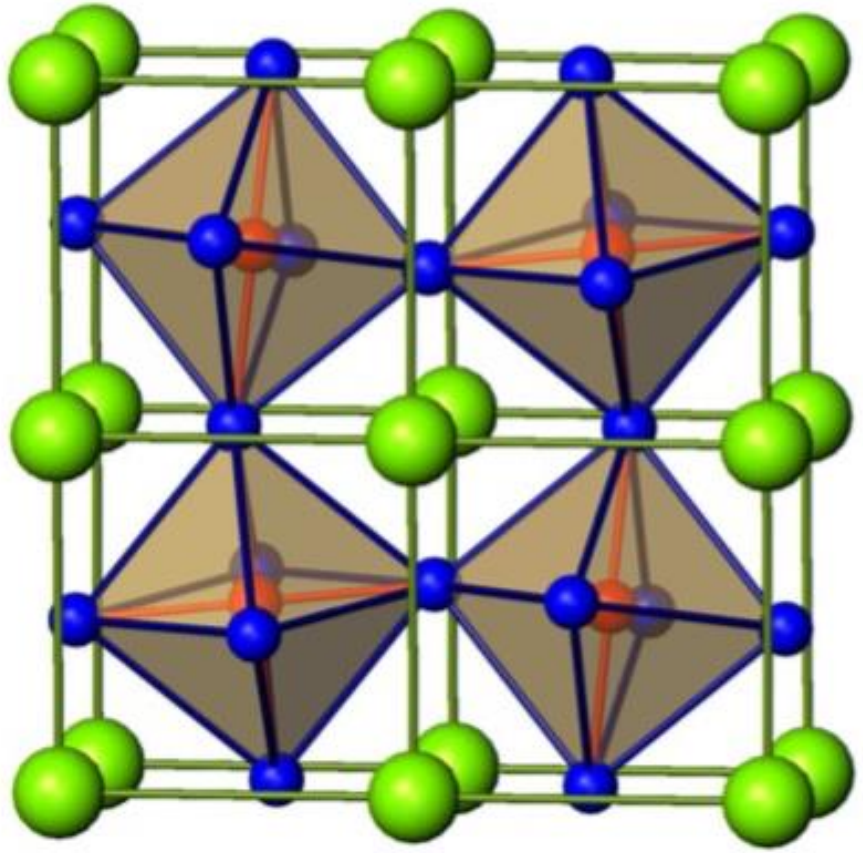
$LaCoO_3$: A Small Mystery

- Rhombohedral perovskite structure at RT; nonmagnetic in bulk
- Observed FM behavior in thin film with T_c~80K
- Traditionally attributed to oxygen vacancy ordering



R3c LCO structure, in pseudocubic axes. CoO_6 octahedral with La

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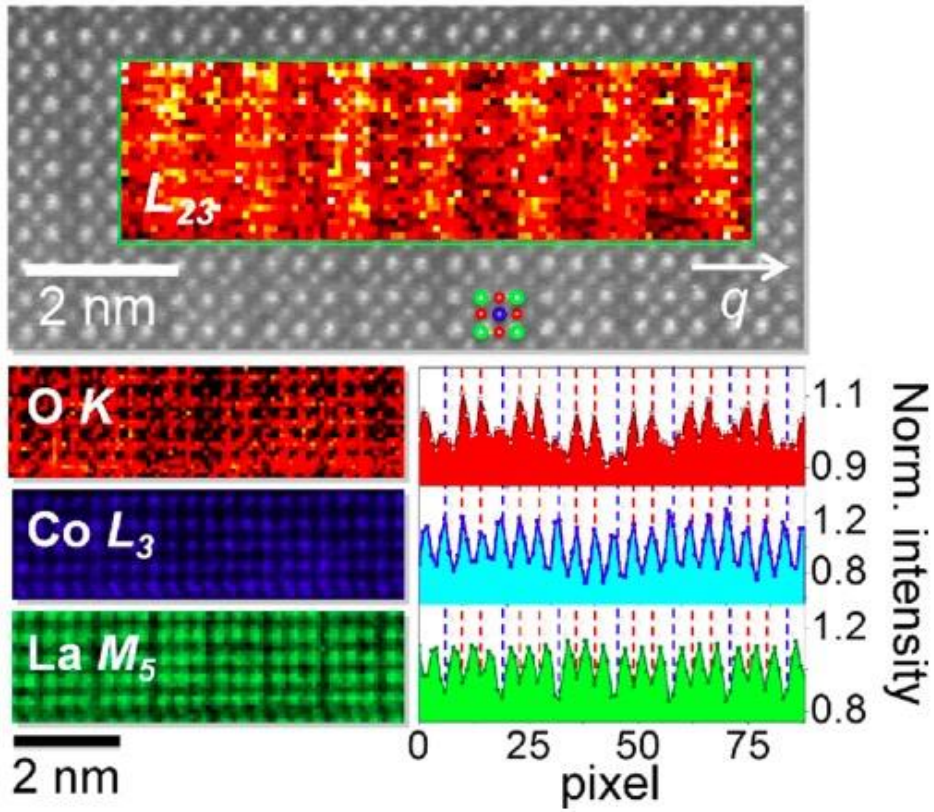
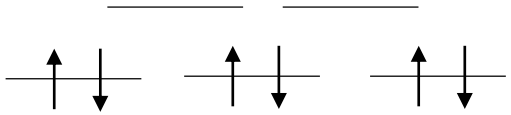


Phys. Rev. Lett. **112**, 087202

Co^{3+}: S=0



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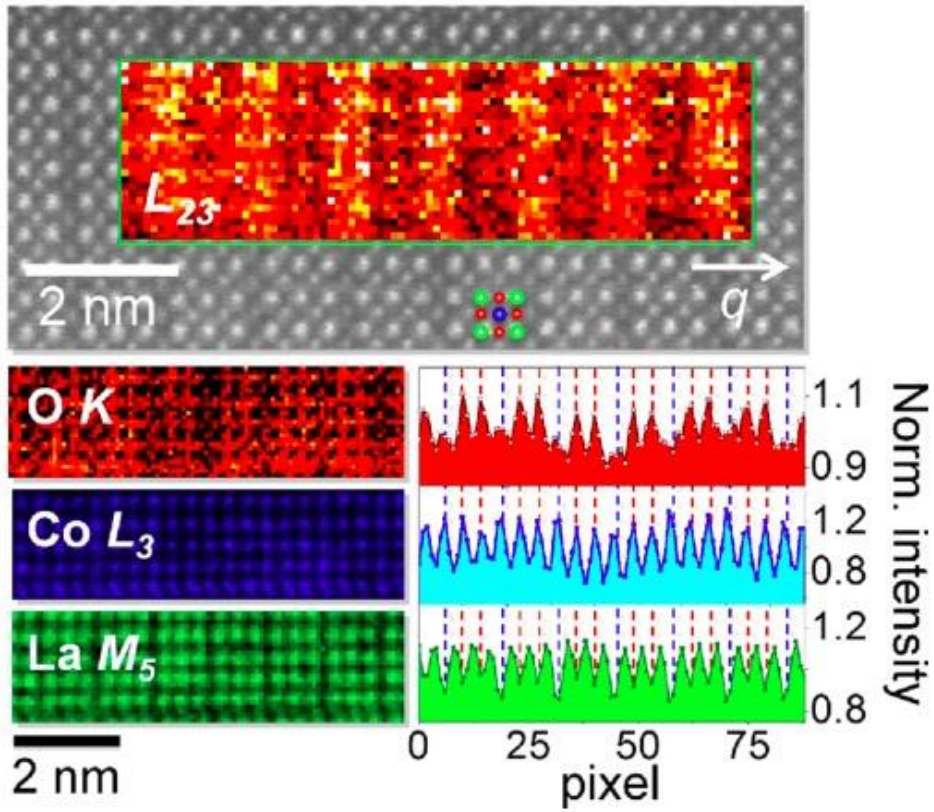

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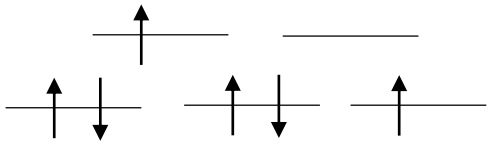
Co^{3+}: S=1



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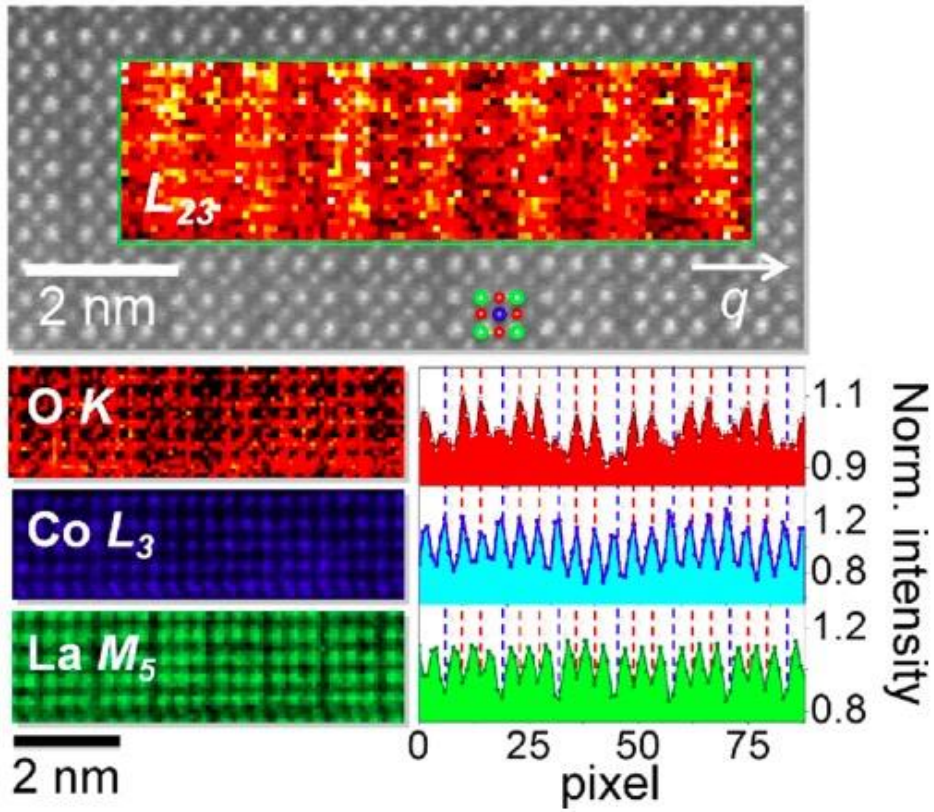

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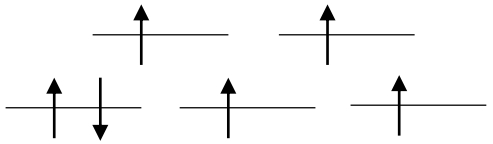
Co^{3+}: S=2



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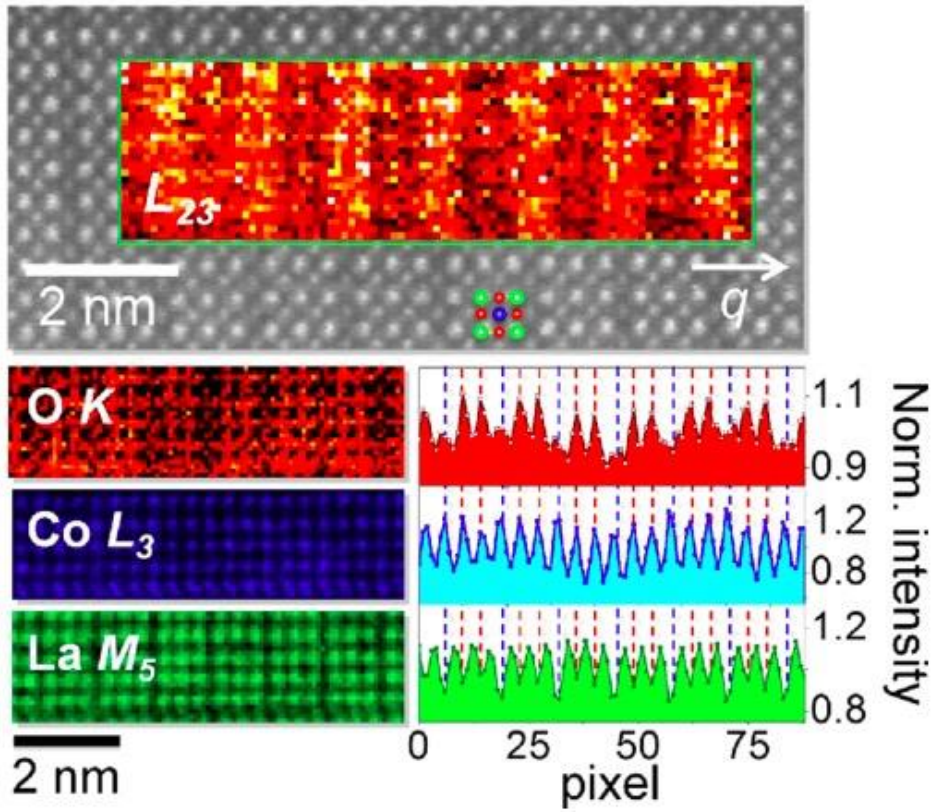

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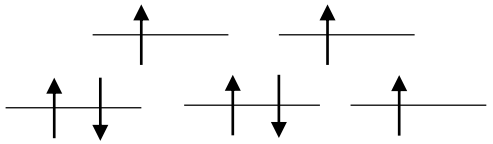
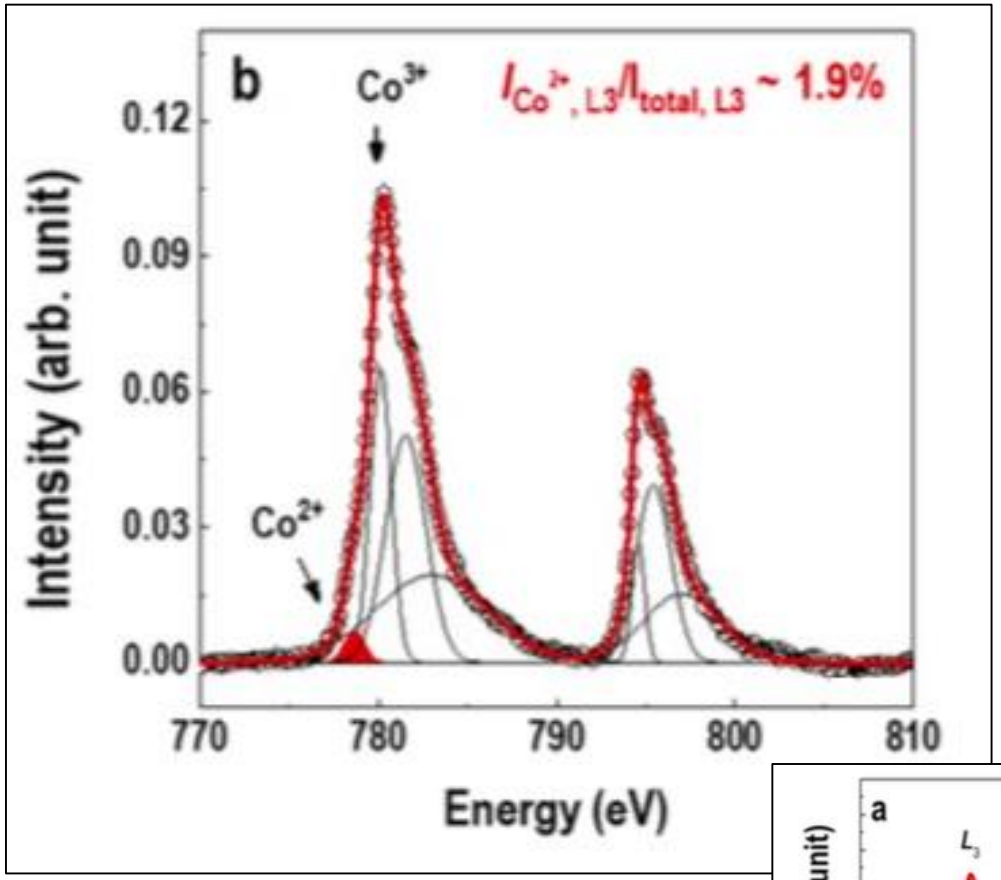
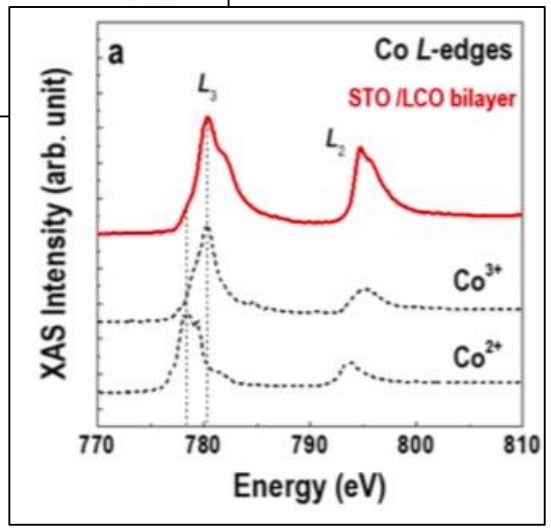
Co^{2+}: S=3/2



$LaCoO_3$ XAS

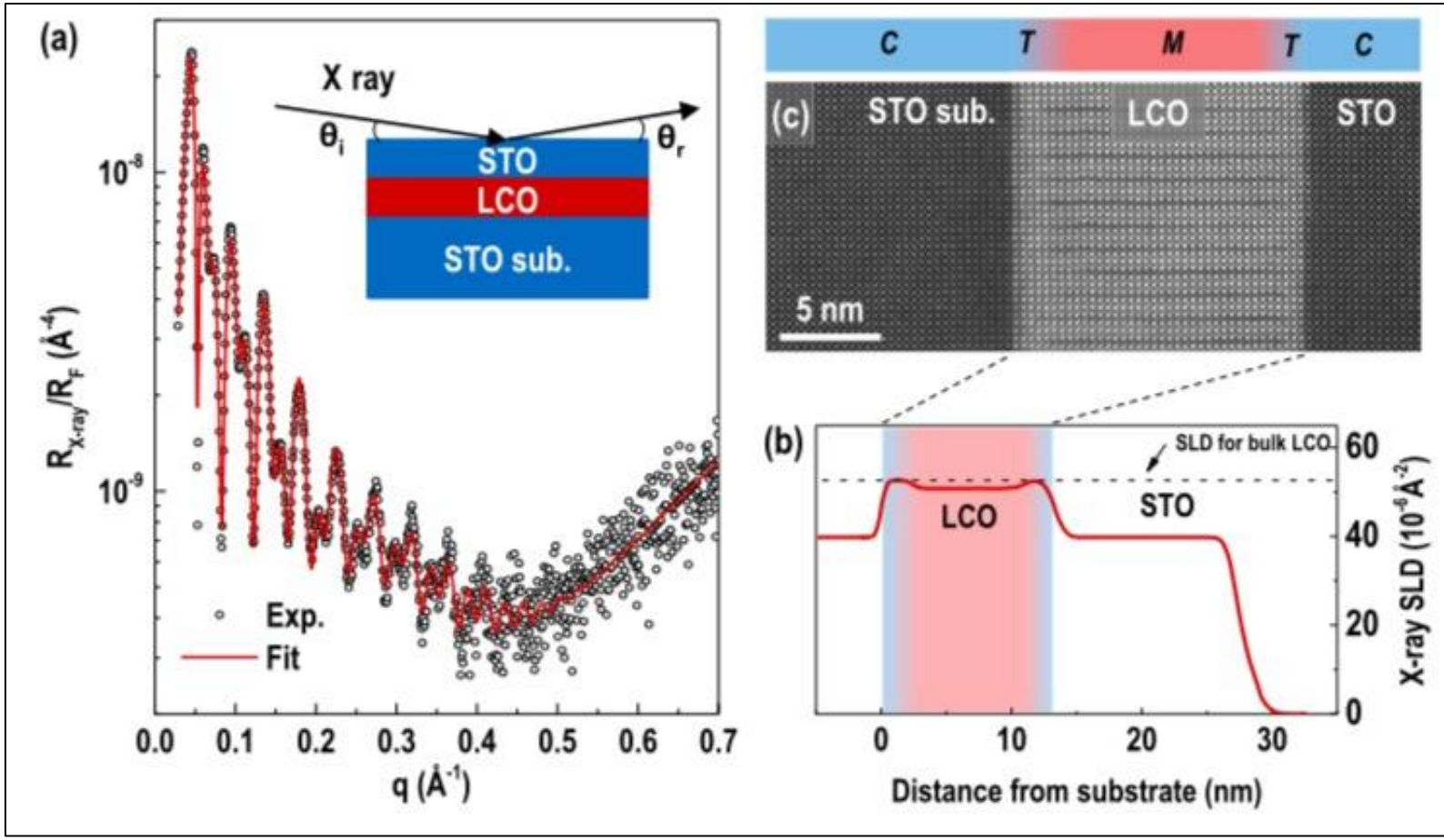
- Don’t see Co^{2+} in as-grown samples; fabrication for TEM causes damaging oxidation?
- Strain-distortion of CoO_6 octahedra lead to nonzero spin on Co
  - “Tetragonally distorted CoO_6 octahedra have nonzero spins, while the monoclinically distorted CoO_6 possess zero spin.”





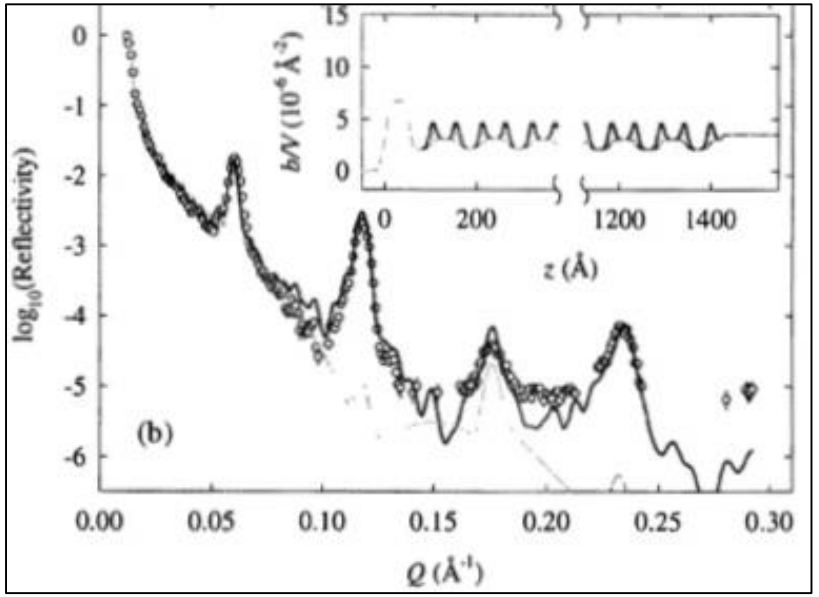
X-ray Depth Profiling

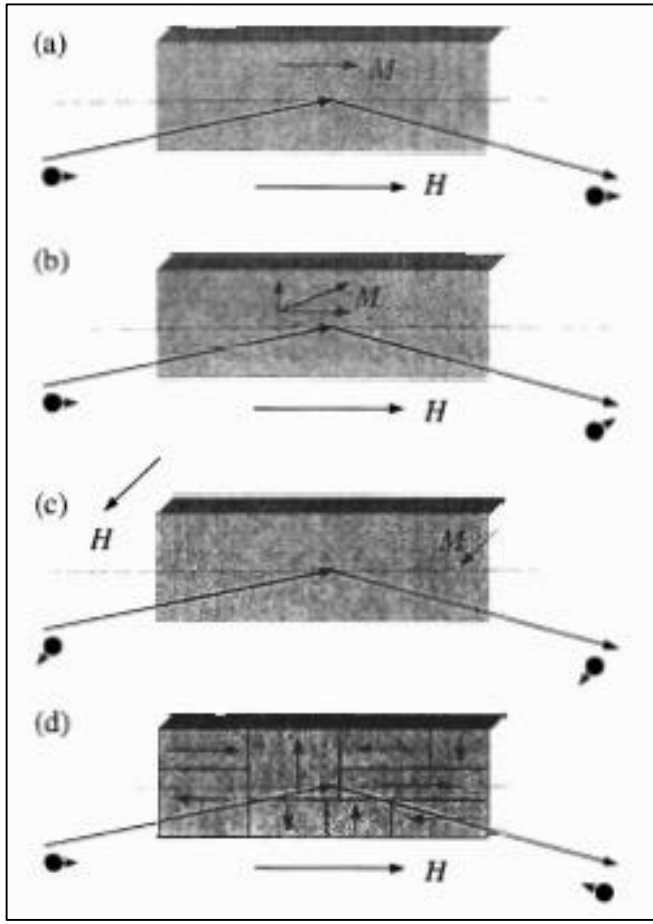
- X-ray densities at interface same as bulk; film interior 1.6% lower
  - Ferroelastic domains → lower density
- Suggests strain gradient affecting LCO; look at magnetic information



Polar Neutron Reflectometry (PNR)

- Neutron polarized parallel or antiparallel to field H
  - Nuclear and magnetic field interactions change intensity and polarization of reflected neutrons
- Glancing angle of incident neutrons control how deep neutrons probe; allow for magnetization determination as function of depth
- Reflectivities R^{++}, R^{--}, R^{+-}, R^{-+} fit to model





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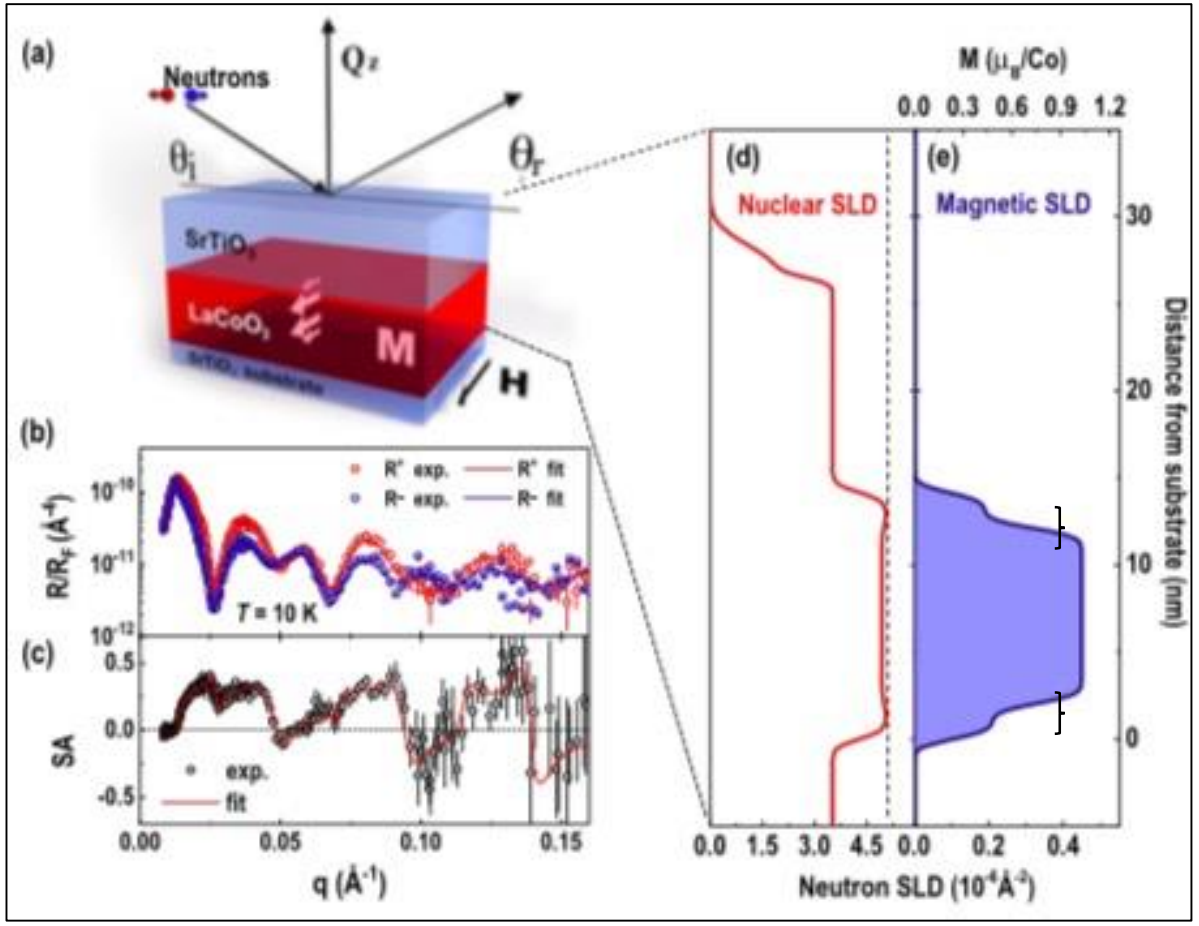
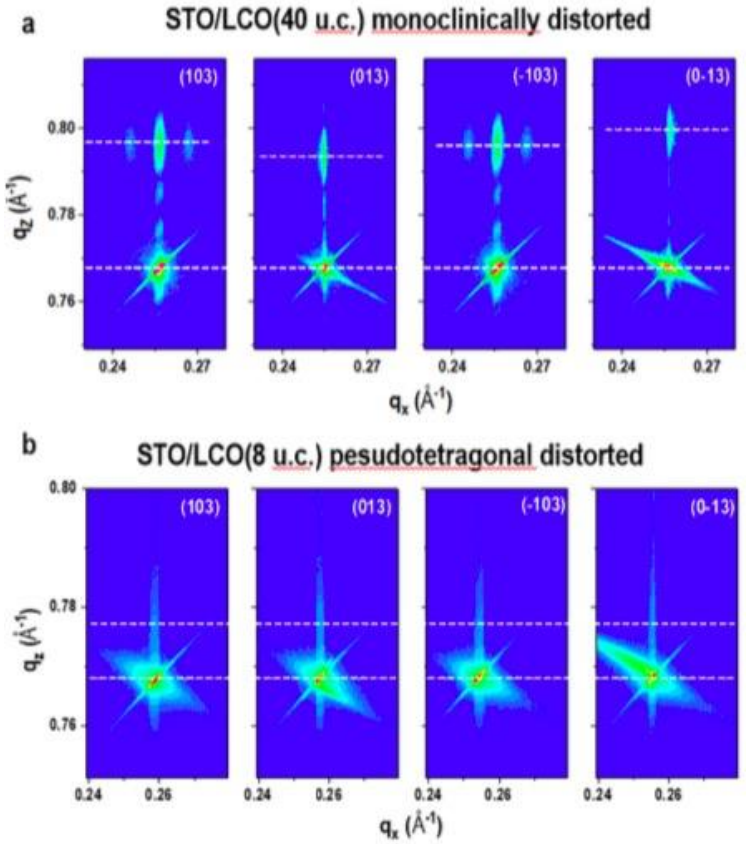
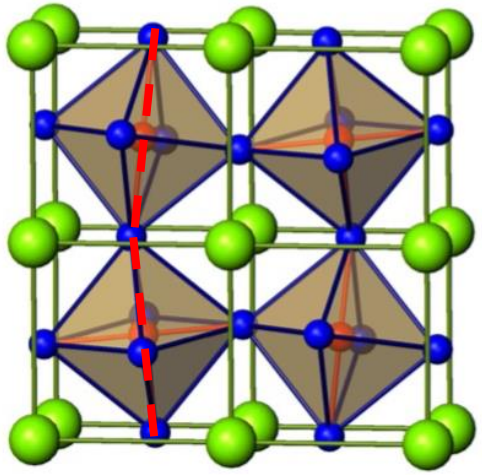
$LaCoO_3$ PNR



- Scattering length density (SLD): determined by nuclear and magnetic density of material
- Magnetization lower at interfaces than in film bulk
- Nuclear SLD lower in film bulk
  - Agrees with x-ray SLD

Strain in LCO Thin-Film





- LCO/STO interface distorted differently than interior, causing magnetization difference
  - Interface thickness = magnetic difference thickness
- Proposed mechanism:
  - $d_{Co\text{-}O}$ = 1.93Å; Co-O-Co bond angle ~163˚ in bulk
  - Tensile strain from STO inc. angle to near 180˚, increase $d_{Co\text{-}O}$ which lowers Δ_{CF}

Testing Compression Effect

- Applied pressure dec. film volume, inc. CF splitting energy to make HS-state of Co^{3+} less favorable
  - Strain of STO enough to account for magnetization