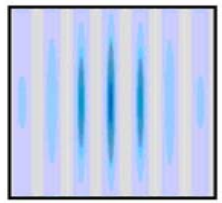
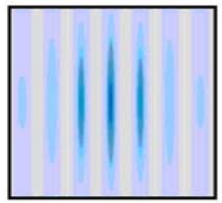


LOCAL STRUCTURE
FROM DIFFRACTION

MICHIGAN STATE
UNIVERSITY

High temperature superconductivity…a bad case of stripes?

High-Temperature Superconductors



LOCAL STRUCTURE FROM DIFFRACTION

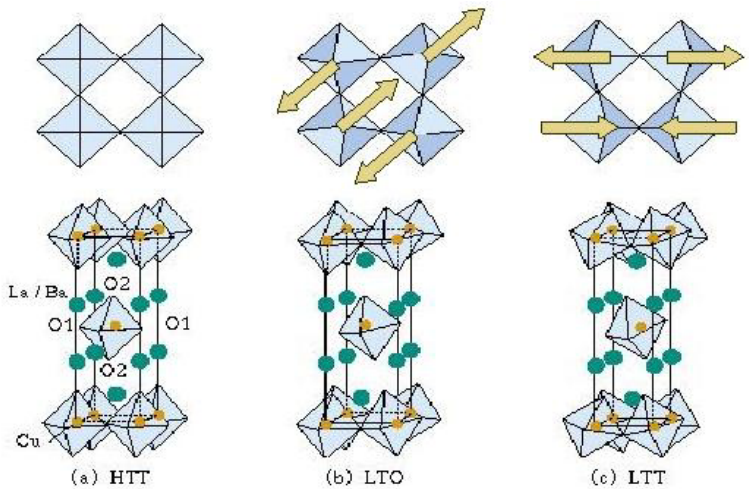
MICHIGAN STATE UNIVERSITY

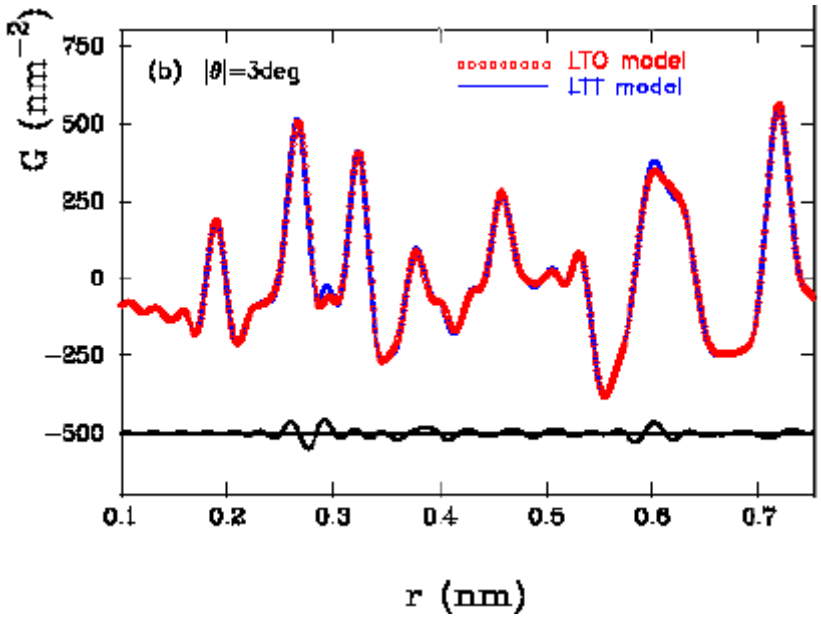
- A revolution happened in condensed matter physics in 1987 when superconductivity (no-loss electrical currents among other things) was observed above liquid-nitrogen temperature: so-called High Temperature Superconductivity. The phenomenon is finding use in applications, and these uses will grow with time, but an understanding of the phenomenon is still lacking.
- It is observed in exotic ceramic oxide materials such as $La_{2-x}Sr_xCuO_4$. Ceramics are not traditionally known for their good electrical properties, except as insulators!
- A new development was made in our understanding in1995 when it was suggested that the charges in these materials are not homogeneously distributed but arranged in striped patterns.
- We are studying these stripes using the local atomic structure and the PDF technique.

Structure and PDF of a high temperature superconductor

LOCAL STRUCTURE FROM DIFFRACTION
MICHIGAN STATE UNIVERSITY

The structure of $La_{2-x}Sr_xCuO_4$ looks like this: (copper [orange] sits in the middle of octahedra of oxygen ions [shown shaded with pale blue].)

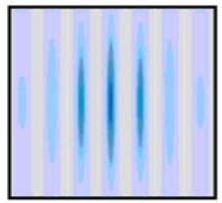




The resulting PDFs look like this. The peak at 1.9A is the Cu-O bond.

So what can we learn about charge-stripes from the PDF?

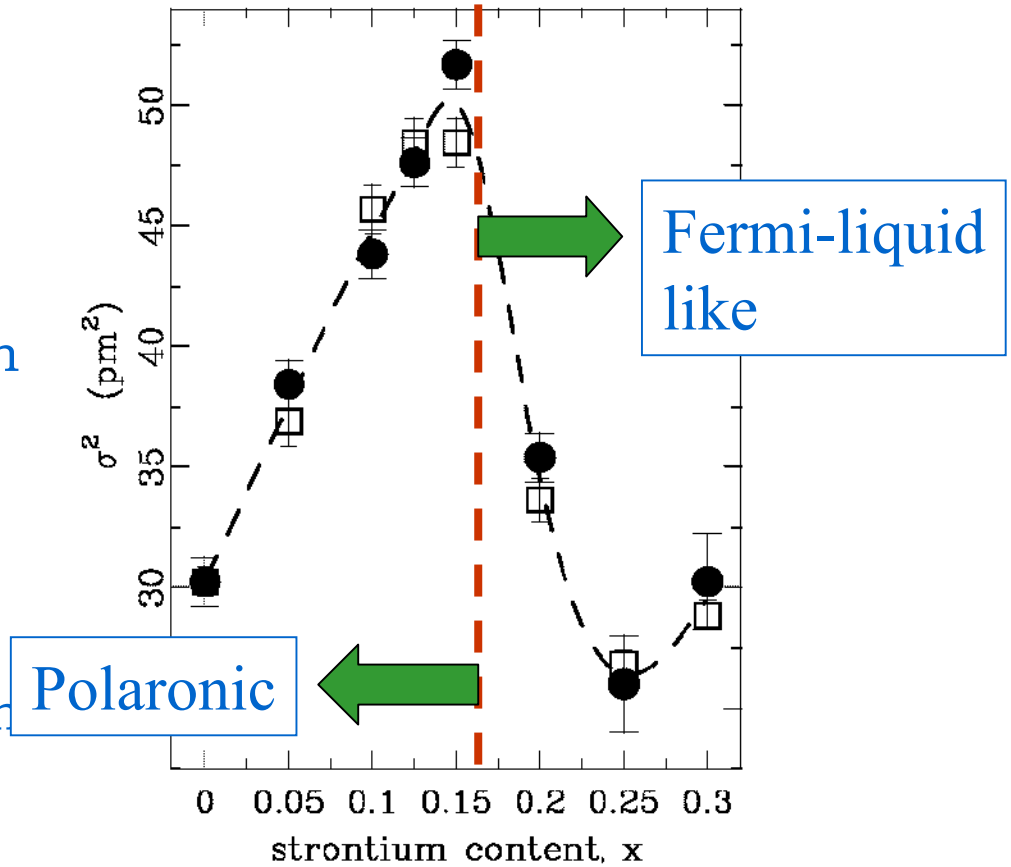
Effect of doping on the octahedra



LOCAL STRUCTURE FROM DIFFRACTION

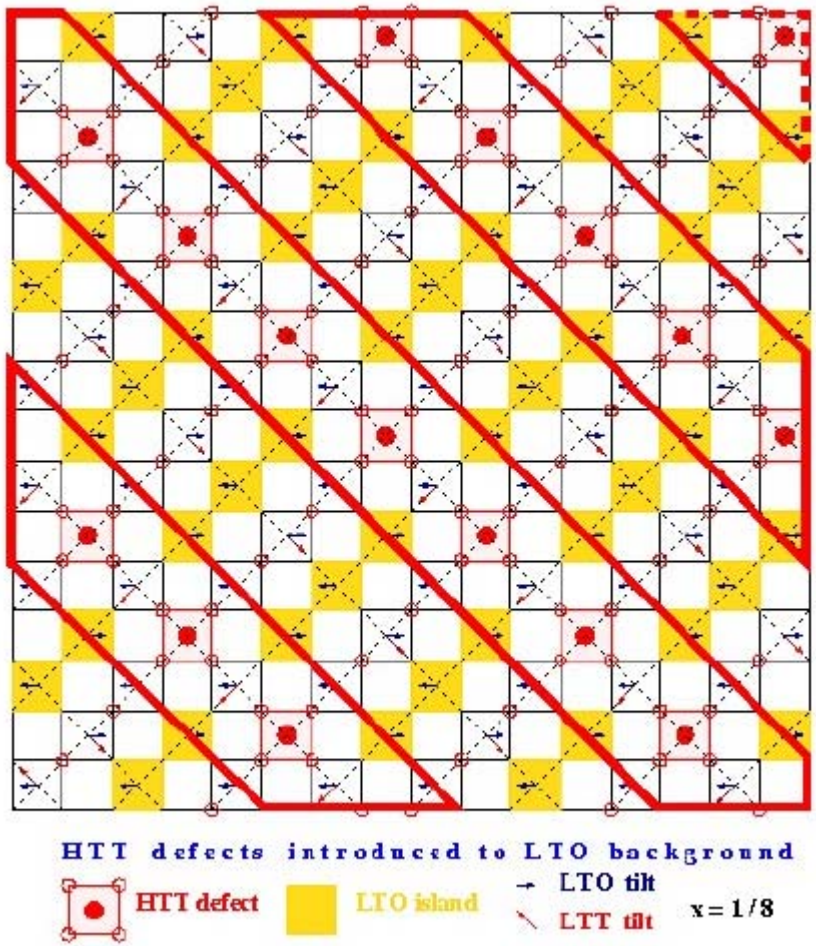
MICHIGAN STATE UNIVERSITY

- Doping holes (positive charges) by adding Sr shortens Cu-O bonds
- localized holes in stripes implies a coexistence of short and long Cu-O in-plane bonds => increase in Cu-O bond distribution width with doping.
- We see this in the PDF: σ^2 is the width of the CuO bond distribution which increases with doping then decreases beyond optimal doping



Bozin *et al*. Phys. Rev. Lett. Submitted; cond-mat/9907017

Stripes and phase separation in the cuprates



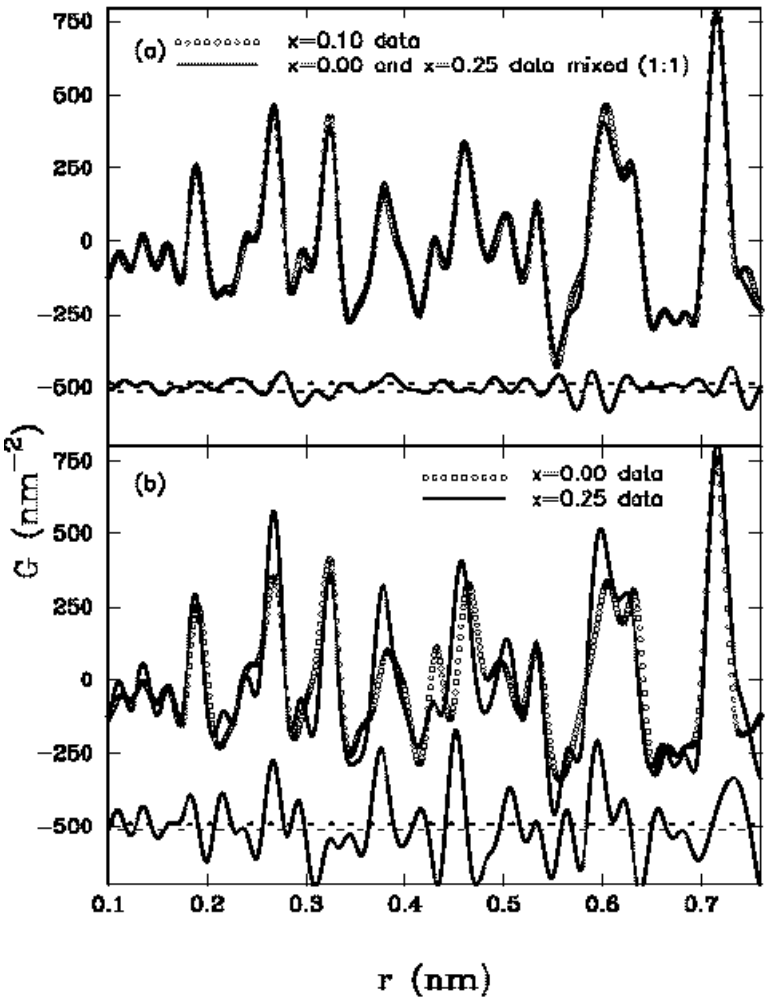
Http:/www.pa.msu.edu/cmp/billinge-group

LOCAL STRUCTURE FROM DIFFRACTION
MICHIGAN STATE UNIVERSITY

- We can see evidence for the striped nature of the charges
- The figure shows the CuO_2 plane; the squares are CuO_6 octahedra viewed from above. Localized charges are shown as red circles
- Stripes are *short-range ordered* in superconductors
- These cause disruption in the background of CuO_6 octahedral tilts
- We also use PDF to look for octahedra tilt disorder

Bozin *et al*. Phys. Rev. B **59** 4445 (1999).

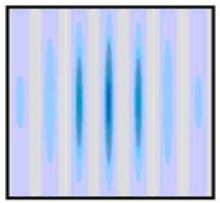
Evidence for tilt disorder at intermediate-*r* ?



- *x*=0.0 data have large (5°) tilts
- *x*=0.25 data have ~0° tilts
- *On the average*, *x*=0.1 has intermediate (3°) tilts
- A mixture of *heavily tilted* and *untilted* PDFs reproduce the *x*=0.1 data (top panel) even though the heavily tilted and untilted PDFs are themselves quite different (bottom panel).
- The PDF of doped $La_{2-x}Sr_xCuO_4$ reflects tilt disorder, consistent with charge stripes, in the local structure

Bozin *et al*. Phys. Rev. B **59** 4445 (1999).

High-temperature Superconductivity:



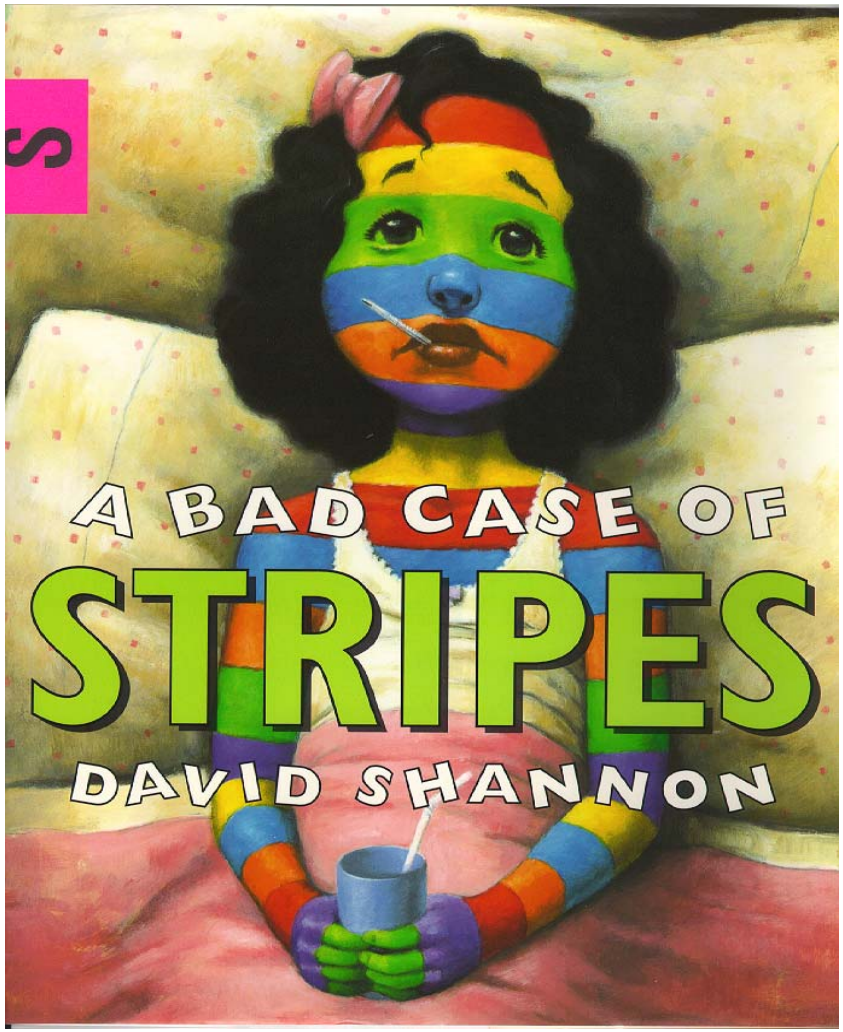
LOCAL STRUCTURE FROM DIFFRACTION

MICHIGAN STATE UNIVERSITY

The PDF supports the presence of charge-stripes in the cuprates

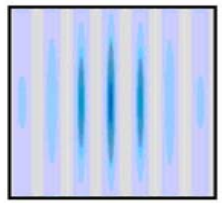
The stripes are coupled to the structure through structural distortions.

Is High-Tc superconductivity just……



?

Acknowledgements



LOCAL STRUCTURE FROM DIFFRACTION

MICHIGAN STATE UNIVERSITY

- People:
  - Emil Bozin (grad student)
  - Matthias Gutmann (post-doc)
  - George Kwei (LANL), Hide Takagi (U. Tokyo), E. L. Brosha (LANL) (collaborators)
- Funding:
  - NSF-DMR
  - Alfred P. Sloan Foundation
  - Center for Fundamental Materials Research