**Spectral weight transfer**

**Optics**

![Graph showing optical conductivity](image1)

**X-Ray Absorption**

![Graph showing X-ray absorption](image2)

**FIG. 7.** Optical conductivity $\sigma(\omega)$ obtained from the ramers-Kronig transformation of the $E_{1c}$ reflectivity spectra for various compositions $x$.


Stripes?


\[ \lambda_{\text{charge}} = 1/\delta \]

\[ \lambda_{\text{magnetic}} = 2/\delta \]
Evidence for (static) “stripes”

La$_{1.48}$Nd$_{0.4}$Sr$_{0.12}$CuO$_4$

J. M. Tranquada, et. al.,
(1450 citations)

- Correlates with 1/8 anomaly
- $\lambda_{\text{charge}} = \lambda_{\text{magnetic}}/2$
- $\lambda_{\text{charge}} = 2/\delta$ – Half-filled (?!)
- Distortion ~ 0.004 Å

Chromium

J. P. Hill, et. al.,
(42 citations)

- Distortion ~ 0.004 Å
- $\lambda_{\text{charge}} = \lambda_{\text{magnetic}}/2$
- $F \sim \rho S^2$

How do we know it’s not just a SDW?
$f(\omega)$ and the unoccupied spectral weight

\[ f_D^{xx} = 82 \]

Hole scatters like Pb atom
Resonant soft x-ray scattering – DON’T CALL IT “RIXS”

- 1.2 m vacuum chamber
- 4 circle geometry
- Vacuum lubricants / coatings
- Channeltron / Au-CsI cathode
- He flow cryostat ($T_B = 18$ K)
- 5 Tesla magnet (vertical field)
- Base pressure $= 5 \times 10^{-10}$ mbar
- National Synchrotron Light Source, X1B

**Momentum-resolved unoccupied density of states**

*Similar to:*
- *Inverse ARPES, but bulk-sensitive*
- *Fourier STM, but can do $T$ dependence*
Experimental Configuration

Sample:
La$_{2-x}$Ba$_x$CuO$_4$, $x = 1/8$
$T_c = 2$ K

Experimental tricks:
1. $T < T_{	ext{LTT}}$
2. Orientation
3. $L = n + 1/2$
4. Cleaving

First observation

\[ k_x = \frac{\pi}{2} \]
Energy Distribution Curve (EDS) or “Resonance Profile”

\[ L = 0.71 \]
Energy Distribution Curve (EDS) or “Resonance Profile”

What a structural superlattice does.
Energy Distribution Curve (EDS) or “Resonance Profile”

- Valence modulation significant. 0.004 Å distortion not detectable.
- UHB peak → spectral weight transfer occurs in real space
- “Mottness” restored in some regions. Driven by frustration of holes
- Quite “stripey” in character
How many holes are involved?


\[ \hat{\mathbf{e}}_f^* \cdot \rho_{\text{stripes}} \cdot \hat{e}_i = (0.00475 \text{Å}^{-3}) A \]

Shown orbital configuration: \( A = 1 \)
Half-filled stripes: \( A = 1/2 \)
How many holes are involved?

**Integrated intensity**

\[ I \propto \left| \hat{\mathbf{E}}_f^* \cdot \mathbf{p}_Q \cdot \hat{\mathbf{E}}_i \right| \frac{\sin \theta_s}{\mu (\sin \theta_s + \sin \theta_i)} \]

**Ellipsoidal approximation**

\[ I = I_{\text{peak}} \Delta q_x \Delta q_y \Delta q_z \]

**Integrated intensities**

\[ I_{002} = (23607 \text{Hz})(.0023\text{Å})^3 = 0.0189 \text{Hz/Å}^3 \]

\[ I_{\text{stripes}} = (0.85 \text{Hz})(0.0133\text{Å})(0.0169\text{Å})(0.256\text{Å}) = 4.89 \times 10^{-5} \text{Hz/Å}^3 \]


\[ \Delta \nu = 0.063 \text{ holes} \]

\[ A = 0.59 \text{ holes} \]

Just an estimate but shockingly close to half-filled stripes.
Summary

What we have learned:

• *Holes directly involved.* Not a simple SDW.

• Spectral weight transfer “oscillates” in real space – Driven by desire to restore “Mottness”

• Valence amplitude = 0.063

• Integral = 0.59 holes. *Entire valence band participates.*

• Related to Wigner crystal in Sr$_{14}$Cu$_{24}$O$_{41}$ (Abbamonte, *Nature*, 431, 1078 (2004). *Commensuration is key.*

Some things we have not learned:

• Lines *vs.* checkers *vs.* bond-centered *vs.* cite-centered