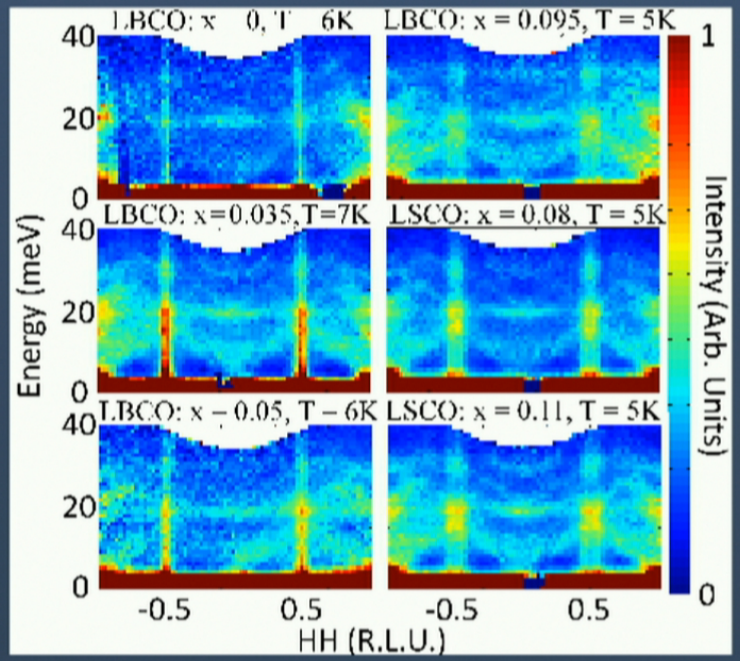
Title: Quasi-Two Dimensional Spin and Phonon Excitations in High Tc related Quantum Magnets

Date: Apr 30, 2015 05:00 PM

URL: http://pirsa.org/15040165

Abstract: New developments in time-of-flight neutron spectroscopy allow a remarkably comprehensive determination of the full spin and phonon excitation spectrum in many materials. I will discuss these new techniques and show results from the "214" family of layered quantum magnets - which are also the La(2-x)Ba/Sr(x)CuO4 high Tc superconductors. We observe the expected highly dispersive spin excitations emanating from the "pi-pi" magnetic zone centres, as well as a host of optic and acoustic phonons, and roughly speaking, the spin and phonon excitations separate as a function of momentum. However, a very interesting resonant phenomena is observed which is coincident with the low energy crossings of the dispersive spin excitations with the relatively dispersion less phonons.

Quasi-Two Dimensional Spin and Phonon Excitations in High-Tc Quantum Magnets



J.J. Wagman [1]
J.P. Carlo [1,2]
D. Parshall [3]
G. van Gastel [1]
M.B. Stone [4]
G.E. Granroth [4]
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Y.J. Kim [5]
H.A. Dabkowska [1]

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[2] Villanova University
[3] NIST Center for Neutron Research
[4] Neutron Sciences Division, ORNL
[5] University of Toronto

Bruce D. Gaulin
McMaster University

Brockhouse Institute for Materials Research

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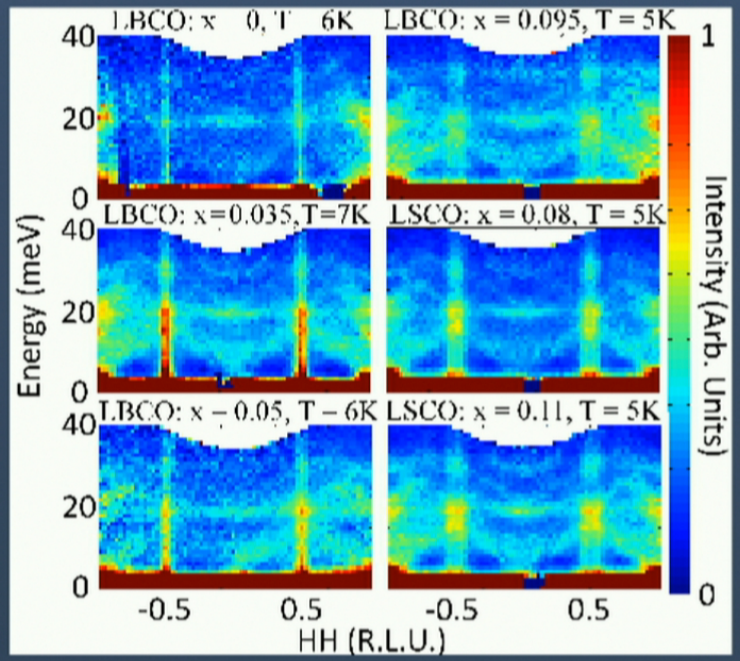

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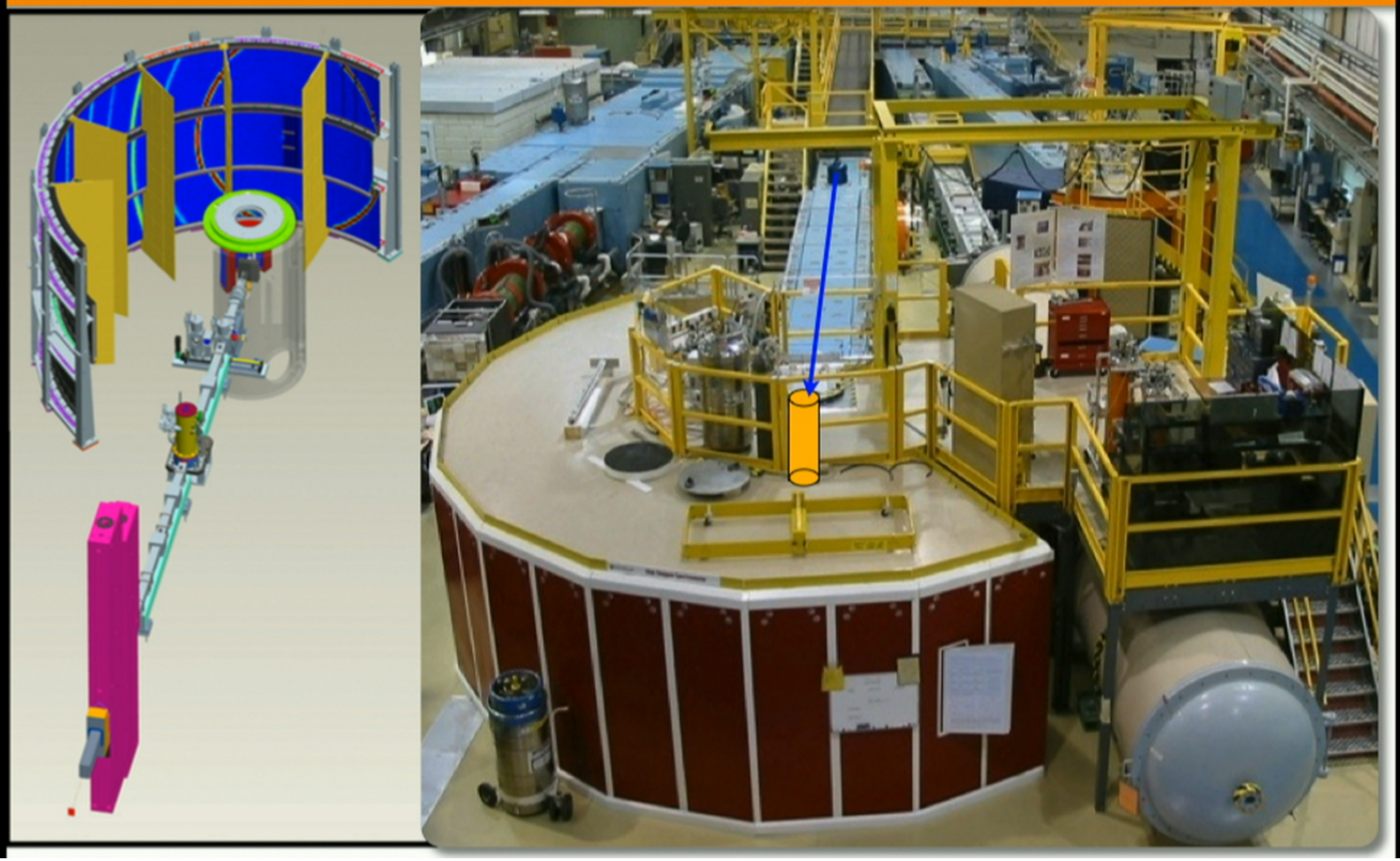
Time of Flight Neutron Scattering



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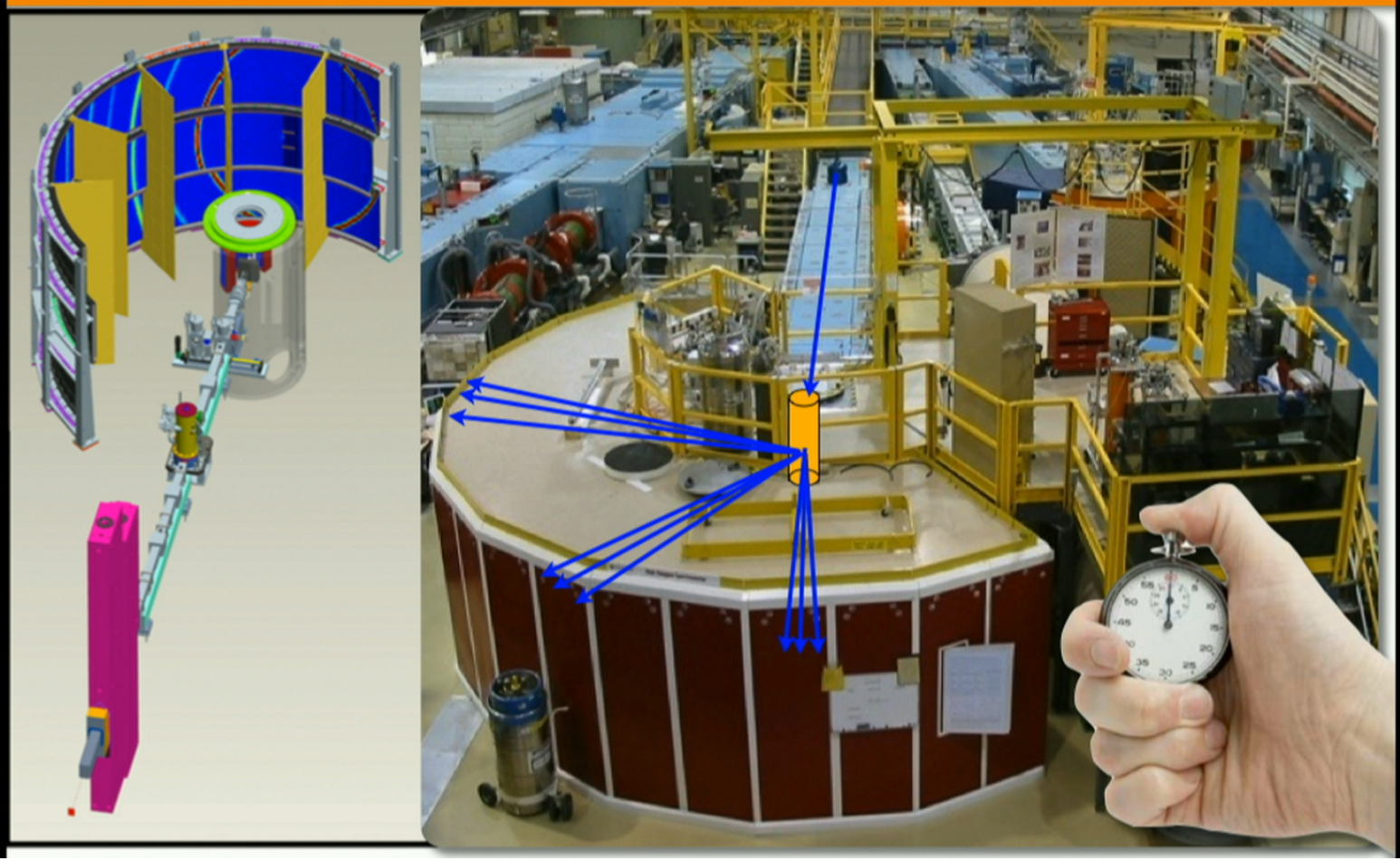
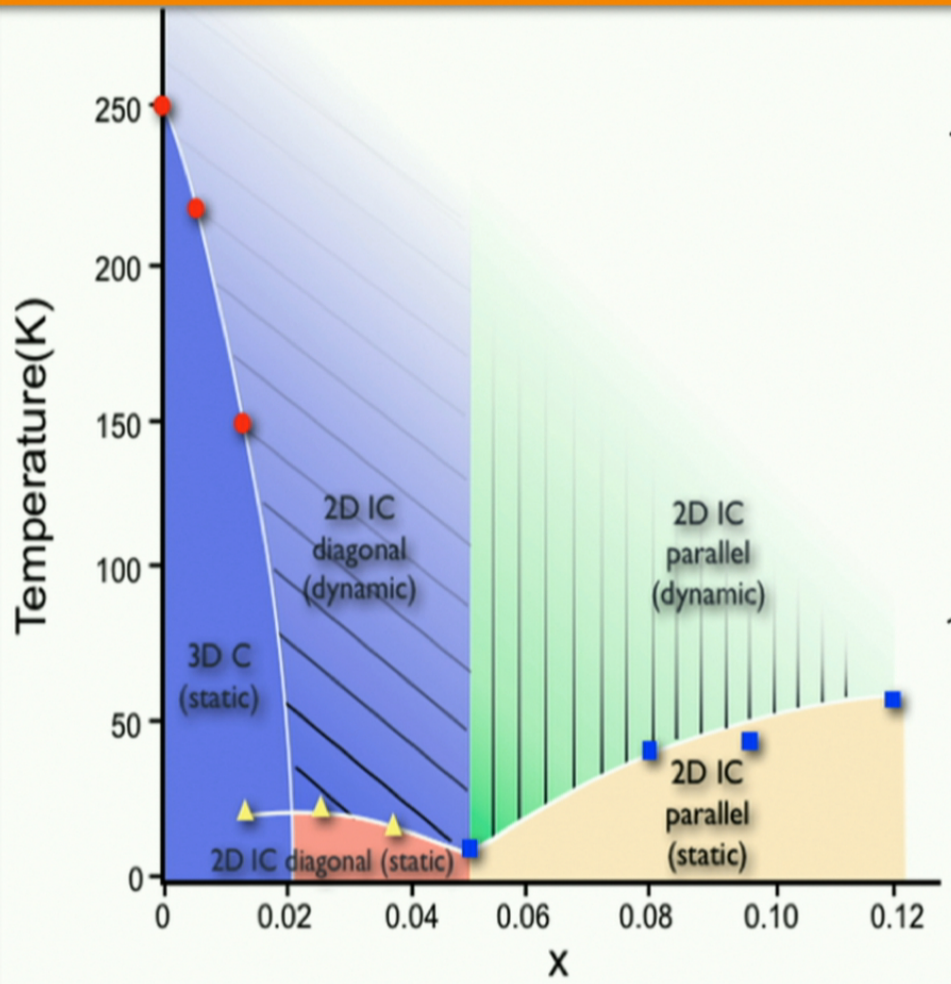
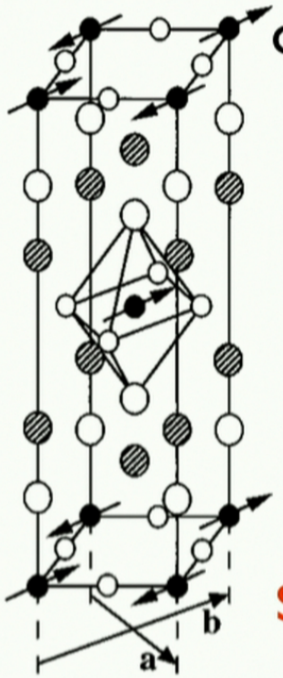


Doping a 2D quantum AF with mobile holes





Cu^{2+}: S = 1/2

La_2CuO_4

Cu^{2+}

O^{2-}

O^{2-}

La^{3+}

Sr^{2+} or Ba^{2+}

$La_{2-x}Ba_xCuO_4$

&

$La_{2-x}Sr_xCuO_4$

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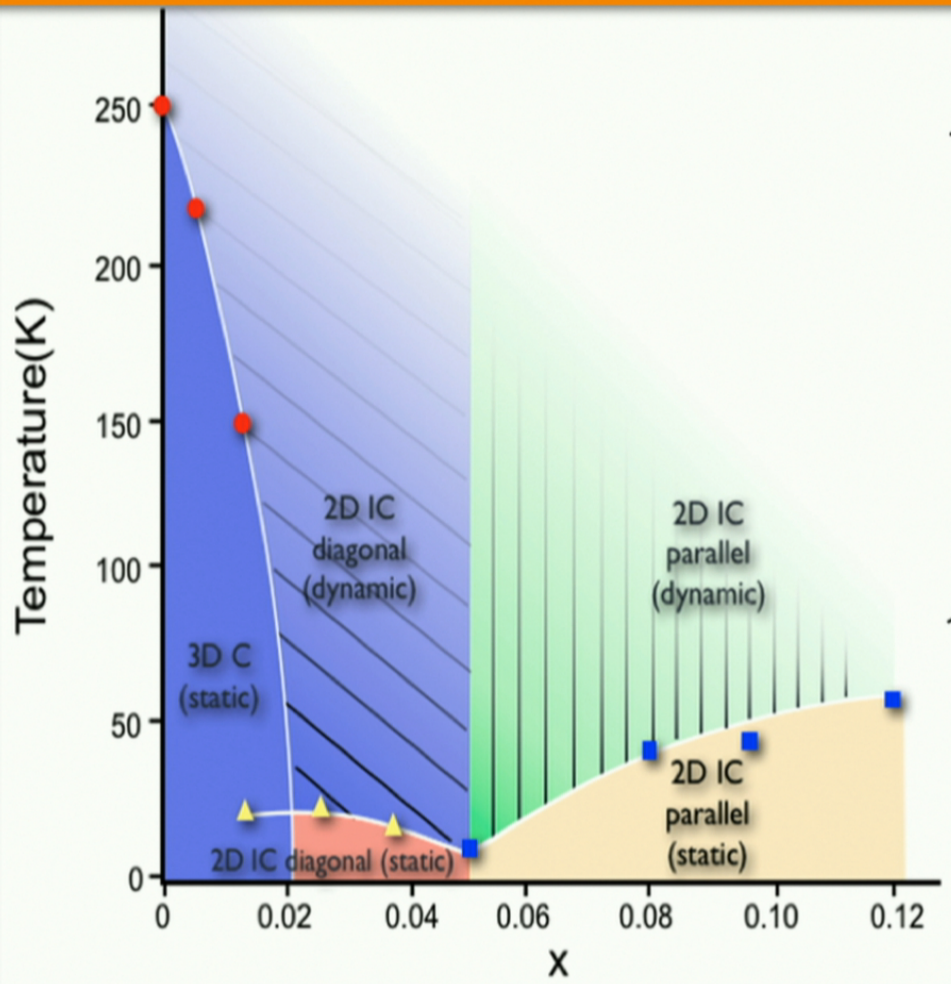

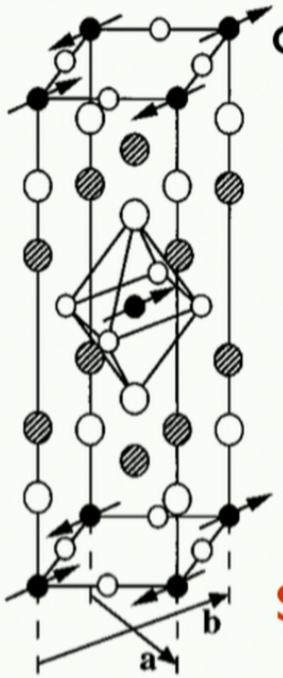

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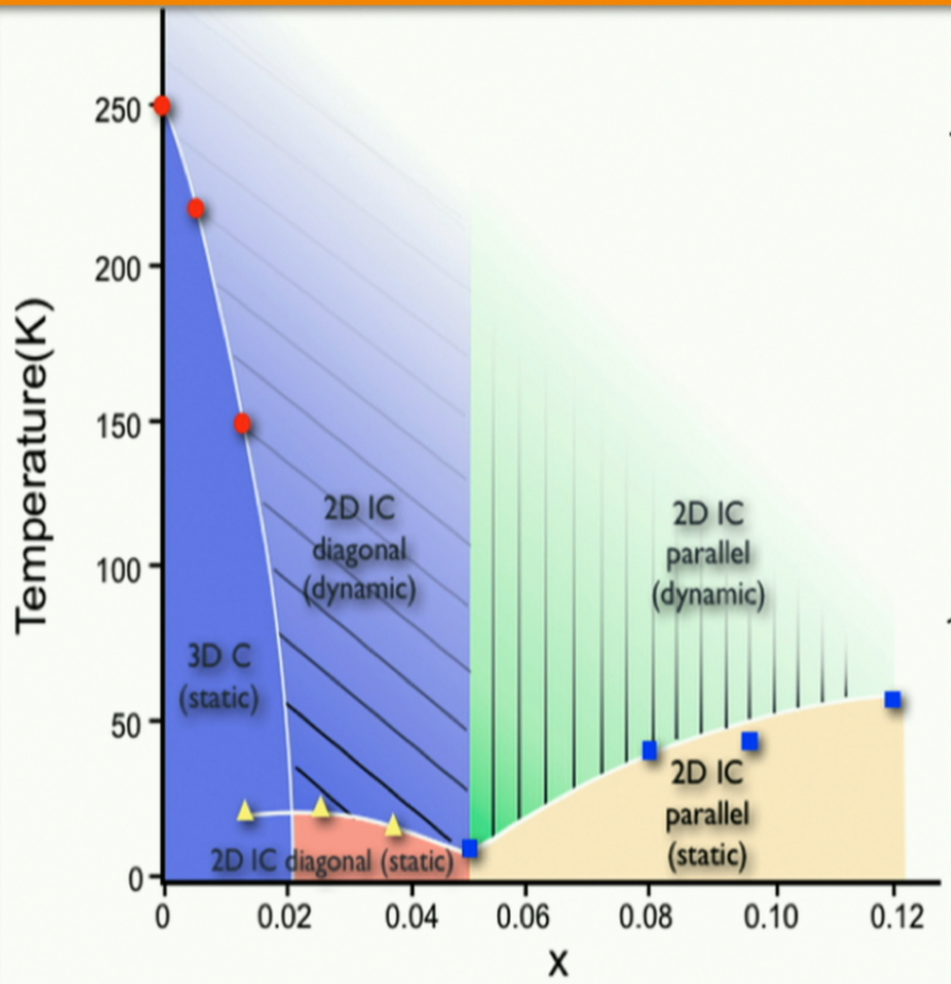

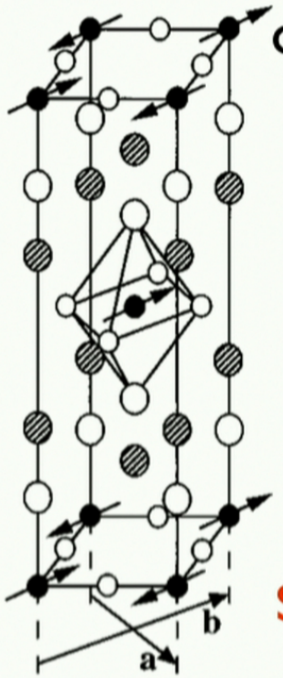

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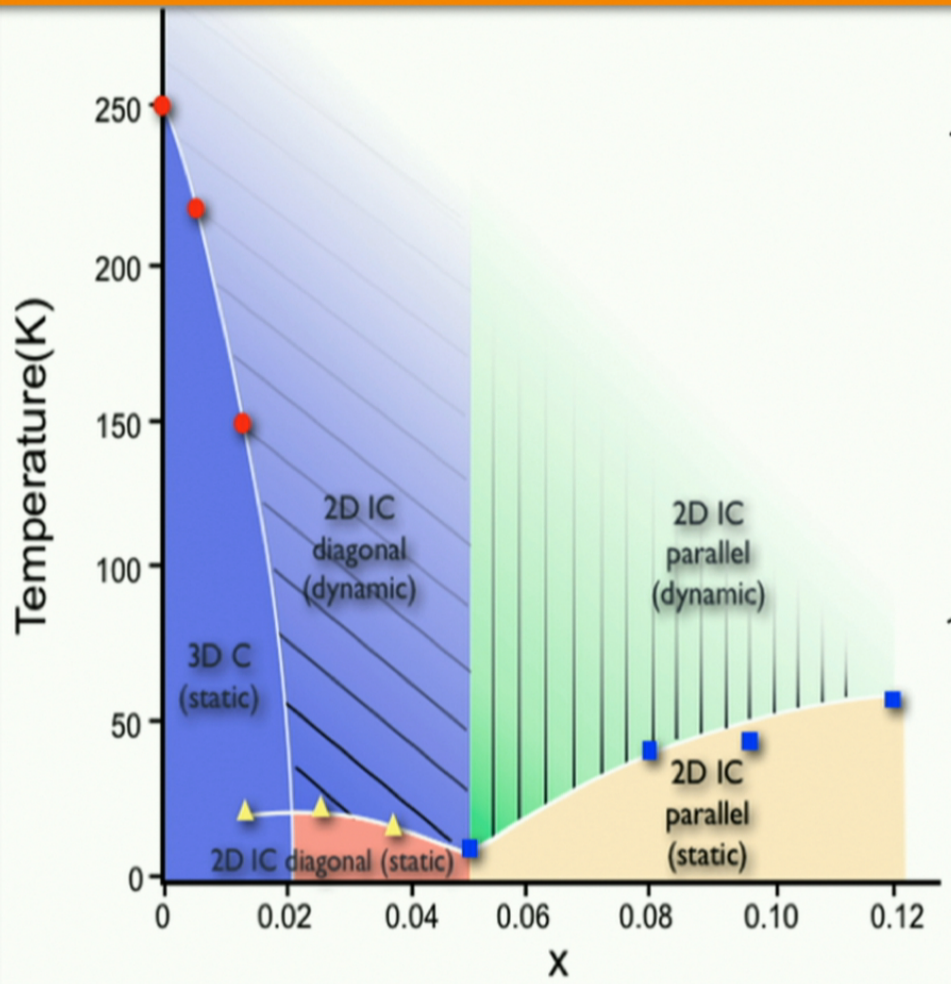

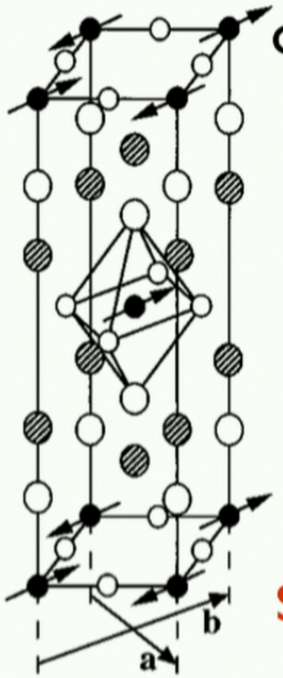

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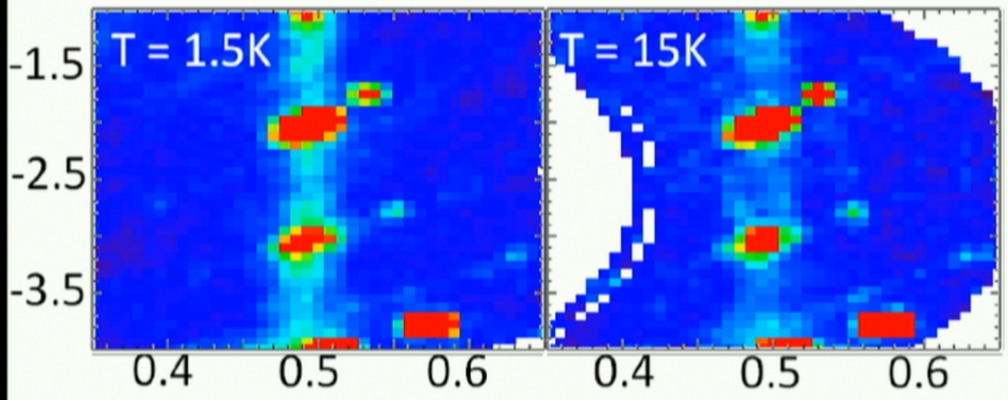
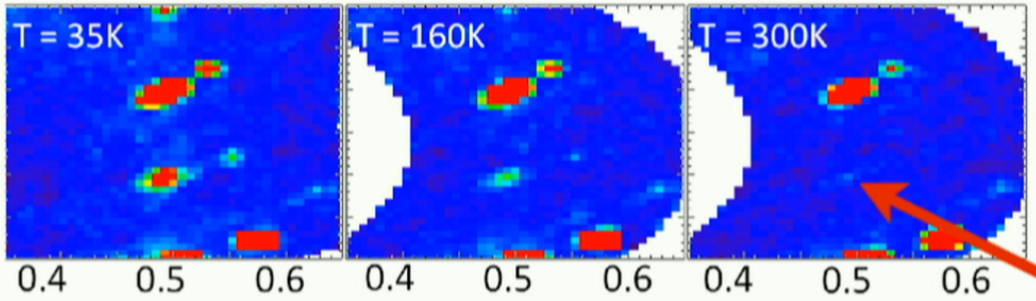
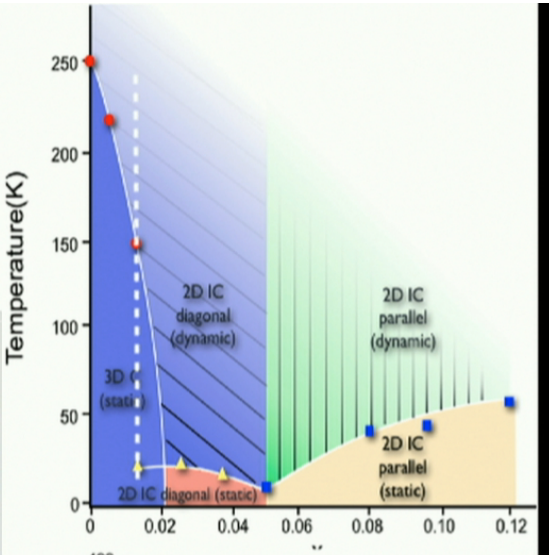
$La_{2-x}Sr_xCuO_4$

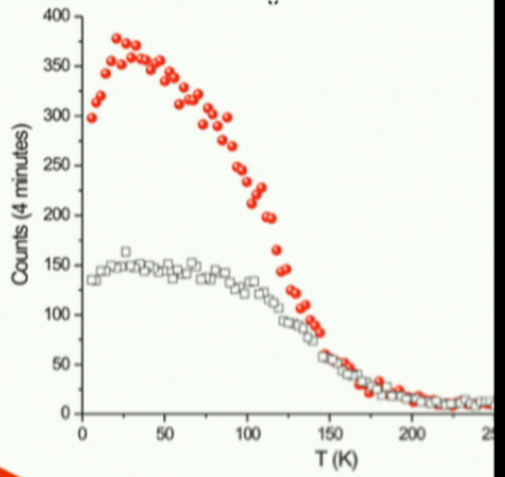
- 3D Long Range Ordered Structure:
  Bragg "spots" - *strong*
- 2D LRO imbedded in 3D Structure:
  1 redundent dimension
  Bragg "rods" - *weaker*
- 1D LRO imbedded in 3D Structure:
  2 redundent dimensions
  Bragg "planes" - *weakest*

Elastic Scattering
LBCO x=0.015







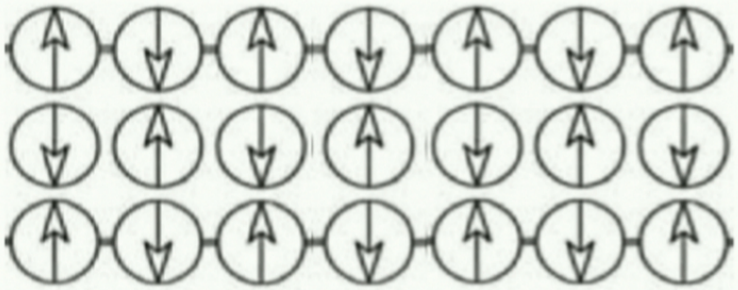


3D magnetic Bragg peak

J. J. Wagman et al., Phys. Rev. B 88, 014412, 2013

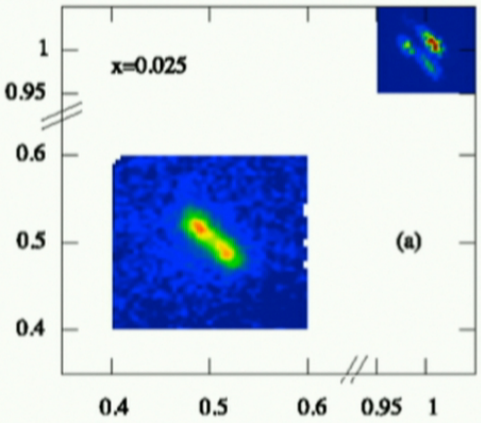
Doping the S=1/2 square lattice with *mobile* holes

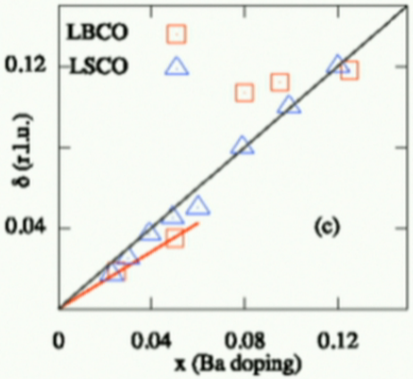
J. M. Tranquada *et al*, Nature **375**, 561 (1995)



"π-π" *order*

$\frac{1}{2} \times 2\pi = \pi$





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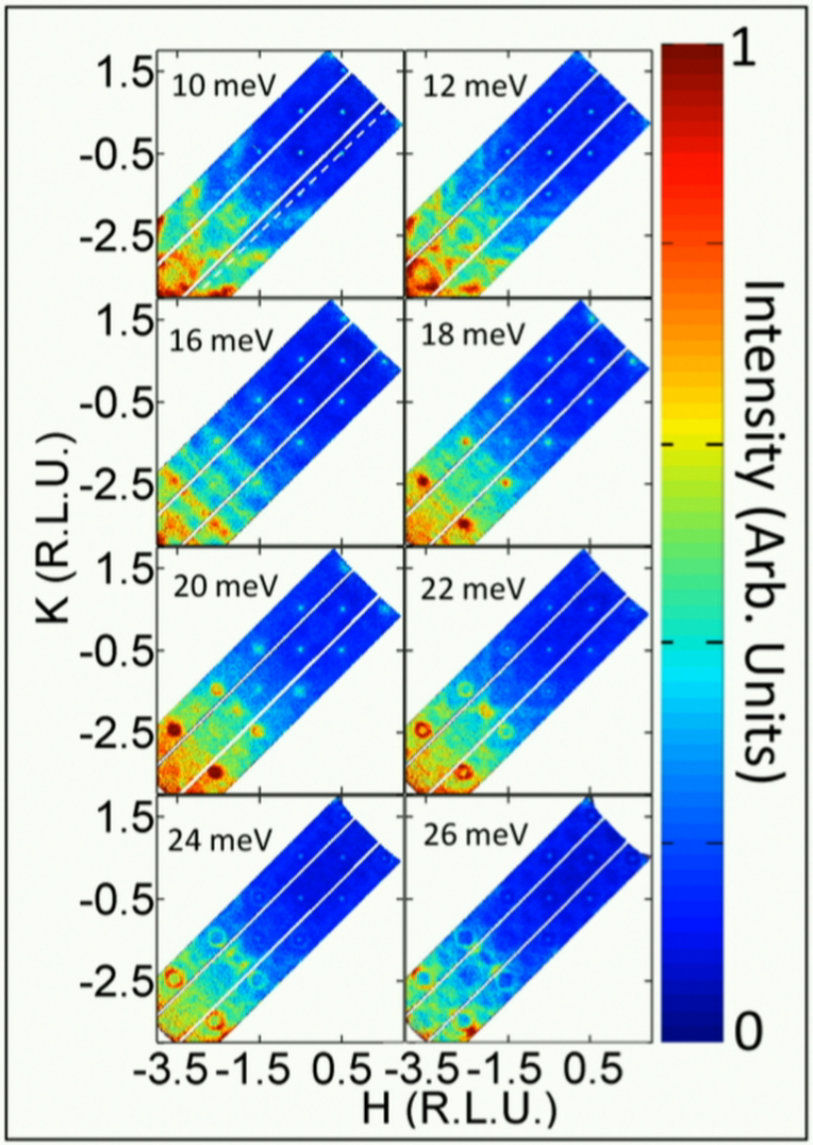
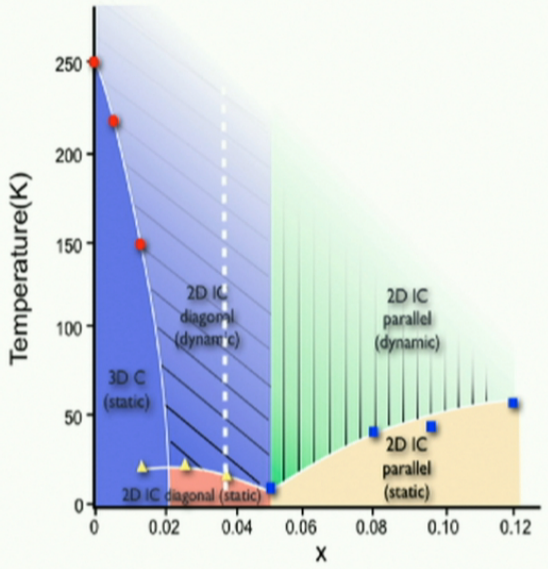
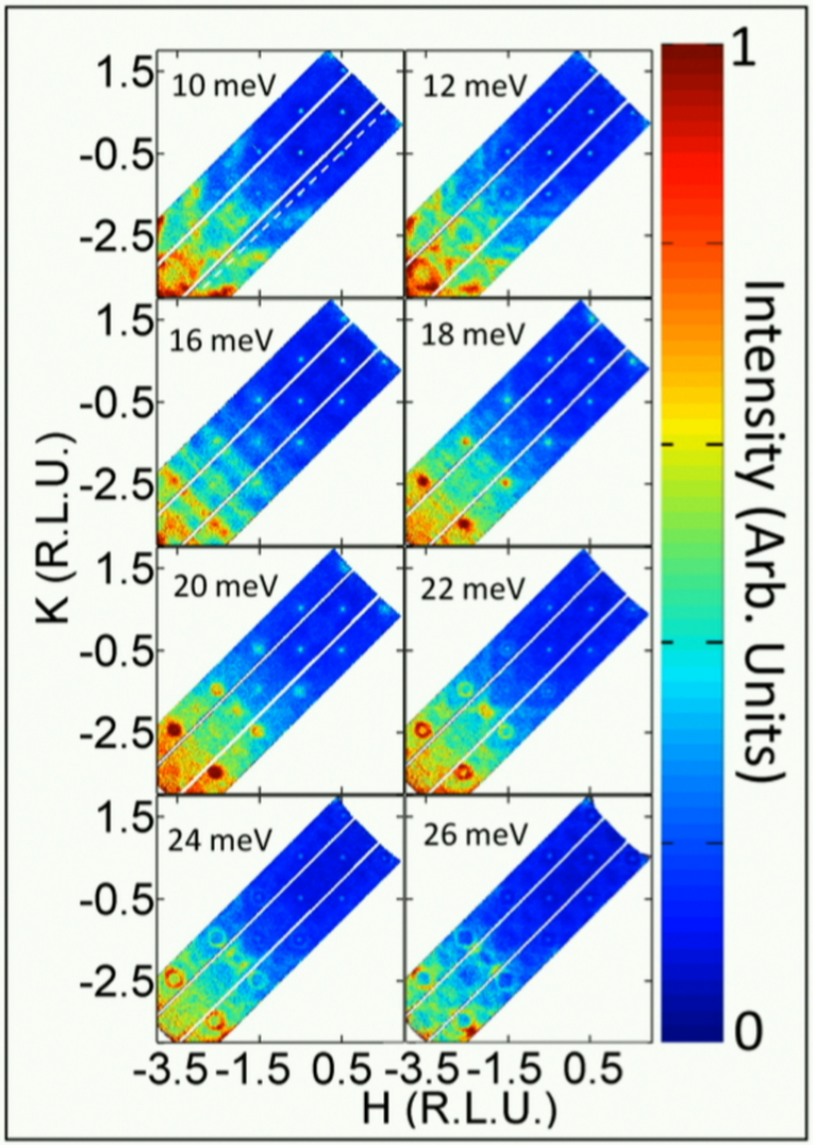
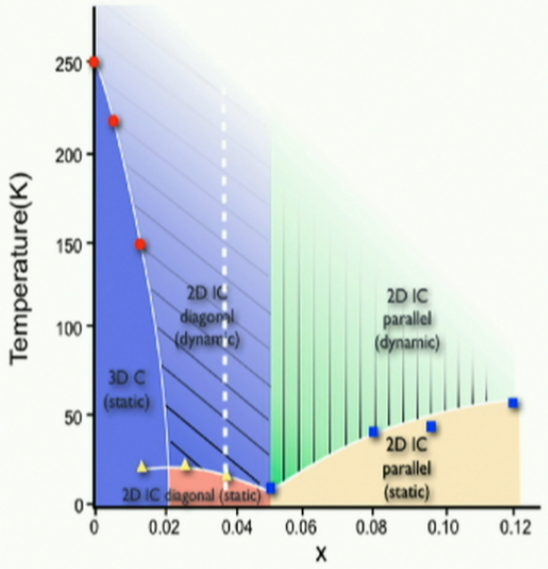
S. R. Dunsiger et al, Phys. Rev. B 78, 092507 (2008)





Inelastic Scattering
LBCO x=0.035

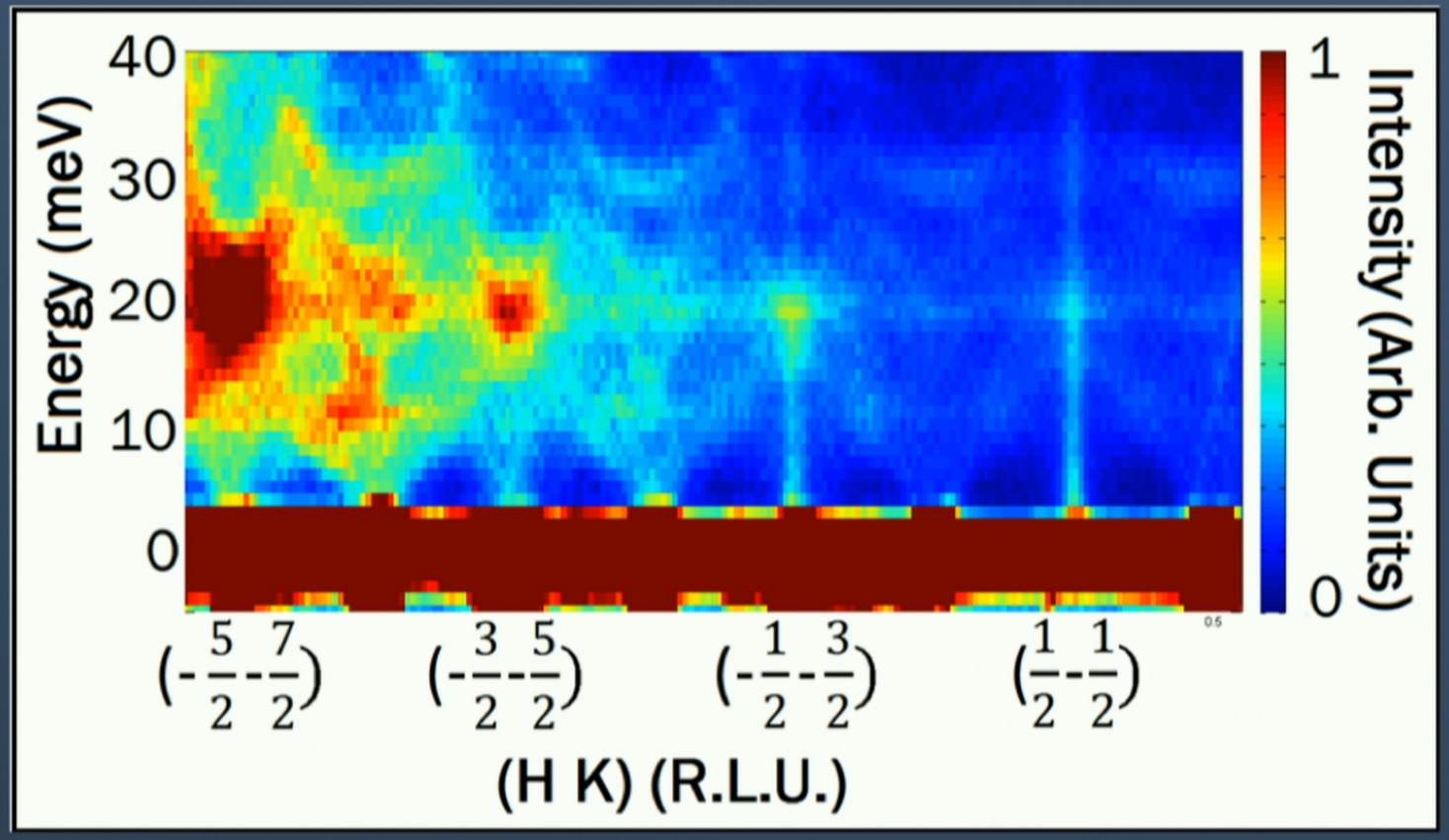


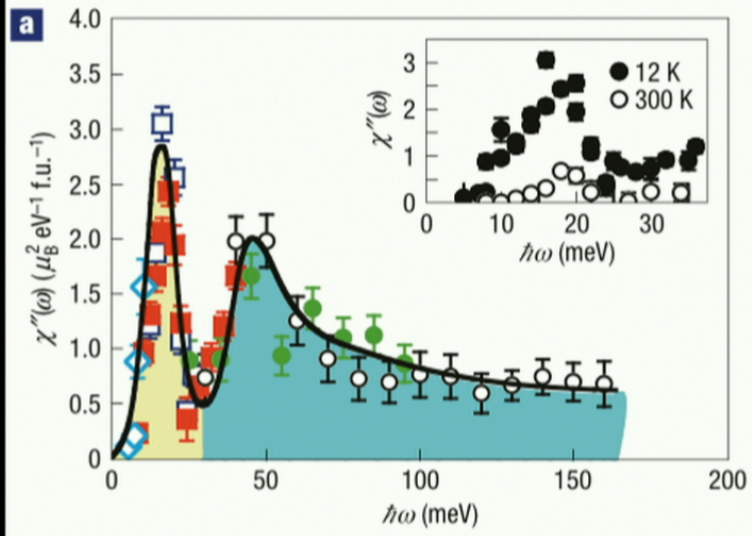


Inelastic Scattering
LBCO x=0.035

Systematics with Q

High Q - phonons Low Q - spin



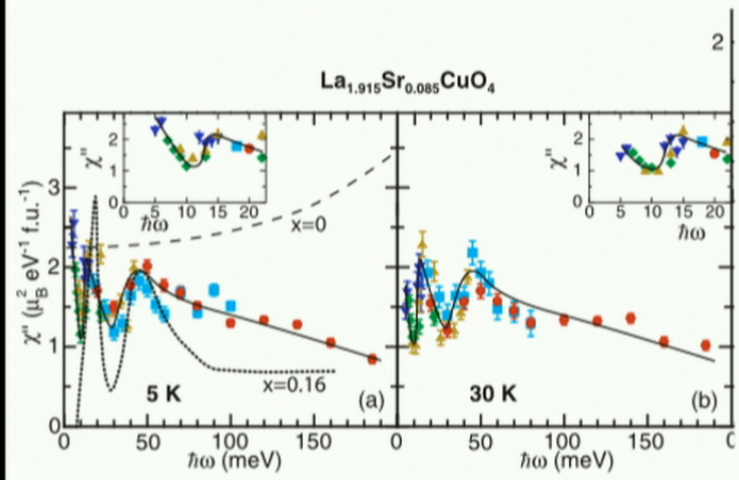


LETTERS

Two energy scales in the spin excitations of the high-temperature superconductor $La_{2-x}Sr_xCuO_4$

B. VIGNOLLE[1], S. M. HAYDEN[1]*, D. F. McMORROW[2,3], H. M. RØNNOW[4], B. LAKE[5], C. D. FROST[3] AND T. G. PERRING[3]

LSCO x=0.16

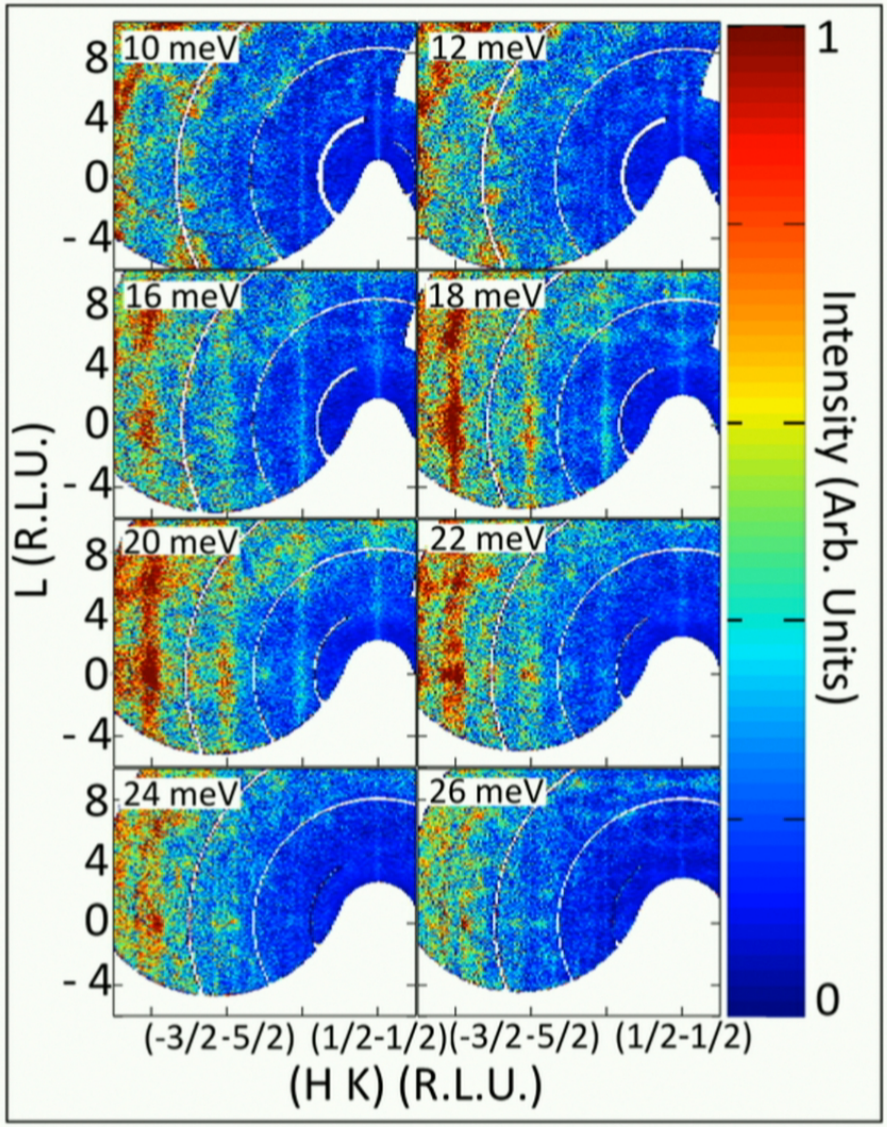


PRL 102, 167002 (2009) PHYSICAL REVIEW LETTERS week ending 24 APRIL 2009

Emergence of Coherent Magnetic Excitations in the High Temperature Underdoped $La_{2-x}Sr_xCuO_4$ Superconductor at Low Temperatures

O. J. Lipscombe,[1] B. Vignolle,[1] T. G. Perring,[2] C. D. Frost,[2] and S. M. Hayden[1]

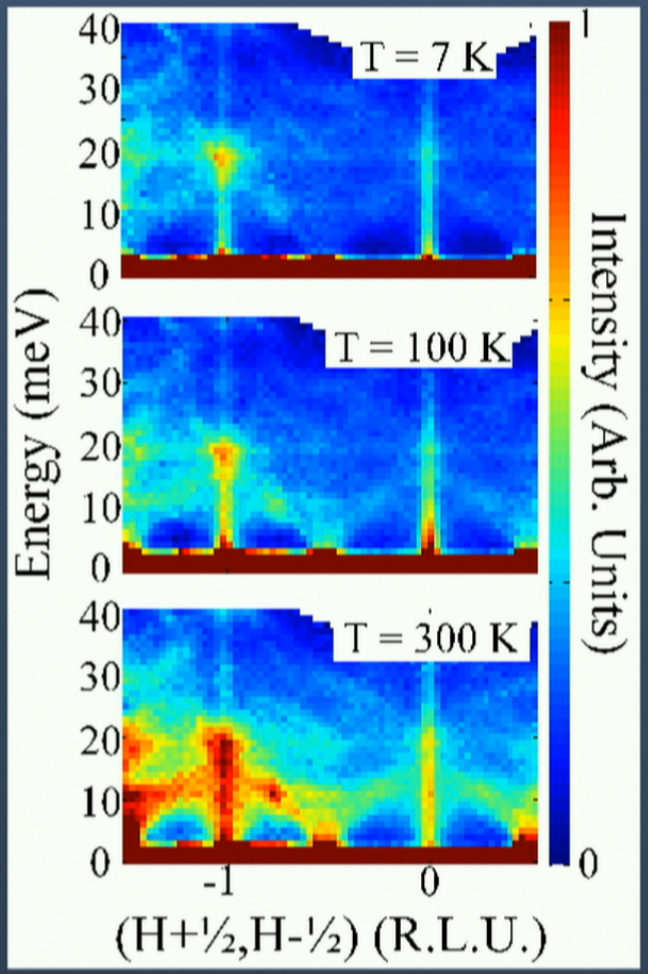
LSCO x=0.085

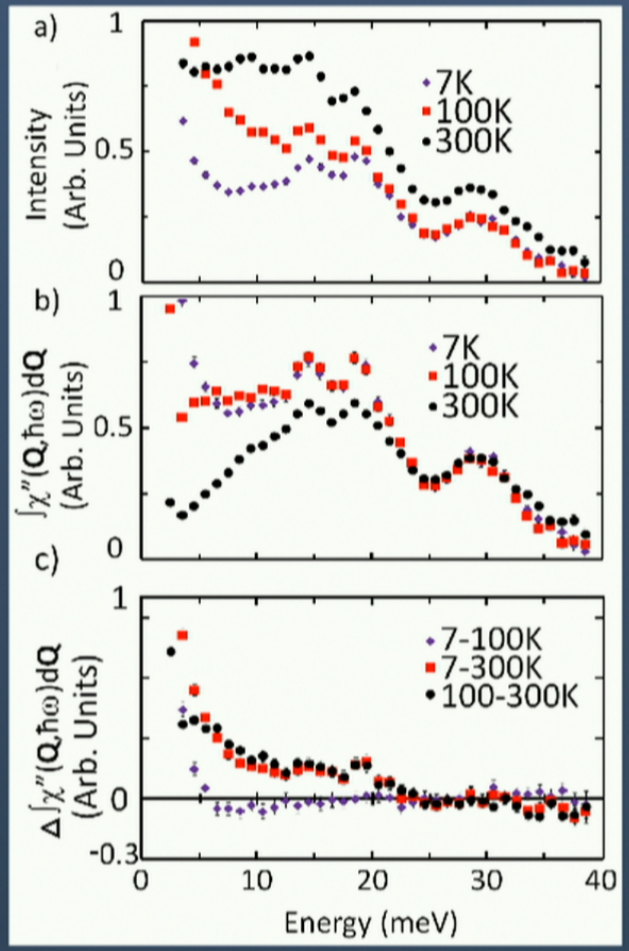


L-dependence

2D LRO
imbedded in 3D Structure:
1 redundent dimension
Bragg "rods" - *weaker*

$$S(\mathbf{Q},\omega,T) = [n(\hbar\omega)+1)] \times \chi''(\mathbf{Q},\omega,T) \quad , \qquad [n(\hbar\omega)+1)] = \frac{1}{1-e^{-\frac{\hbar\omega}{k_B T}}}$$





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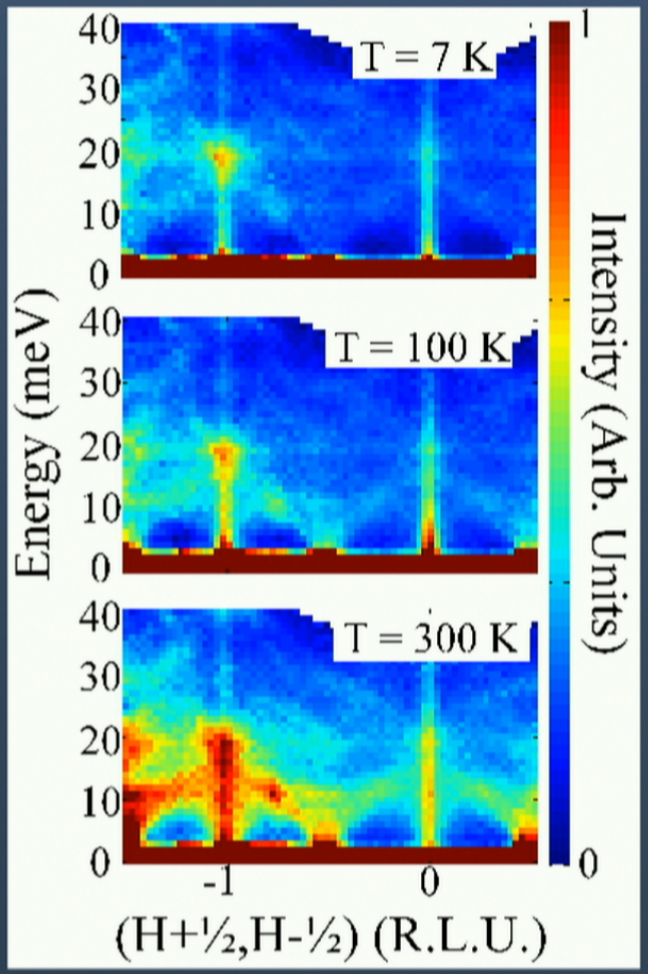
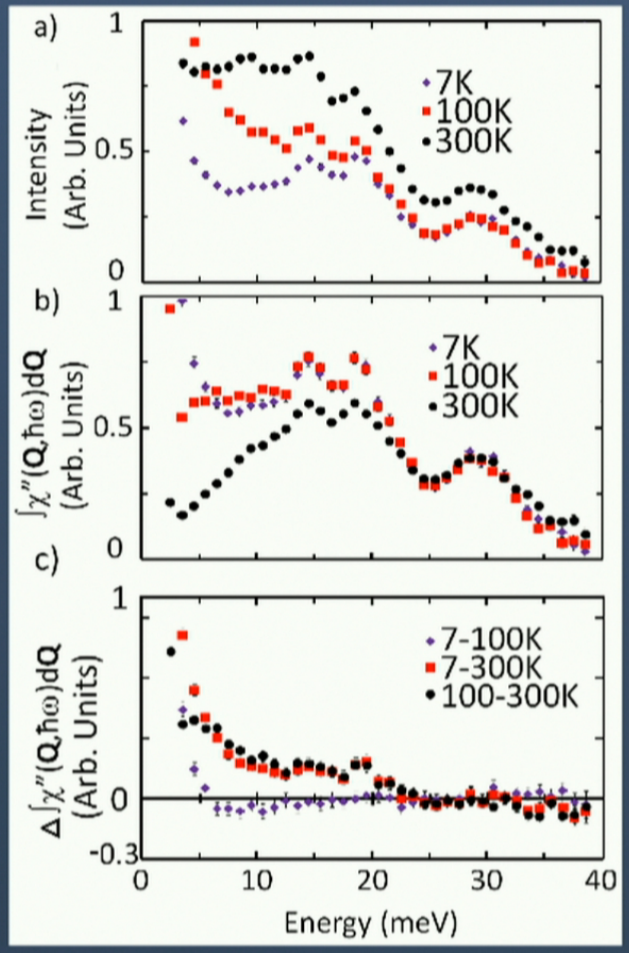
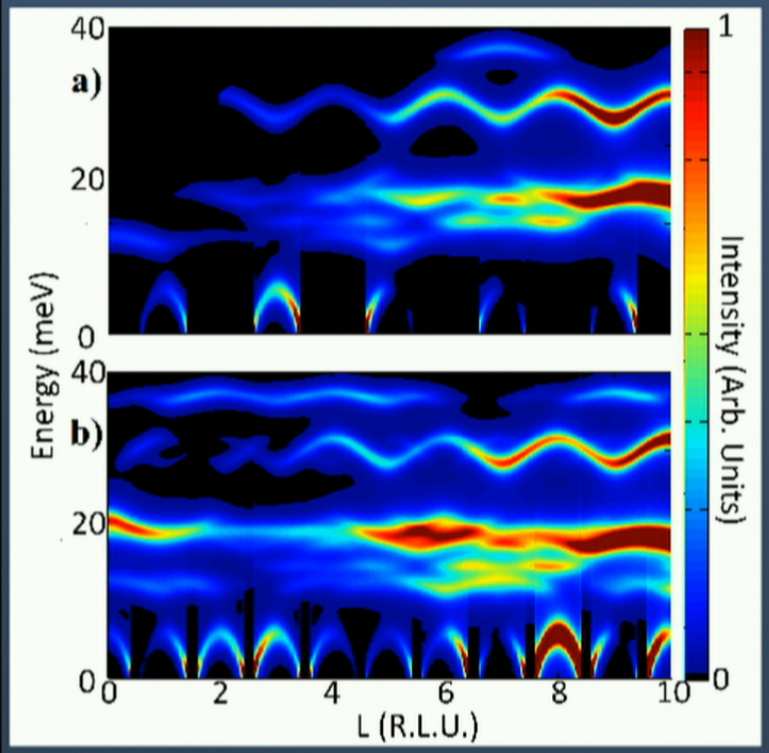
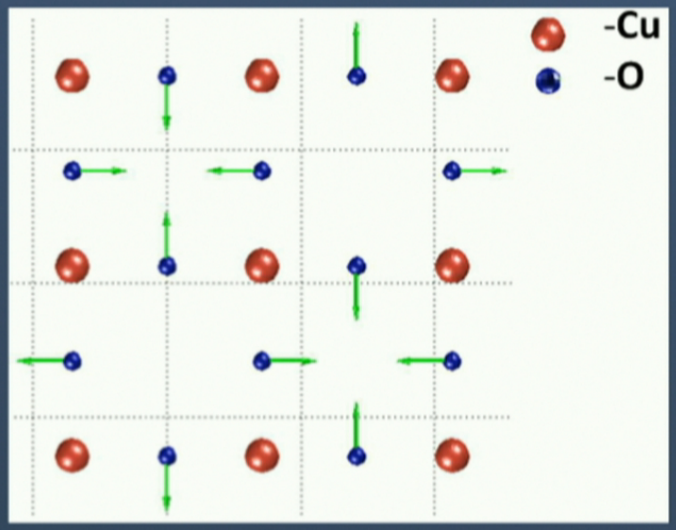




What is the nature of these phonon eigenvectors?

DFT calculation





eigenvector
for 19 meV optic phonon

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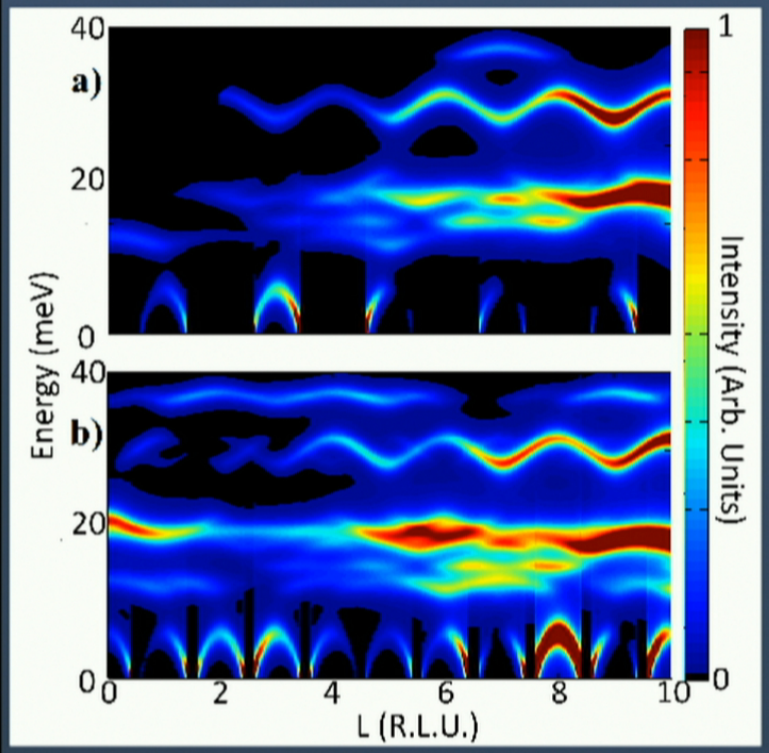

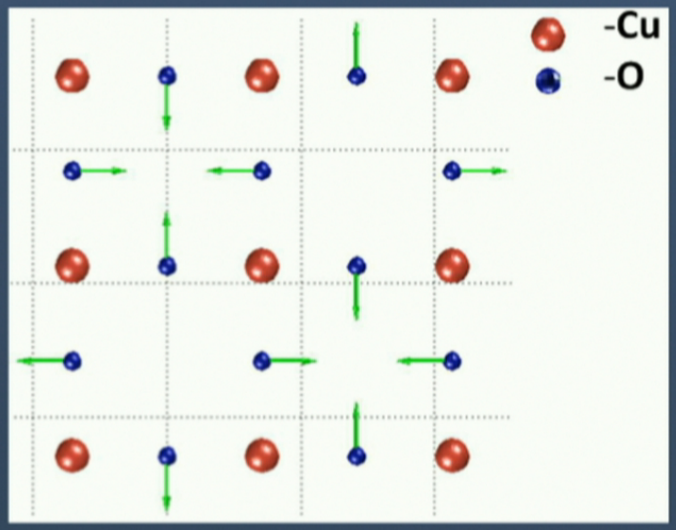

eigenvector
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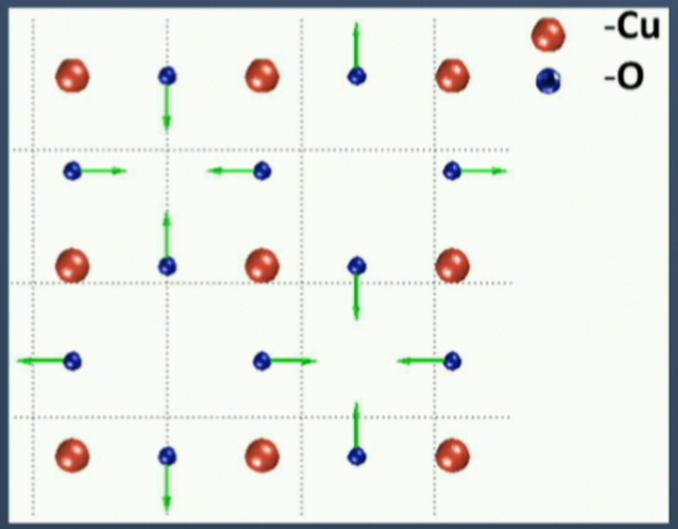
19 meV optic phonon eigenvector should couple strongly to magnetism

Goodenough - Kanamori rules



eigenvector
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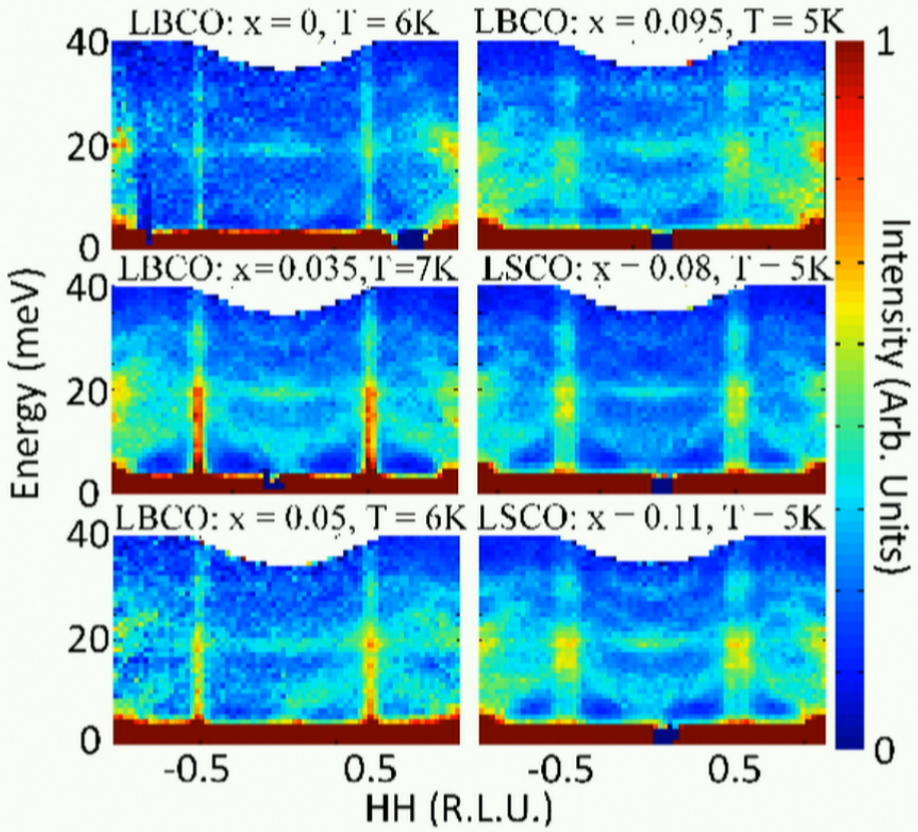
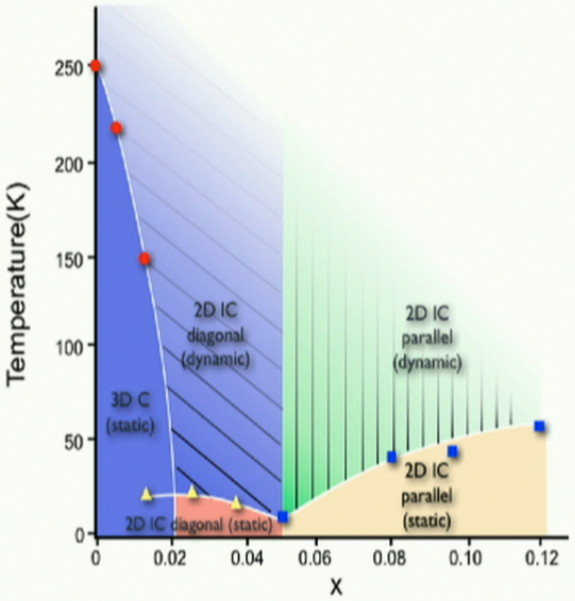
Antiferro J
strong

Ferro J
weak

Doping dependence in LBCO and LSCO





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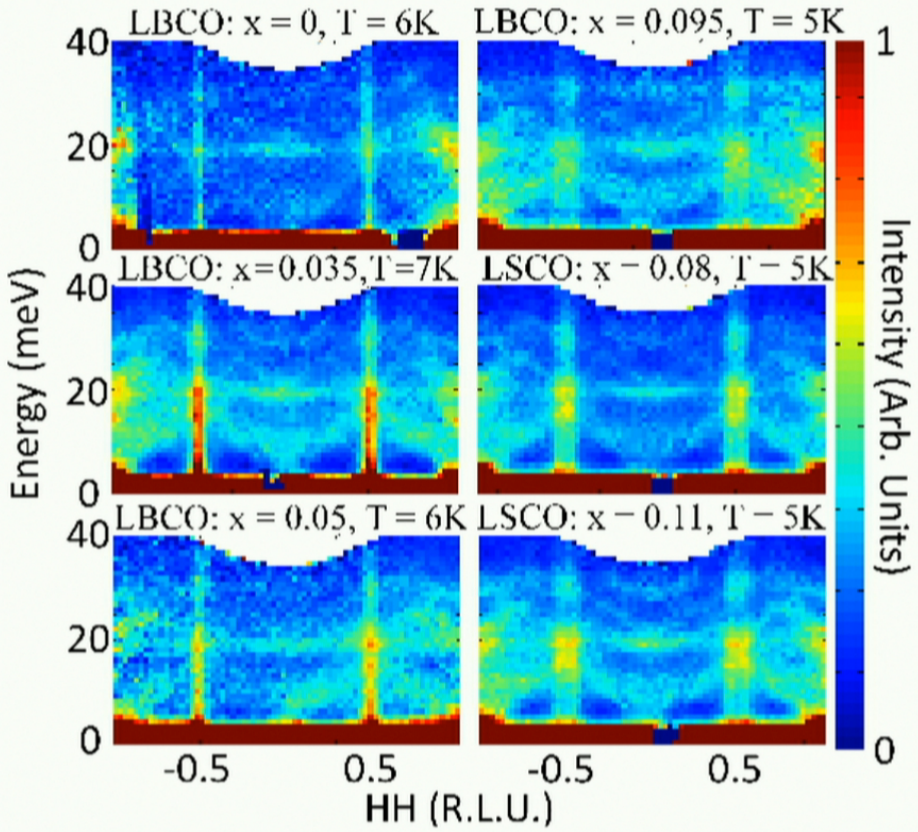

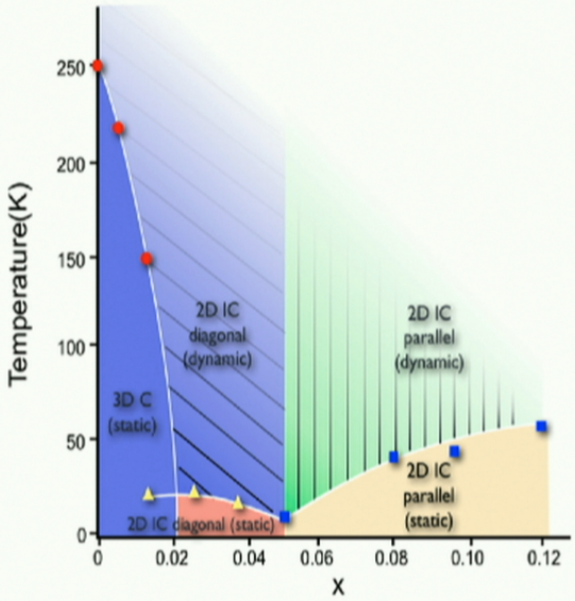

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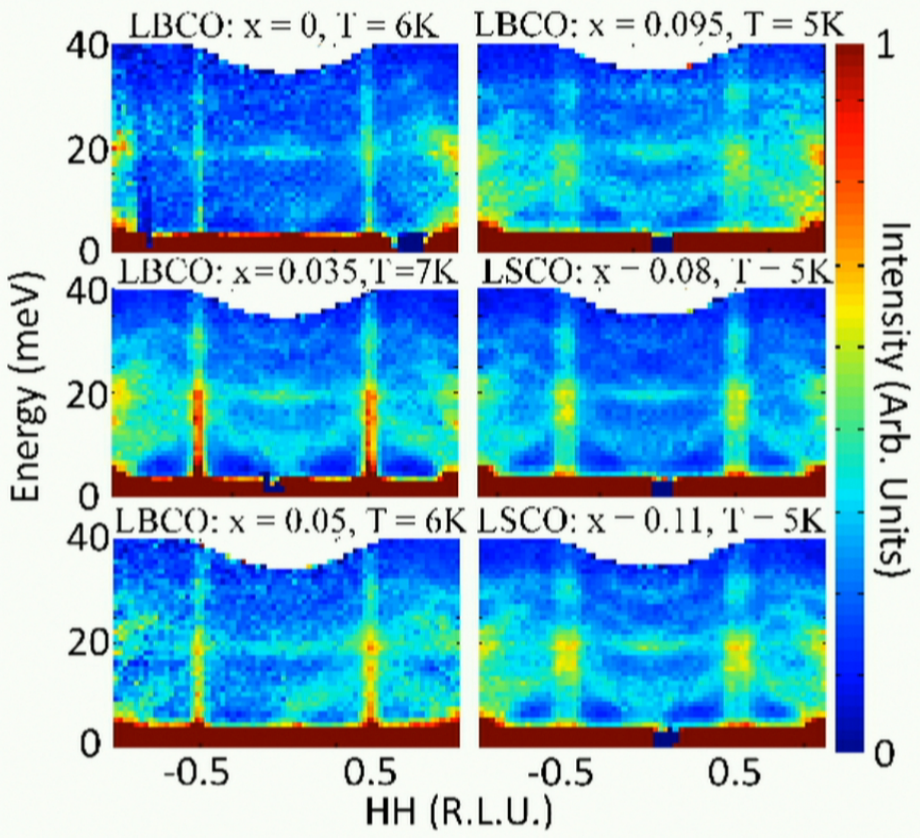

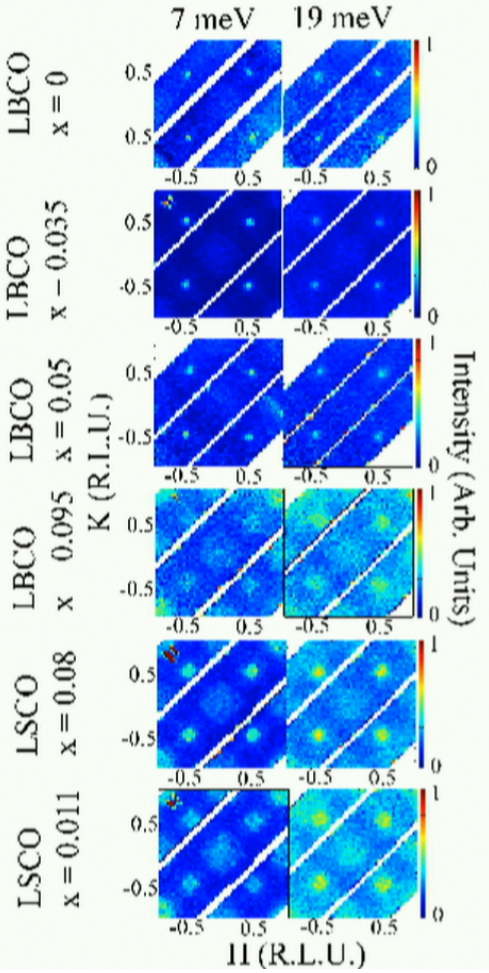

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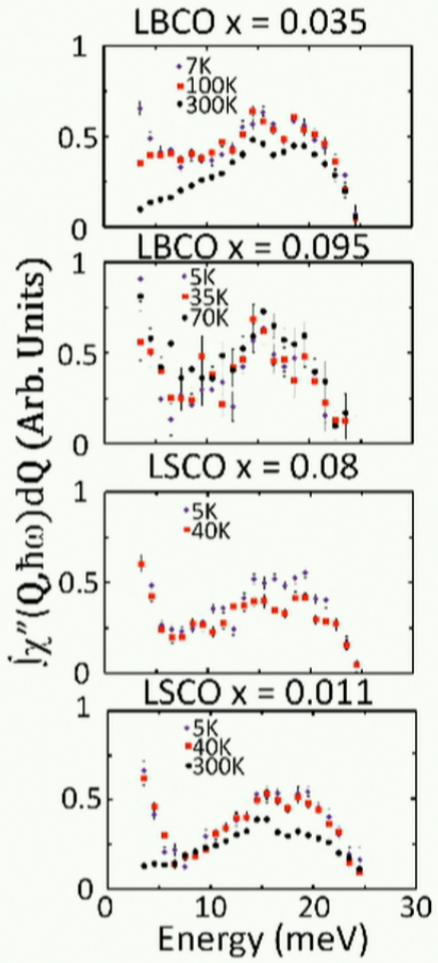
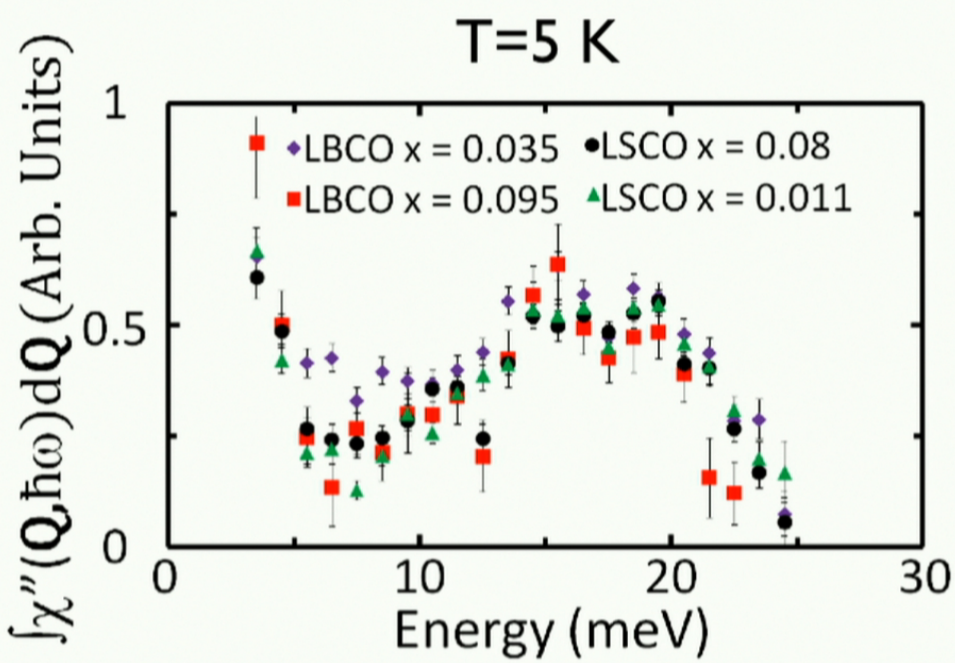
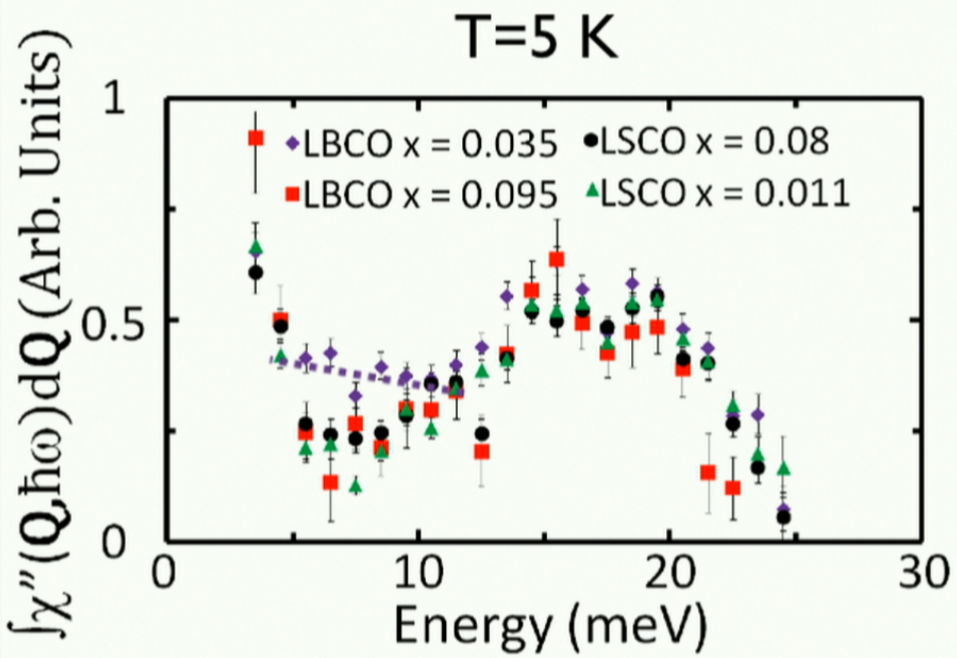
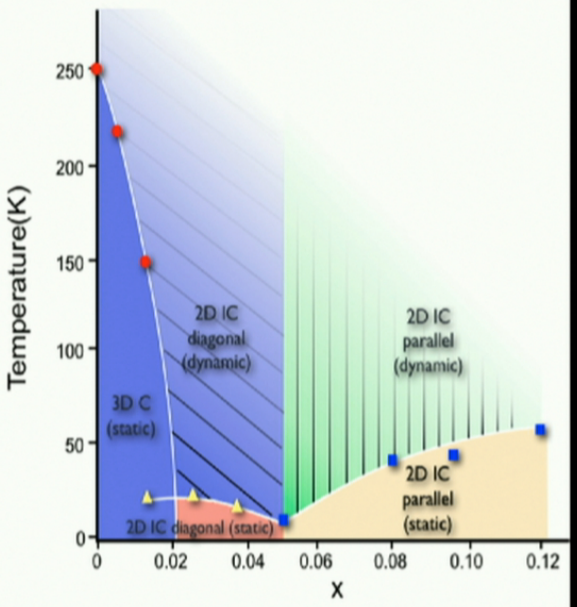




- "Resonance" is present at all concentrations
- Hybridized spin-phonon excitation?
- low energy suppression of X" occurs as function of doping, *not temperature* !

Doping dependence in LBCO and LSCO





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Collaboration:

J. J. Wagman et al., Phys. Rev. B 88, 014412, 2013
J. J. Wagman et al., arXiv:1412.2706 and Phys. Rev. B, to appear