

Recent uses of diffraction in correlated electron systems research

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GLAM/SSRL

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Degrees of freedom

- Spin
- Charge (aka orbital)
- Ionic

Interactions

Coulomb

Strongly correlated electron systems

PERIODIC TABLE
Atomic Properties of the Elements

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Frequently used fundamental physical constants
For the most accurate values of these and other constants, visit physics.nist.gov/constants
1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs

Speed of light in vacuum c 299 792 458 m s⁻¹ (exact)
Planck constant h 6.626 070 15 × 10⁻³⁴ J s ($h = h/2\pi$)
elementary charge e 1.602 176 634 × 10⁻¹⁹ C
electron mass m_e 9.109 383 56 × 10⁻³¹ kg
proton mass m_p 1.672 621 63 × 10⁻²⁷ kg
fine-structure constant α 1/137.036
 R_∞ 10 973 732 m⁻¹
 $R_\infty c$ 3.289 842 × 10¹⁵ Hz
 $R_\infty hc$ 13.605 698 eV
Boltzmann constant k 1.380 658 × 10⁻²³ J K⁻¹

■ Solids
■ Liquids
■ Gases
■ Artificially Prepared

1 1 H 1.00794 13 5964	2 IIA Li 6.941 3 0917	3 IIIB Be 9.012182 16 26 9 5227	4 IIIA B 10.811 14 007	5 IIIA C 12.0107 16 26 11 2903	6 IVA N 14.0067 14 5341	7 VA O 15.9994 16 26 13 6181	8 VIA F 18.9984032 16 26 17 4228	9 VIA Ne 20.1797 16 26 21 5045	10 VIA Na 22.98976928 16 26 5 1301	11 VIA Mg 24.3050 16 26 7 6452	12 VIA Al 26.9815386 16 26 5 9858	13 VIA Si 28.0855 16 26 8 1517	14 VIA P 30.973761508 16 26 10 4607	15 VIA S 32.065 16 26 10 3600	16 VIA Cl 35.453 16 26 12 9670	17 VIA Ar 39.948 16 26 15 7596	18 VIA K 39.0983 16 26 4 3407	19 VIA Ca 44.0578 16 26 6 1132	20 VIA Sc 44.955910 16 26 6 5615	21 VIA Ti 47.88 16 26 6 8281	22 VIA V 50.9415 16 26 6 7482	23 VIA Cr 51.9961 16 26 6 7905	24 VIA Mn 54.938044 16 26 7 4340	25 VIA Fe 55.845 16 26 7 9024	26 VIA Co 58.933200 16 26 7 8810	27 VIA Ni 58.933200 16 26 7 6366	28 VIA Cu 63.546 16 26 9 3942	29 VIA Zn 65.409 16 26 9 3942	30 VIA Ga 69.723 16 26 5 9603	31 VIA Ge 72.64 16 26 7 8904	32 VIA As 74.9216 16 26 9 7896	33 VIA Se 78.96 16 26 9 7524	34 VIA Br 79.904 16 26 11 8138	35 VIA Kr 83.796 16 26 13 9966	36 VIA Rb 85.4678 16 26 4 1771	37 VIA Sr 87.62 16 26 5 8949	38 VIA Y 88.90585 16 26 6 2173	39 VIA Zr 91.224 16 26 6 6339	40 VIA Nb 92.90638 16 26 6 6339	41 VIA Mo 95.94 16 26 6 6339	42 VIA Tc 98 16 26 7 20	43 VIA Ru 101.07 16 26 7 3805	44 VIA Rh 101.07 16 26 7 4559	45 VIA Pd 106.42 16 26 8 3369	46 VIA Ag 107.8682 16 26 7 5702	47 VIA Cd 112.411 16 26 9 3938	48 VIA In 114.818 16 26 7 3439	49 VIA Sn 118.710 16 26 7 3439	50 VIA Sb 121.760 16 26 6 6084	51 VIA Te 127.60 16 26 6 0096	52 VIA I 126.90447 16 26 10 4513	53 VIA Xe 131.29 16 26 12 1298	54 VIA Cs 132.90545 16 26 3 9039	55 VIA Ba 137.327 16 26 5 2117	56 VIA Hf 178.49 16 26 6 8251	57 VIA Ta 180.9479 16 26 6 8251	58 VIA W 183.84 16 26 6 8251	59 VIA Re 186.207 16 26 7 8335	60 VIA Os 190.23 16 26 8 4382	61 VIA Ir 192.222 16 26 8 9670	62 VIA Pt 195.078 16 26 9 9584	63 VIA Au 196.96657 16 26 9 2265	64 VIA Hg 200.59 16 26 10 4375	65 VIA Tl 204.3833 16 26 8 1082	66 VIA Pb 207.2 16 26 8 1082	67 VIA Bi 208.98038 16 26 7 2655	68 VIA Po 209 16 26 8 44	69 VIA At 210 16 26 8 44	70 VIA Rn 222 16 26 10 7485	71 VIA Fr 223 16 26 4 0727	72 VIA Ra 226 16 26 5 2784	73 VIA La 138.9055 16 26 5 5789	74 VIA Ce 140.116 16 26 5 5387	75 VIA Pr 140.90768 16 26 5 473	76 VIA Nd 144.24 16 26 5 5256	77 VIA Pm 145 16 26 5 582	78 VIA Sm 150.36 16 26 5 6437	79 VIA Eu 151.964 16 26 5 6704	80 VIA Gd 157.25 16 26 6 1498	81 VIA Tb 158.92534 16 26 5 8936	82 VIA Dy 162.500 16 26 5 9389	83 VIA Ho 164.93032 16 26 6 0215	84 VIA Er 167.259 16 26 6 1077	85 VIA Tm 168.93421 16 26 6 1843	86 VIA Yb 173.04 16 26 6 2542	87 VIA Lu 174.967 16 26 5 4259	88 VIA Ac 227 16 26 5 17	89 VIA Th 232.0381 16 26 6 3097	90 VIA Pa 231.03688 16 26 5 89	91 VIA U 238.02891 16 26 6 1941	92 VIA Np 237 16 26 6 2657	93 VIA Pu 244 16 26 6 0260	94 VIA Am 243 16 26 5 9978	95 VIA Cm 247 16 26 6 1979	96 VIA Bk 247 16 26 6 1979	97 VIA Cf 251 16 26 6 2817	98 VIA Es 252 16 26 6 42	99 VIA Fm 257 16 26 6 50	100 VIA Md 258 16 26 6 58	101 VIA No 259 16 26 6 65	102 VIA Lr 262 16 26 6 9
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Atomic Number Ground-state Level
 Symbol Name
 Atomic Weight
 Ground-state Configuration Ionization Energy (eV)

58 Ce^0
 Cerium
 140.116
 $[\text{Xe}]4f^5d^1s^2$
 5.3387

89 Ac^0
 Actinium
 227
 $[\text{Rn}]6d^1s^2$
 5.17

Based upon ^{12}C . () indicates the mass number of the most stable isotope. For a description of the data, visit physics.nist.gov/data NIST SP 966 (September 2003)

f-electron systems/rare earth intermetallics
 Heavy fermions/mixed valency/Kondo systems
 SC, Hidden order

Other new superconductors
 (organic...)

d-electron systems

Transition metal oxides

High temperature SC

CMR manganites

Orbital ordered systems

Outline

Diffuse scattering/superstructure/CDW

Charge texture and nanoscale disorder in HTSC

Ladder/chain quasi-1D physics

Multiferroics

Jahn-Teller polarons in manganites

Phase separation and decomposition

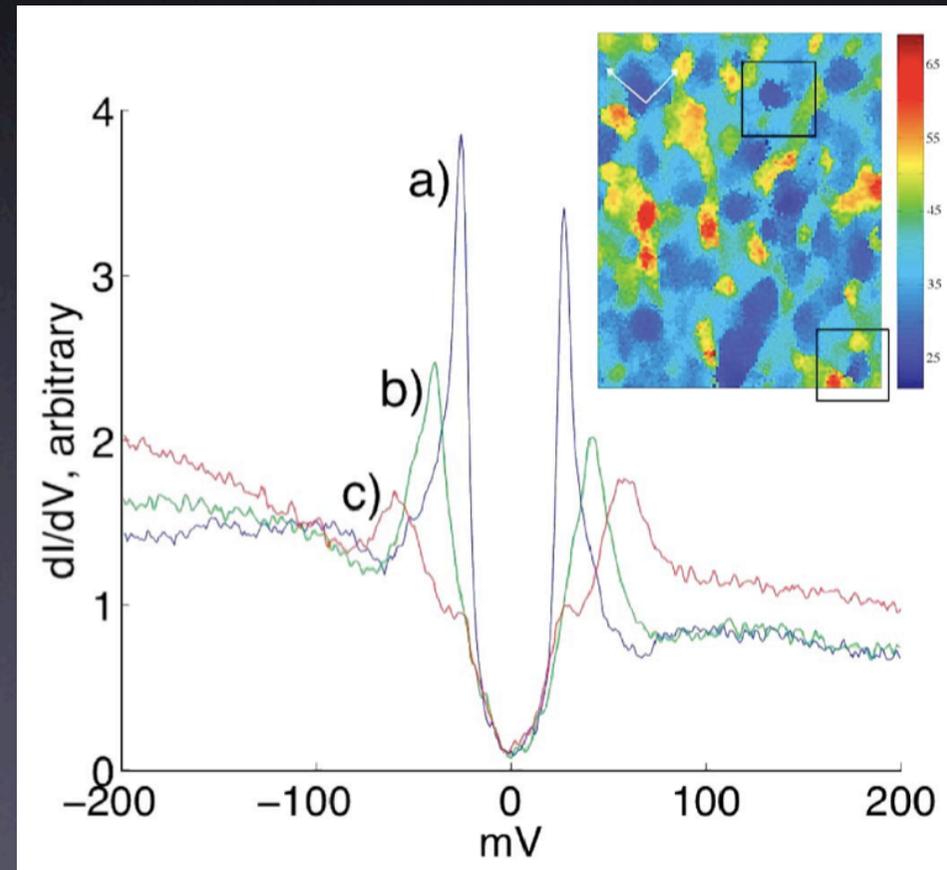
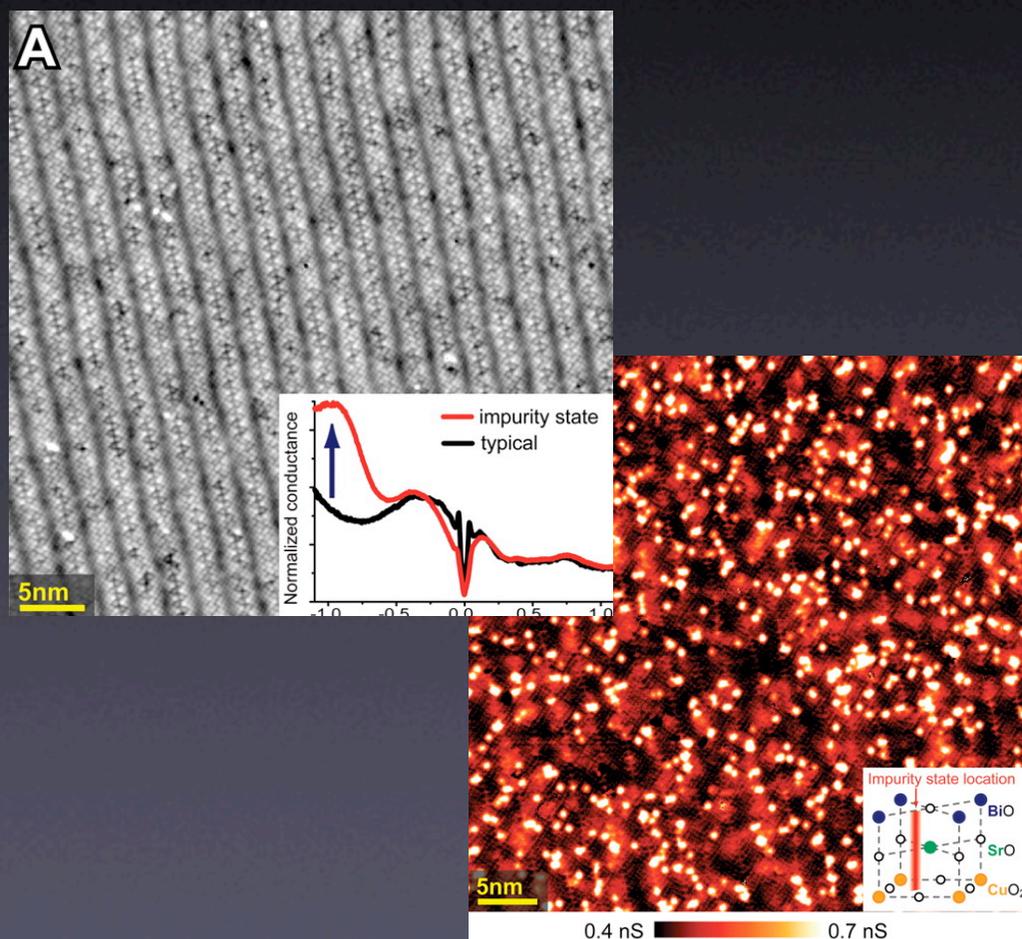
Orbital order/Hidden order

Magnetic scattering

Static charge texture and nanoscale disorder in BSCCO

(High temperature superconductor)

BSCCO is the HTSC best studied by ARPES *and* STM

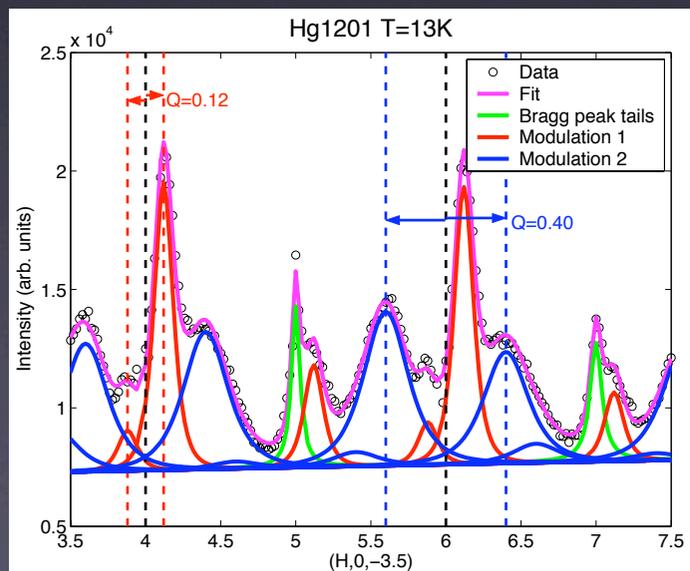
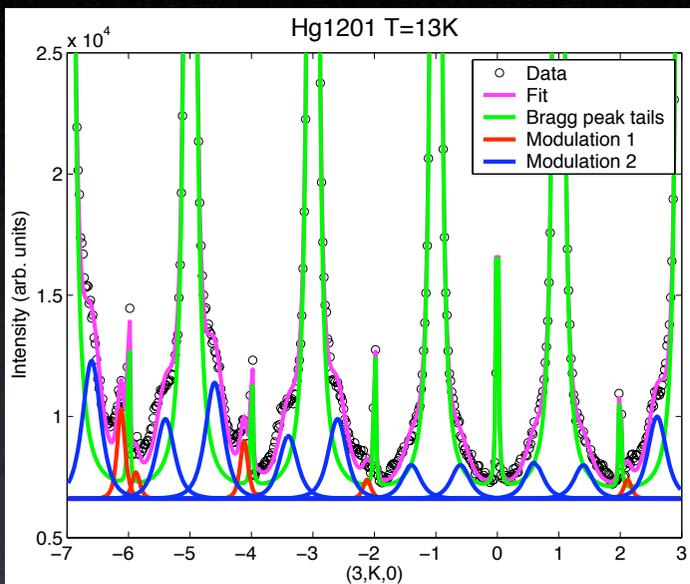


A. Fang, et al, PRL 96 017007 (2006)

K. McElroy, et al, Science 309, 1048 (2005)

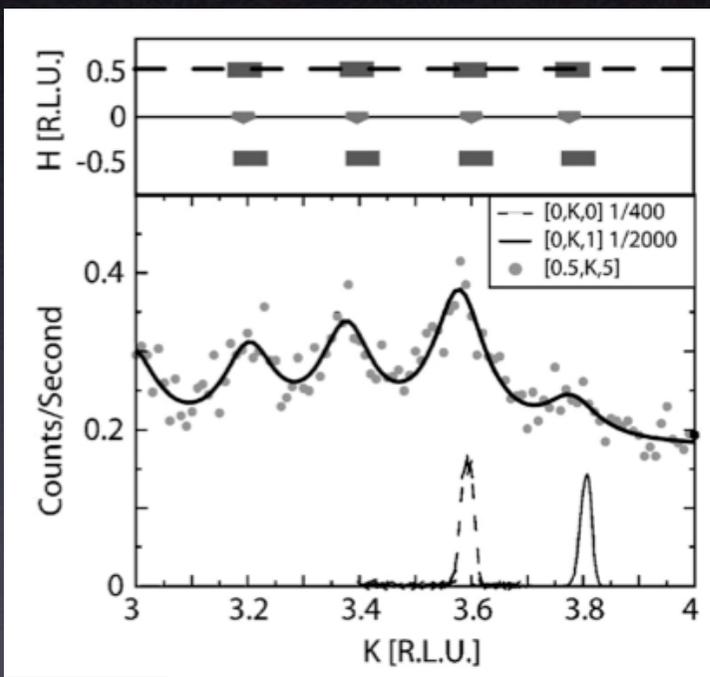
Nano-patches in High-Tc cuprates

HgBa₂CuO_{4+δ} (Hg1201)



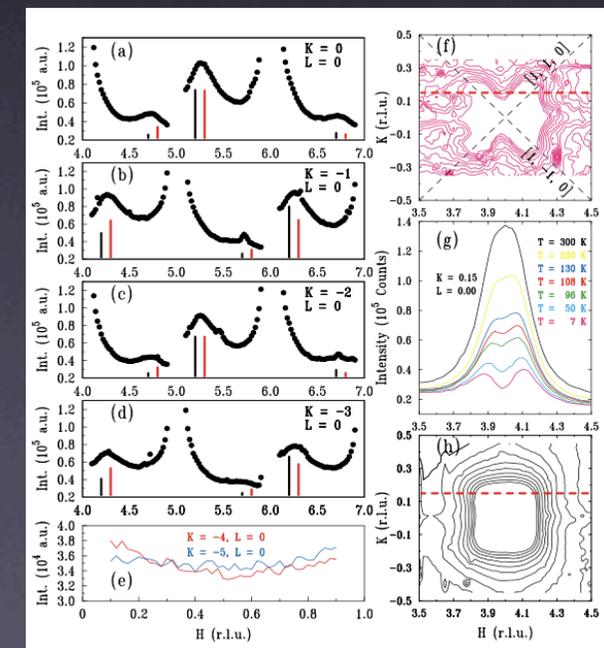
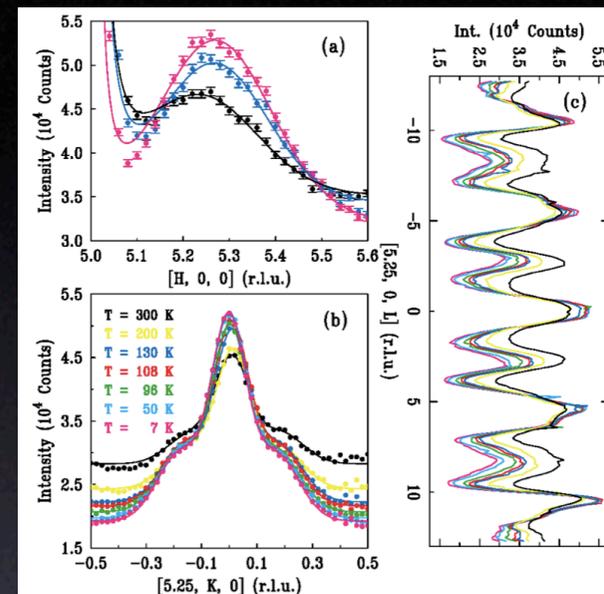
G. Chabot Couture, et al (unpublished)

Bi₂Sr₂CaCu₂O_{8+δ} (Bi-2212)



J. Castellán, et al, PRB 73, 174505 (2006)

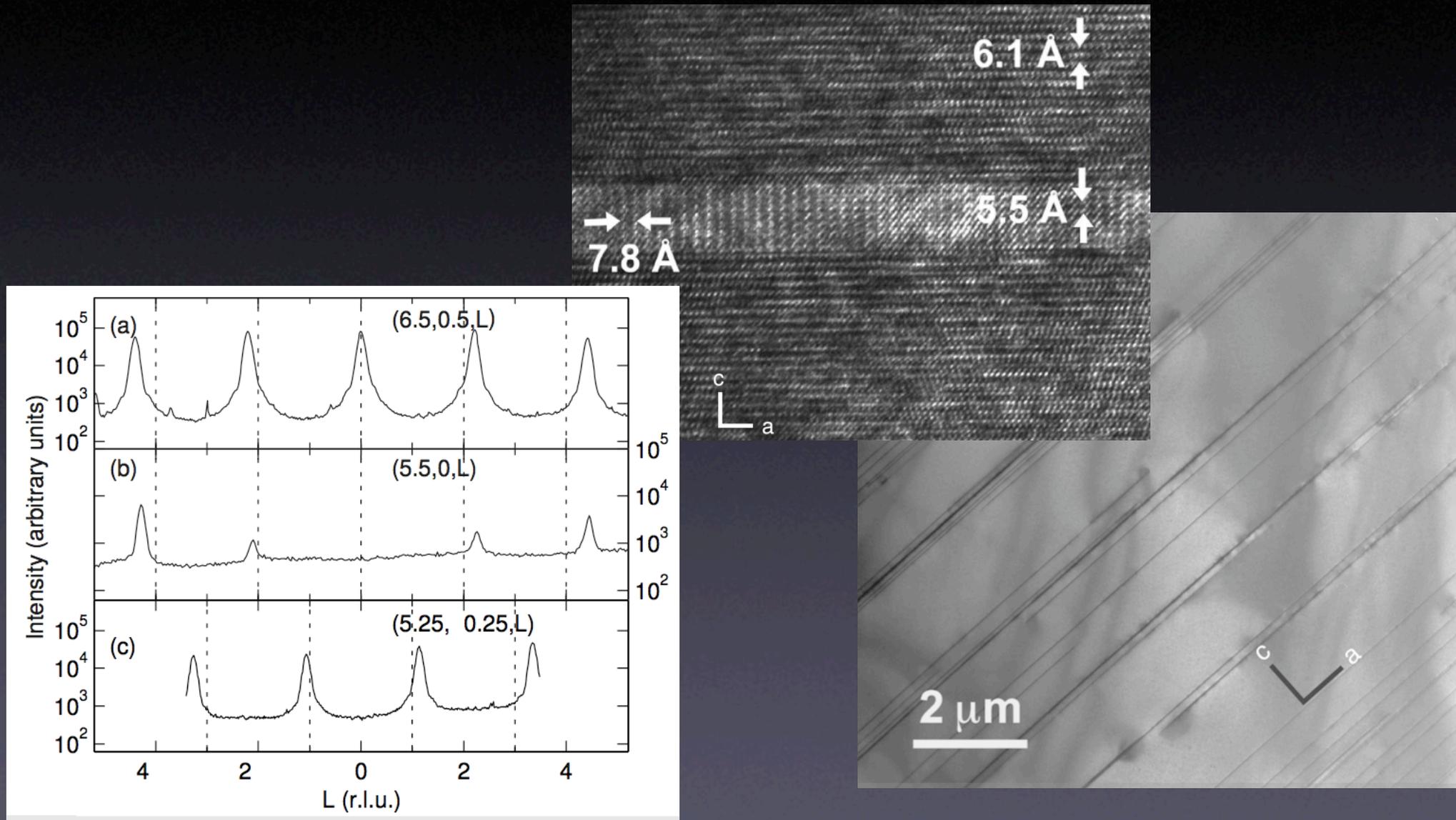
YBa₂Cu₃O_{6.92} (YBCO)



Z. Islam, et al, PRL 93, 157008 (2004)

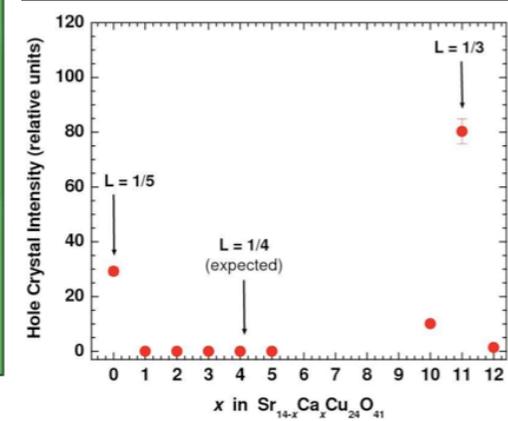
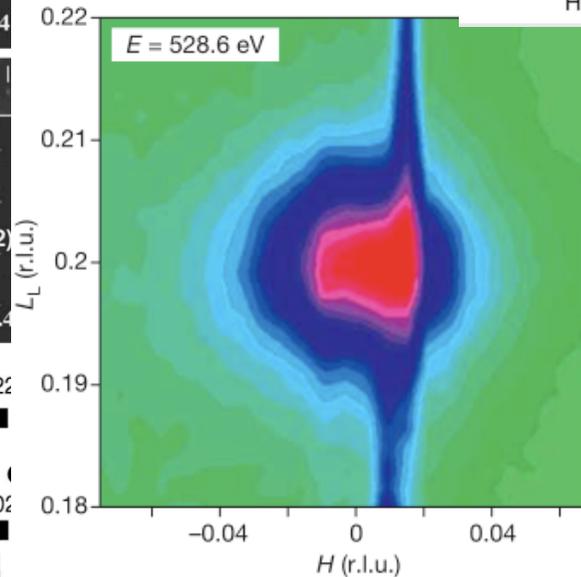
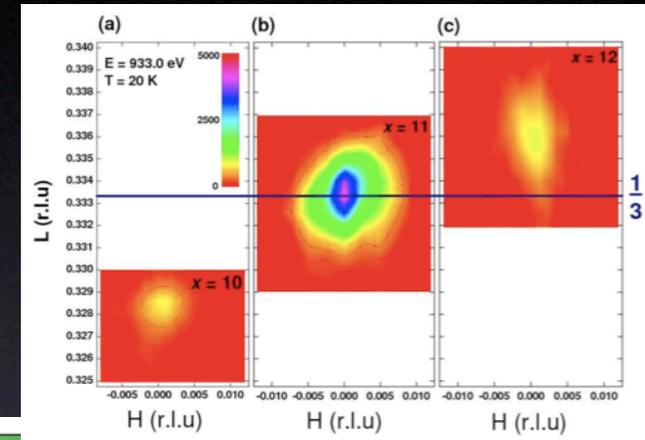
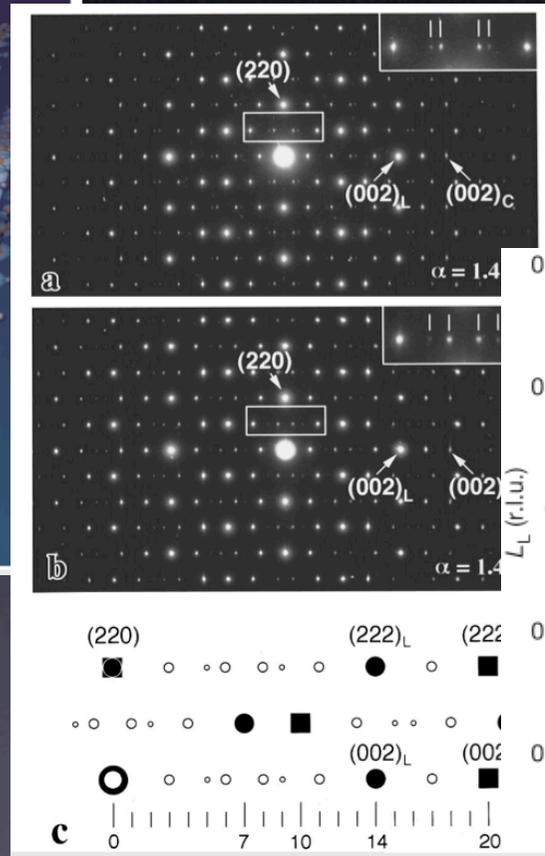
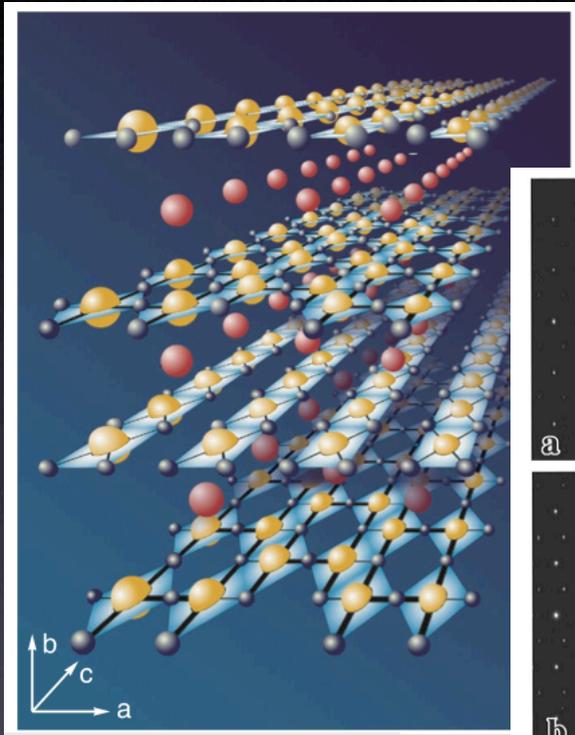
Uses of Nonresonant Diffraction

Decomposition phase of electron-doped HTSC $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_4$

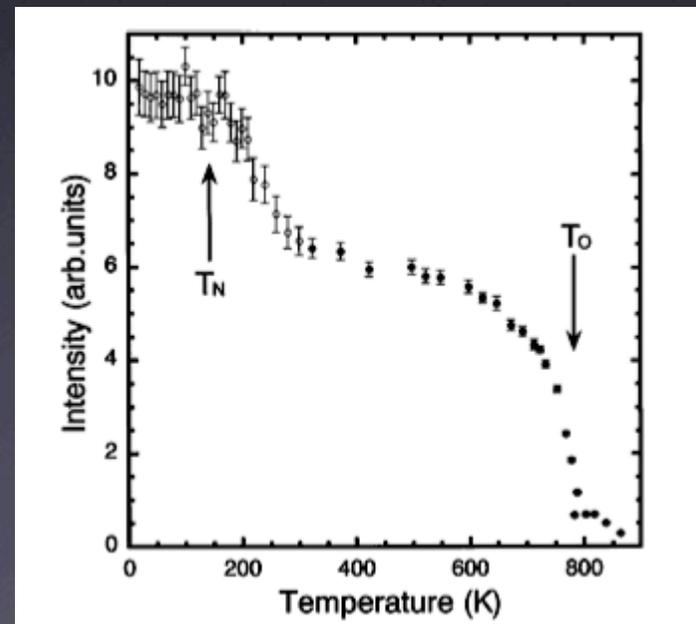
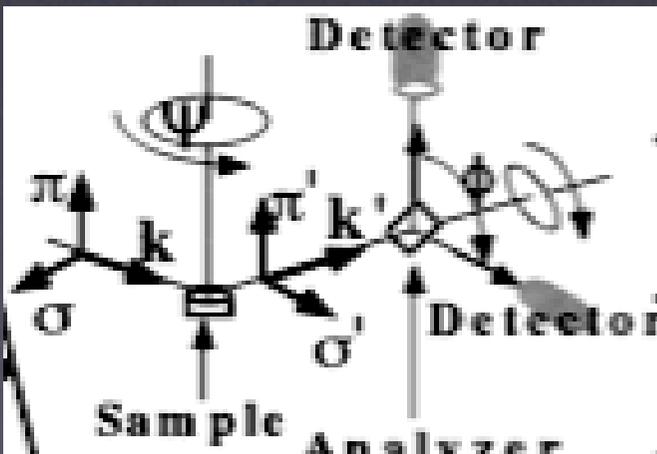
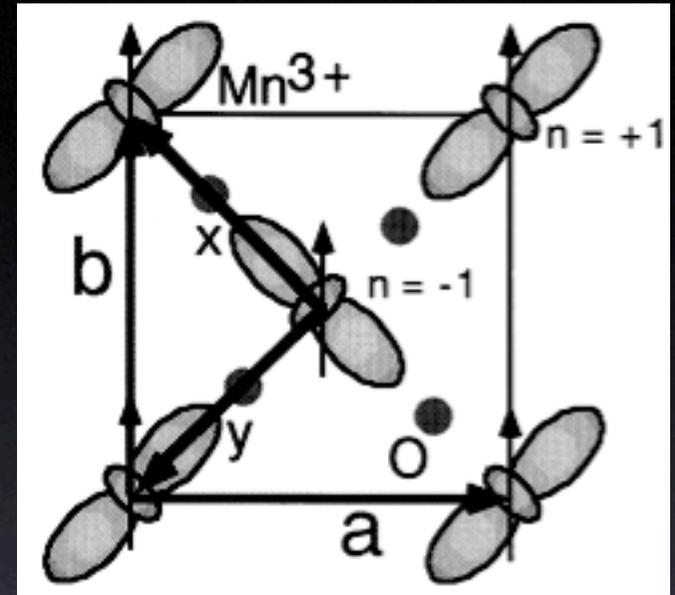
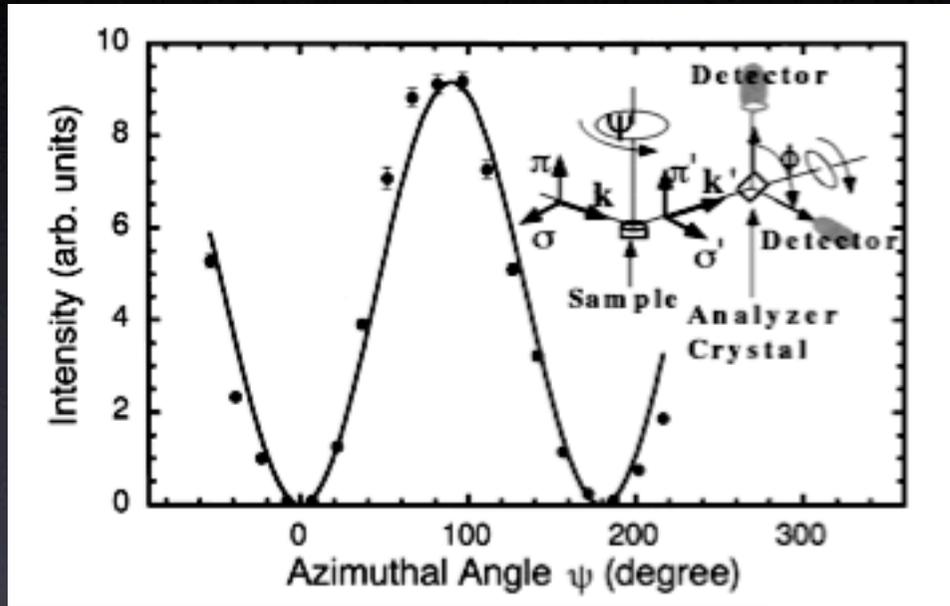


ID/Quasi-1D Physics

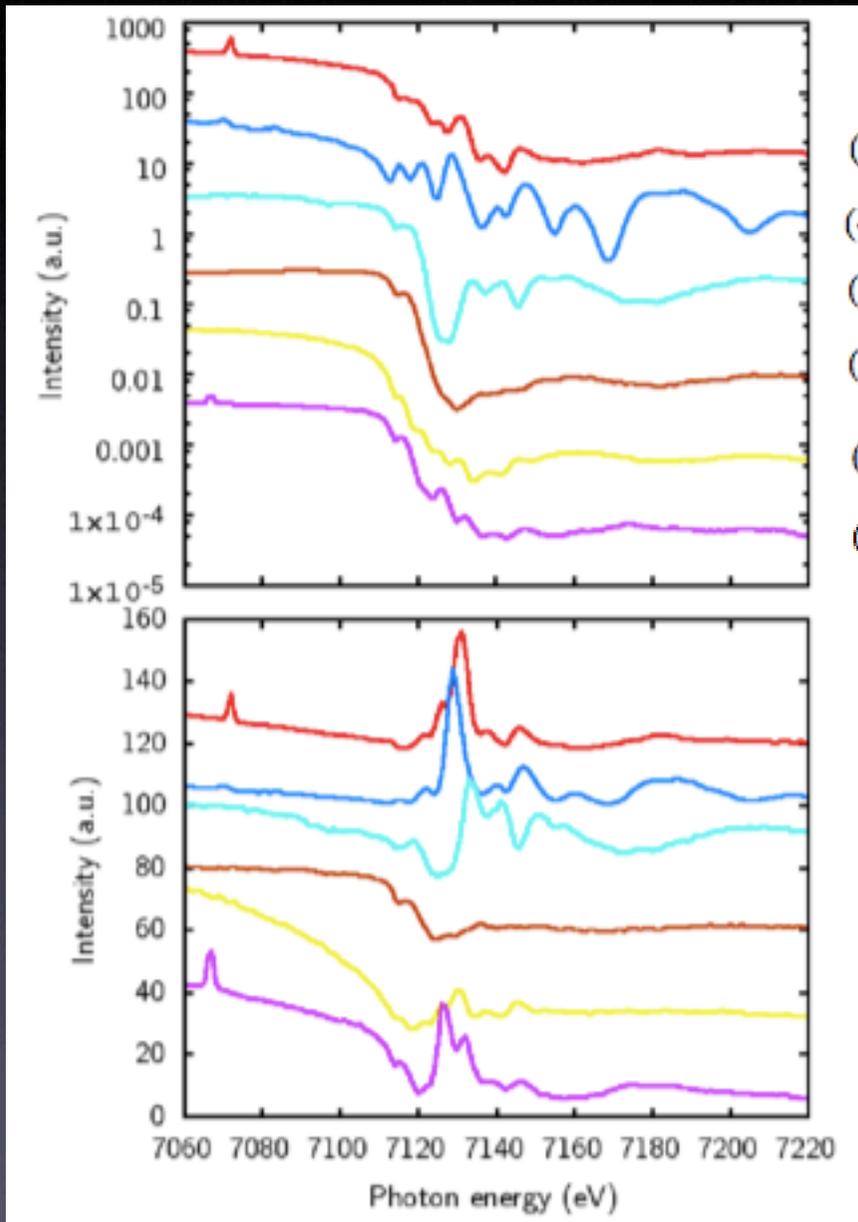
Novel CDW in adaptive misfit $\text{Sr}_{14}\text{Cu}_{24}\text{O}_{41}$



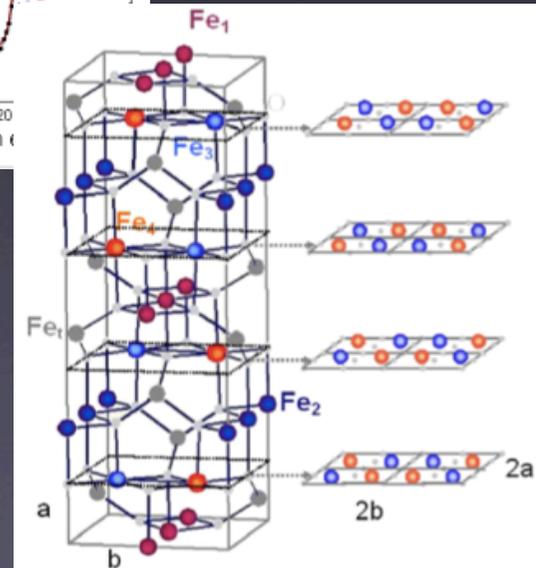
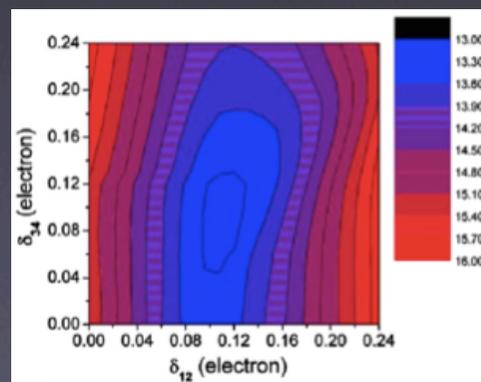
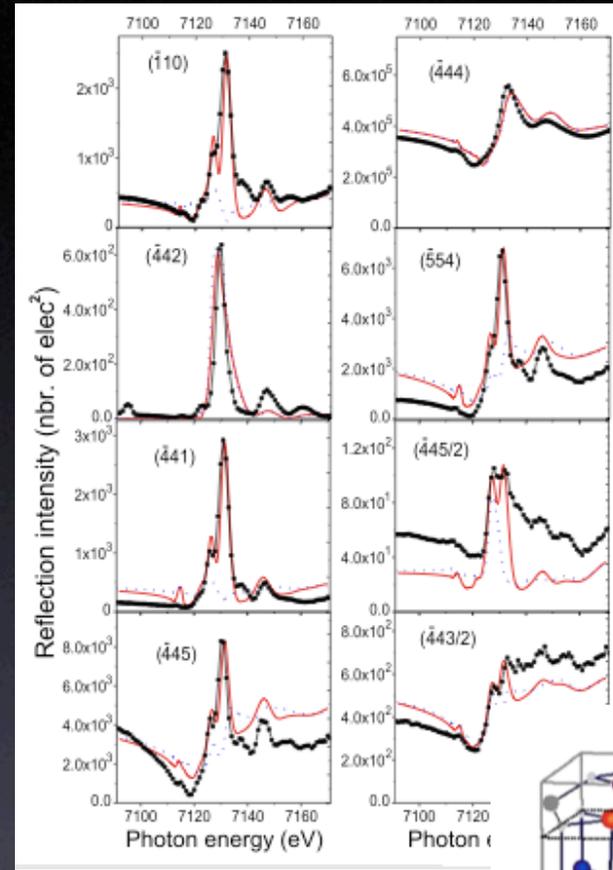
Orbital order-a new broken symmetry



OO in Magnetite

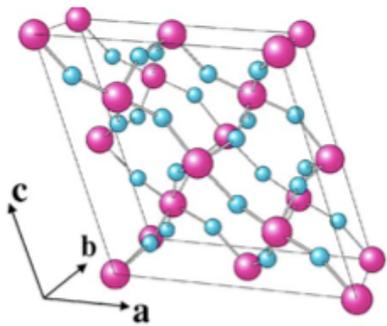


- (4 4 1)
- (4 4 2)
- (4 4 3)
- (4 4 4)
- (4 4 5)
- (3 3 3/2)

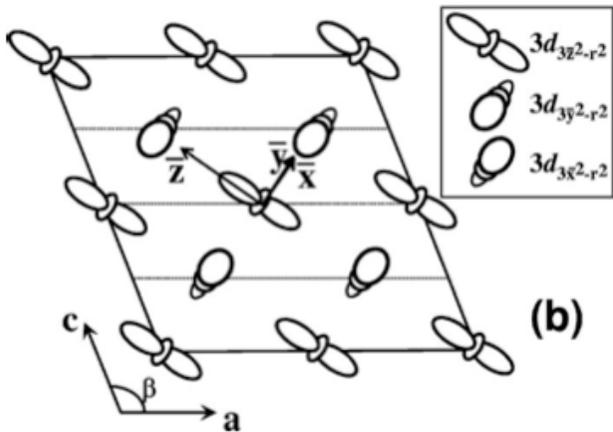


Multiferroics

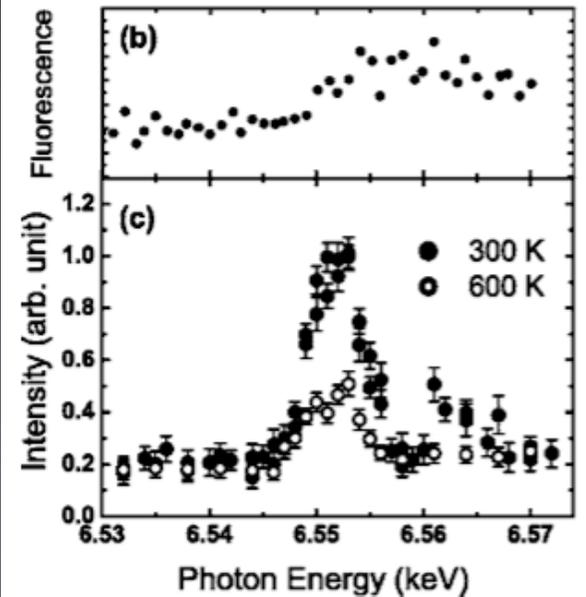
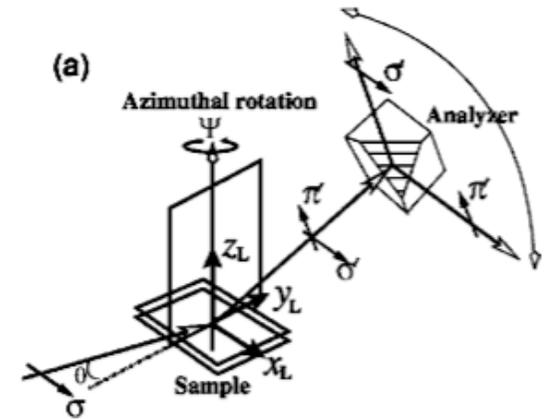
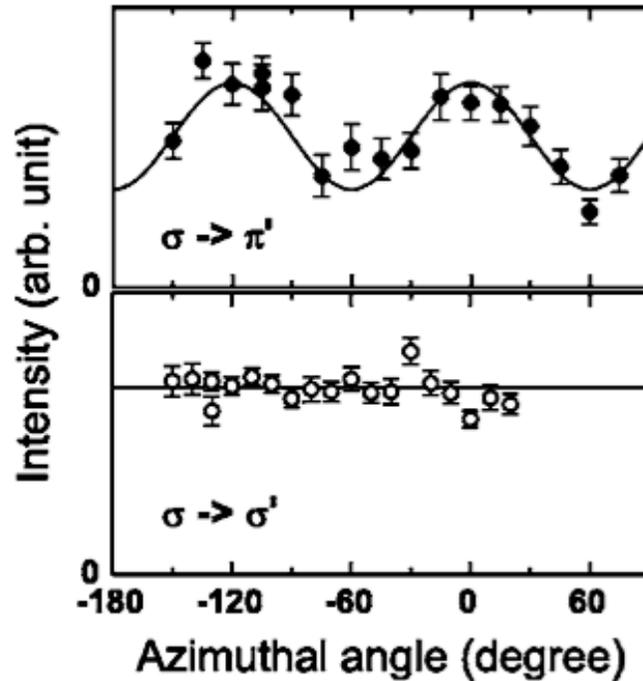
Coupled displacive and magnetic order parameters



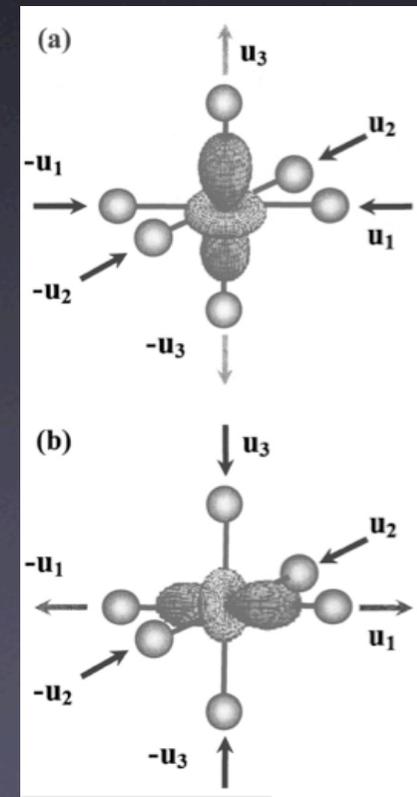
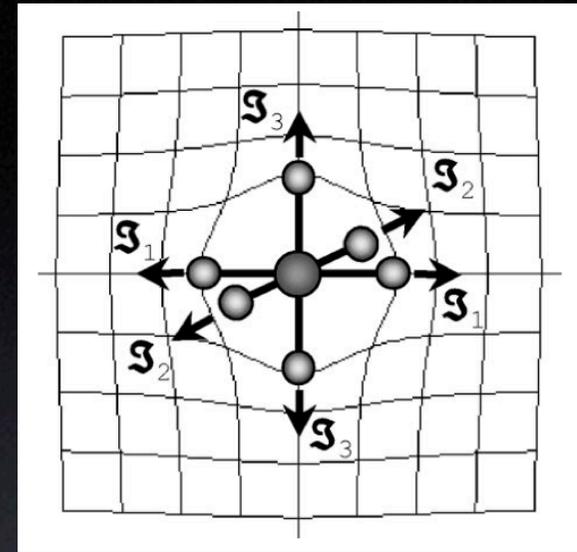
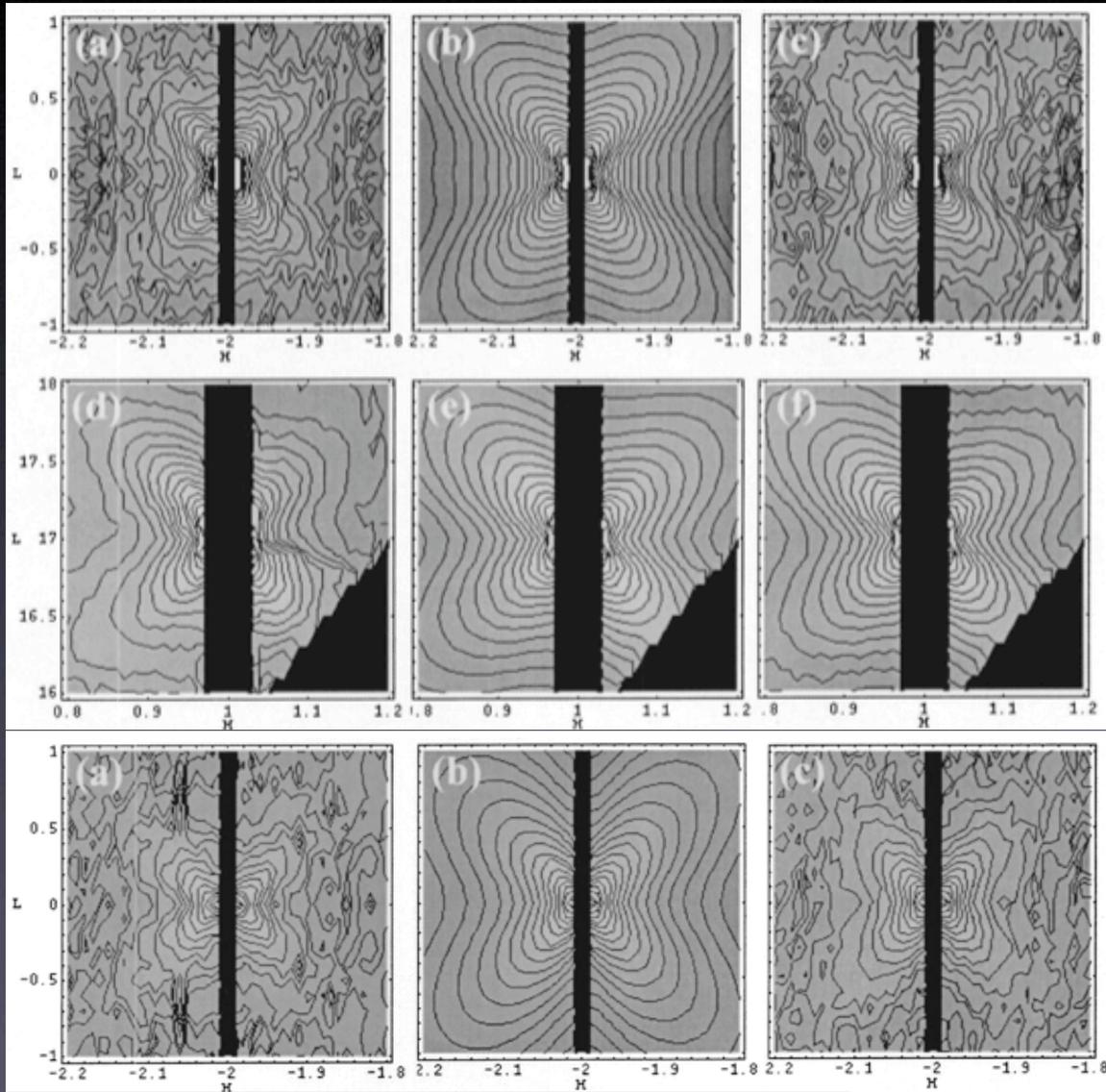
(a)



(b)

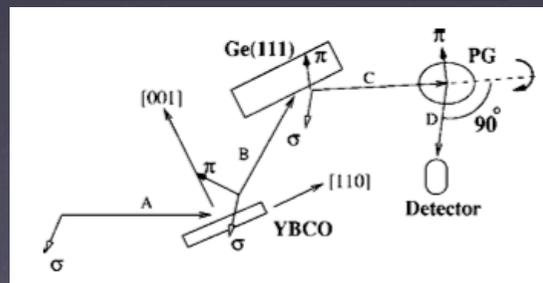
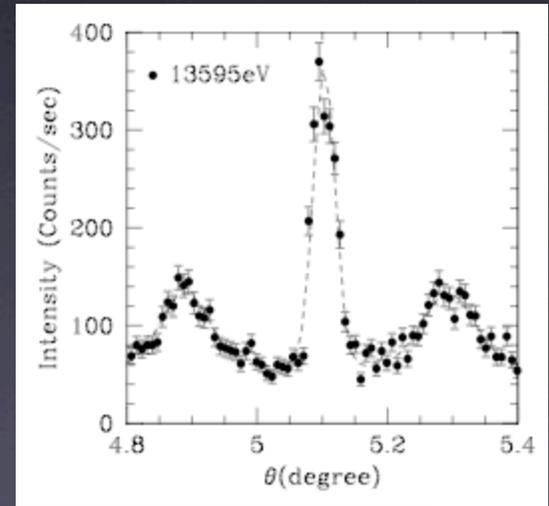
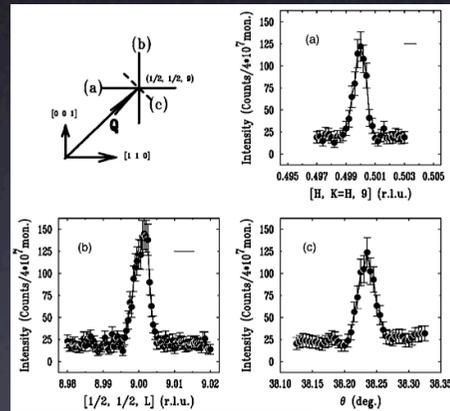
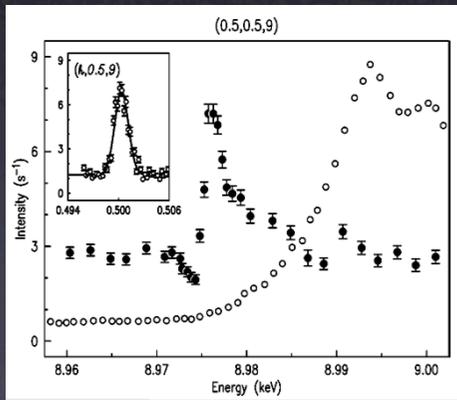
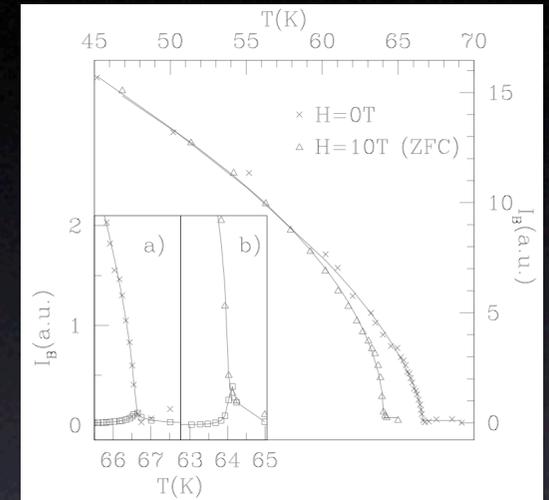
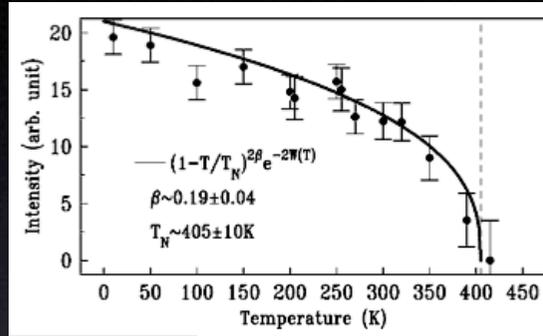
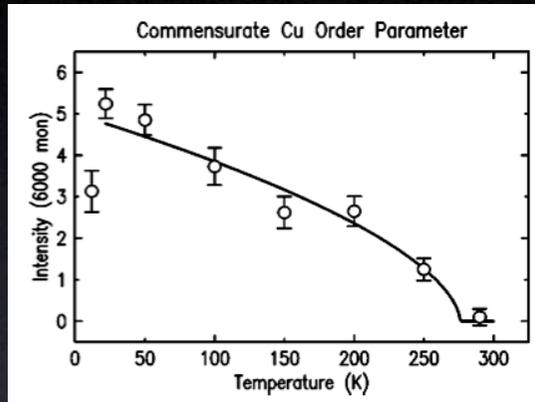


Jahn-Teller distortion and polarons in manganites



Magnetic ordering studies with X-rays

Now demonstrated for $S \geq 1/2$ spins



Resonant (NSLS+ESRF)

Non-resonant (APS+SSRL)