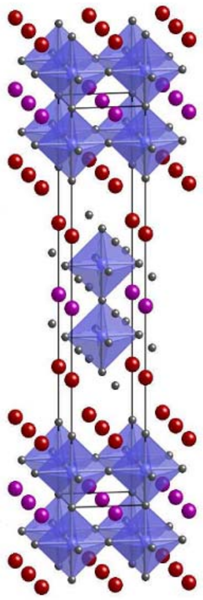


Fermiology of bilayer colossal magnetoresistant manganites

Mark S. Golden
Van der Waals-Zeeman Institute
Universiteit van Amsterdam
FOM-A-11

© Mark S. Golden 2007

Outline

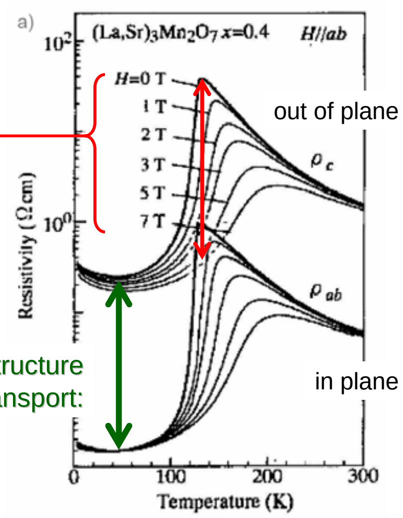
- Intro. to colossal magneto-resistant maganites
  - bilayer systems: $La_{2-2x}Sr_{1+2x}Mn_3O_7$
- Angle-resolved photoemission data:
  - history, status quo
  - Fermi surfaces
  - quasiparticles
  - coupling to boson mode(s)
  - surprises in the temperature dependence
- Summary, conclusions and outlook

© Mark S. Golden 2007

Colossal (negative) magnetoresistance: CMR

- double exchange means: ferromagnetic (FM) situation favours hopping
- CMR effects of 4000%

CMR



quasi 2D structure
→ anisotropy in c and ab transport:

T. Kimura and Y. Tokura, Annu. Rev. Mat. Sci., 2000

© Mark S. Golden 2007

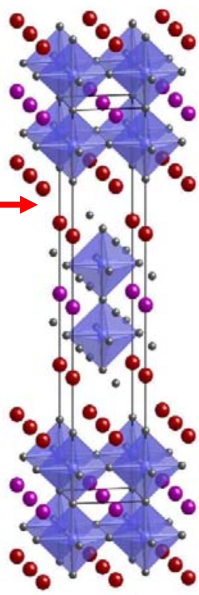
Bilayer managanites

- reduced dimensionality
  - greater role for fluctuations
  - connection to the high Tc cuprates ?
  - strong anisotropy
- (even) larger CMR effect
- cleavage surfaces suitable for surface sensitive probes:
  - ARPES
  - STM / STS

cleavage here

La,Sr,O rock salt blocks

double MnO_2 planes

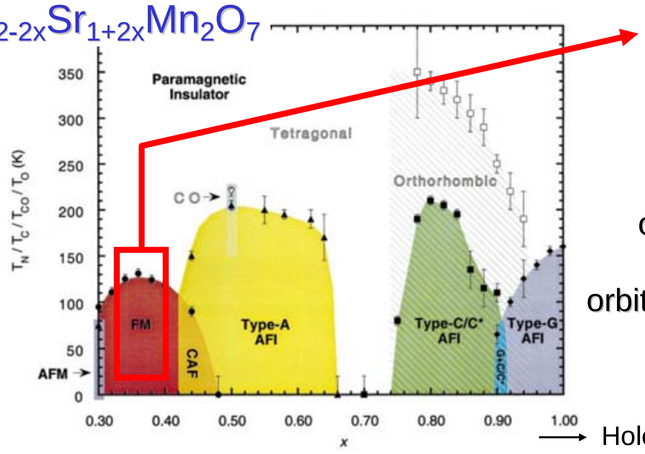


pic: Matt Rosseinsky

© Mark S. Golden 2007

T,*x* phase diagramme

- $La_{2-2x}Sr_{1+2x}Mn_2O_7$



focus here

Picture from: Ling *et al.* PRB **62** 15096 (2000)

spins
⇳
charges
⇳
orbitals (lattice)

→ Hole doping, *x*

$La_2Sr_1Mn_2O_7$ as 'parent insulator', *x* gives no. of additional holes

© Mark S. Golden 2007

Outline

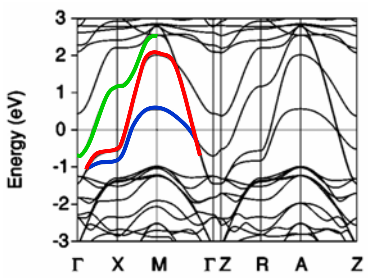
- Intro. to colossal magneto-resistant maganites
  - bilayer systems: $La_{2-2x}Sr_{1+2x}Mn_3O_7$
- Angle-resolved photoemission data:
  - history, status quo
  - Fermi surfaces
  - quasiparticles
  - coupling to boson mode(s)
  - surprises in the temperature dependence
- Summary, conclusions and outlook

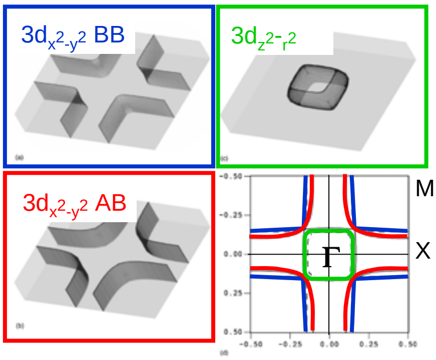
© Mark S. Golden 2007

Expectations from band structure calculations

- DFT says: half-metallic ferromagnet

Majority band: quasi-2D Fermi surface





- e_g bandwidth: both $3d_{x^2-y^2}$ and $3d_{z^2-r^2}$ are occupied

Pics from: Huang *et al.* PRB **62** 13318 (2000)

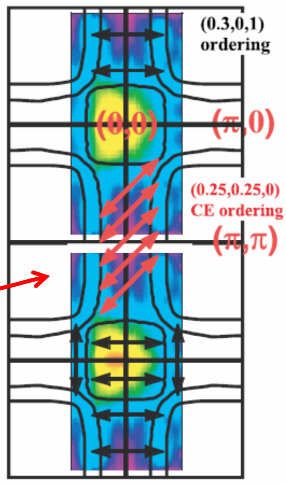
© Mark S. Golden 2007

ARPES of 2L manganites: history

Colorado group:

ghost Fermi surface, pseudogap
Dessau *et al.*, PRL1998
data: x=0.4

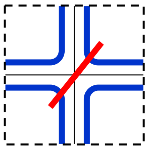
Fermi surface nesting
(no QP's anywhere)
Chuang *et al.*, Science 2001
data: x=0.4



hν=50eV
integrated ±200meV of E_F

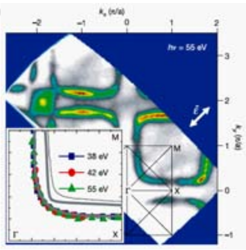
© Mark S. Golden 2007

ARPES of 2L manganites: status quo



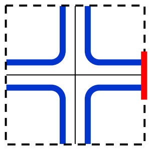
general statement 2L manganites: nodal metal (Fermi arc)

data: x=0.4



Stanford

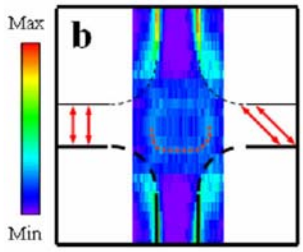
Manella *et al.* Nature (2005)



QP's at antinode

no QP's for x=0.4

data: x=0.36, 0.38, 0.4

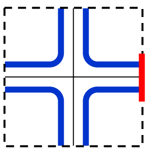


Colorado

Z. Sun et al. PRL (2006)

© Mark S. Golden 2007

ARPES of 2L manganites: status quo

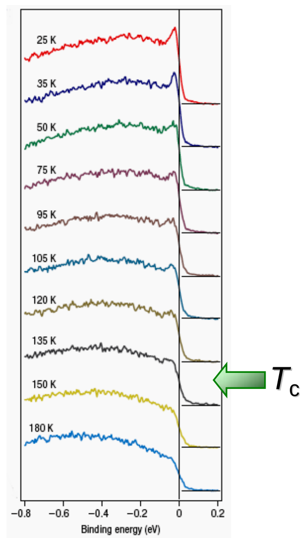


metallicity above T_c (phase separation)

data: x=0.38, AB band

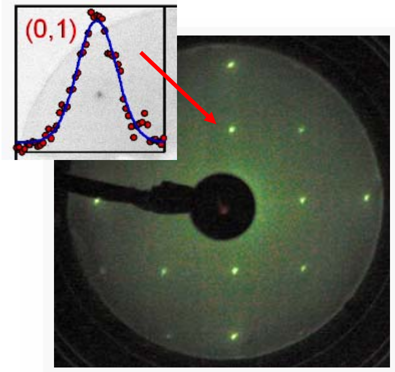
Colorado

Z. Sun et al. Nature Physics (2007)

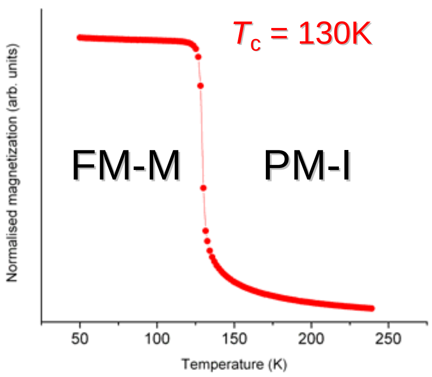


© Mark S. Golden 2007

Crystal characterisation: x=0.36



LEED image (T= 40K, 95eV) of cleaved LSMO (x= 0.36) surface



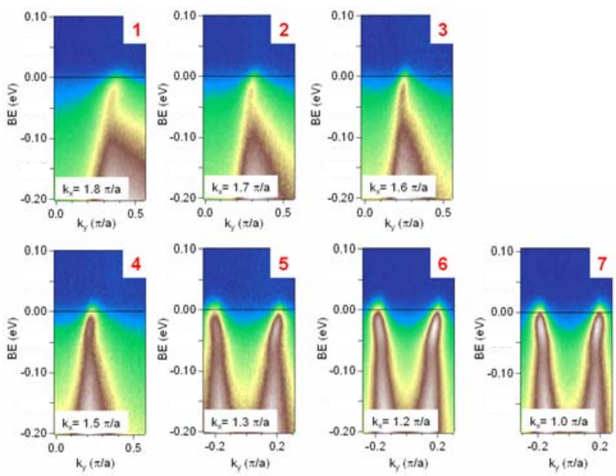
Magnetization (// to a-axis), ZFC, external field 100 Gauss

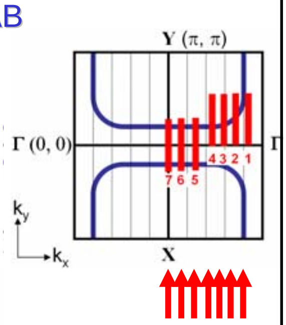
- sharp transitions, excellent cleavage surfaces

© Mark S. Golden 2007

Hunting down the QP's

- low energy spectral weight all round the AB Fermi surface





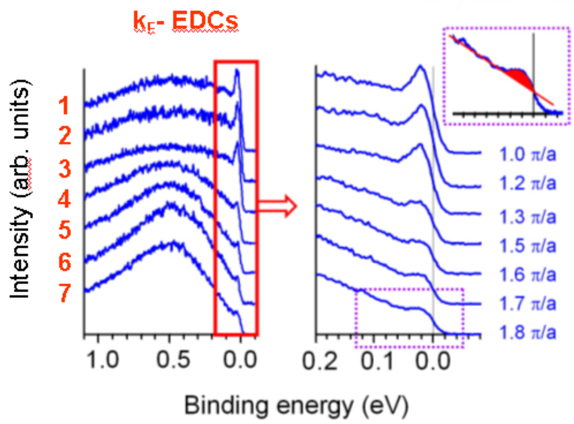
hν=56eV

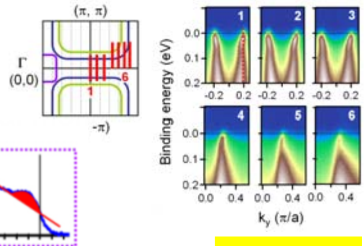
S. de Jong *et al.* 2006

© Mark S. Golden 2007

Energy distribution curves

- note:
  'QPs' at all k_F's for LSMO





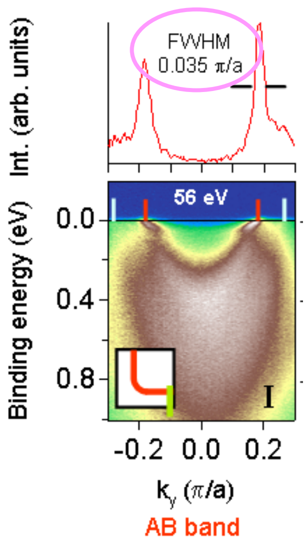
hν=56eV

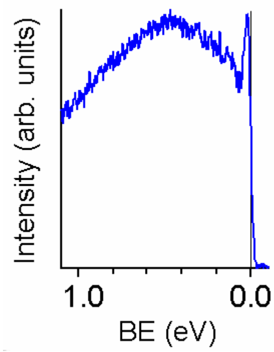
peaks not yet resolution limited……

S. de Jong *et al.* 2006

© Mark S. Golden 2007

μ - ARPES: AB band (at the SLS)





hν=56eV

at (π/a,0)

- antibonding band:
  sharp QP, resolution limited width

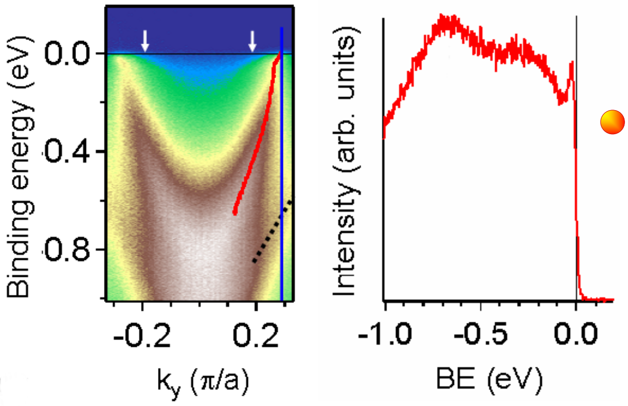
S. de Jong *et al.* 2006

© Mark S. Golden 2007

μ - ARPES: BB band (at the SLS)

hν=73eV

at (π/a,0)



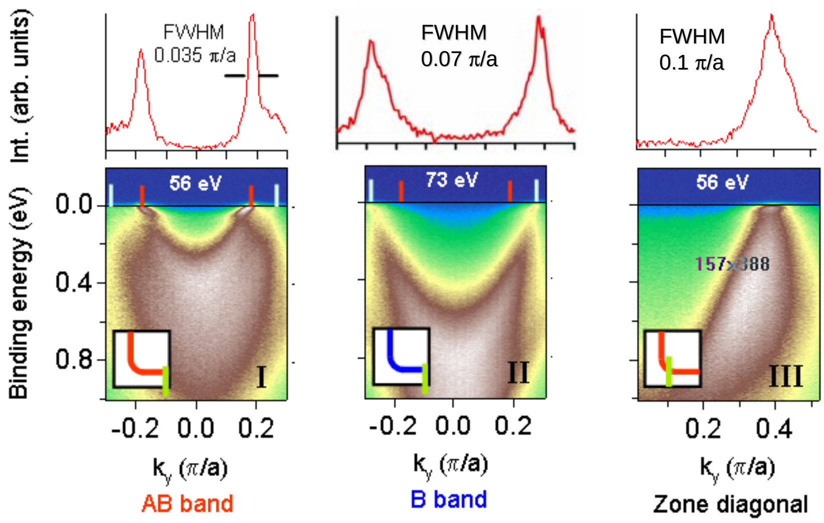
- bonding band:
  sharp QP
  ? extra feature

- bonding band:
  E_F MDC width (0.07 π/a) is double that of the AB band

S. de Jong *et al.* 2006

© Mark S. Golden 2007

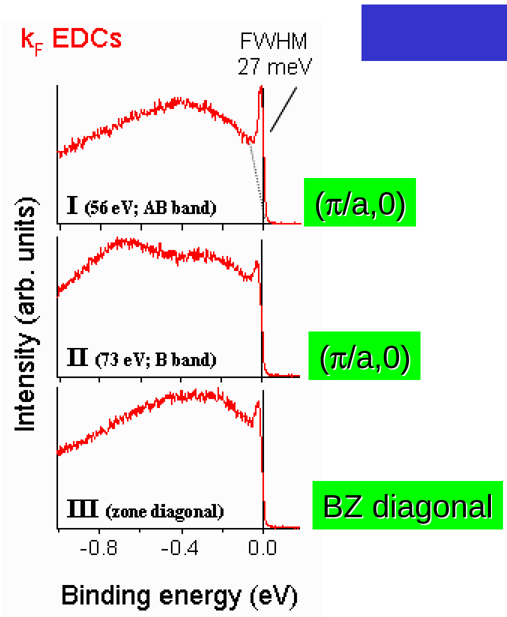
What about the BZ diagonal ?



S. de Jong *et al.* 2006

© Mark S. Golden 2007

k_F EDC's



- for x=0.36:

  QP's visible for:

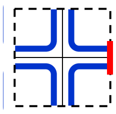
  AB FS at (π/a,0) and zone diagonal

  and for BB FS at (π/a,0)

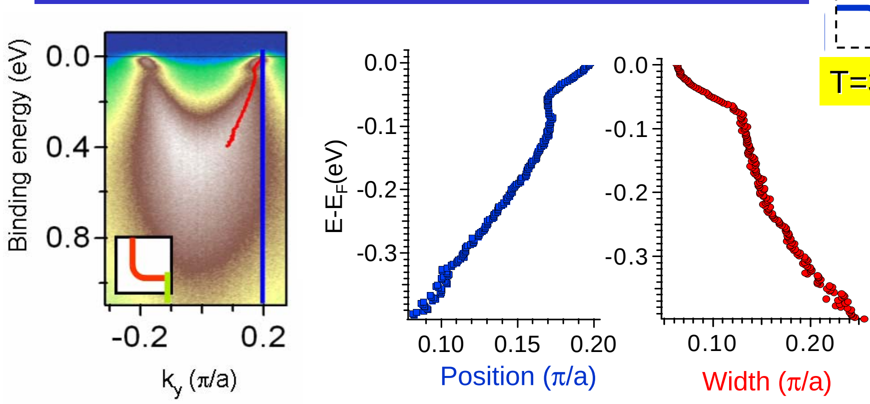
S. de Jong *et al.* 2006

© Mark S. Golden 2007

Renormalisation effects at (π/a,0)



T=30K



- coupling to collective (bosonic) mode(s):

  clear deviation from non-interacting dispersion between 60 and 110meV

  also seen in MDC width (→ QP inverse life-time)

S. de Jong *et al.* 2006

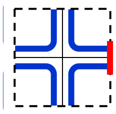
© Mark S. Golden 2007

Outline

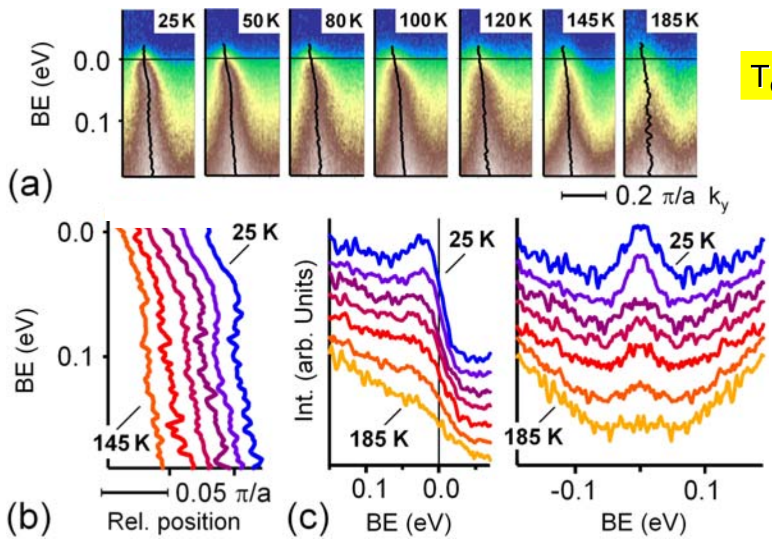
- Intro. to colossal magneto-resistant maganites
  - bilayer systems: $La_{2-2x}Sr_{1+2x}Mn_3O_7$
- Angle-resolved photoemission data:
  - history, status quo
  - Fermi surfaces
  - quasiparticles
  - coupling to boson mode(s)
  - surprises in the temperature dependence
- Summary, conclusions and outlook

© Mark S. Golden 2007

Temperature dependence at (π/a,0)



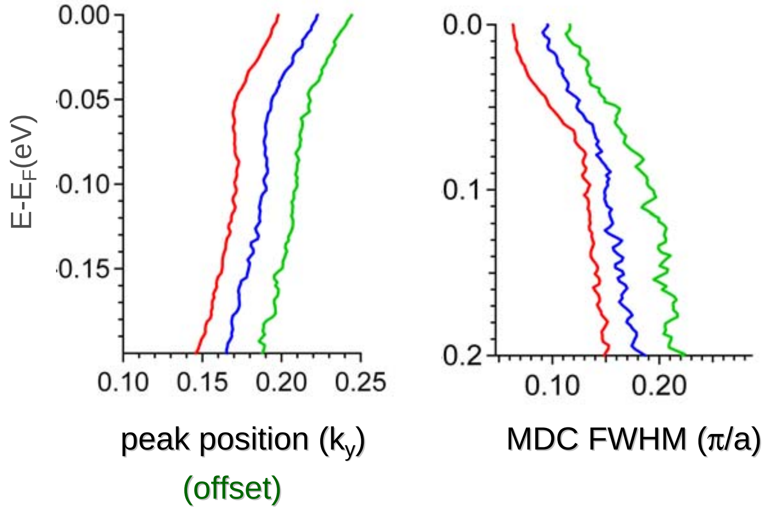
T_C=130K



S. de Jong *et al.* 2006

© Mark S. Golden 2007

T-dependence: renormalisation effects (π/a,0)



hν=56eV

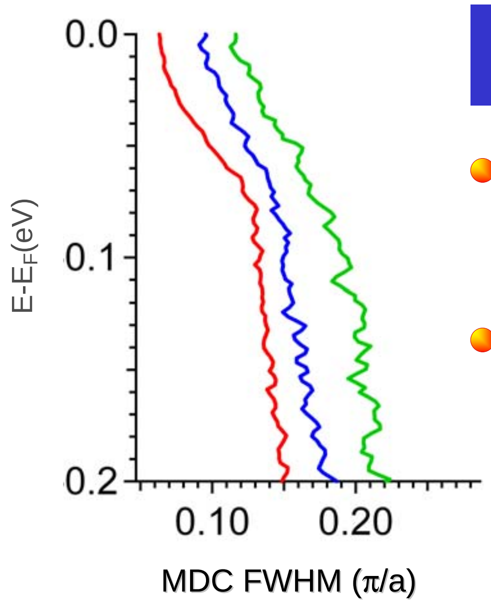
at (π/a,0)

T=30
T=95
T=145

S. de Jong *et al.* 2006

© Mark S. Golden 2007

T-dependence: MDC width at (π/a,0)



- strong T-dependence for low energies
- change in form within FM-M phase (30 → 95K)

hν=56eV

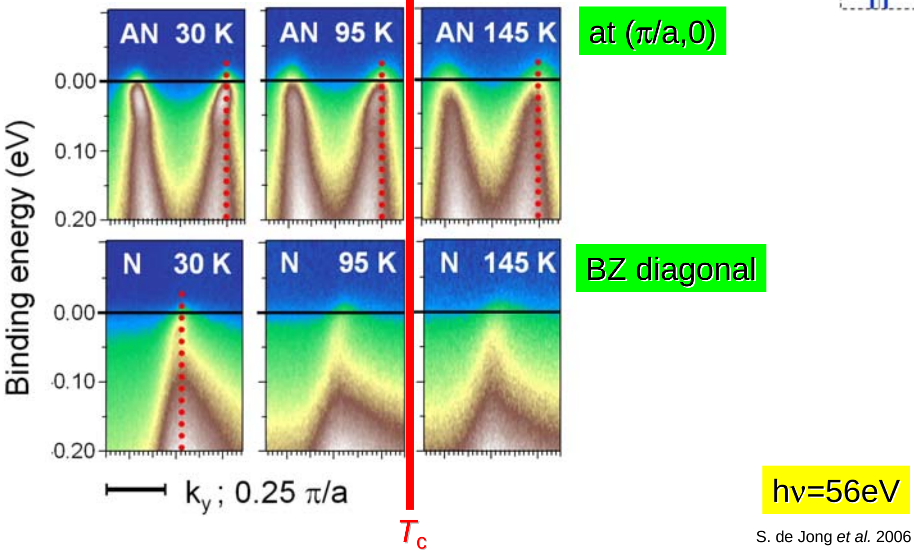
at (π/a,0)

T=30
T=95
T=145

S. de Jong *et al.* 2006

© Mark S. Golden 2007

T-dependence: at (π/a,0) and BZ diagonal

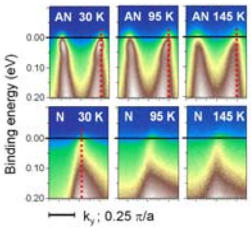


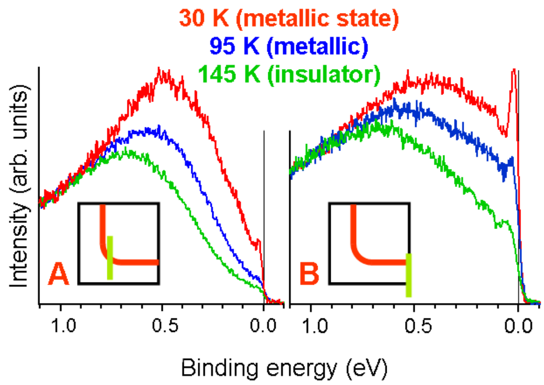
S. de Jong *et al.* 2006

CORPES workshop. 24th April, 2007

© Mark S. Golden 2007

T-dependence: k_F EDC's at (π/a,0) and BZ diagonal





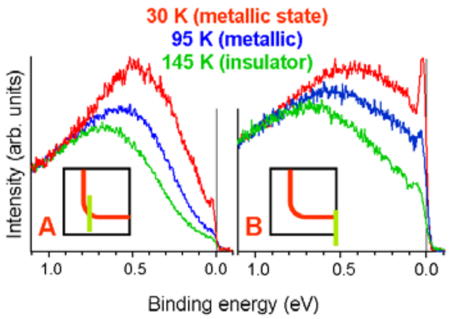
- giant temperature dependence. k-dependent.
  - QP peak more robust an antinode
  - spectral weight shift even larger at node

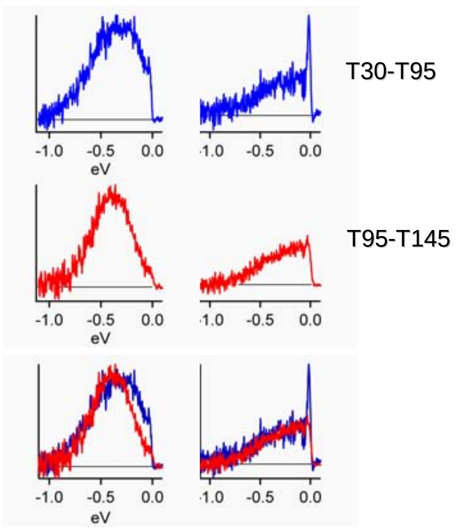
S. de Jong *et al.* 2006

CORPES workshop. 24th April, 2007

© Mark S. Golden 2007

T-dependence: metallic phase above T_c ?





- two phase model doesn't work here
  - QP peak only for T<Tc
  - different high E behaviour for the two k-points

© Mark S. Golden 2007

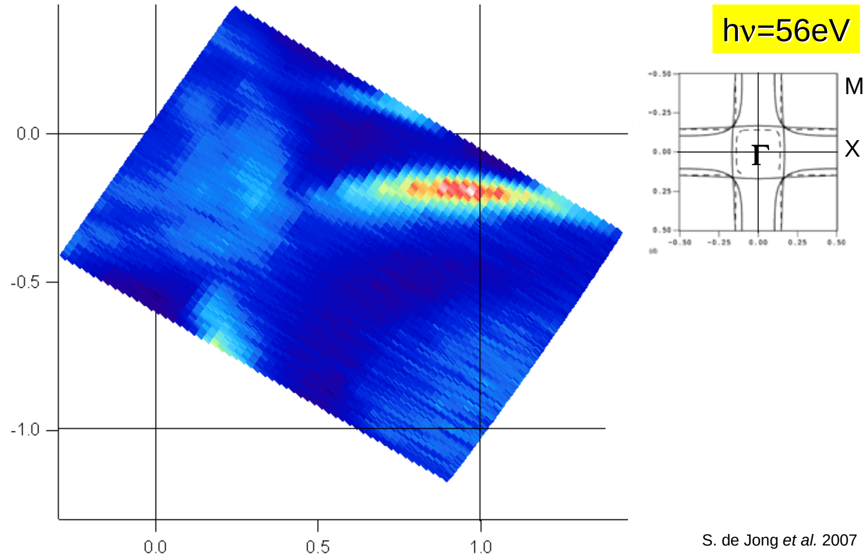
Conclusions

- quasiparticles are to be found on both the AB (at zone face and diagonal) and BB Fermi surfaces for x = 0.36
- no such thing as a (general) nodal metal
- strong renormalisation effects clearly identified:
  - phonon-orbitons
  - strongly T-dep.: magnetism

  } analysis underway
- anomalous temperature dependence:
  - huge shifts of spectral weight
  - can't fit a 2-phase model

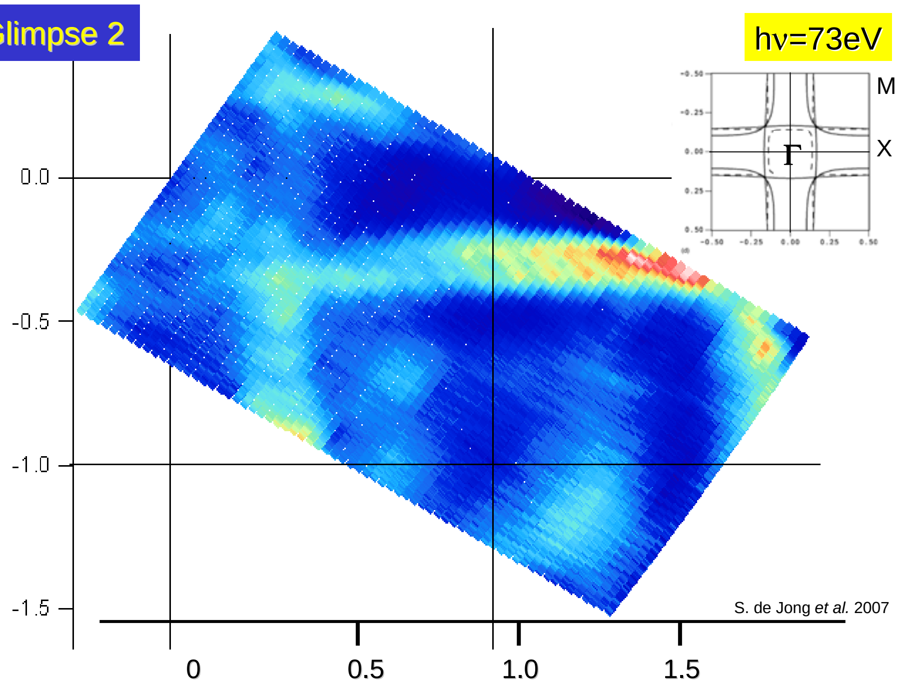
© Mark S. Golden 2007

Glimpse of something hot off the beamline......



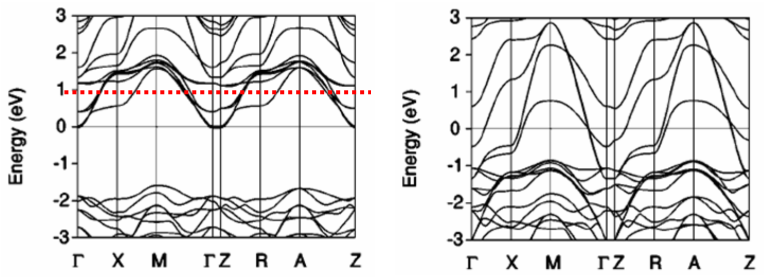
© Mark S. Golden 2007

Glimpse 2



? possible breakdown of 100% spin polarisation ?

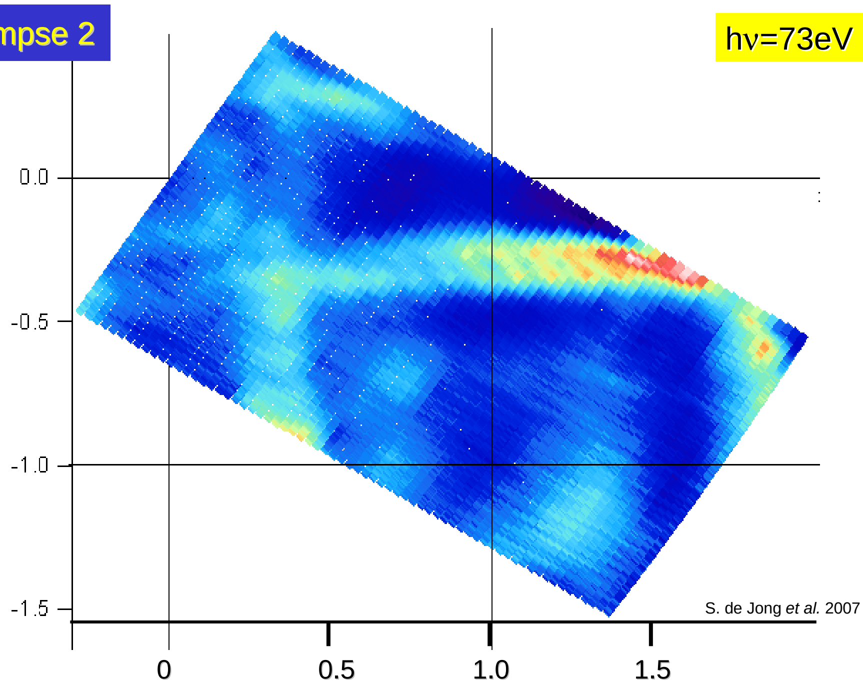
minority (LSDA) majority (LSDA)



© Mark S. Golden 2007

Glimpse 2

hv=73eV



S. de Jong *et al.* 2007

The Credits

Quantum Electron Matter Group, University of Amsterdam
Sanne de Jong, Yingkai Huang, Wing Kiu Siu, Iman Santoso, Wim Koops, Freek Massee, Ton Gortenmulder

SLS
Vladimir Strocov, Luc Patthey, Ming Shi

Support at BESSY
Rolf Follath, Patrick Bressler
Olaf Schwarzkopf

Funding
FOM, EU, UvA

Yingkai Huang

Sanne de Jong