Spin, orbital, and lattice correlations in Fe(Te,Se) superconductors

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Strong Correlations and Unconventional Superconductivity
KITP, UCSB
September 22, 2014

U.S. DEPARTMENT OF ENERGY | Office of Science

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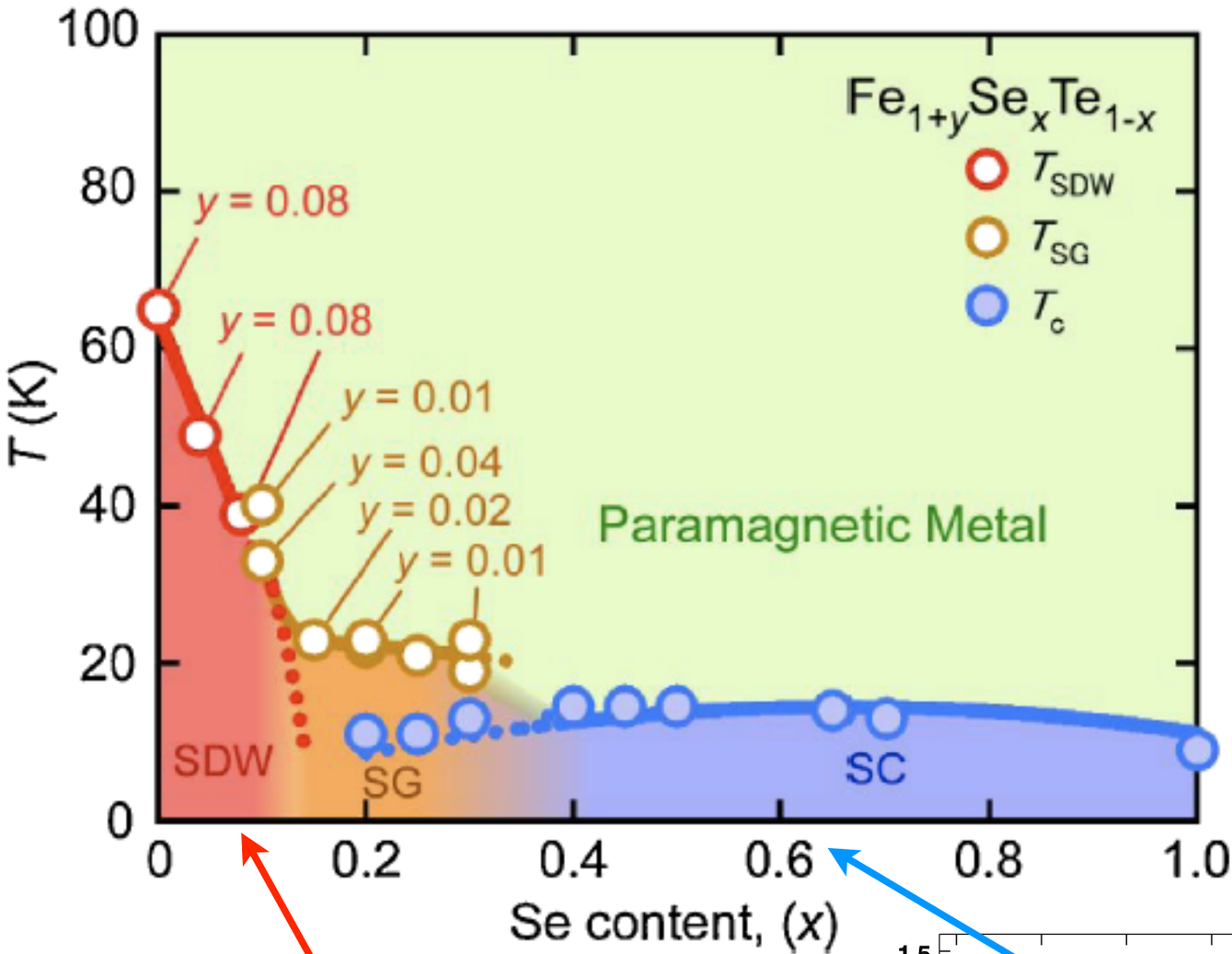
Outline

In superconducting $FeTe_{1-x}Se_x$:

- Spin correlations are short range
- Characteristic Q changes with T
- Likely due to orbital ordering

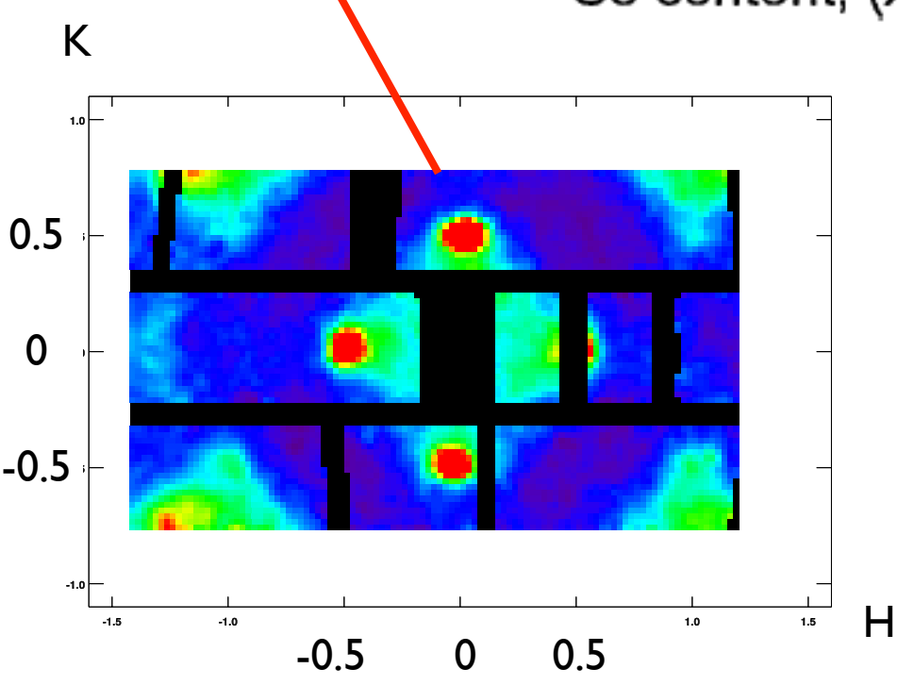
Fe(Se,Te) phase diagram

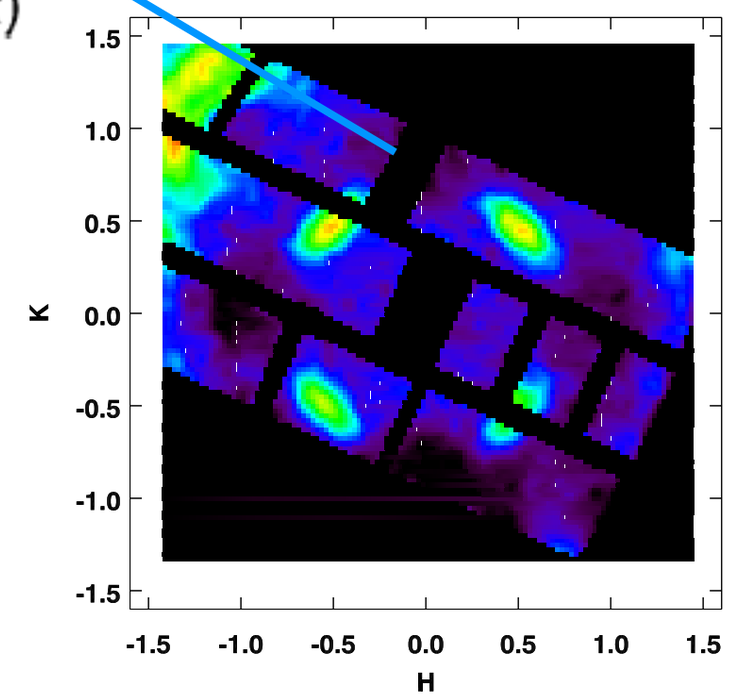


Issues

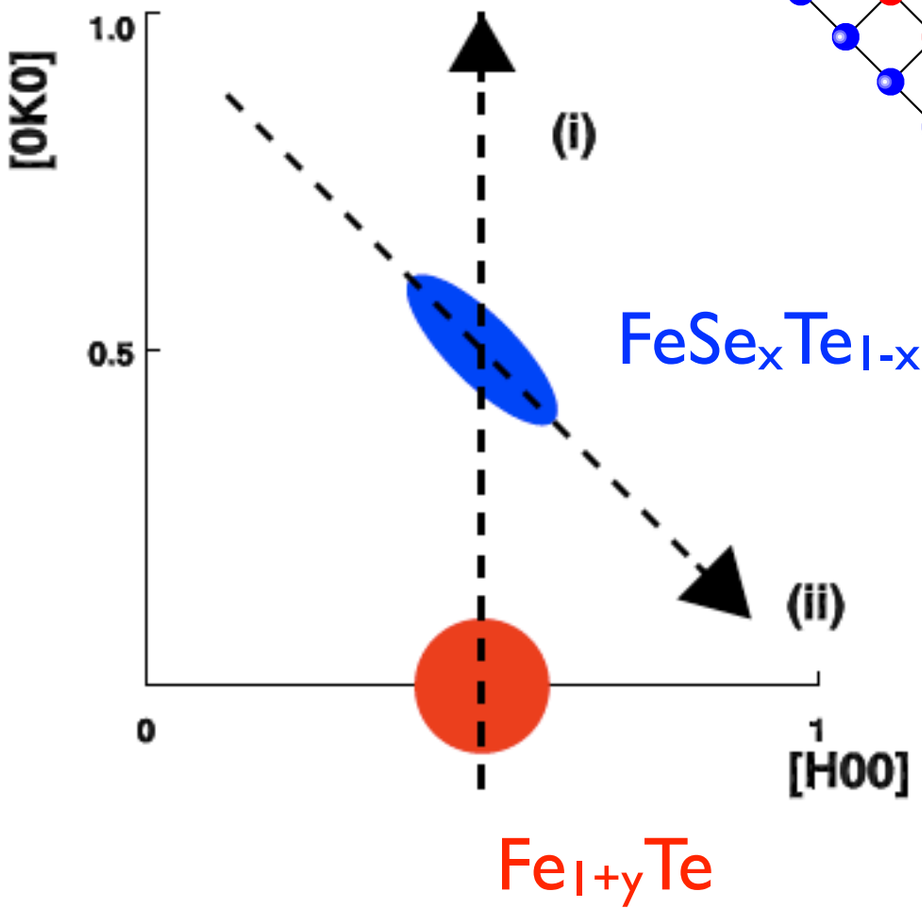
- Itinerant antiferromagnets
- At least four 3d bands cross E_F
- Degeneracy of d_{xz} and d_{yz}
  - Possible orbital ordering

Katayama *et al.*, JPSJ (2010)





Two types of spin correlations

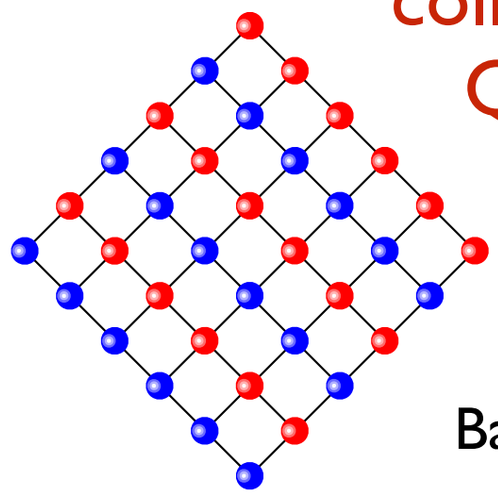


$FeSe_xTe_{1-x}$

$Fe_{1+y}Te$

collinear or stripe

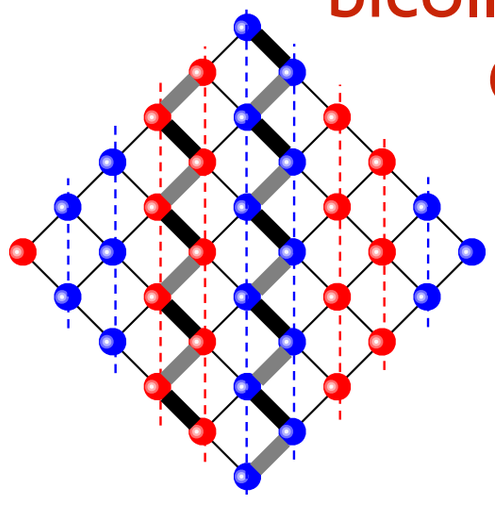
Q = (0.5, 0.5)



$BaFe_2As_2$ - type AF

bicollinear or bistripe

Q = (0.5, 0)

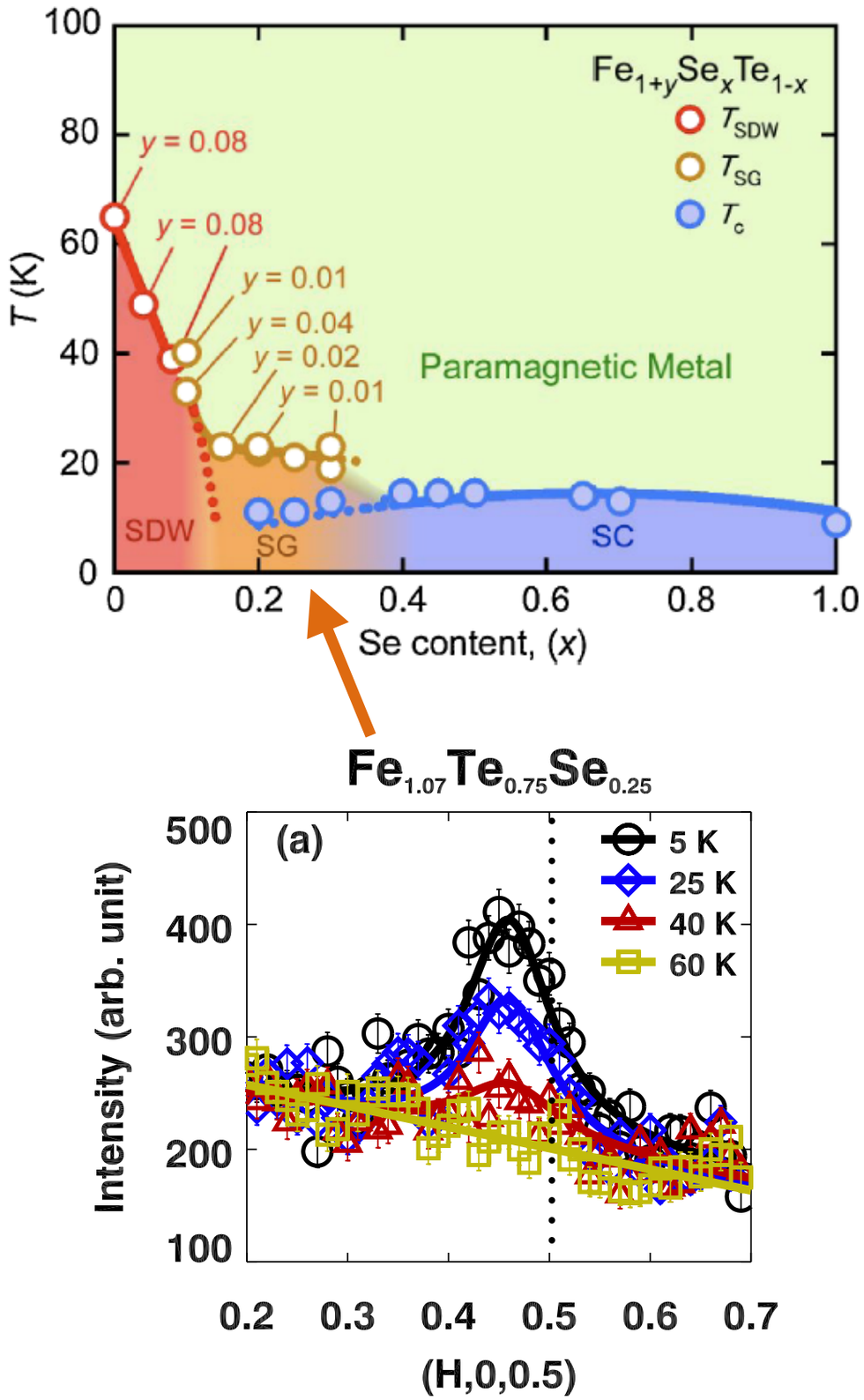


AF order in $Fe_{1+y}Te$

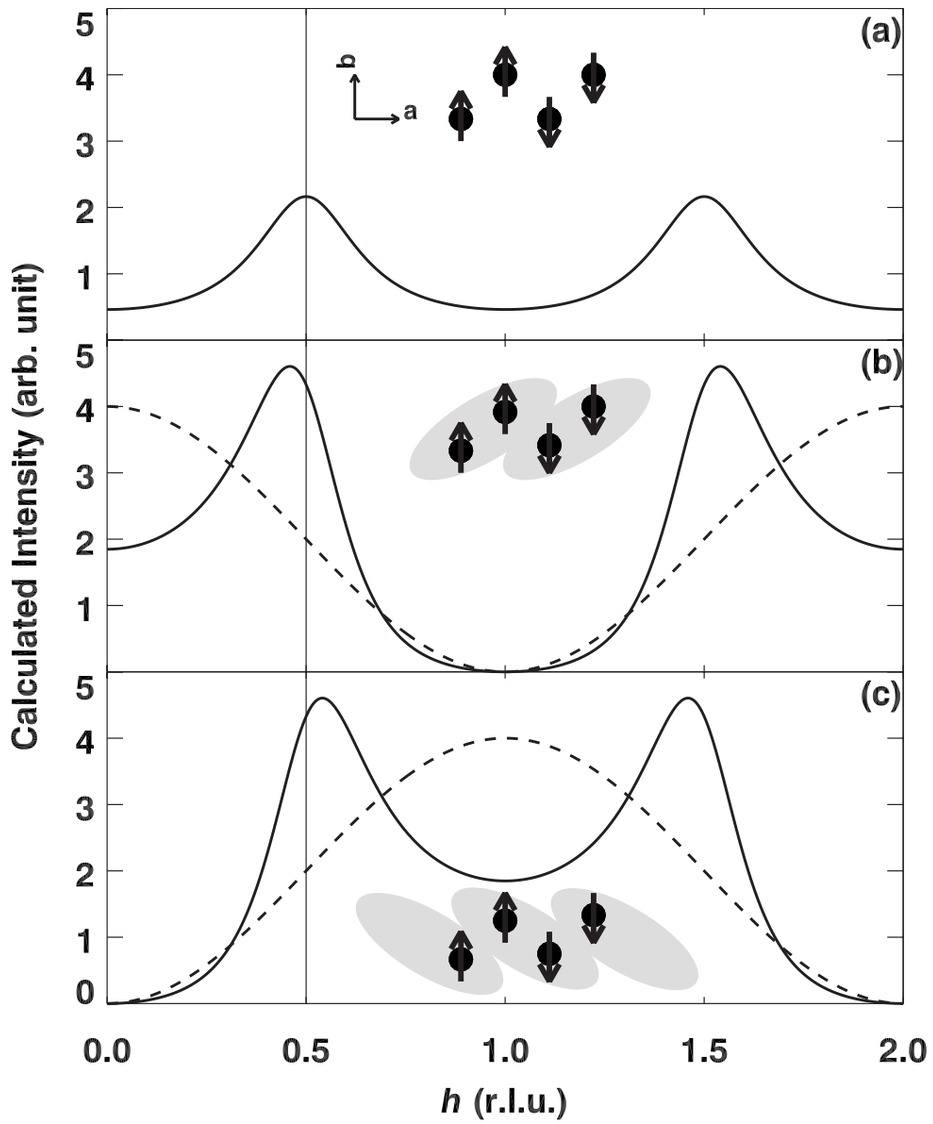
W. Bao *et al.*, PRL (2009)

S. Li *et al.*, PRB (2009)

Spin glass: incommensurate SRO



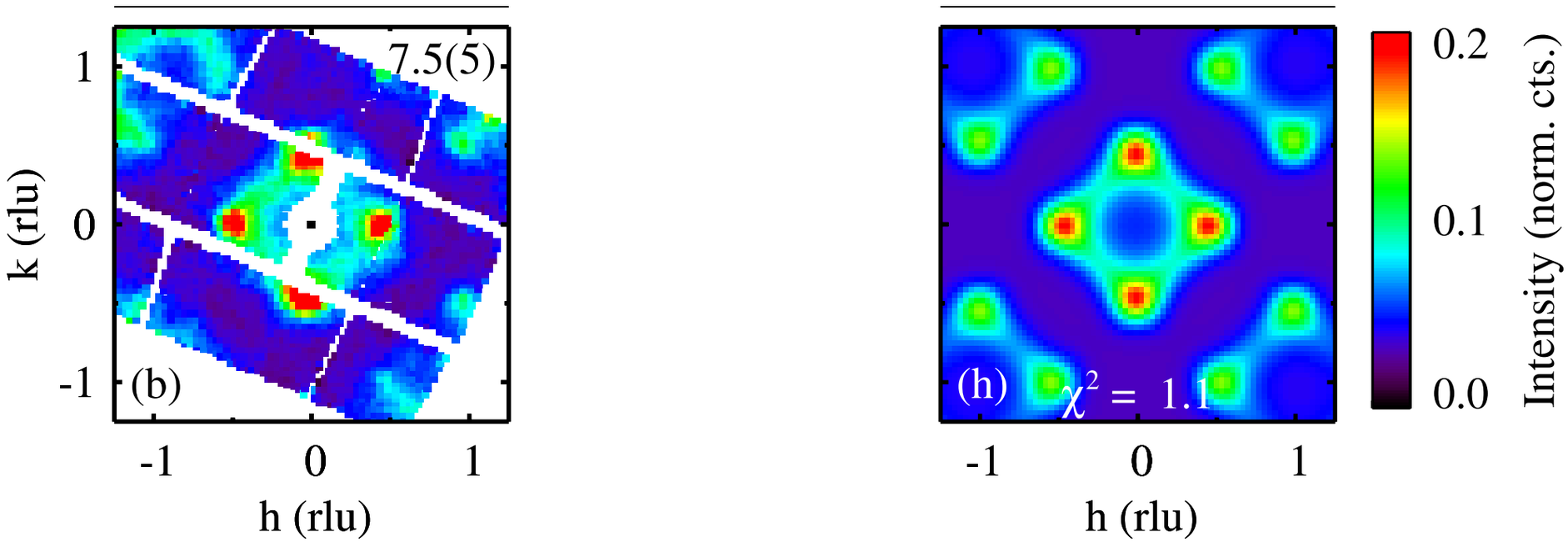
Model:
exponentially decaying correlations among identical plaquettes

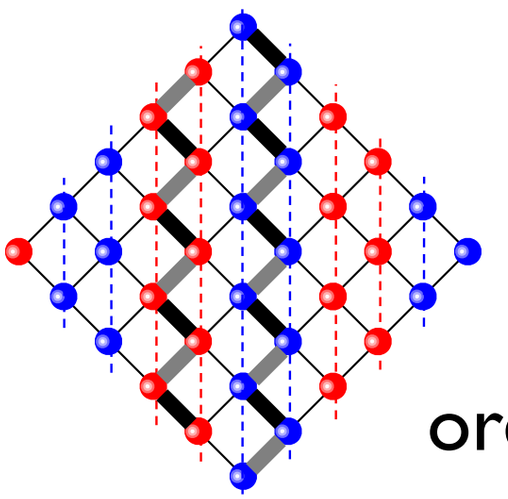


Wen *et al.*, PRB (2009)

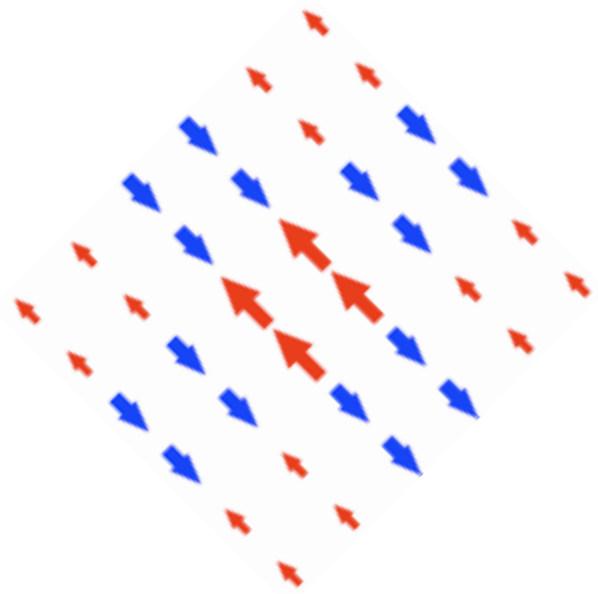
$Fe_{1.1}Te$

Excitations at 7.5 meV in ordered state





order

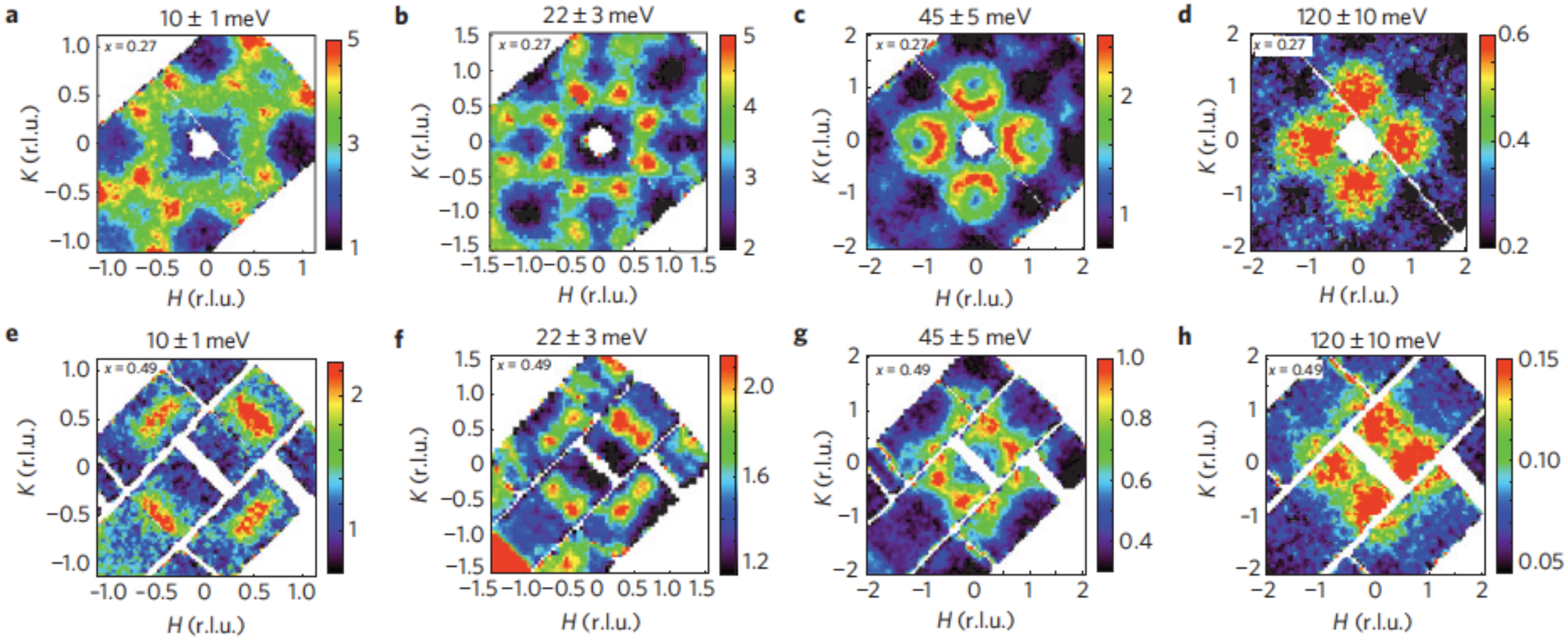


model for excitation

Zaliznyak *et al.*, PRL (2011)

$Fe_{1+y}Se_xTe_{1-x}$

x=0.27 non-bulk SC



x=0.49 bulk SC

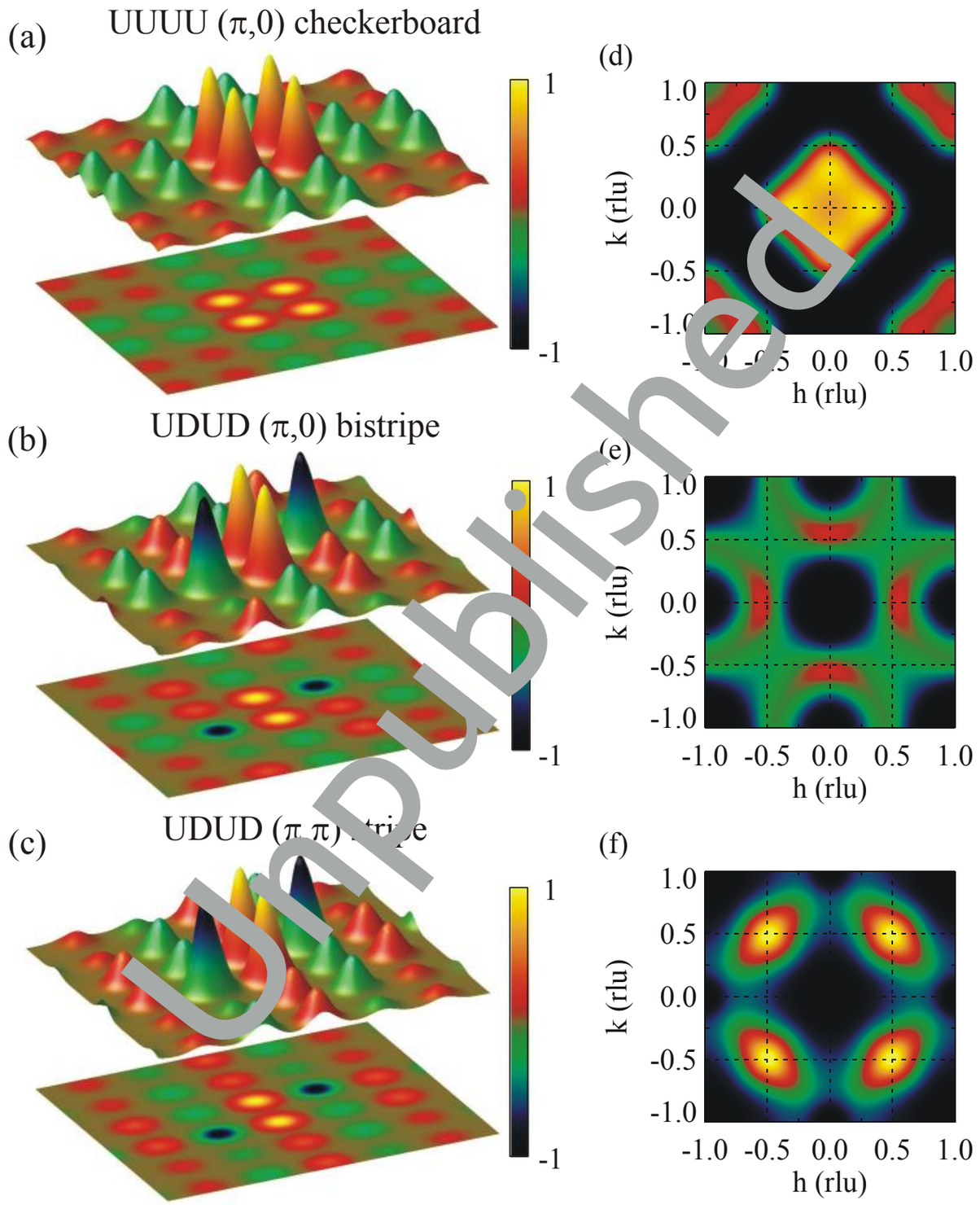
Lumsden *et al.*, Nat. Phys. (2010)

Generalized plaquette models

Checkerboard
(π, 0)

Bi-stripe
(π, 0)

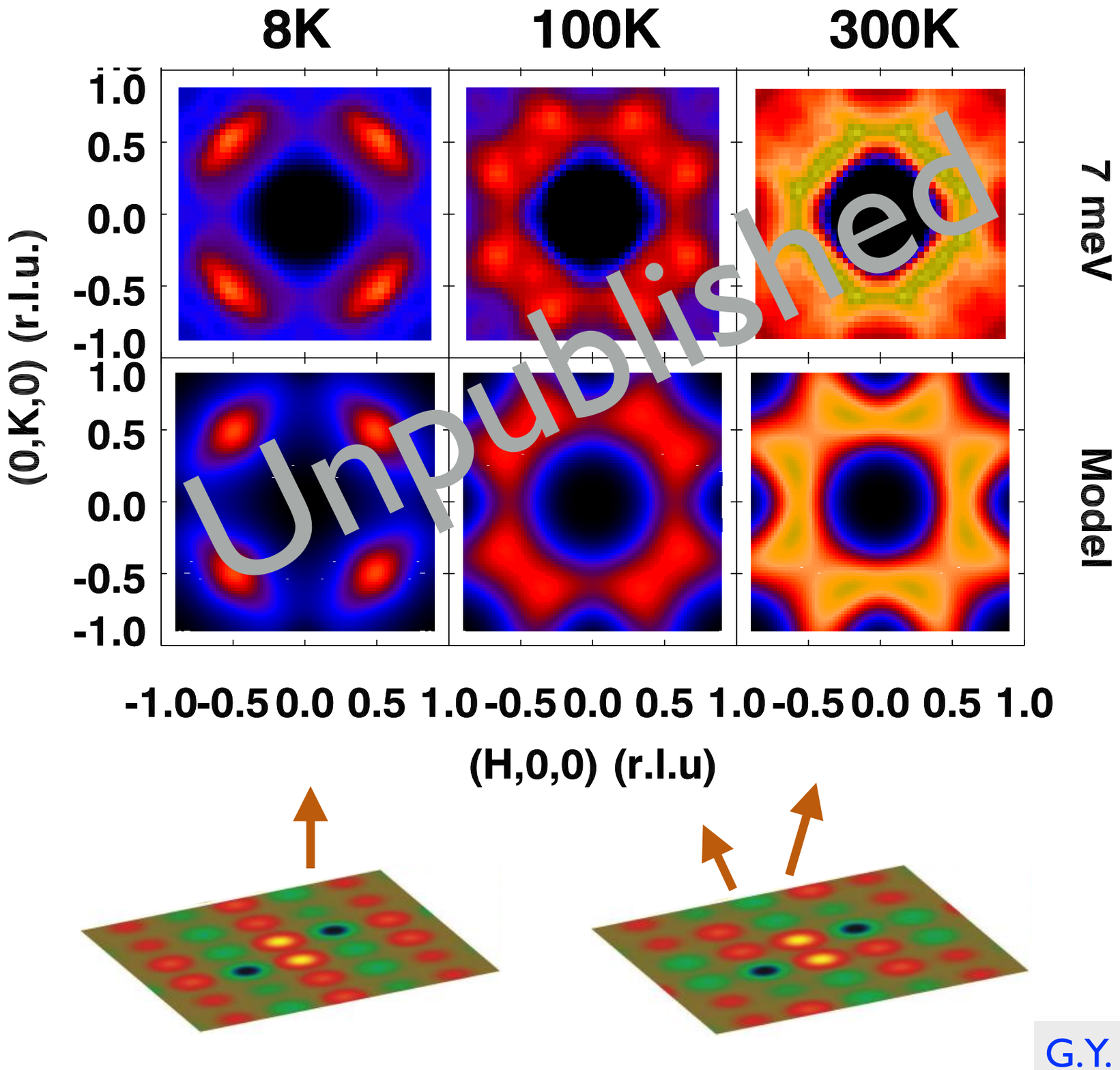
Stripe
(π, π)



Zaliznyak *et al.*, preprint

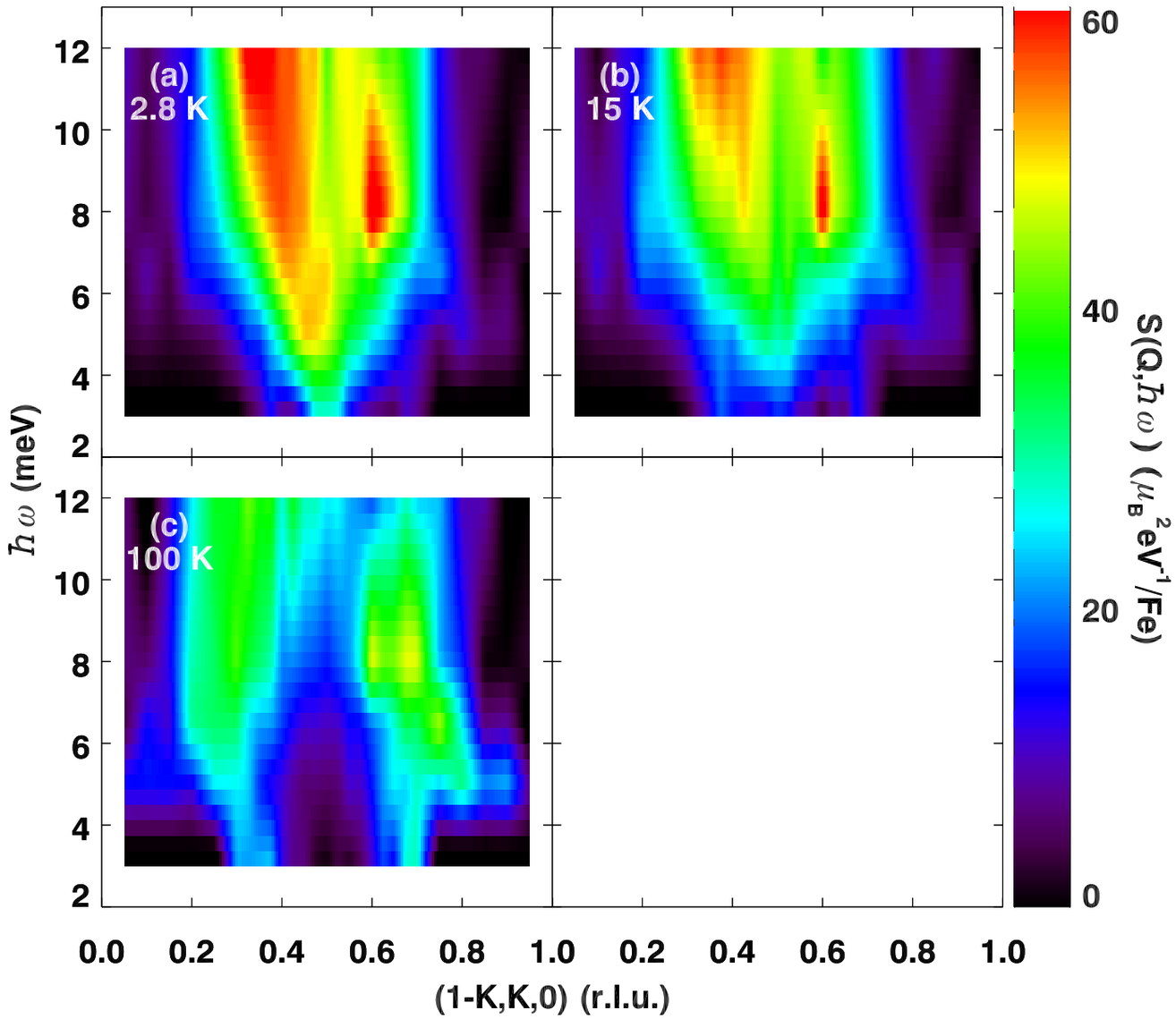
Unpublished

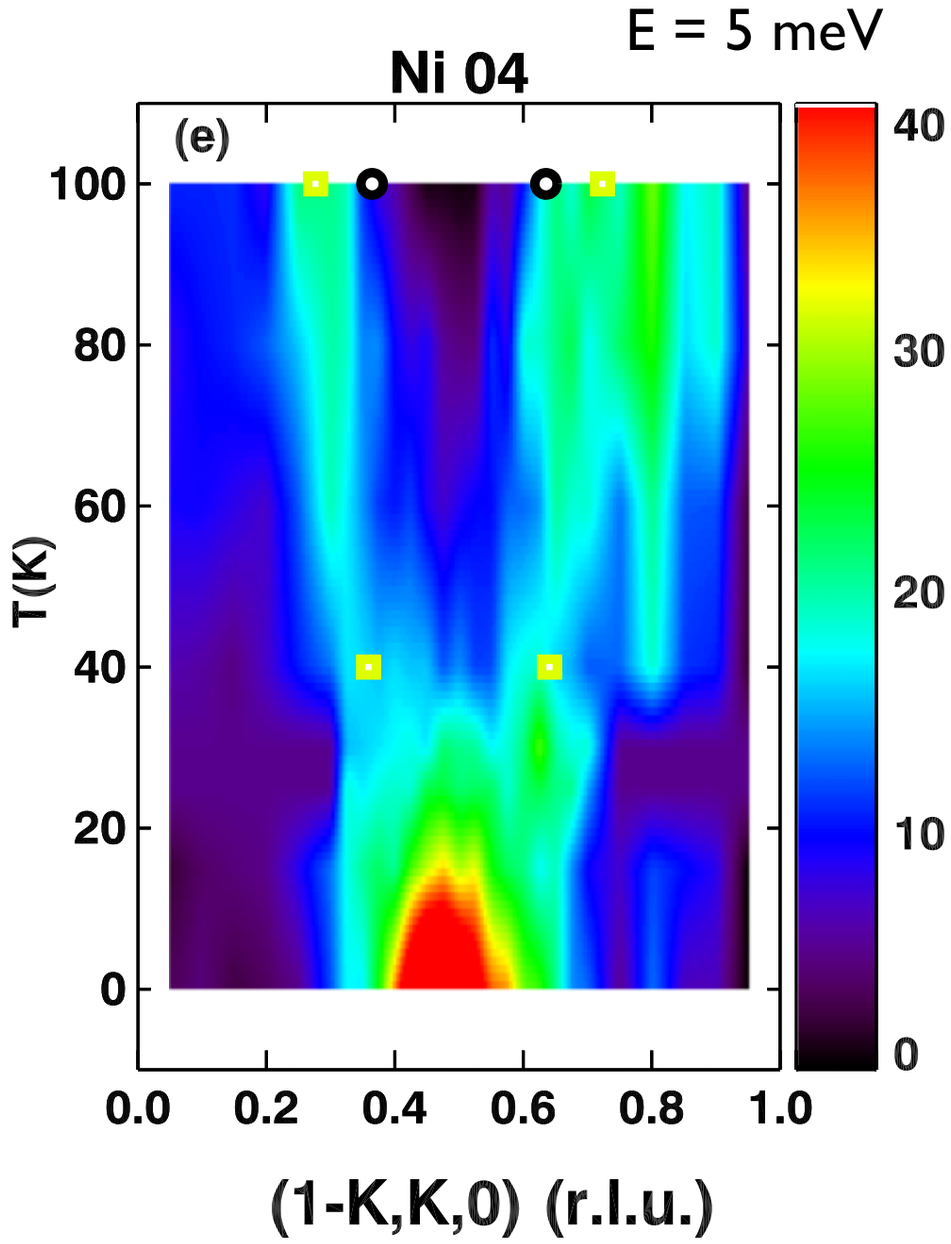
$FeTe_{0.3}Se_{0.7}$ T_c = 14 K

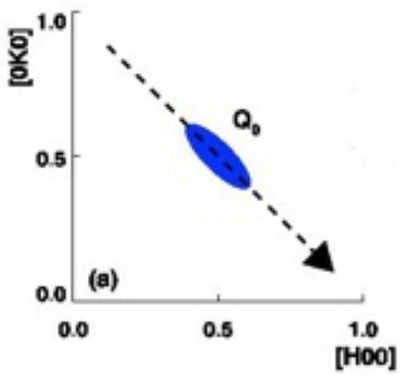


G.Y. Xu *et al.*, unpublished

Thermal evolution of magnetic dispersion



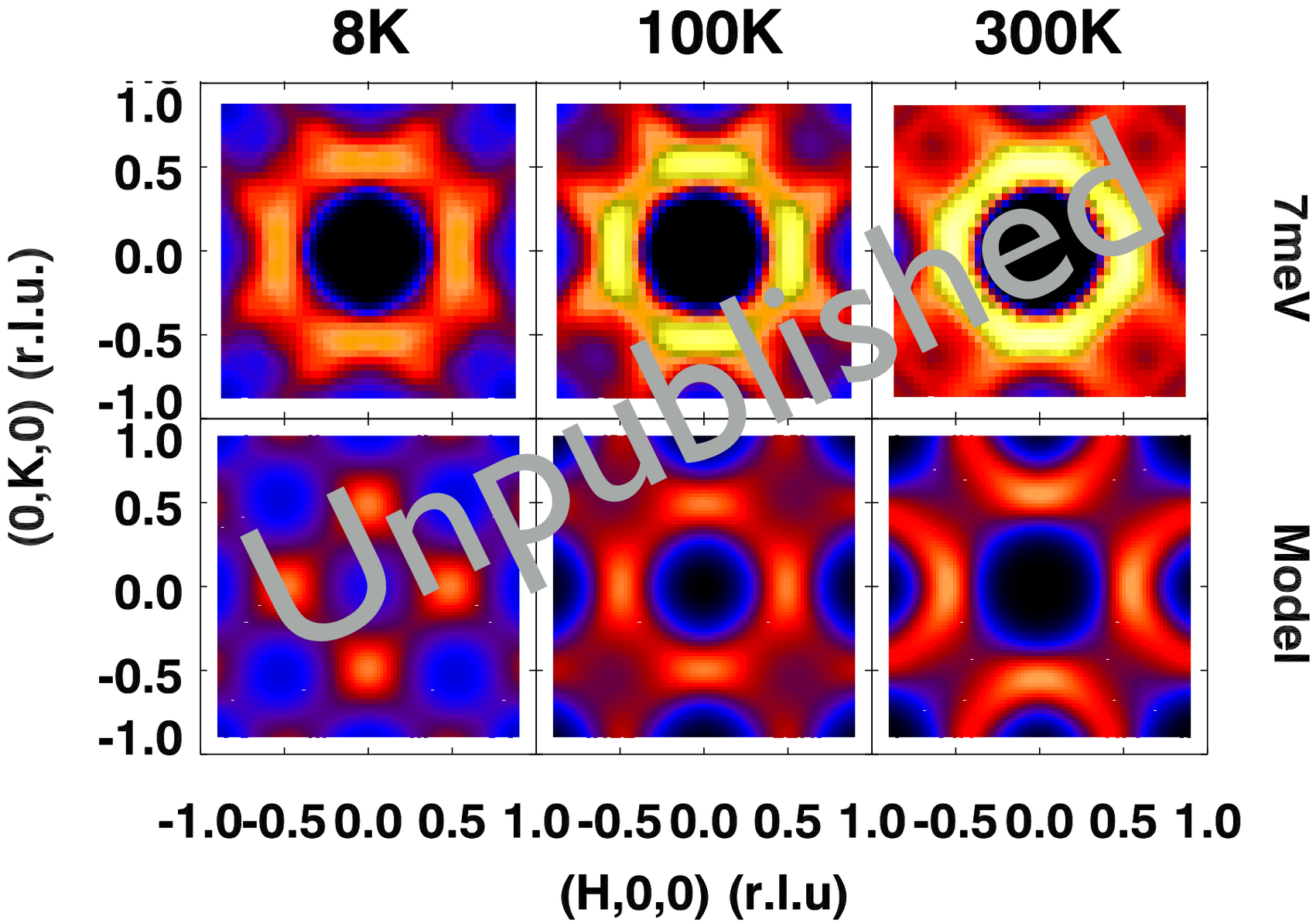




$Fe_{0.96}Ni_{0.04}Te_{0.5}Se_{0.5}$ T_c = 8 K

Z. Xu *et al.*, PRL (2012)

$Fe_{1.08}Te_{0.55}Se_{0.45}$ non-SC



models: (π,0) correlations with various plaquette choices

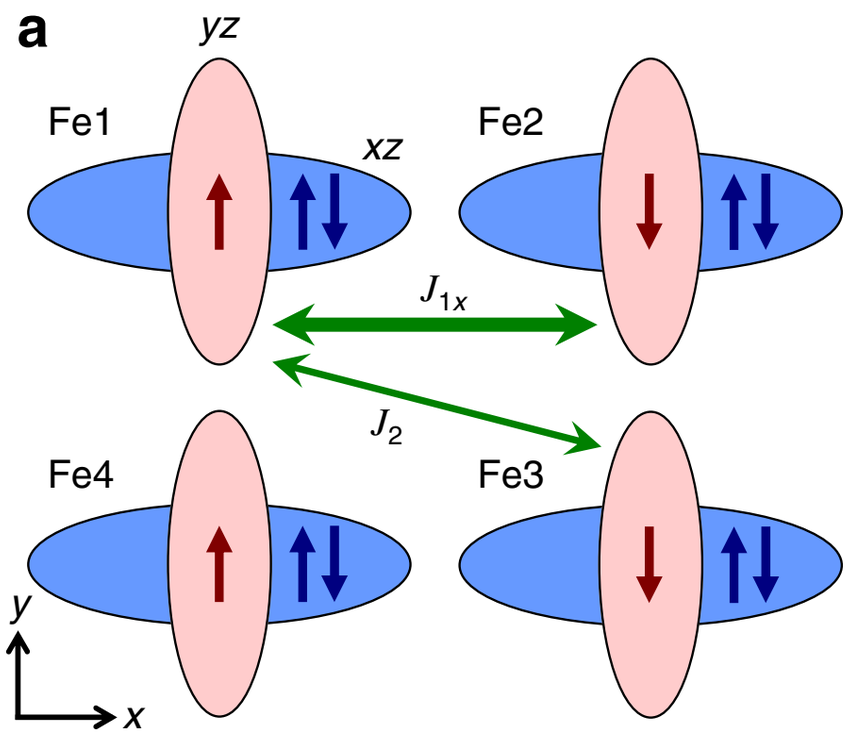
Never see (π,π) in non-superconducting samples!

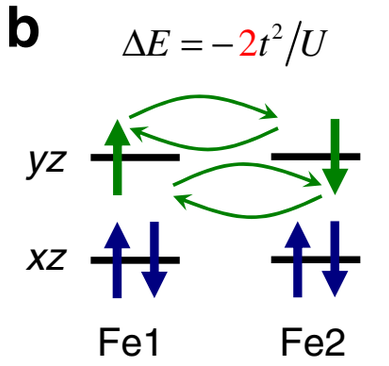
G.Y. Xu *et al.*, unpublished

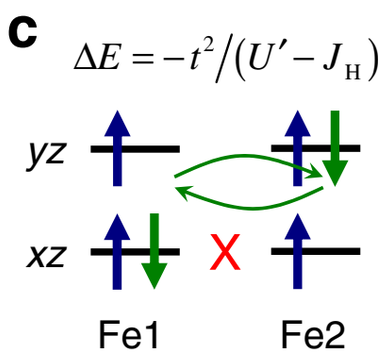
Temperature dependent change in spin-correlation pattern is quite unusual.

What could cause this?

Magnetic interactions influenced by orbital order



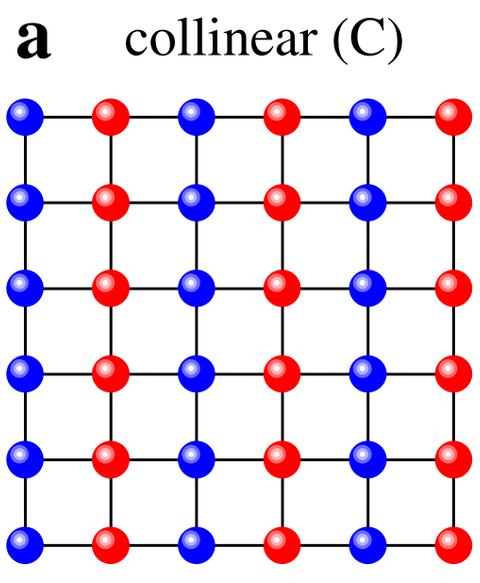


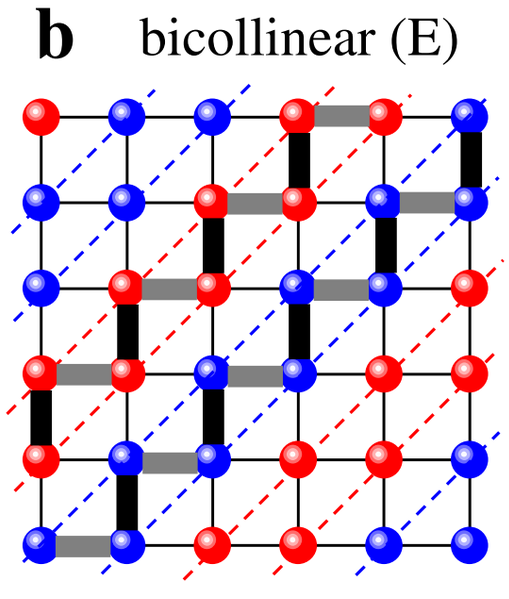


$J_{1y} = 0.1\ J_{1x}$

$J_2 = 0.4\ J_{1x}$

C.C. Lee *et al.*, PRL (2009)





Competition between superexchange and double-exchange has been invoked to explain multiple magnetic structures

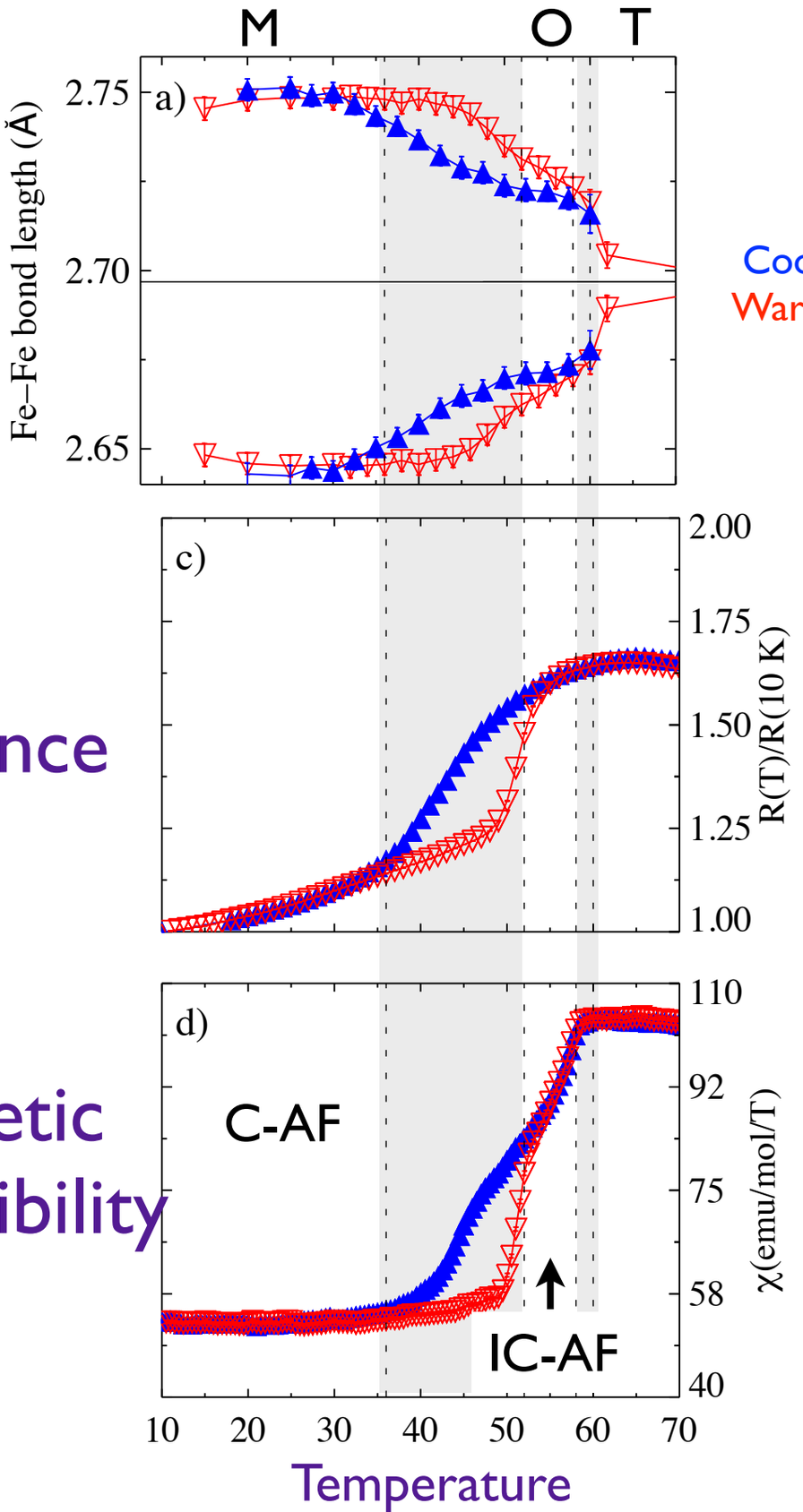
W.G. Yin *et al.*, PRL (2010)

$Fe_{1.1}Te$

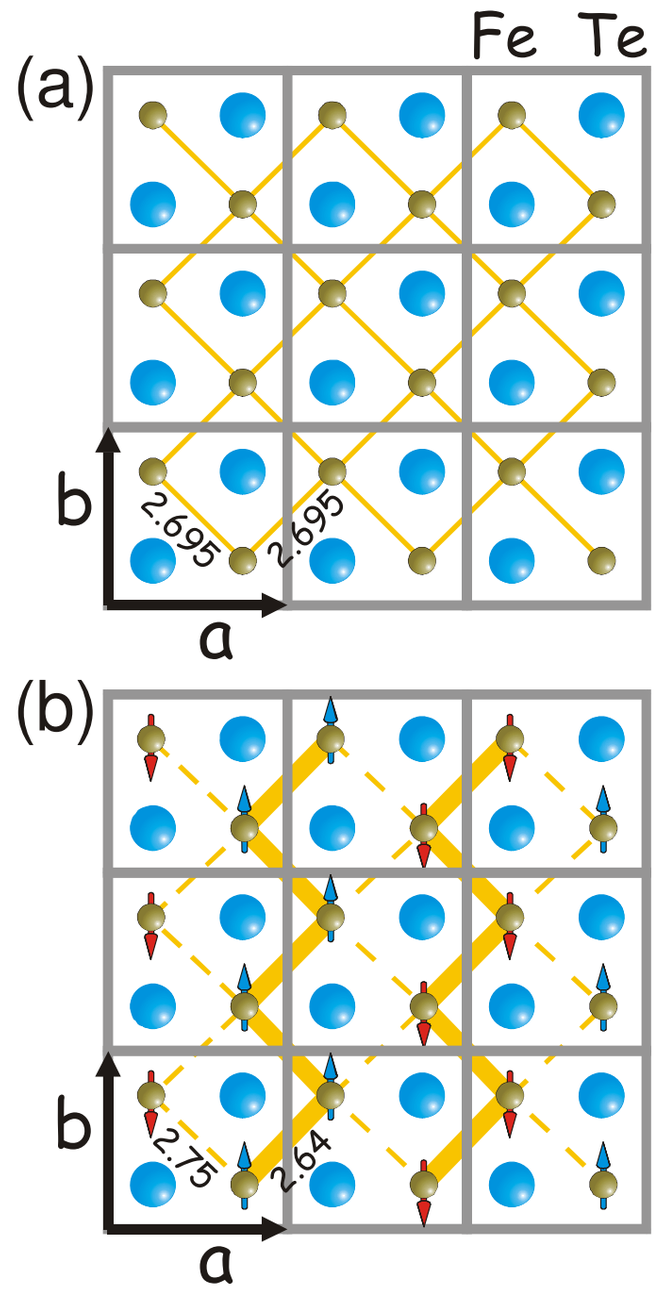
Fe-Fe bond length

Resistance

Magnetic susceptibility



Cooling
Warming

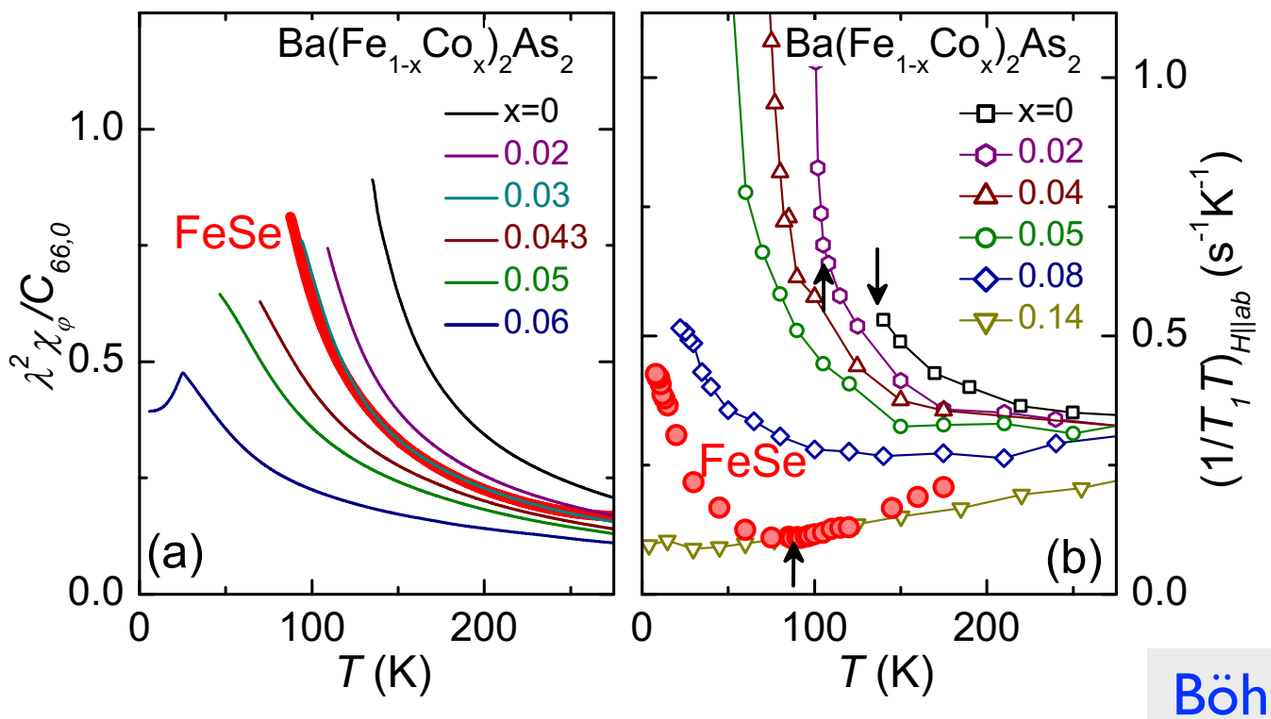


Commensurate AF order and conductivity are tied to a first order transition to an Fe-Fe bond-order wave; orbital order implied.

Fobes *et al.*, PRL (2014)

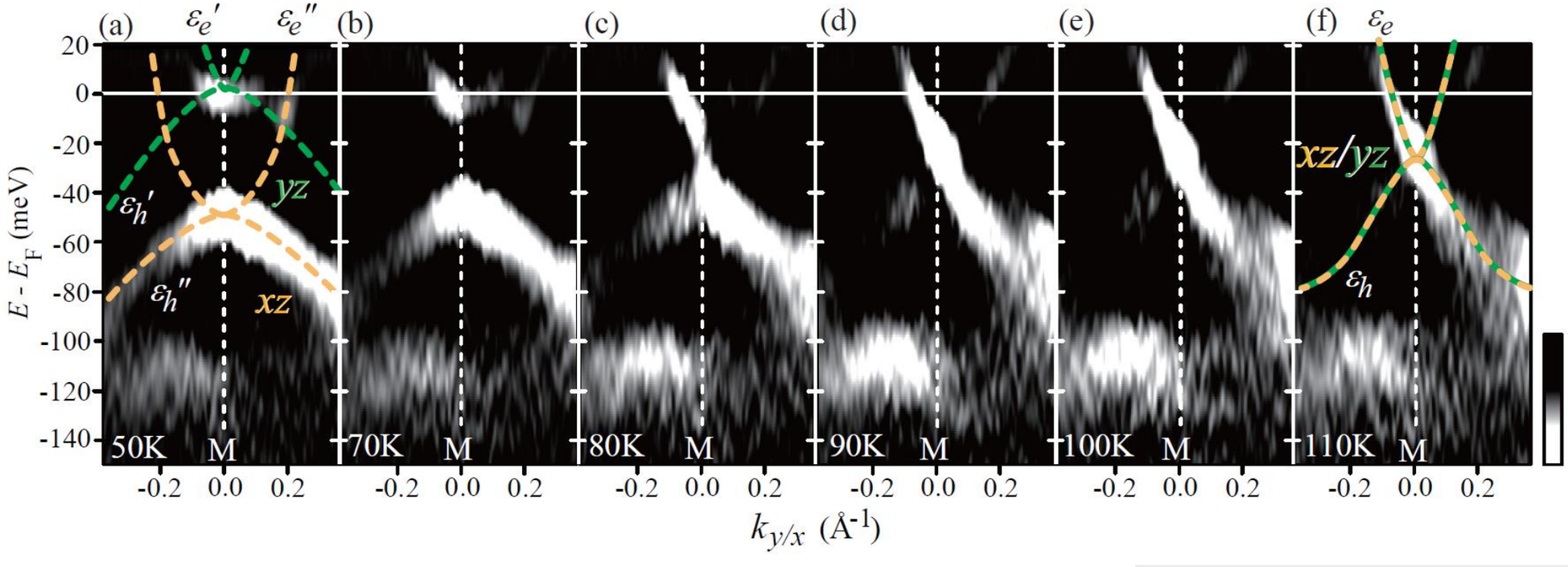
FeSe: Orbital order below 80 K O-T transition

normalized nematic susceptibility



Se spin-lattice relaxation rate

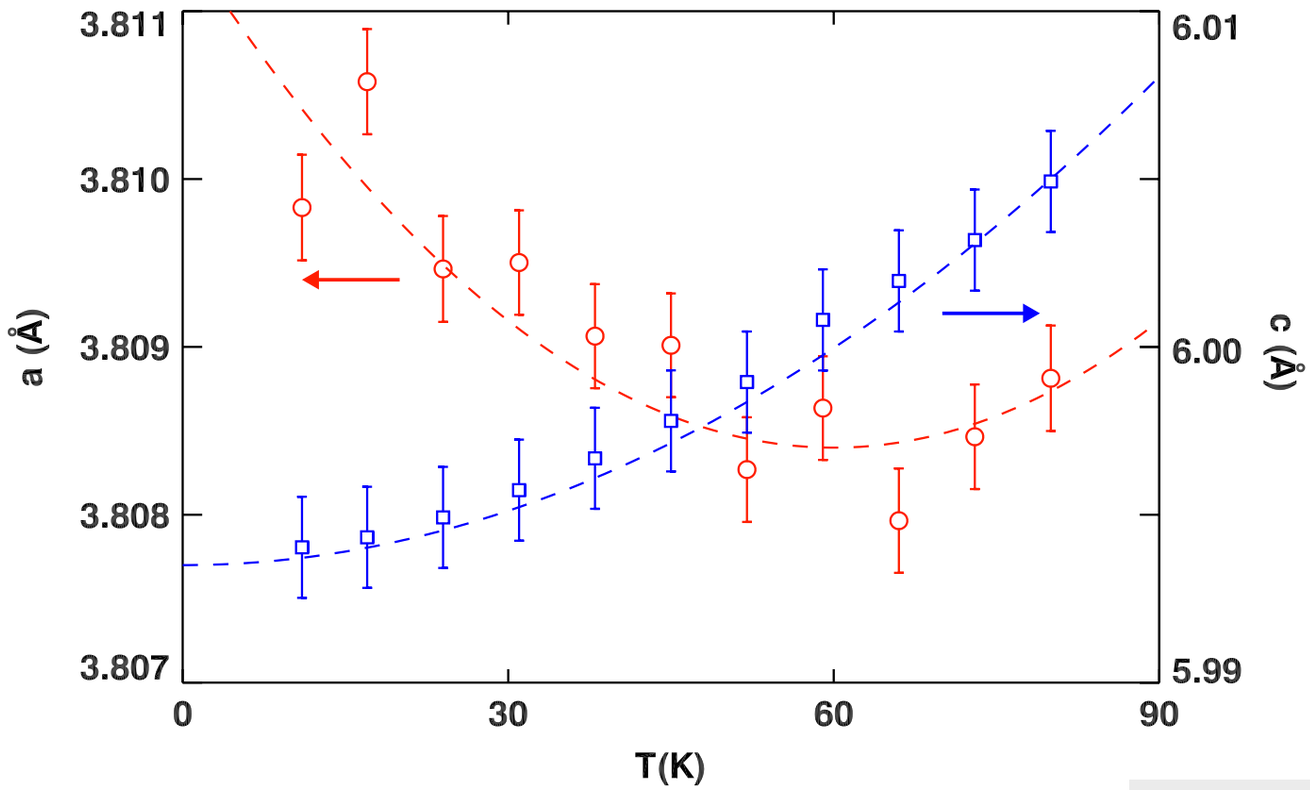
Böhmer *et al.*, arXiv:1407.5497

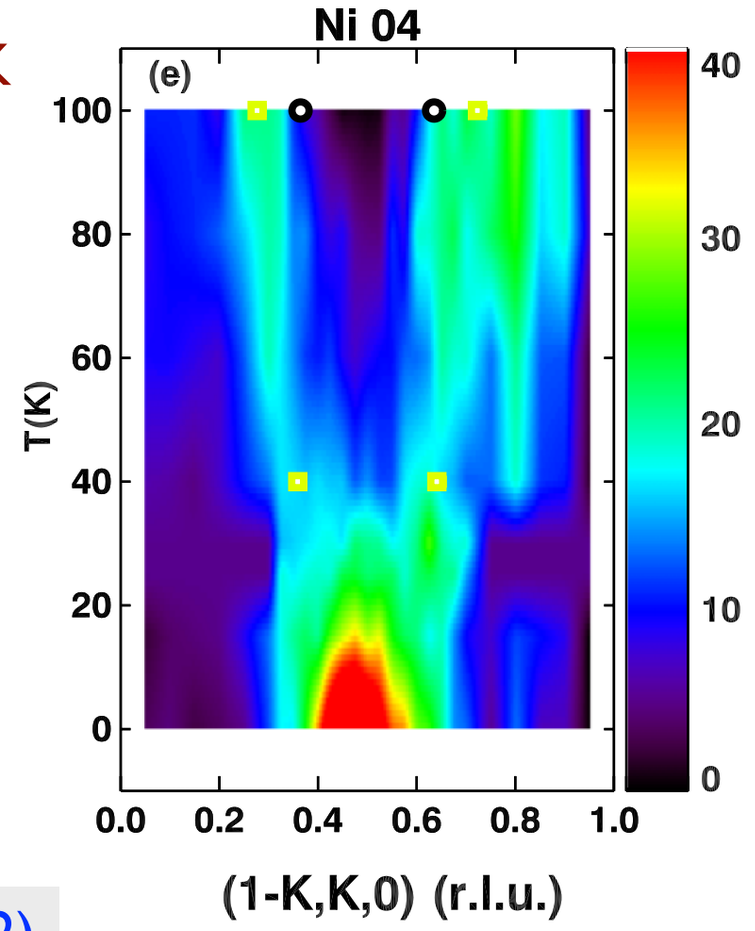


ARPES (2nd deriv) from detwinned crystal

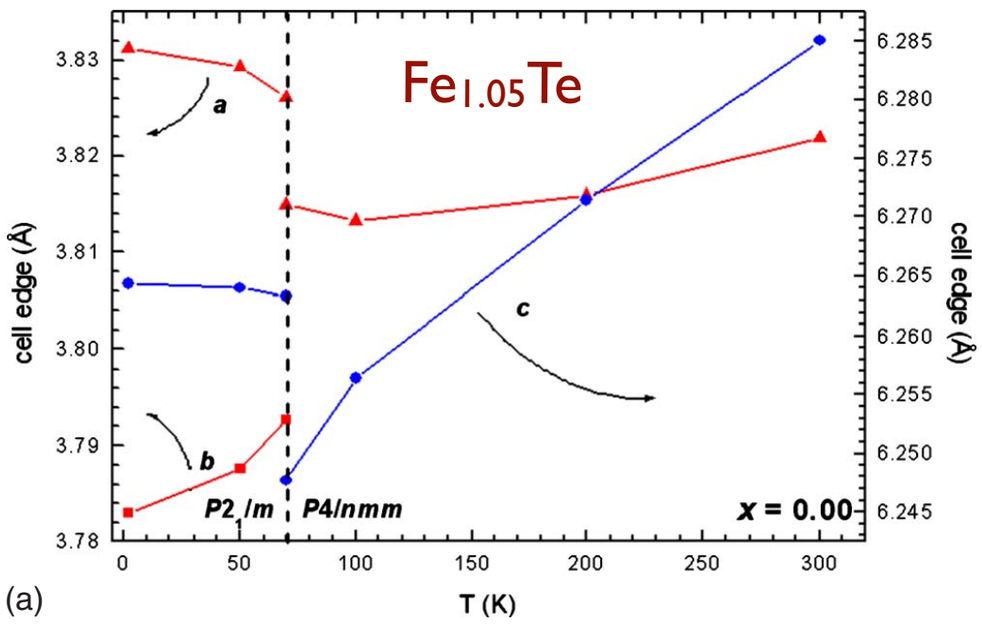
Shimojima *et al.*, arXiv:1407.1418

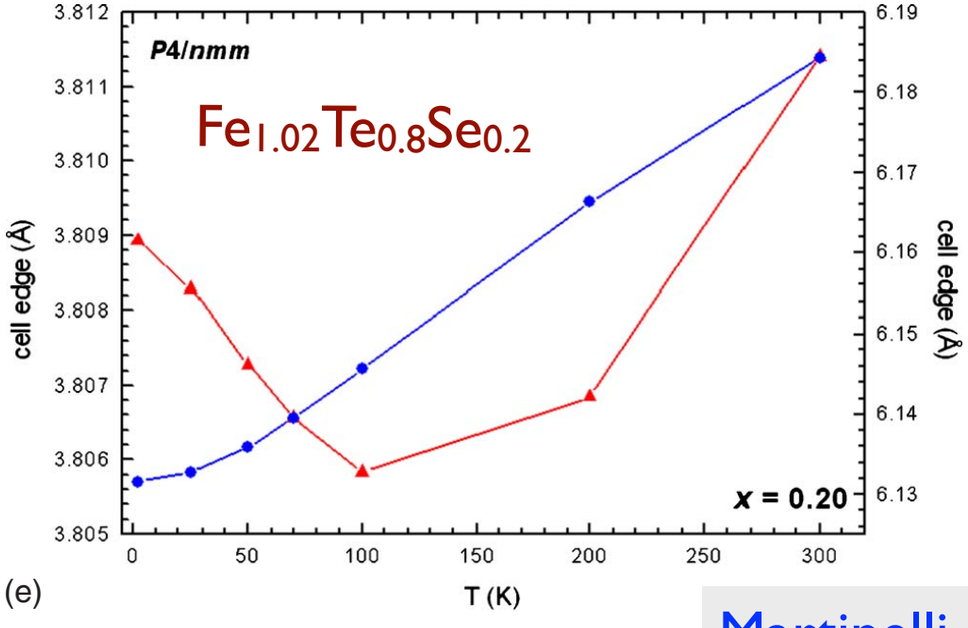
Anomalous expansion: evidence of orbital correlations?





Z. Xu *et al.*, PRL (2012)



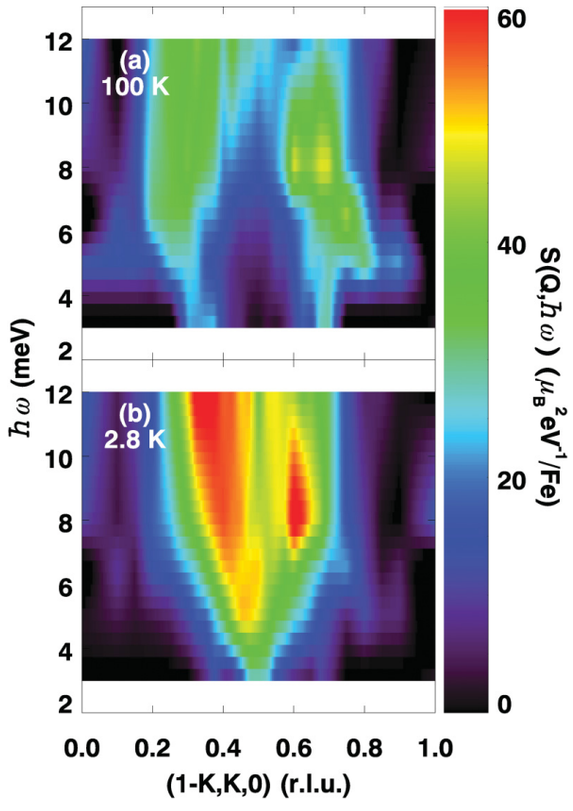


Martinelli *et al.*, PRB (2010)

Dynamic orbital correlations and spin fluctuations

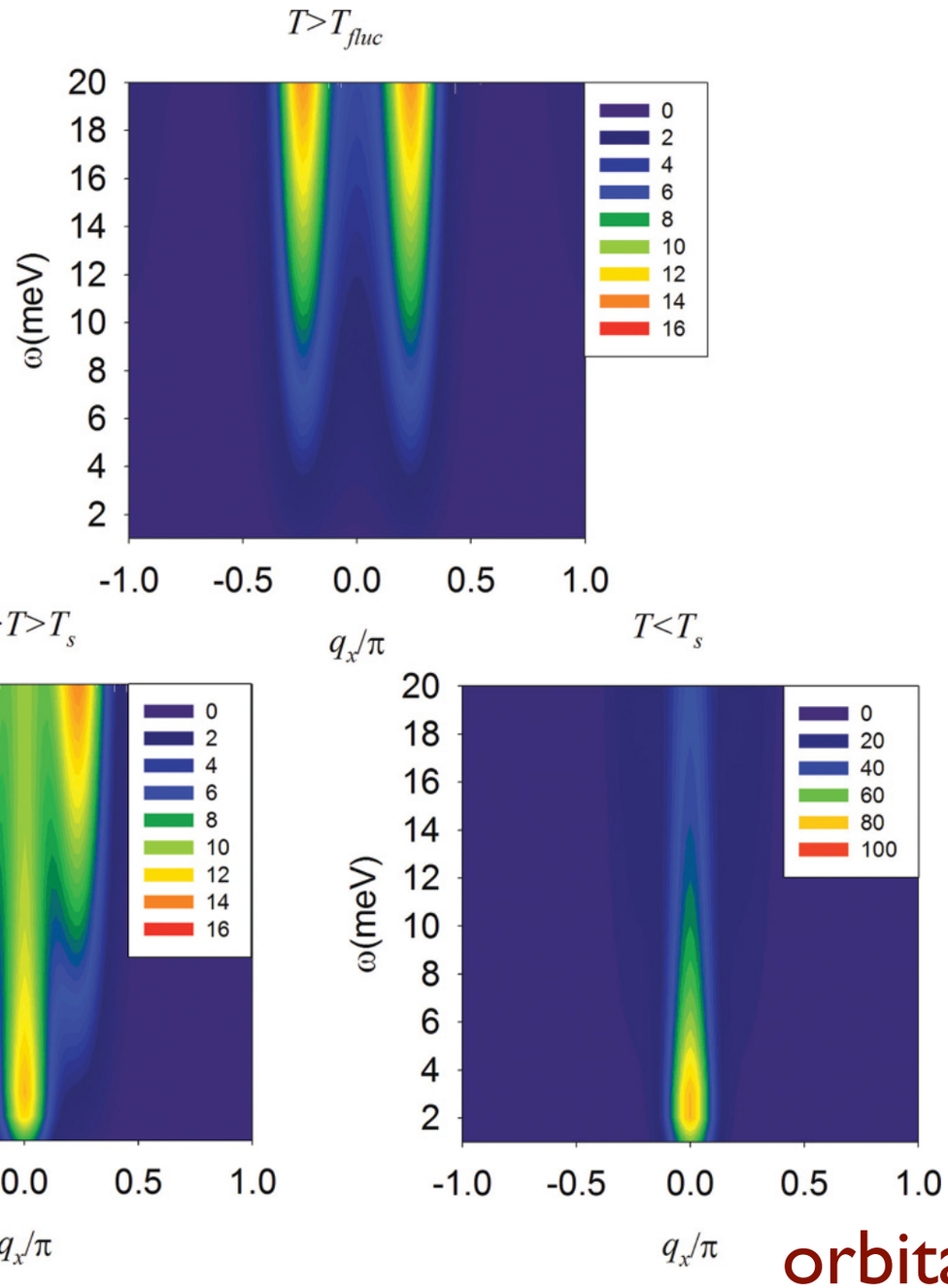
magnetic neutron scattering

$Fe_{0.96}Ni_{0.04}Te_{0.5}Se_{0.5}$ T_c = 8 K



Z. Xu *et al.*, PRL (2012)

no orbital correlations



dynamic orbital correlations

orbital order

Wei-Cheng Lee *et al.*, PRB (2012)

Conclusions

In superconducting $FeTe_{1-x}Se_x$:

- Spin correlations are short range
- Characteristic Q changes with T
- Likely due to orbital ordering