Isotropic superconducting gaps with enhanced pairing on electron Fermi surfaces in $FeTe_{0.55}Se_{0.45}$

Yiming Xu

Materials Sciences Division
Lawrence Berkeley National Laboratory

New Trends in Photoemission, October 5, 2011

Collaborators

APRES:

IOP, China: **H. Miao**, P. Richard, Y.-B. Huang, T. Qian, Y.-B. Shi, N. Xu, X.-P. Wang, P. Zhang, H. Ding†

Tohoku University: Y. Tanaka, K. Nakayama, K. Umezawa, T. Sato, T. Takahashi

BNL, NSLS H.-B. Yang

Theory:

Purdue University: J.-P. Hu

IOP, China: X. Dai

Samples:

BNL Z.-J. Xu, J.-S. Wen, G.-D. Gu

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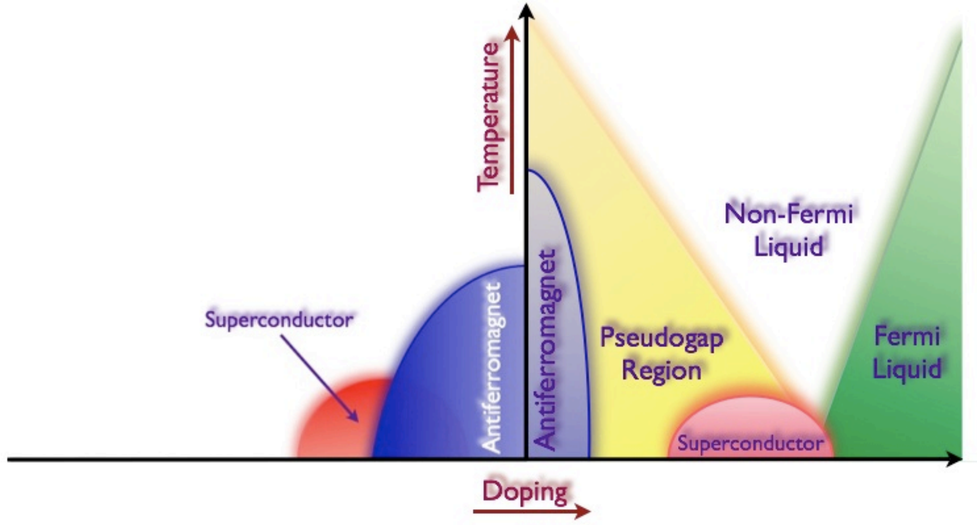
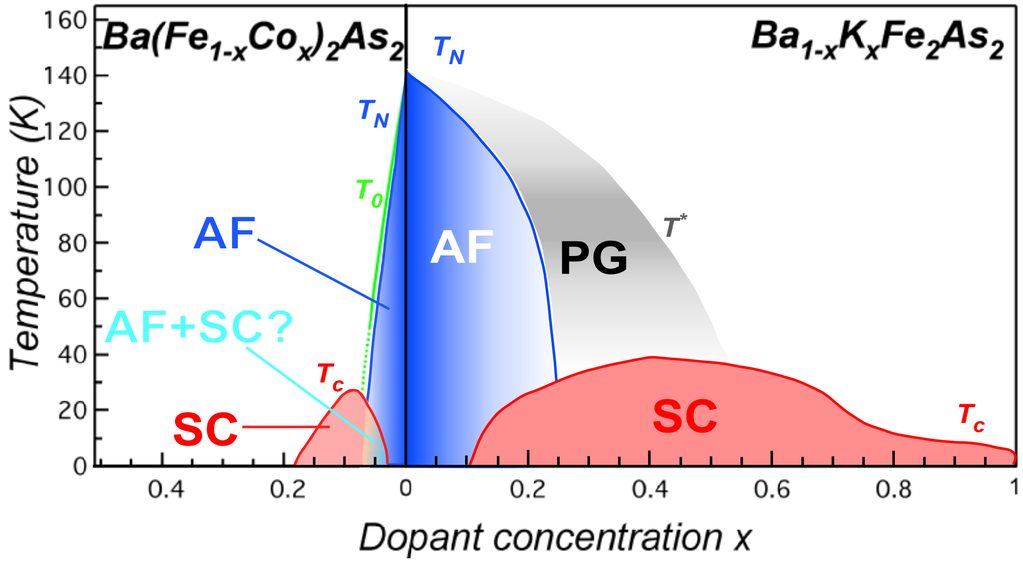
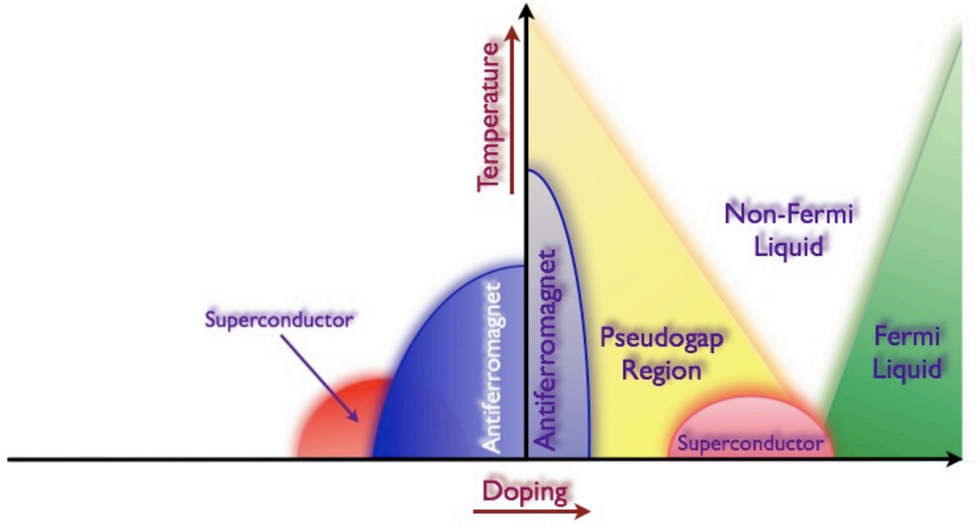
cuprates *vs* pnictides

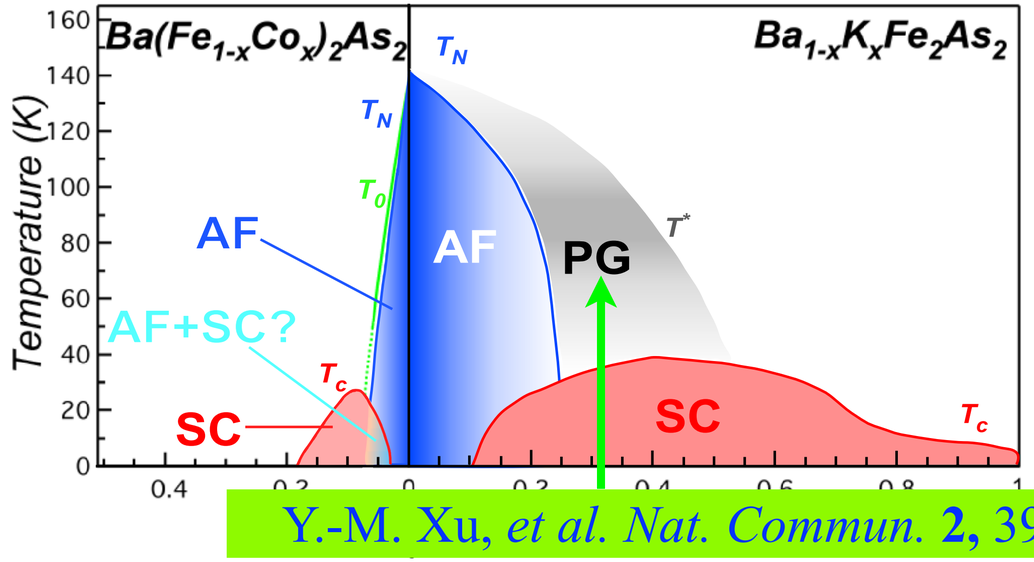




	cuprates	**pnictides**
Cooper pair	yes	yes
isotope effect	small on OPD	controversial
spin structure in pair	singlet	singlet
parent compound	AF Mott insulator	AF SDW semimetal
T_N of parent compound	~300 K	~140 K
electron correlation	strong	intermediate
low energy orbitals	Cu $3d_{x^2-y^2}$ - O $2p_{x,y}$	Fe $3d_{xy,\ yz,\ zx}$
Fermi surface	one	five
pairing symmetry	*d*-wave	*s*±-wave

cuprates *vs* pnictides





Y.-M. Xu, *et al. Nat. Commun.* **2,** 392 (2011)

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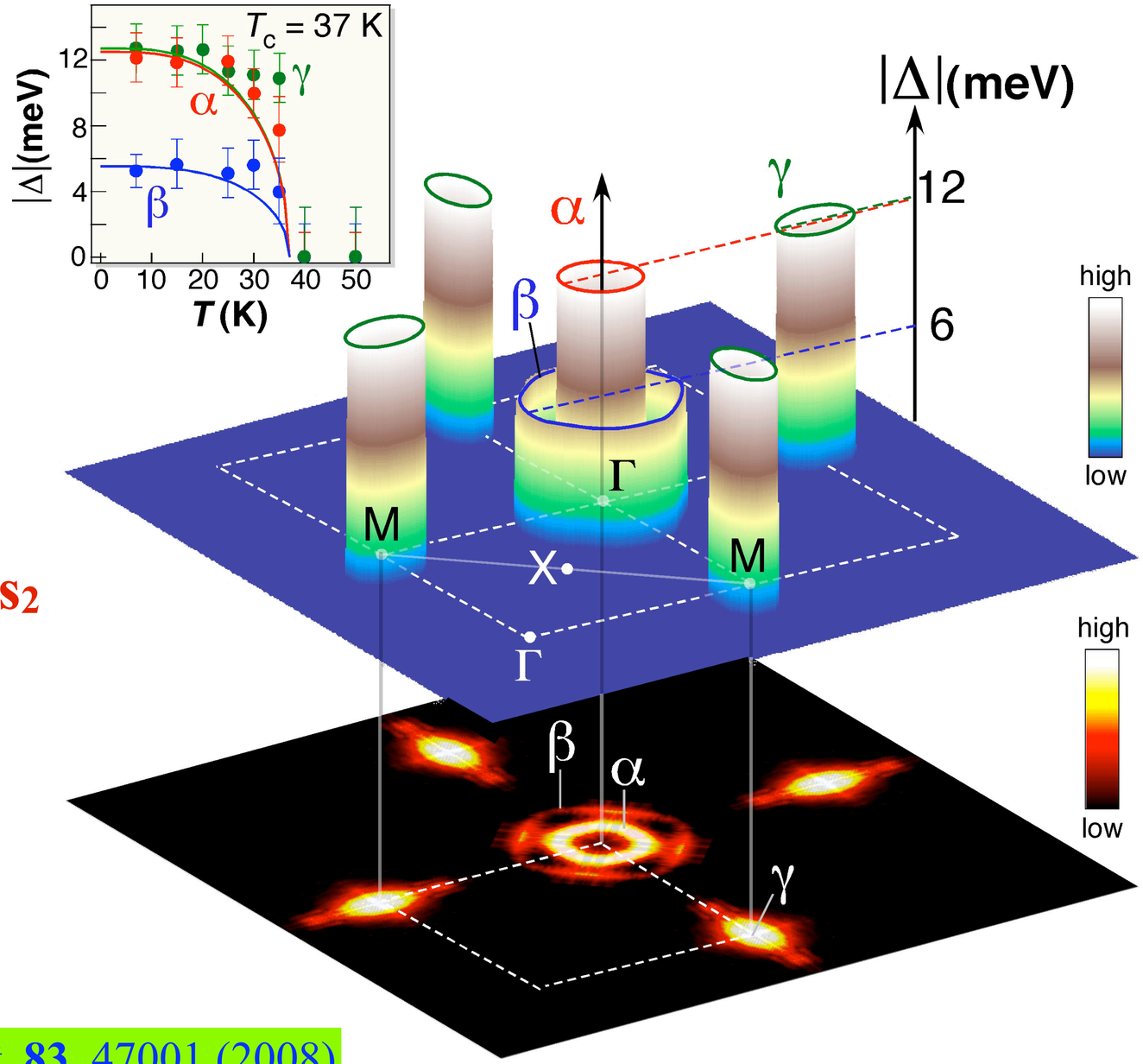
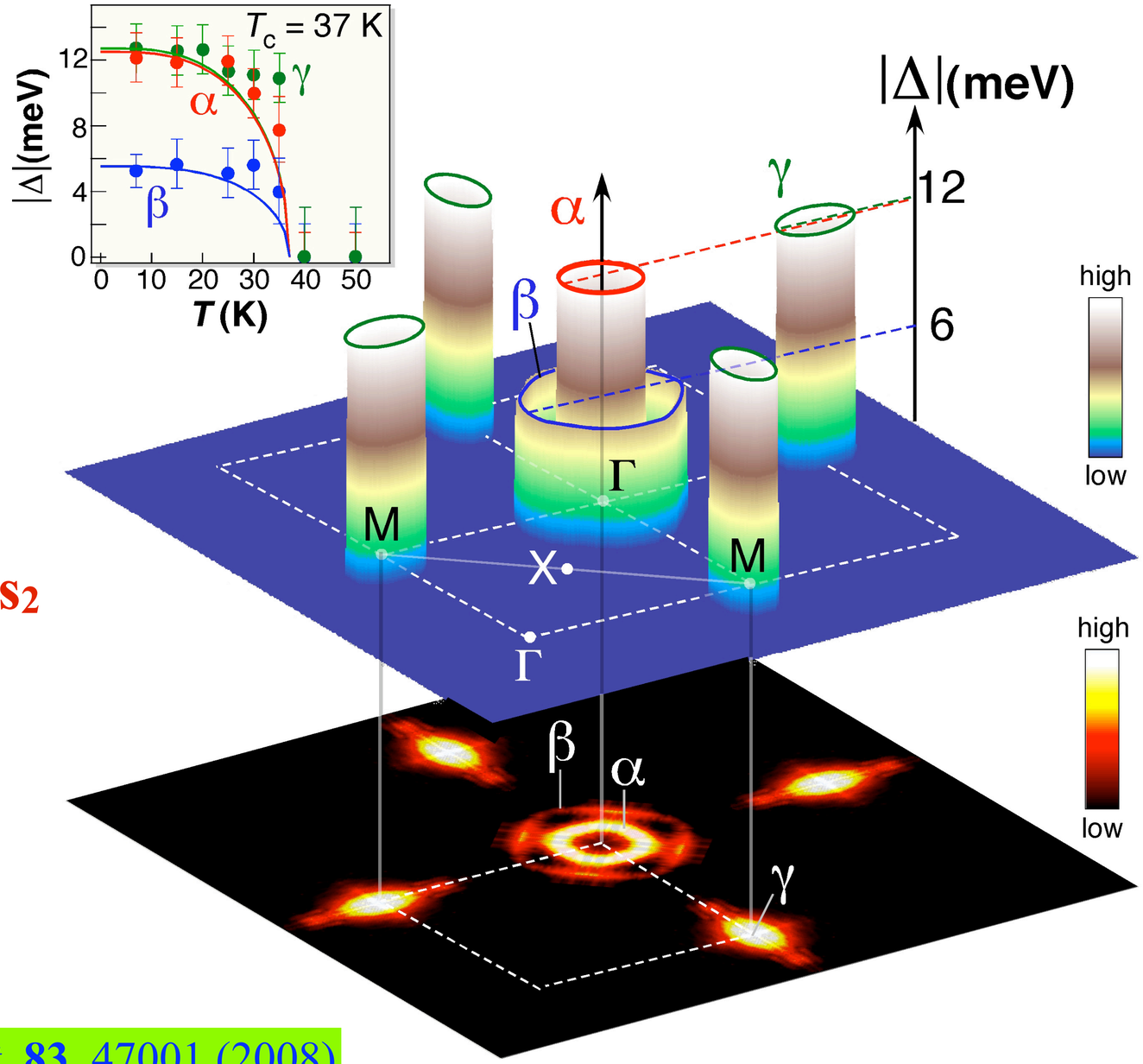
weak coupling *vs* strong coupling



$Ba_{0.6}K_{0.4}Fe_2As_2$

H. Ding, *et al. Europhys. Lett.* **83,** 47001 (2008)

weak coupling *vs* strong coupling



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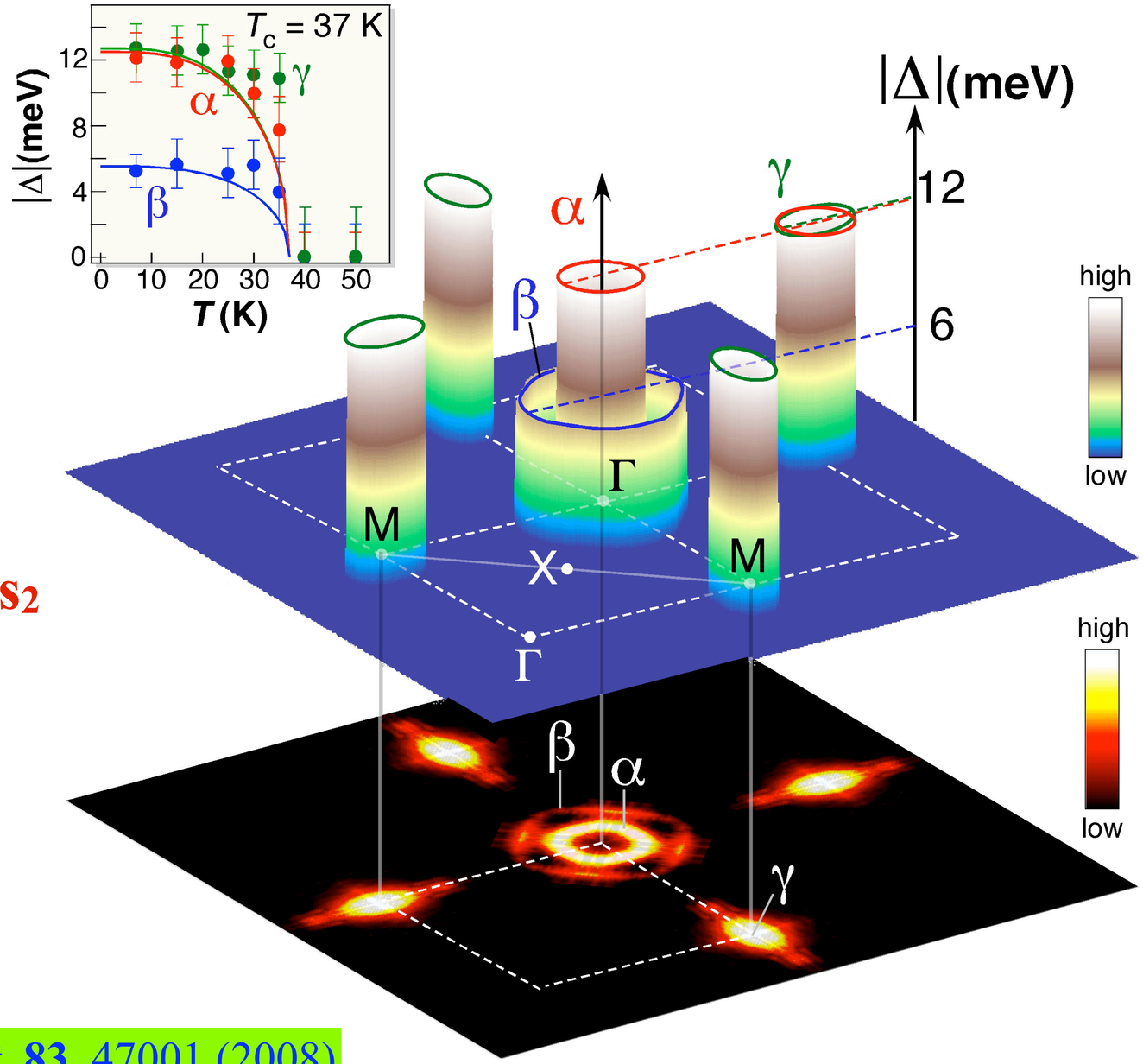

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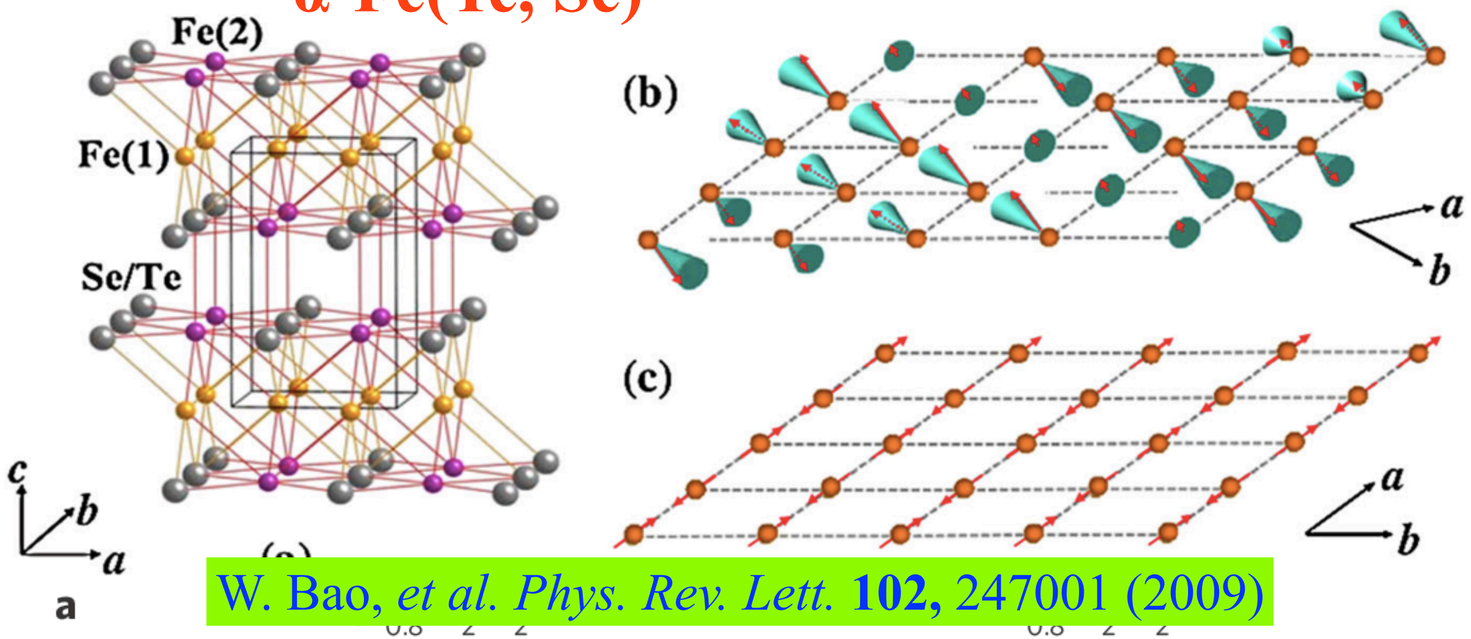
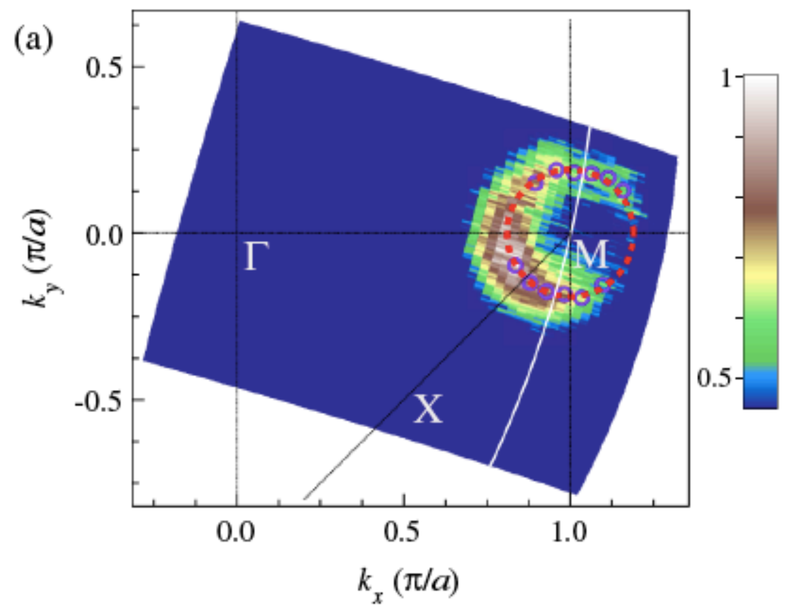
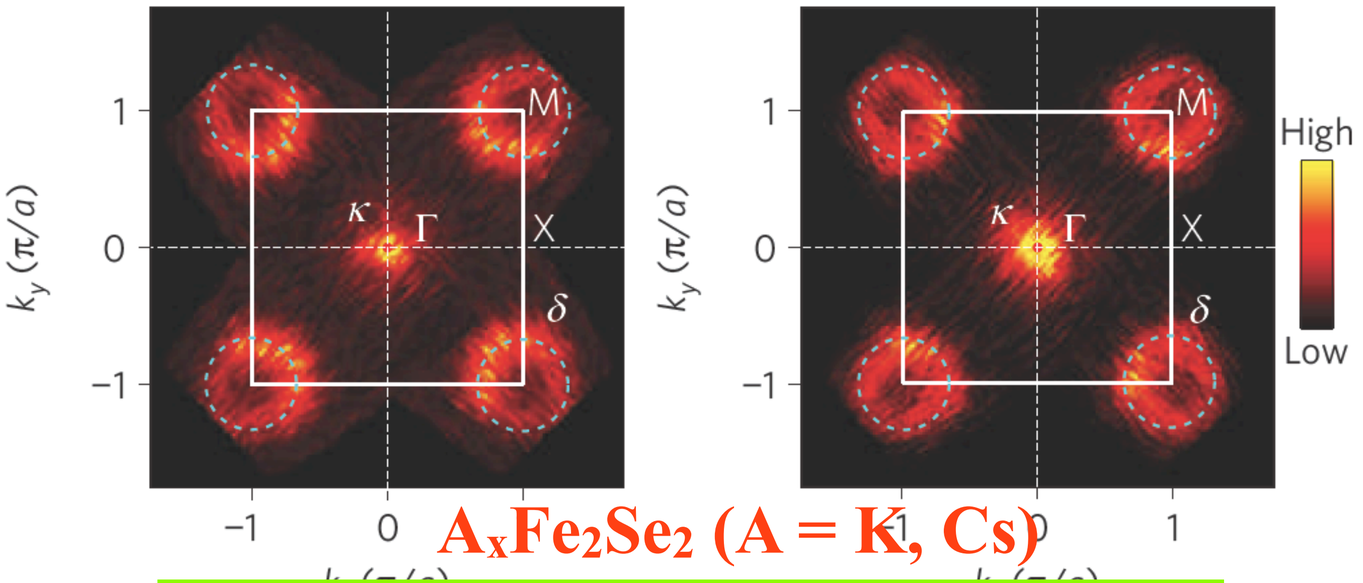
weak coupling *vs* strong coupling

α-Fe(Te, Se)



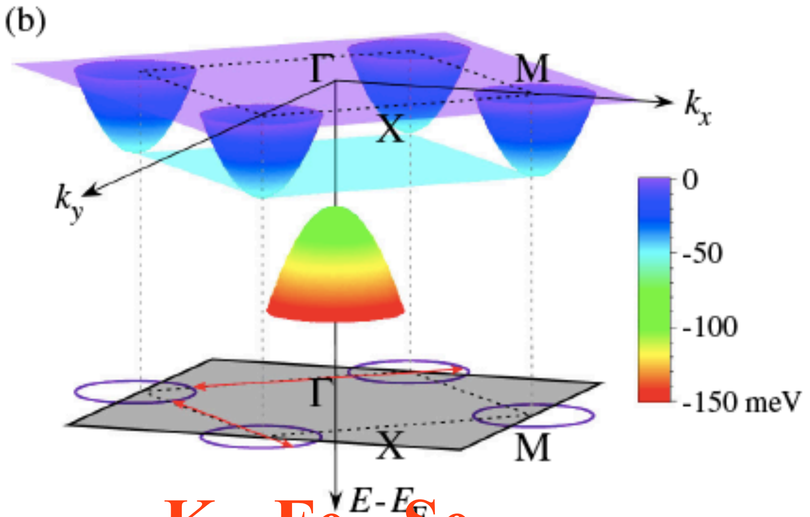
W. Bao, *et al. Phys. Rev. Lett.* **102,** 247001 (2009)





$A_xFe_2Se_2$ (A = K, Cs)

Y. Zhang, *et al. Nature Materials* **10,** 273 (2011)

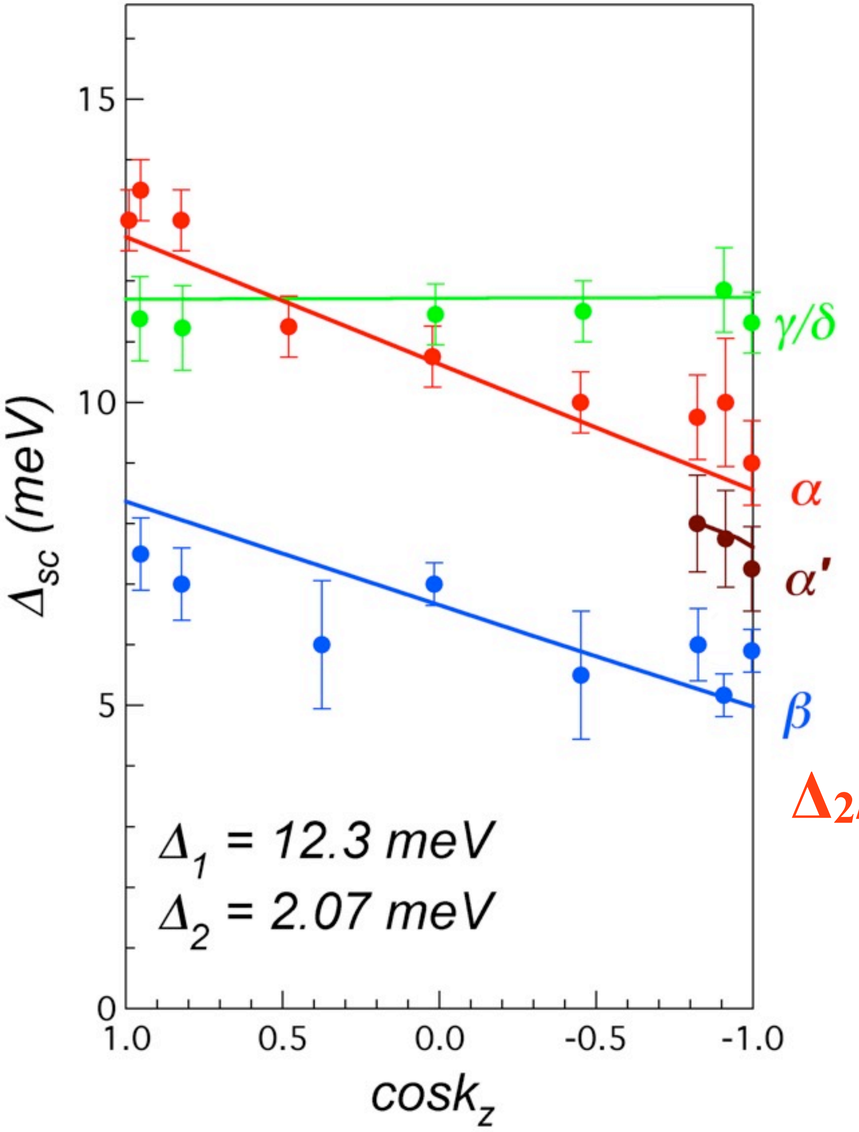


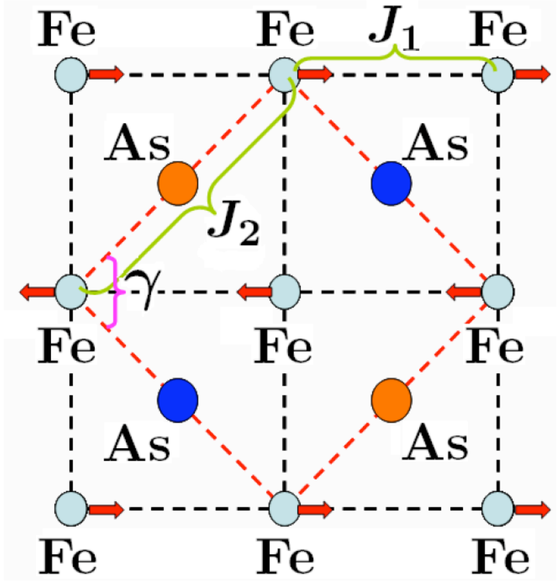
$K_{0.8}Fe_{1.7}Se_2$

T. Qian, *et al. Phys. Rev. Lett.* **106,** 187001 (2011)

$Ba_{0.6}K_{0.4}Fe_2As_2$ weak coupling *vs* strong coupling

$$\Delta(k_x, k_y, k_z) = \Delta_1 \cos k_x \cos k_y + \frac{\Delta_2}{2}(\cos k_x + \cos k_y)\cos k_z + \Delta_3(\cos k_x \cos k_y)\cos k_z$$

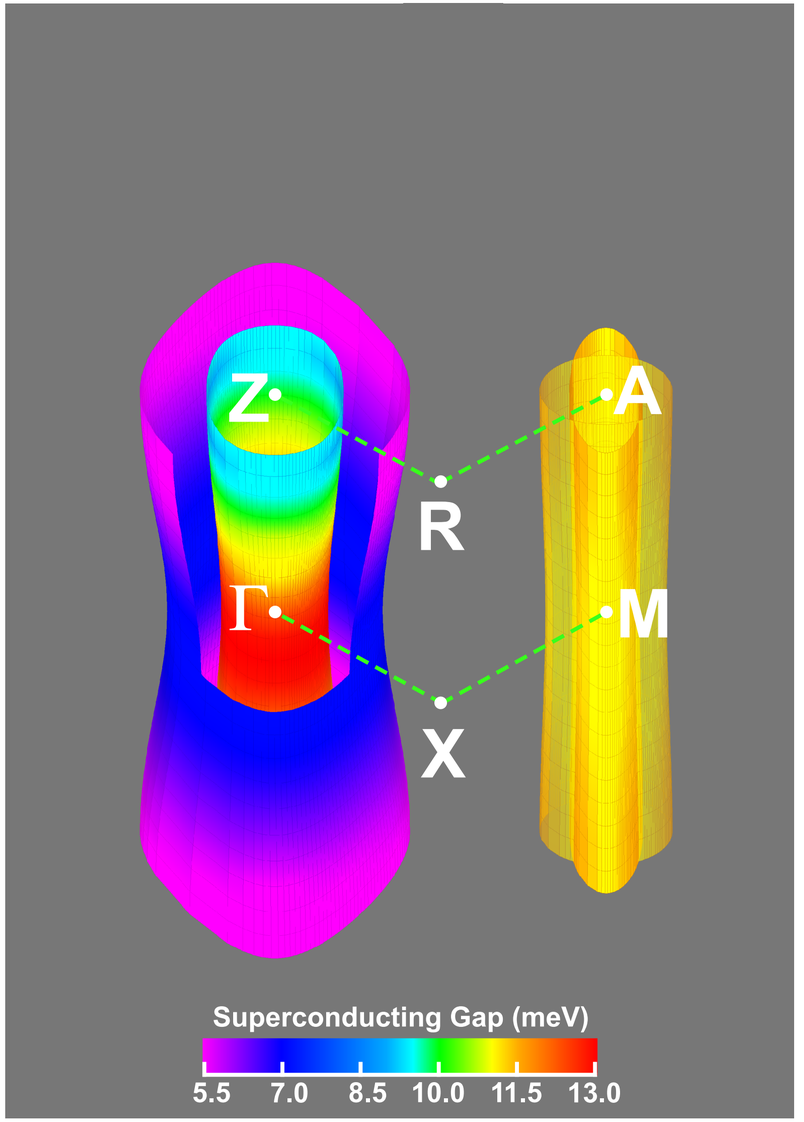




$\Delta_2/\Delta_1 \approx J_c/J_{ab} \approx 0.17$

$J_c = 5$ meV

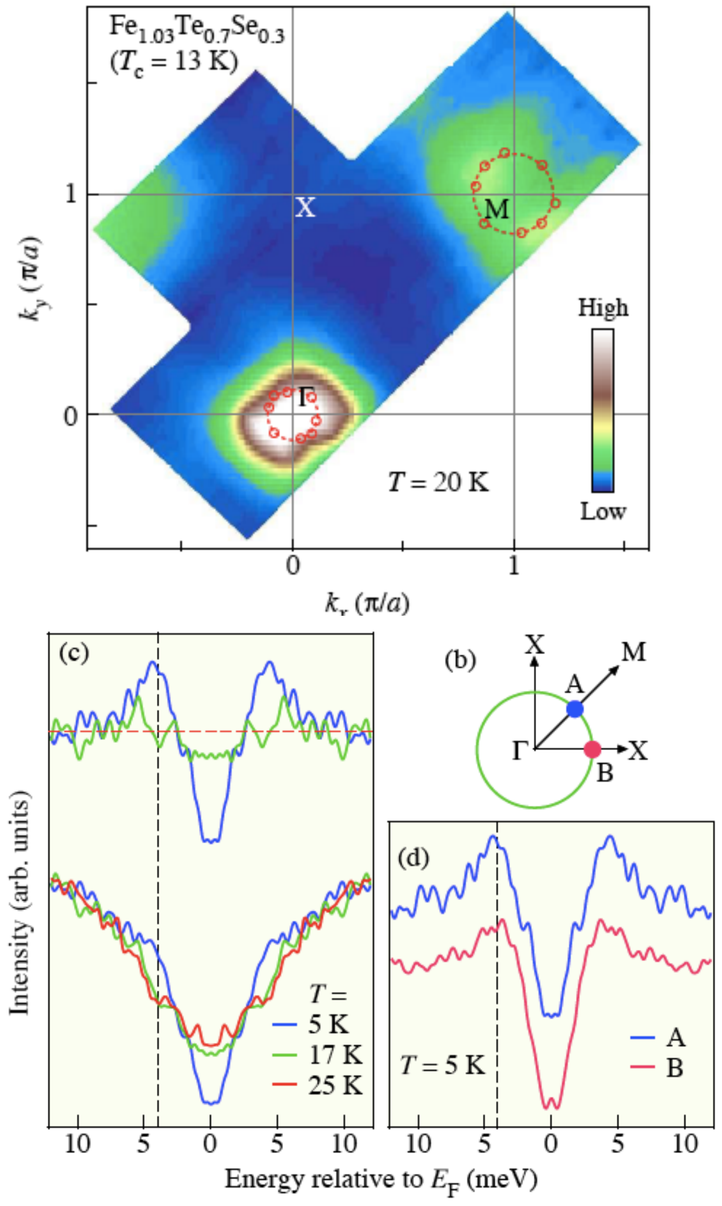
$J_{ab} = 30$ meV



Y.-M. Xu, *et al. Nature Physics* **7**, 198-202 (2011)

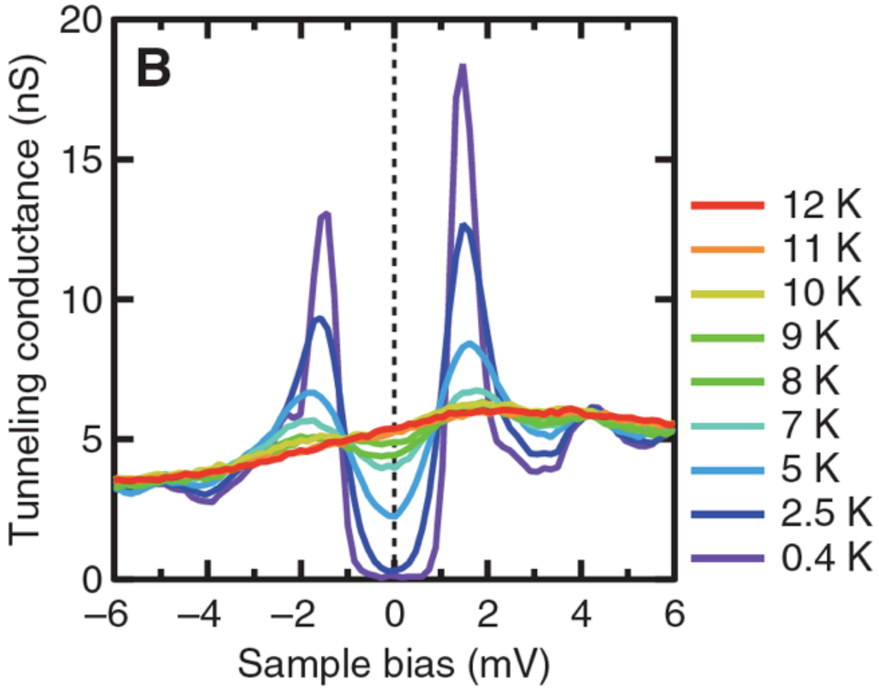
α-Fe(Te, Se)

ARPES



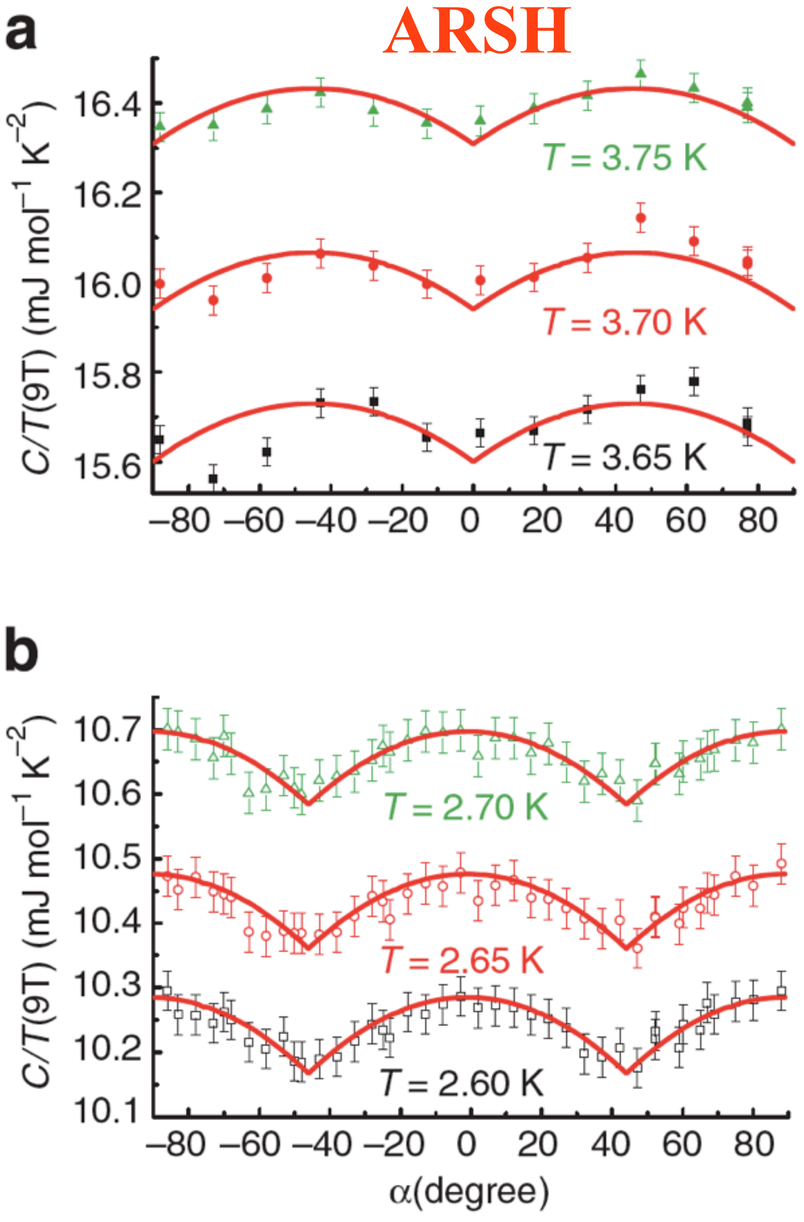
K. Nakayama, *et al. Phys. Rev. Lett.* **105,** 197001 (2010)

STM



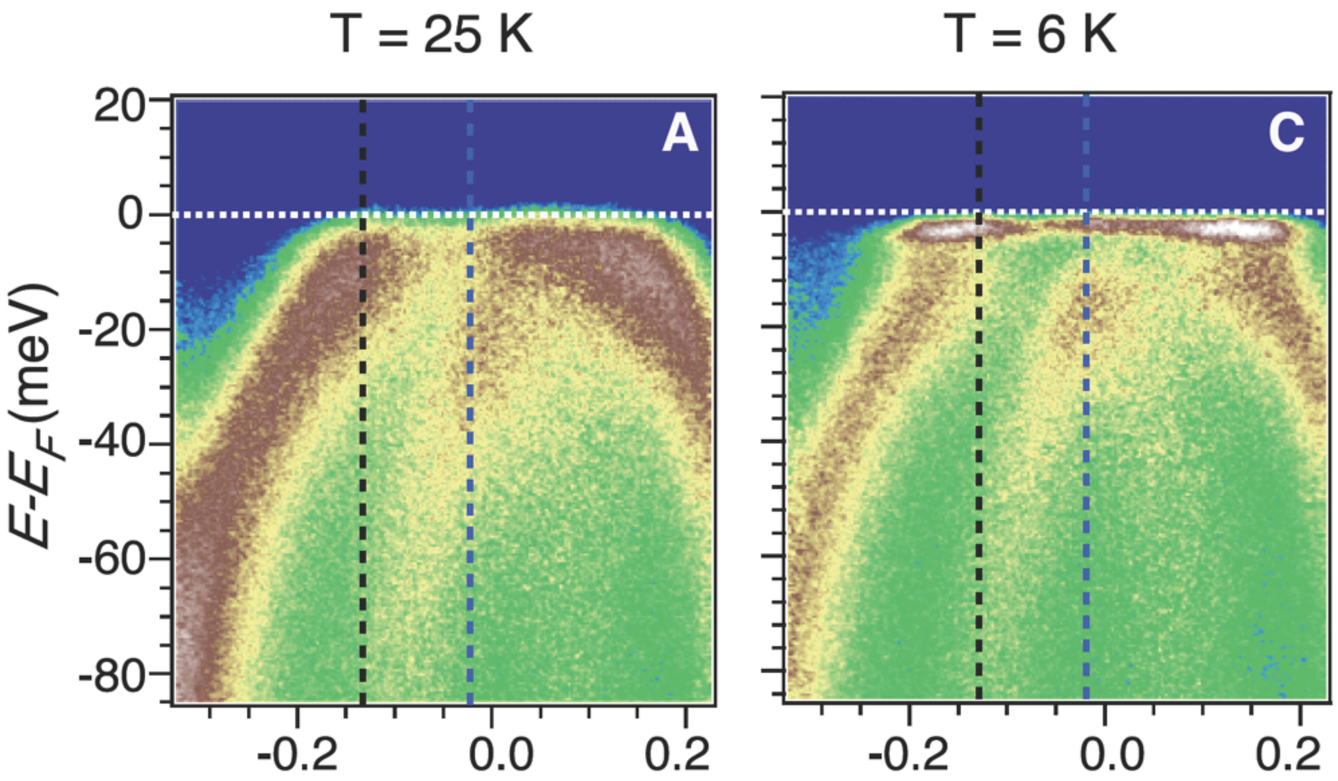
T. Hanaguri, *et al. Science.* **328,** 474 (2010)

ARSH



B. Zeng, *et al. Nat. Commun* **1,** 112 (2010)

band structure

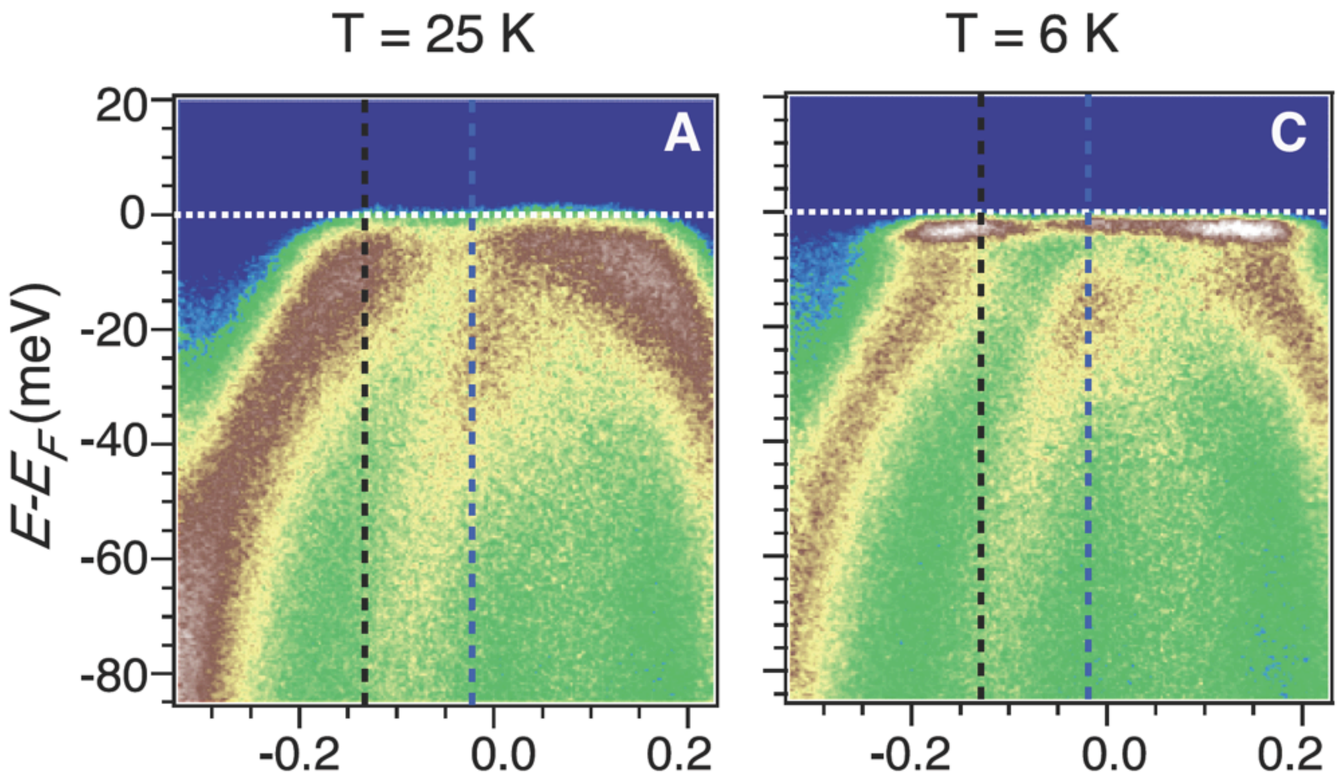


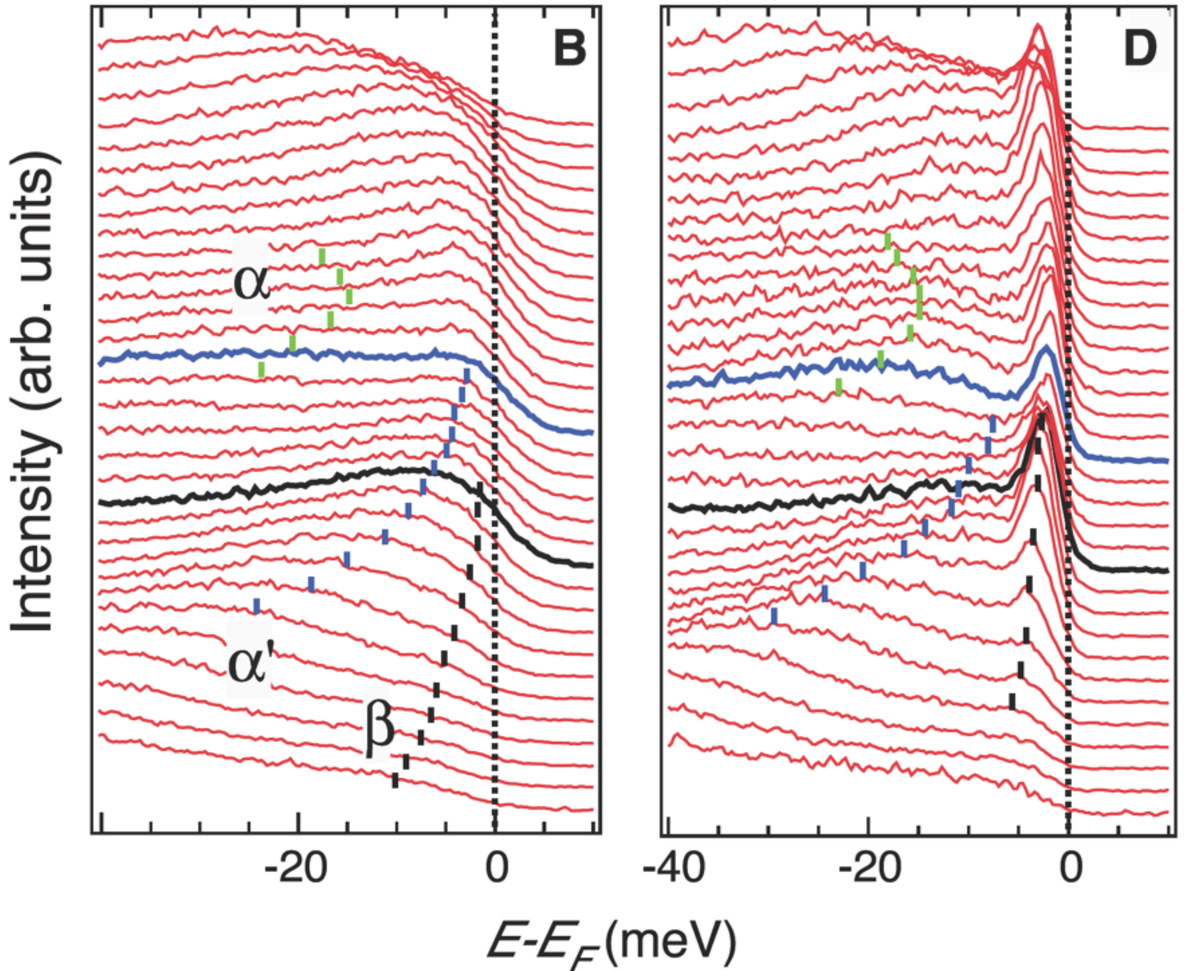
$FeTe_{0.55}Se_{0.45}$

T_c = 14. 5 K

H. Miao, *et al. arXiv:* 1107.0985 (2011)

band structure





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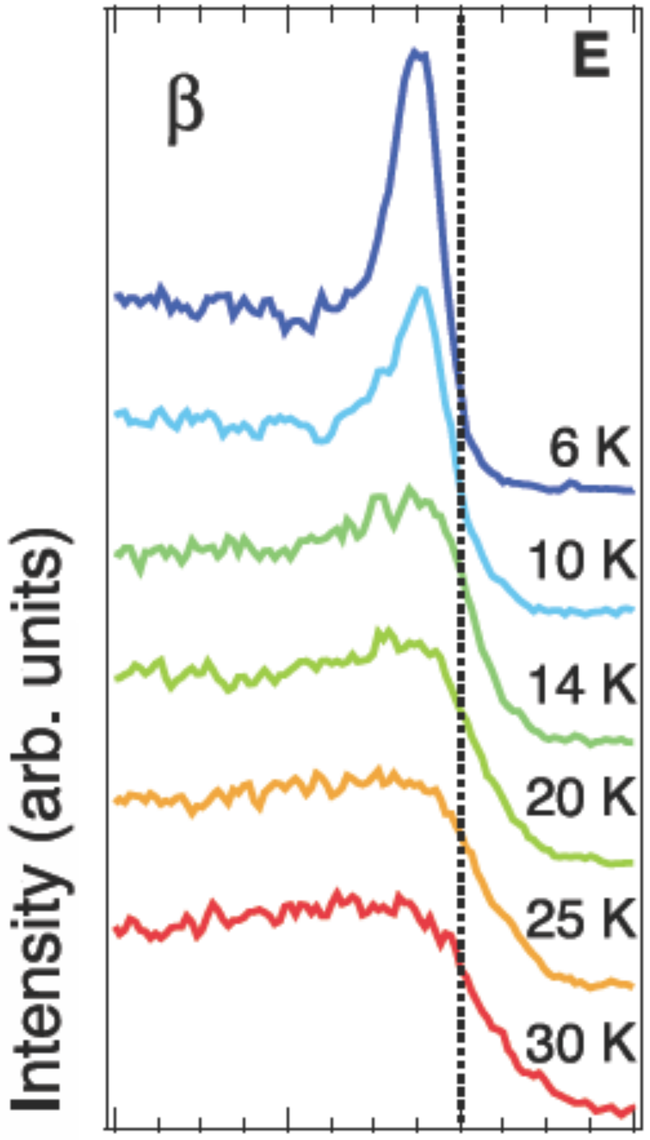
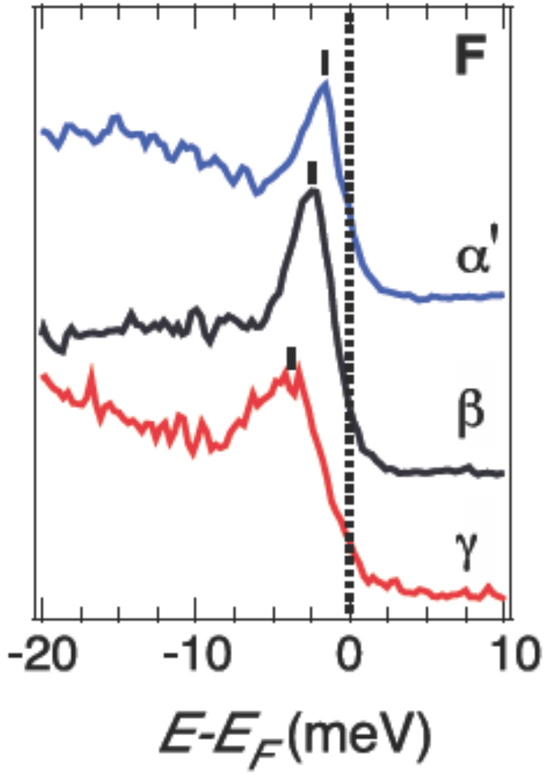
superconducting gap on different FS sheets





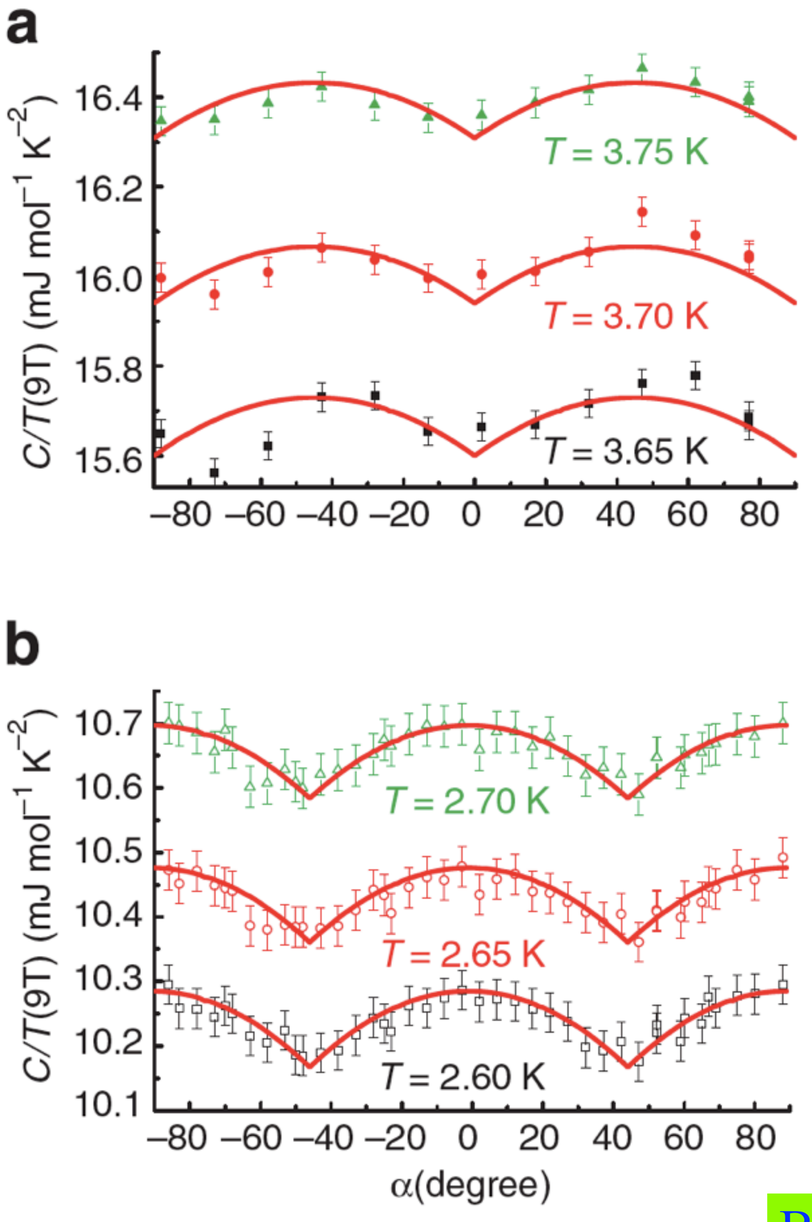
1.7 meV

2.5 meV

4.2 meV

H. Miao, *et al. arXiv:* 1107.0985 (2011)

superconducting gap on different FS sheets



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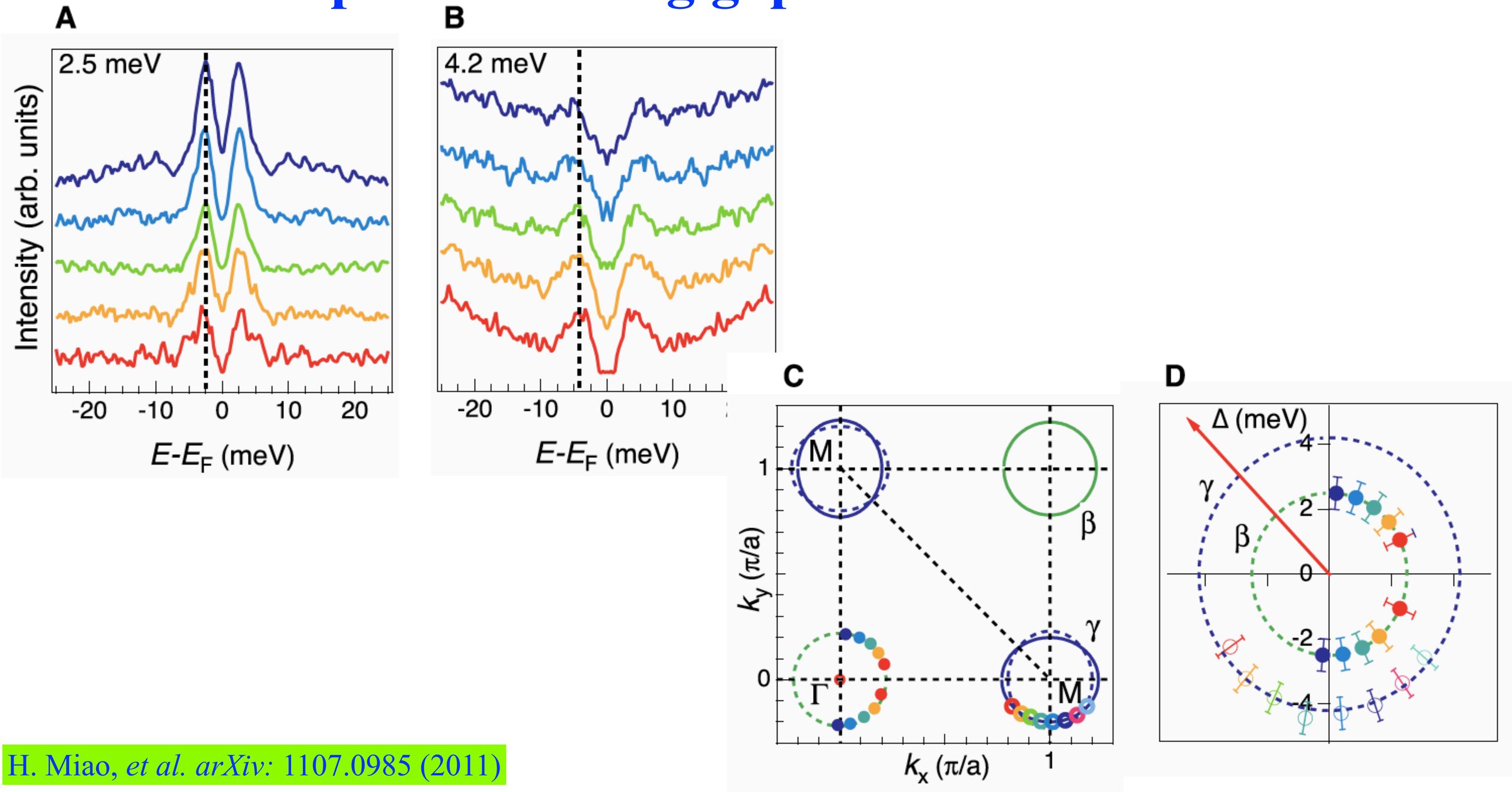
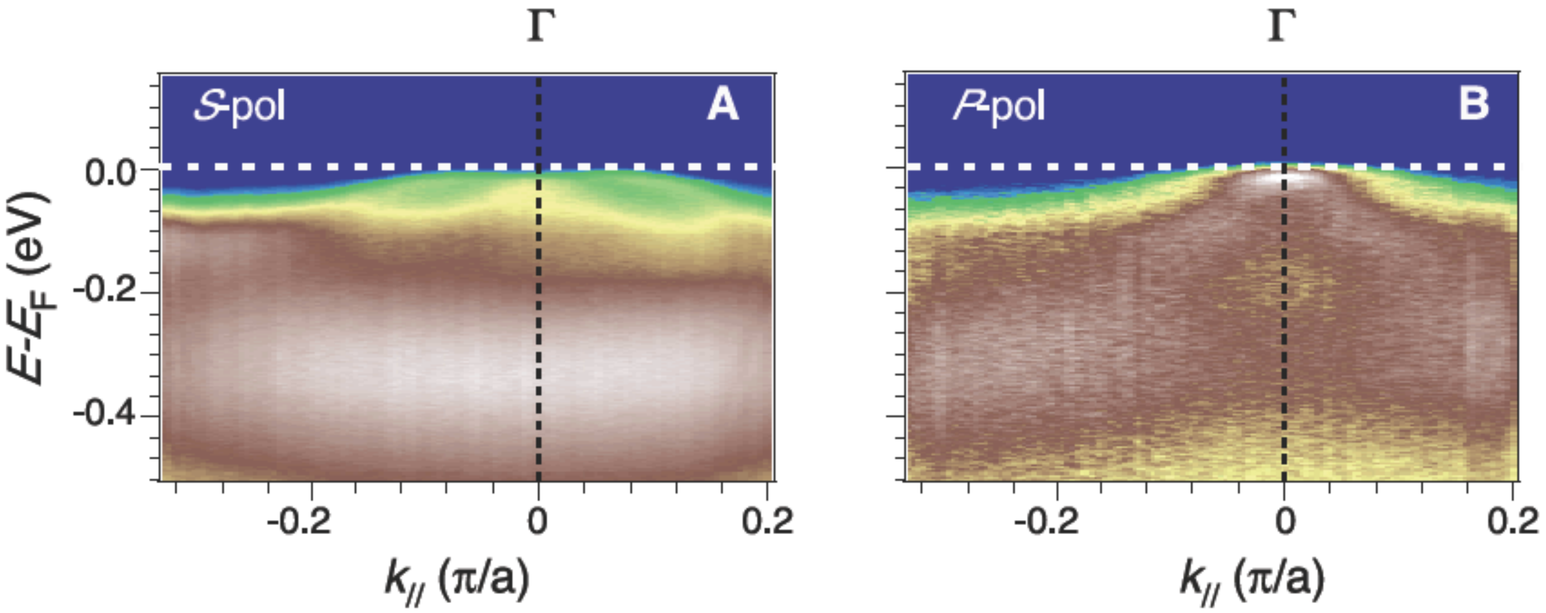
superconducting gap on different FS sheets



H. Miao, *et al. arXiv:* 1107.0985 (2011)

orbital character for each observed band



Γ-M

H. Miao, *et al. arXiv:* 1107.0985 (2011)

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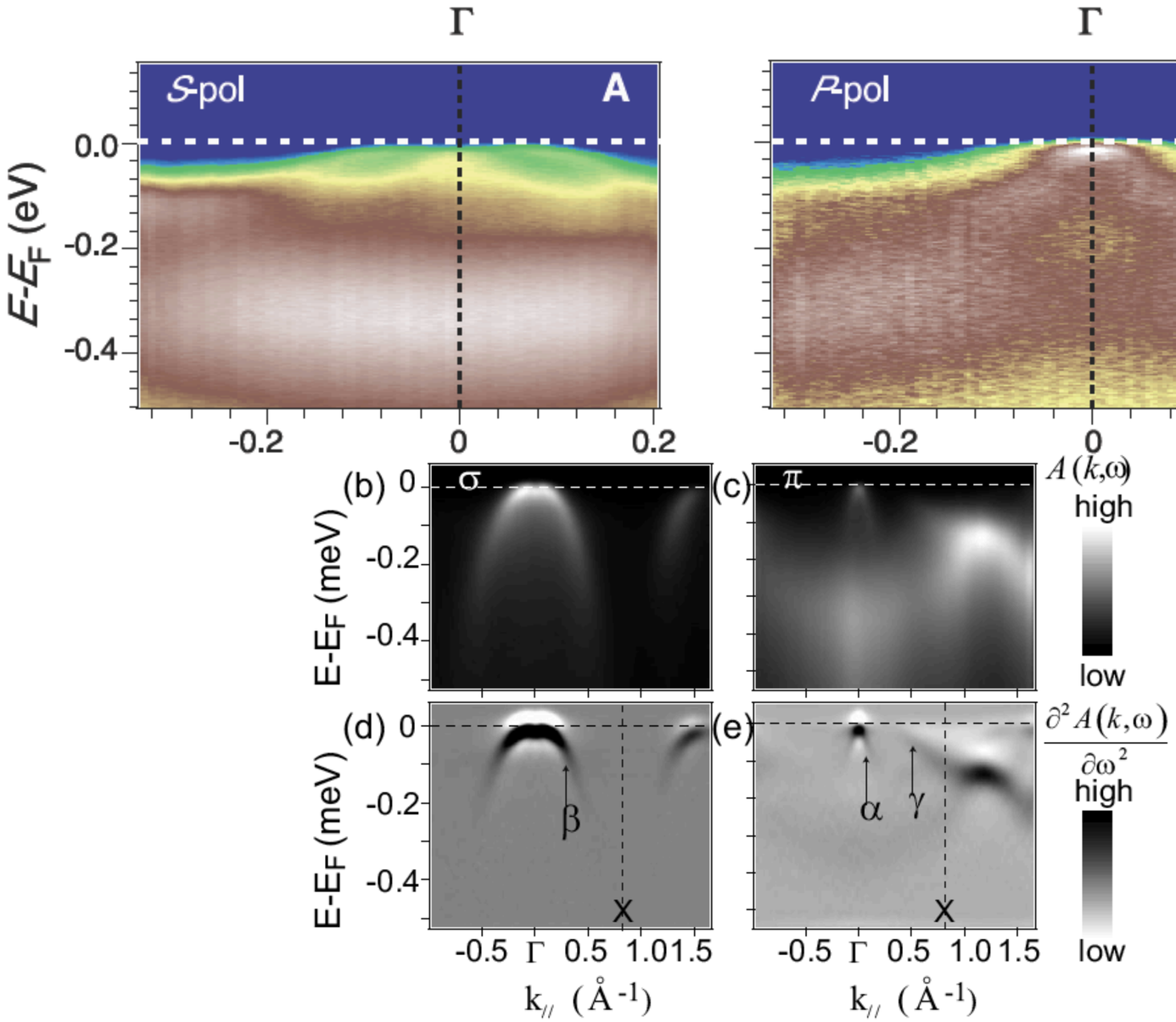


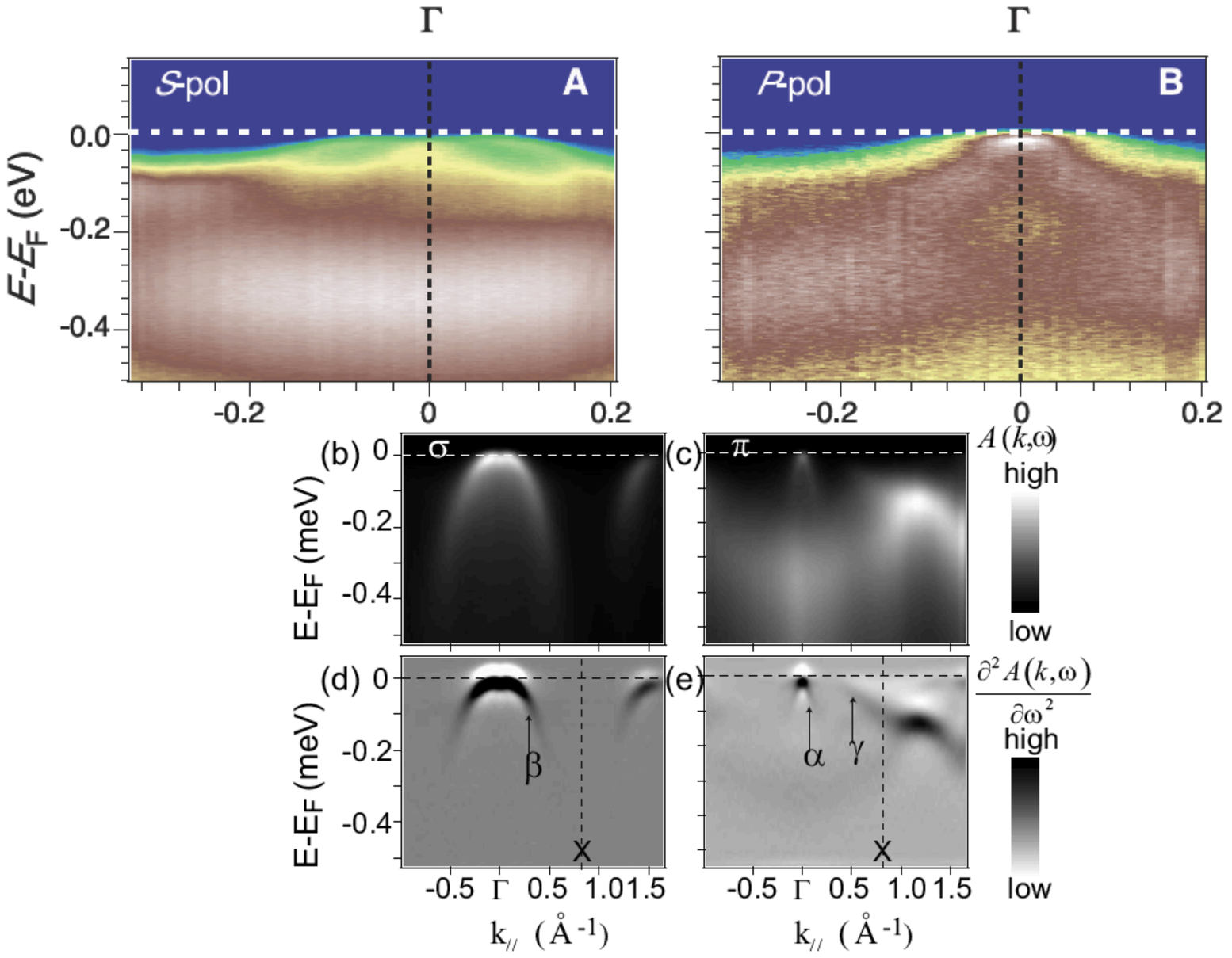
Γ-M

Γ-X

F. Chen, *et al. Phys. Rev. B* **81,** 014526 (2010)

H. Miao, *et al. arXiv:* 1107.0985 (2011)

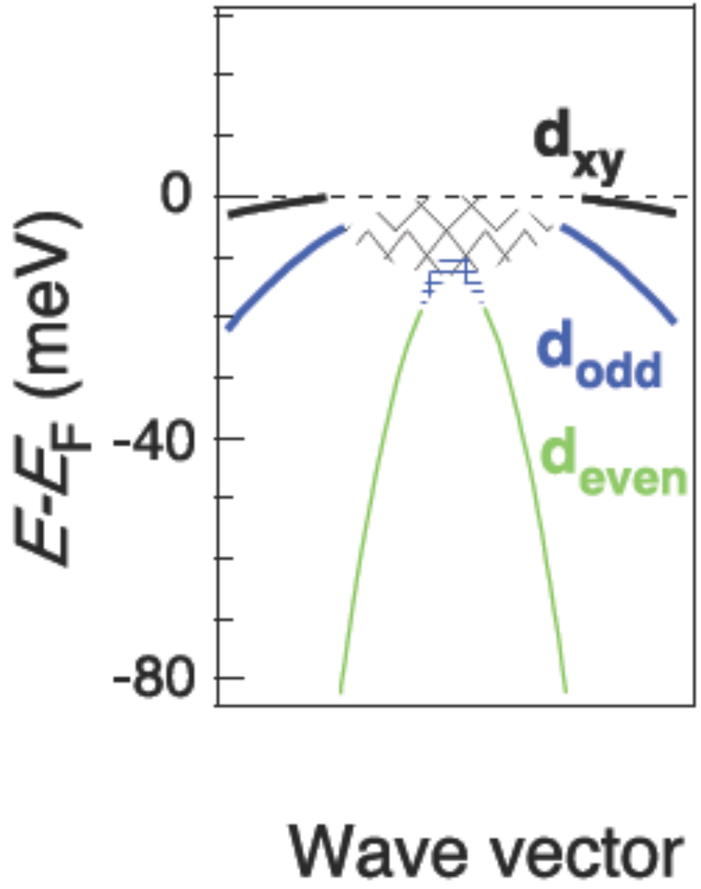
orbital character for each observed band



$d_{even/odd}$: even/odd combination of the d_{xz} and d_{yz} orbitals

Γ-M

Γ-X

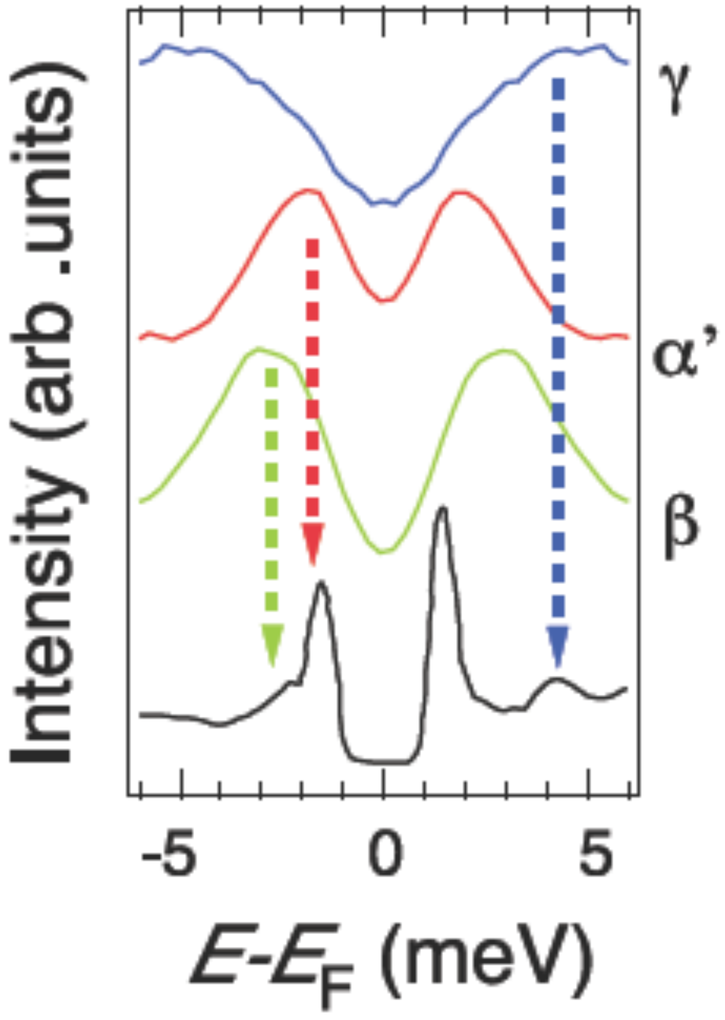


F. Chen, *et al. Phys. Rev. B* **81,** 014526 (2010)

H. Miao, *et al. arXiv:* 1107.0985 (2011)

comparison with other experimental techniques

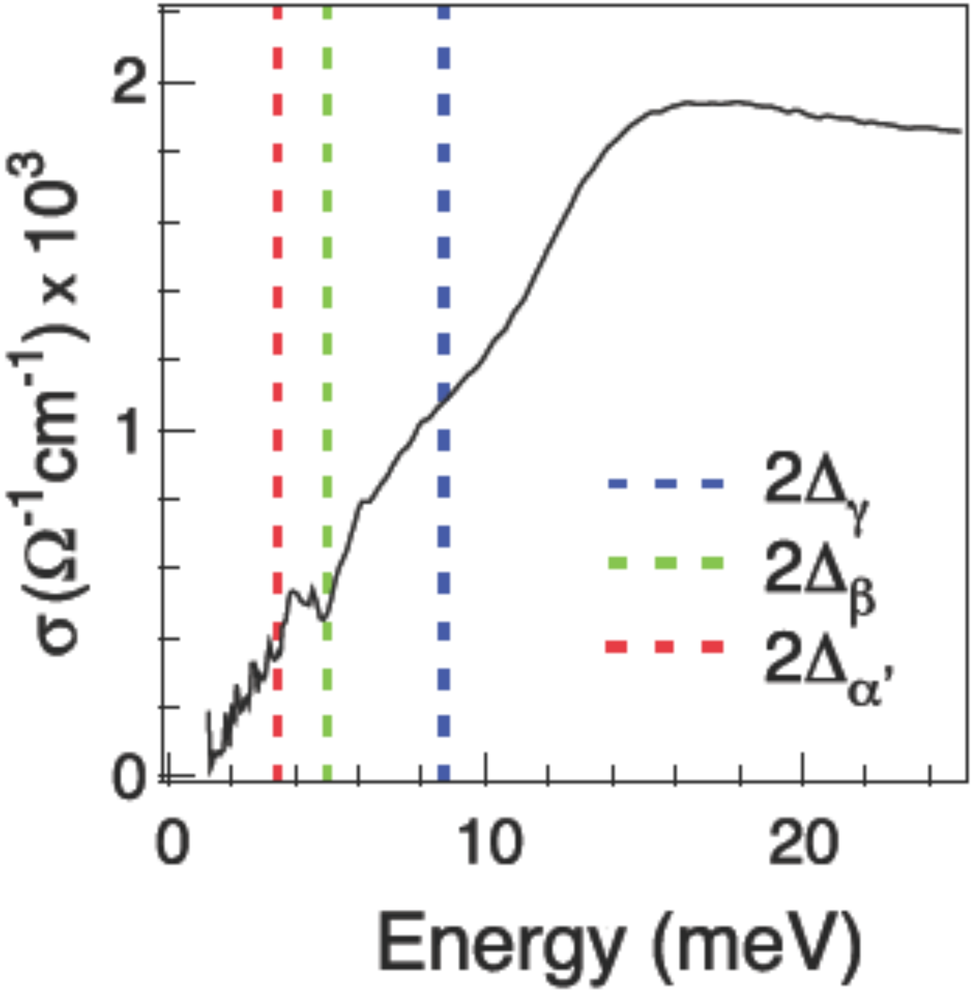
STM



T. Hanaguri, *et al.* *Science.* **328,** 474 (2010)

C. C. Homes, *et al.* *Phys. Rev. B* **81,** 180508 (R) (2010)

optical



H. Miao, *et al. arXiv:* 1107.0985 (2011)

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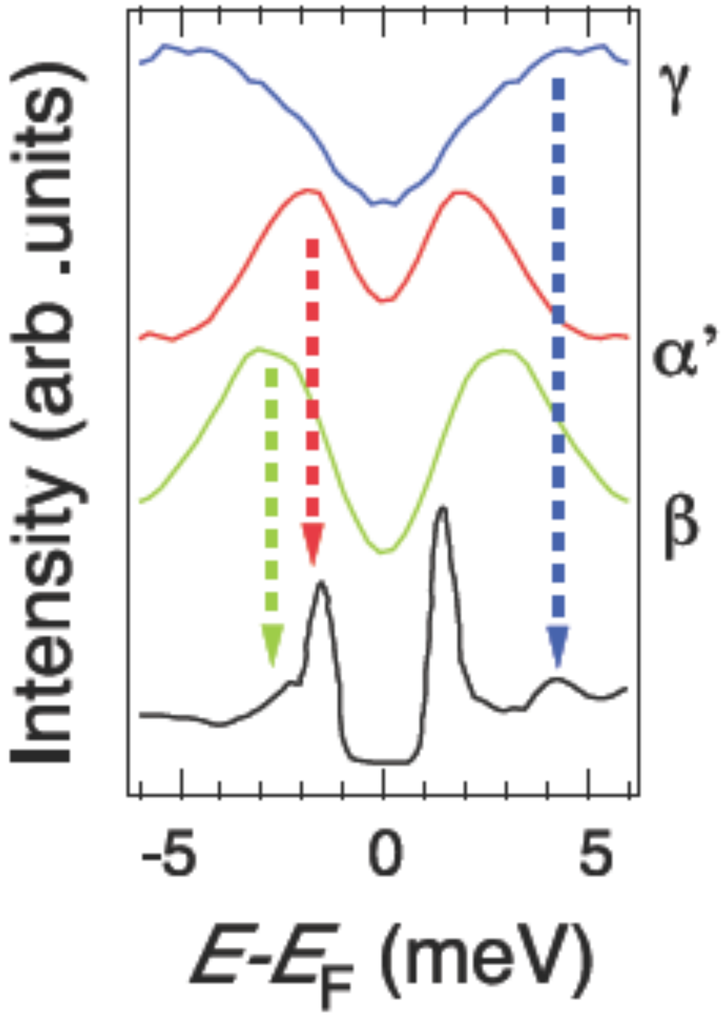
STM



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H. Miao, *et al. arXiv:* 1107.0985 (2011)

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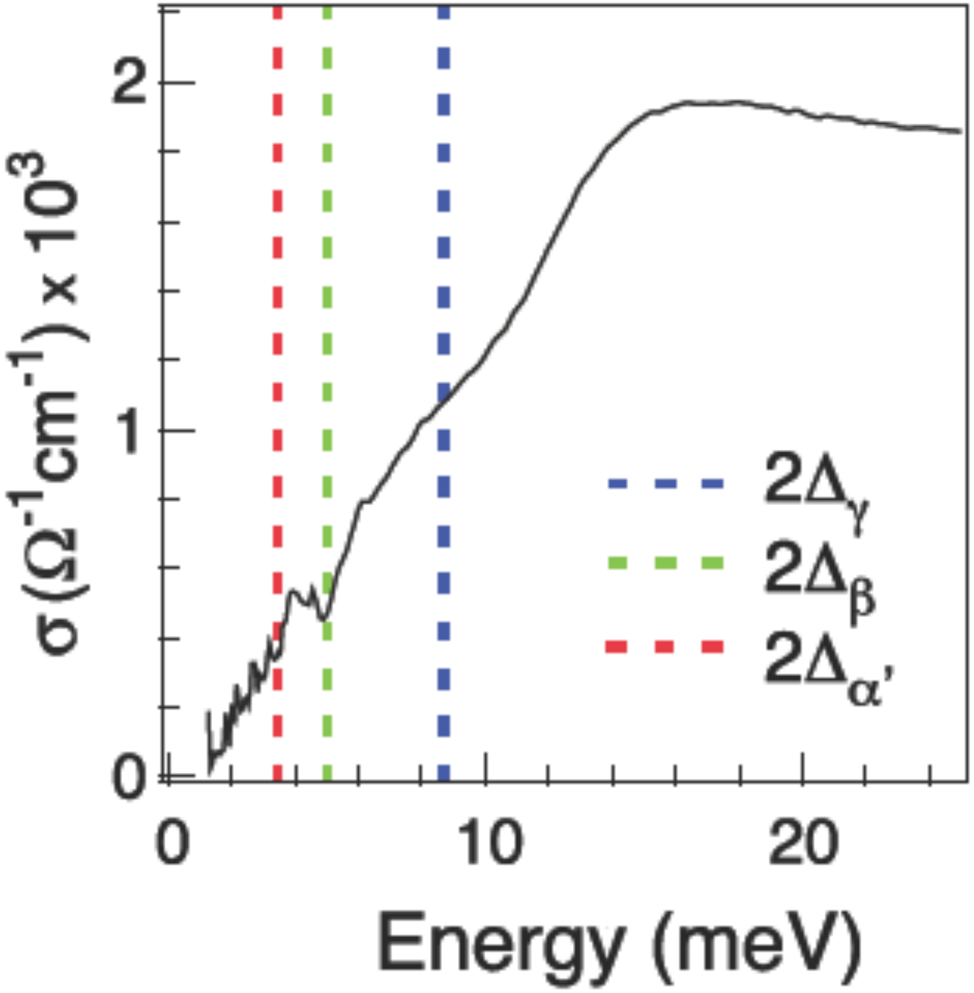
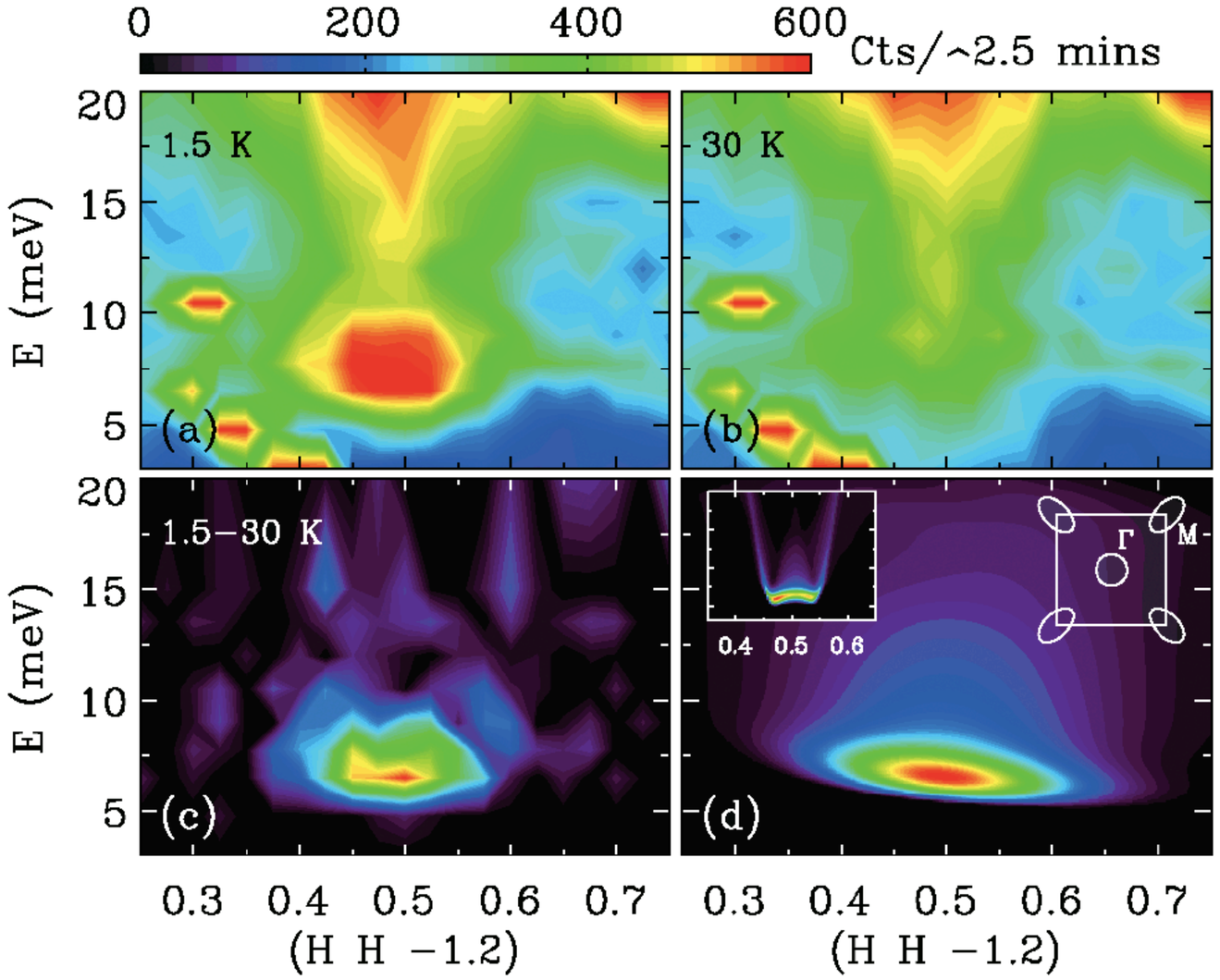
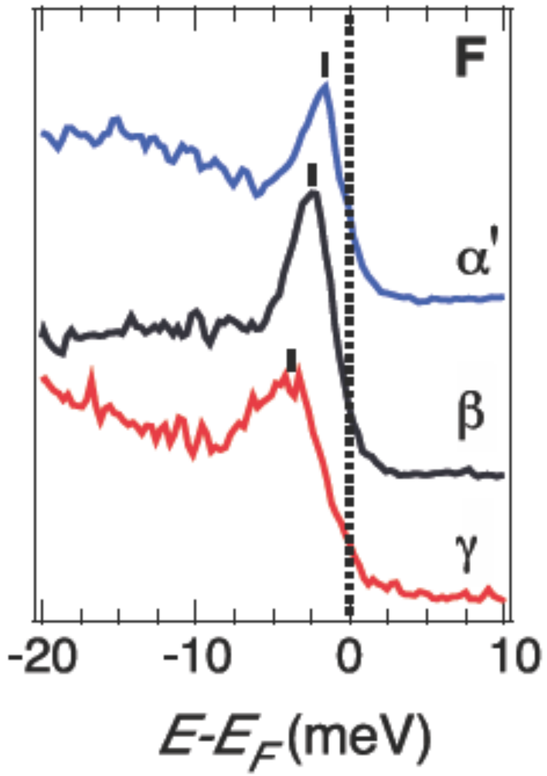


bulk sensitive

comparison with other experimental techniques

neutron scattering





1.7 meV

2.5 meV
+
4.2 meV

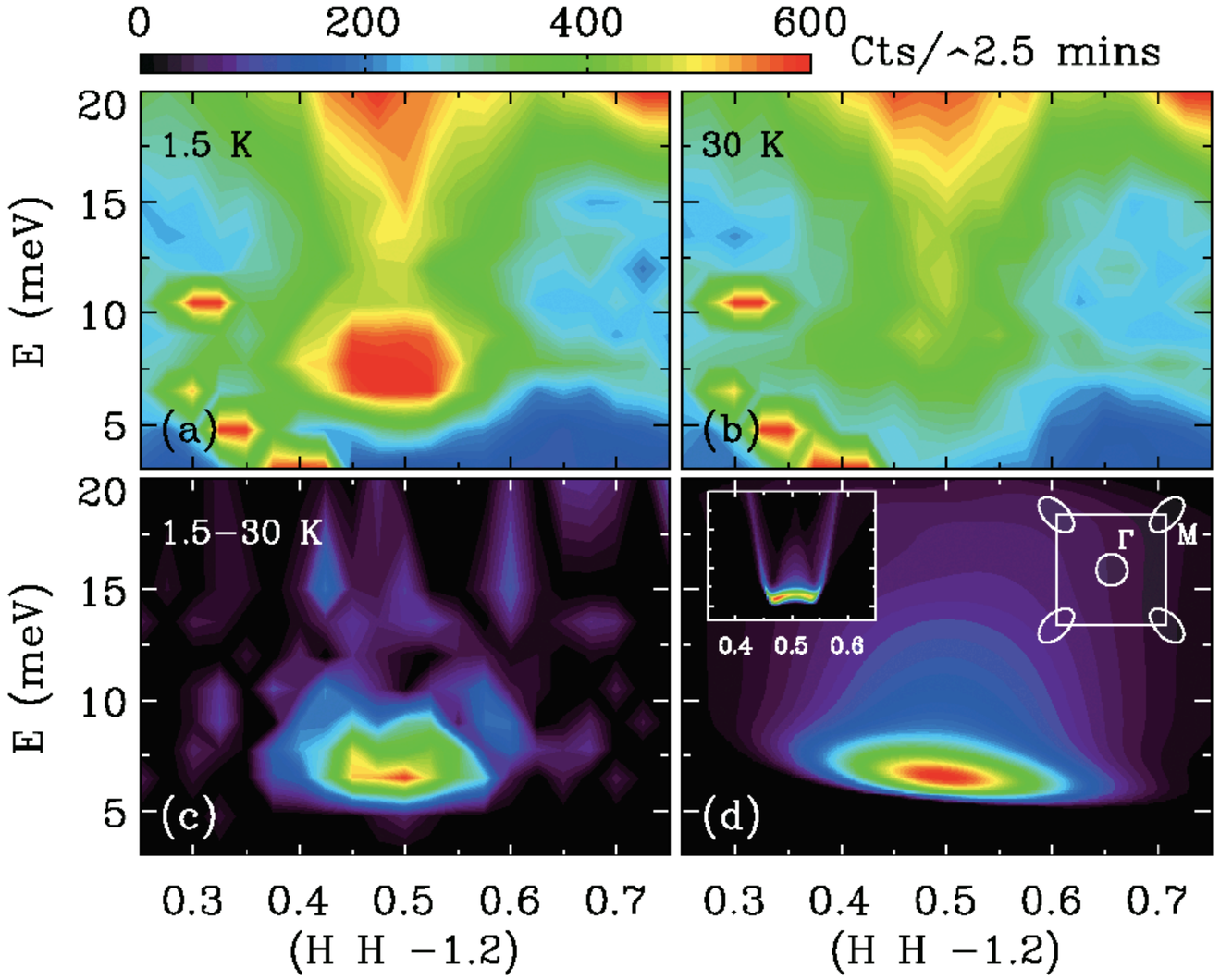
~ 7 meV

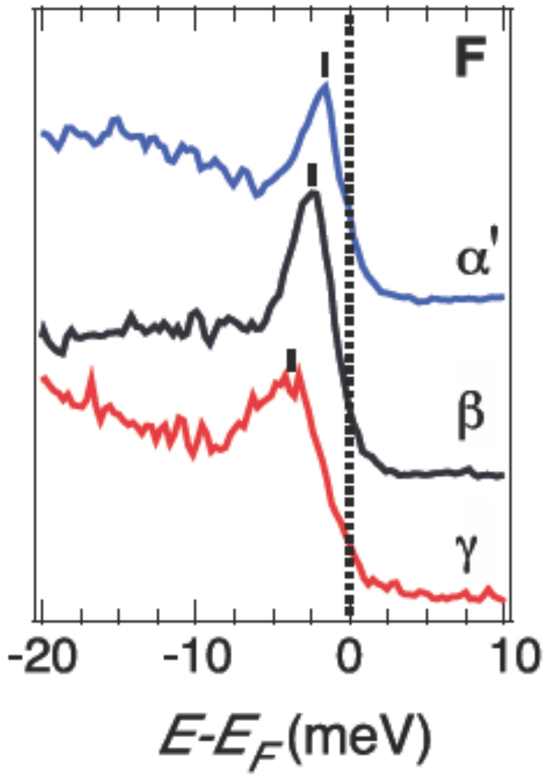
H. Miao, *et al. arXiv:* 1107.0985 (2011)

Y.-M. Qiu, *et al. Phys. Rev. Lett.* **103,** 067008 (2009)

comparison with other experimental techniques

neutron scattering





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2.5 meV
+
4.2 meV

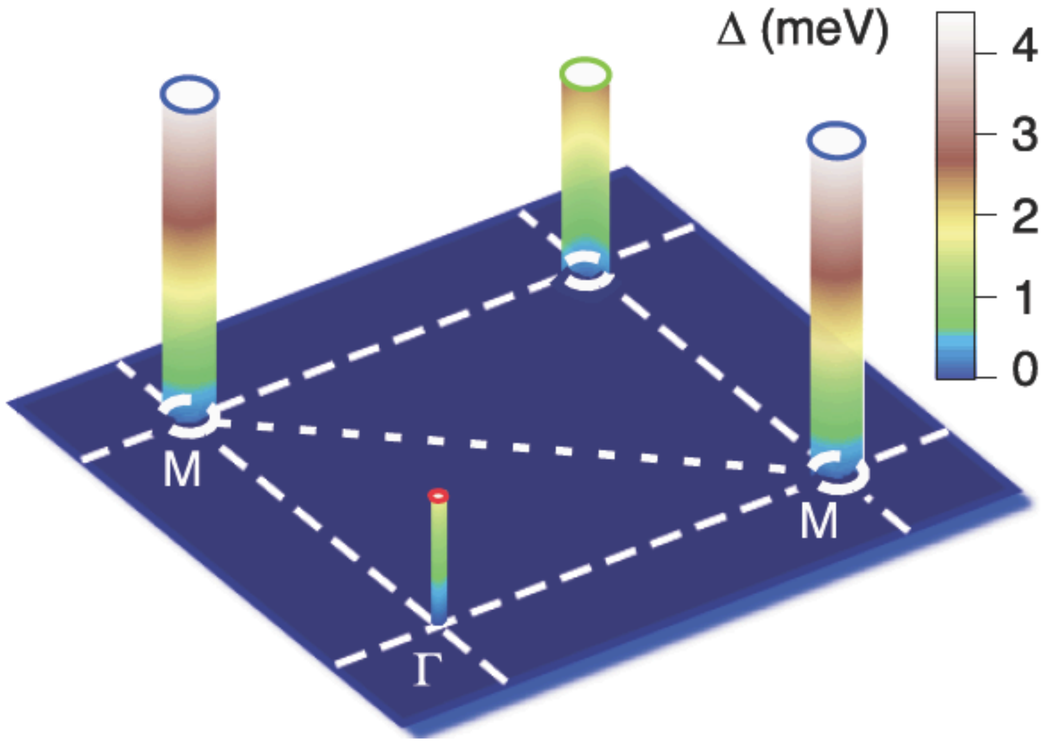
~ 7 meV

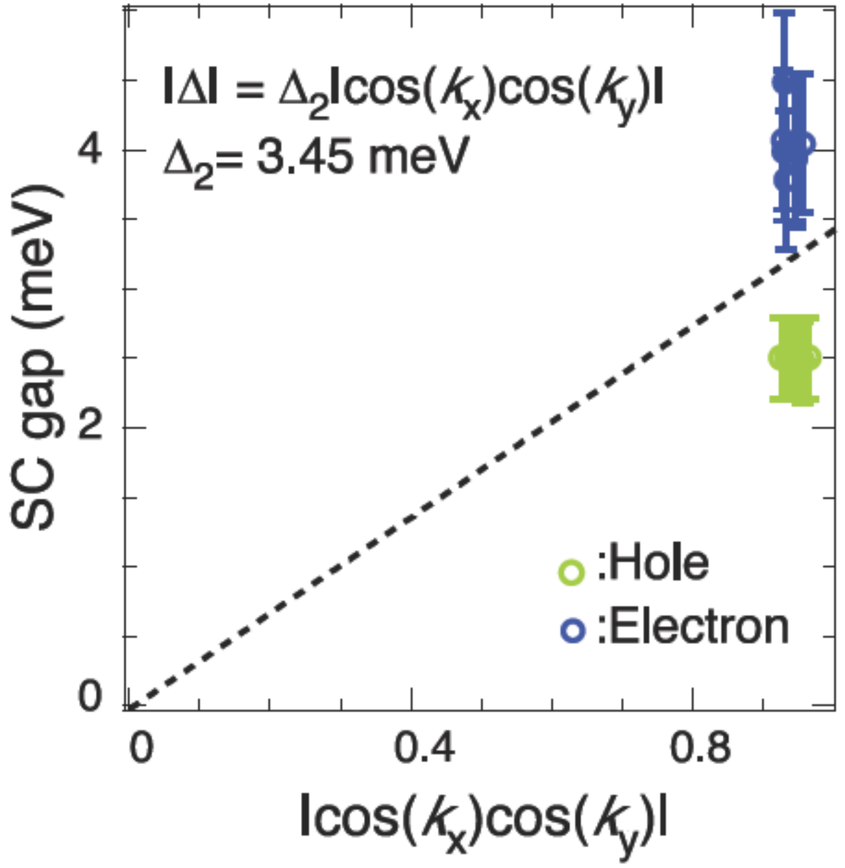
scattering between the β (hole) and γ (electron) FSs

H. Miao, *et al. arXiv:* 1107.0985 (2011)

Y.-M. Qiu, *et al. Phys. Rev. Lett.* **103,** 067008 (2009)

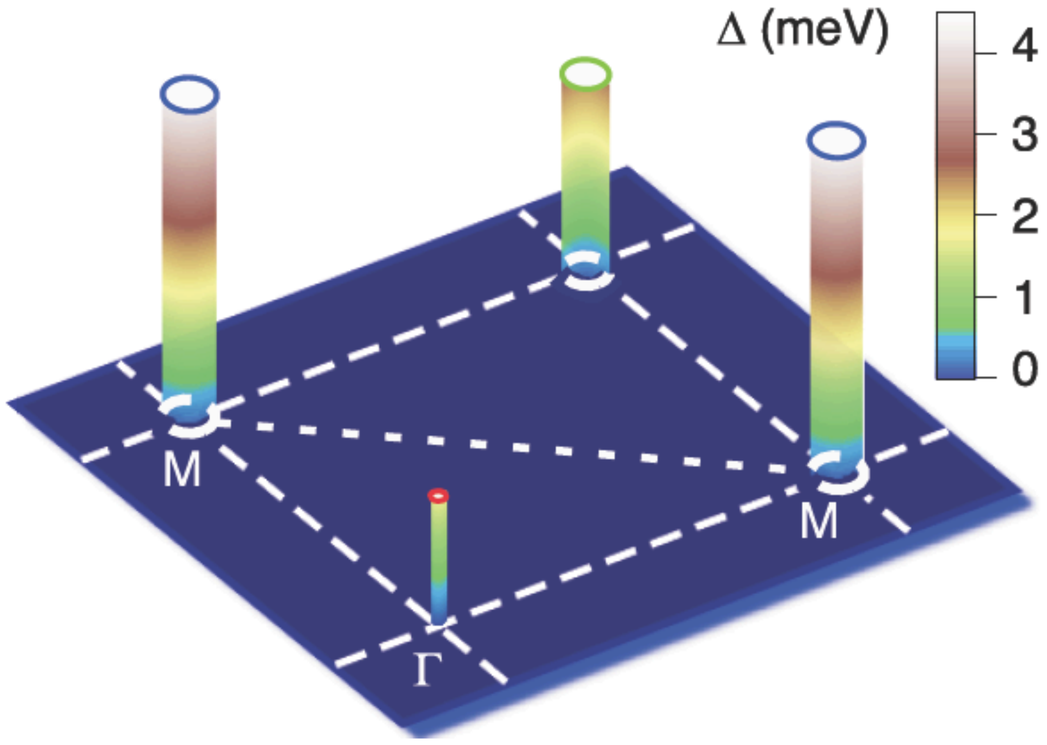
superconducting gap function

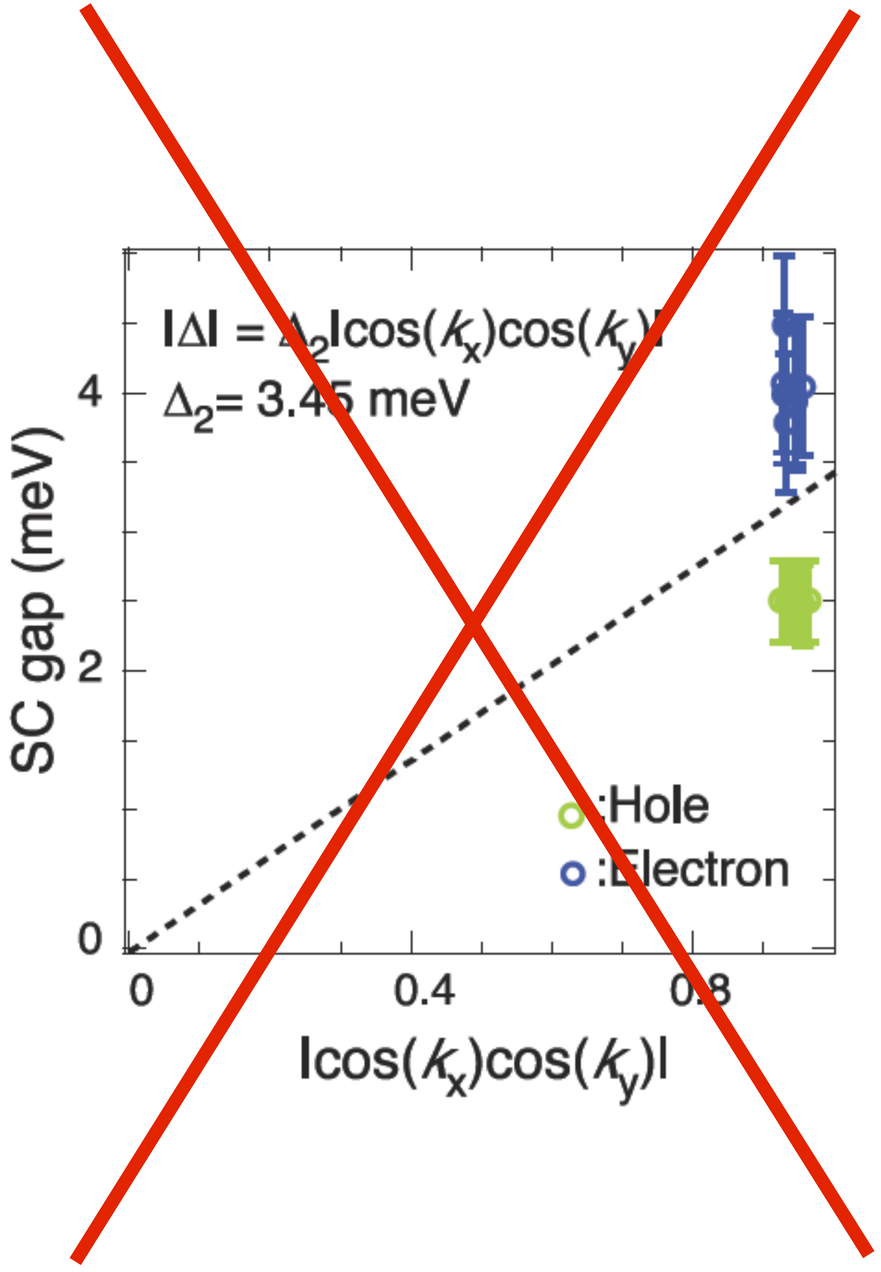




H. Miao, *et al. arXiv:* 1107.0985 (2011)

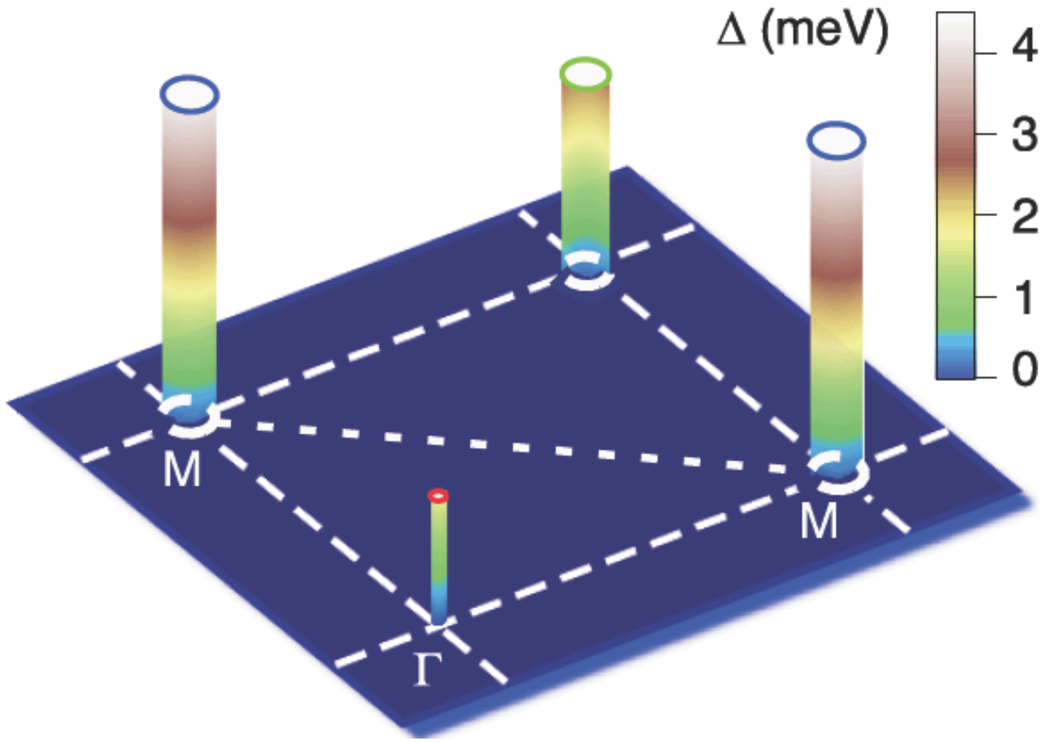
superconducting gap function

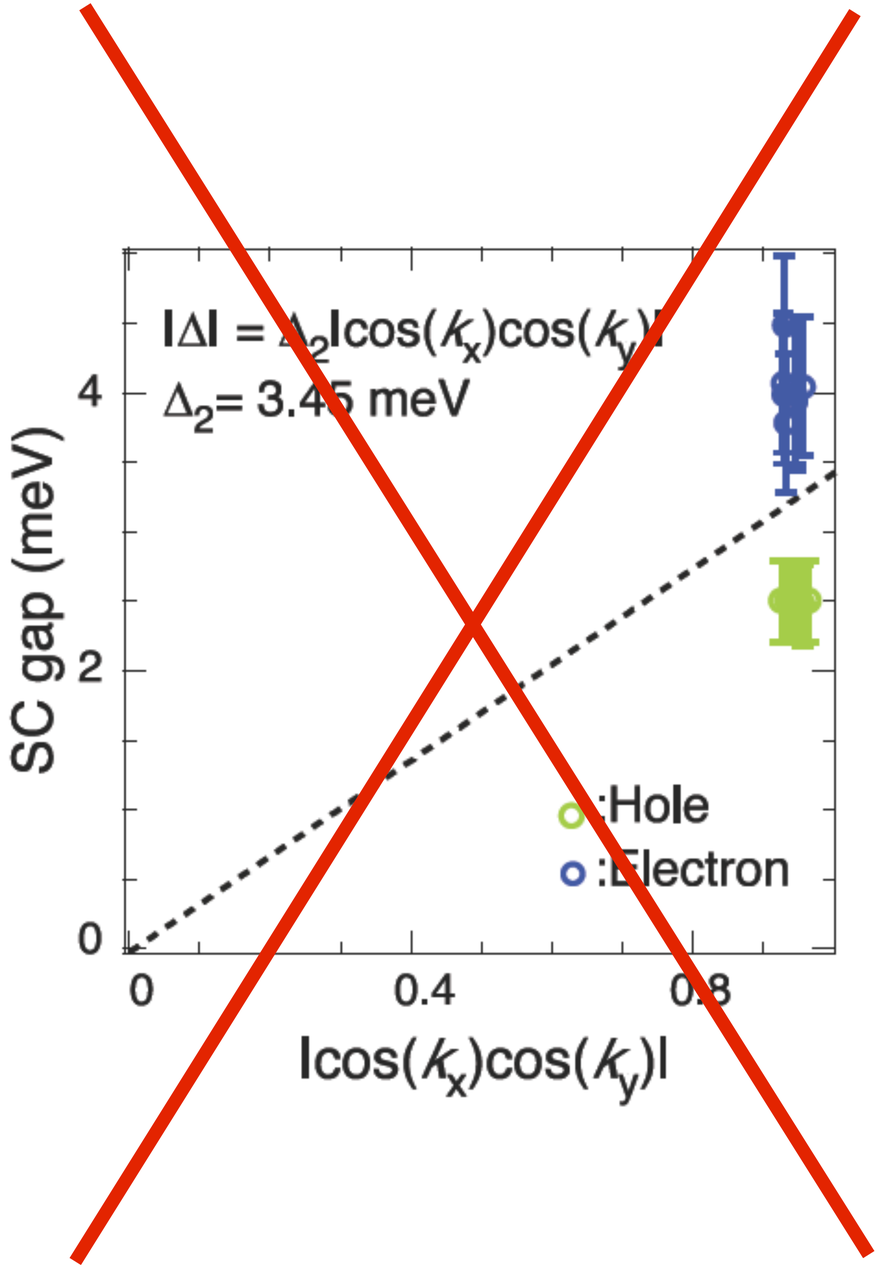




H. Miao, *et al. arXiv:* 1107.0985 (2011)

superconducting gap function



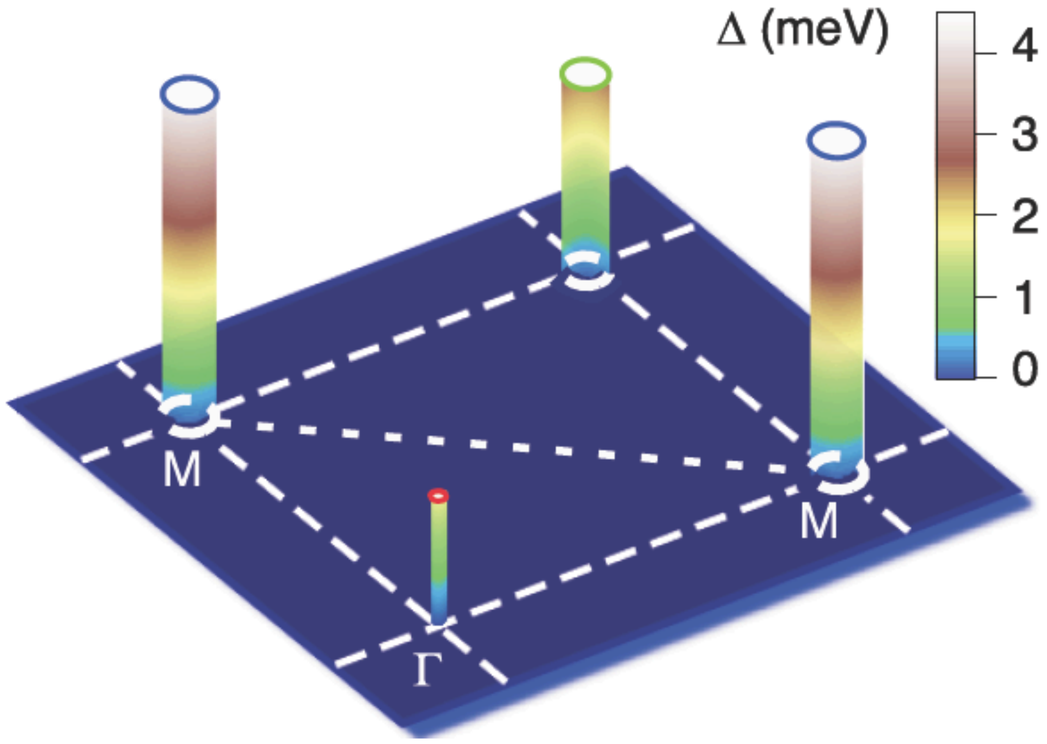


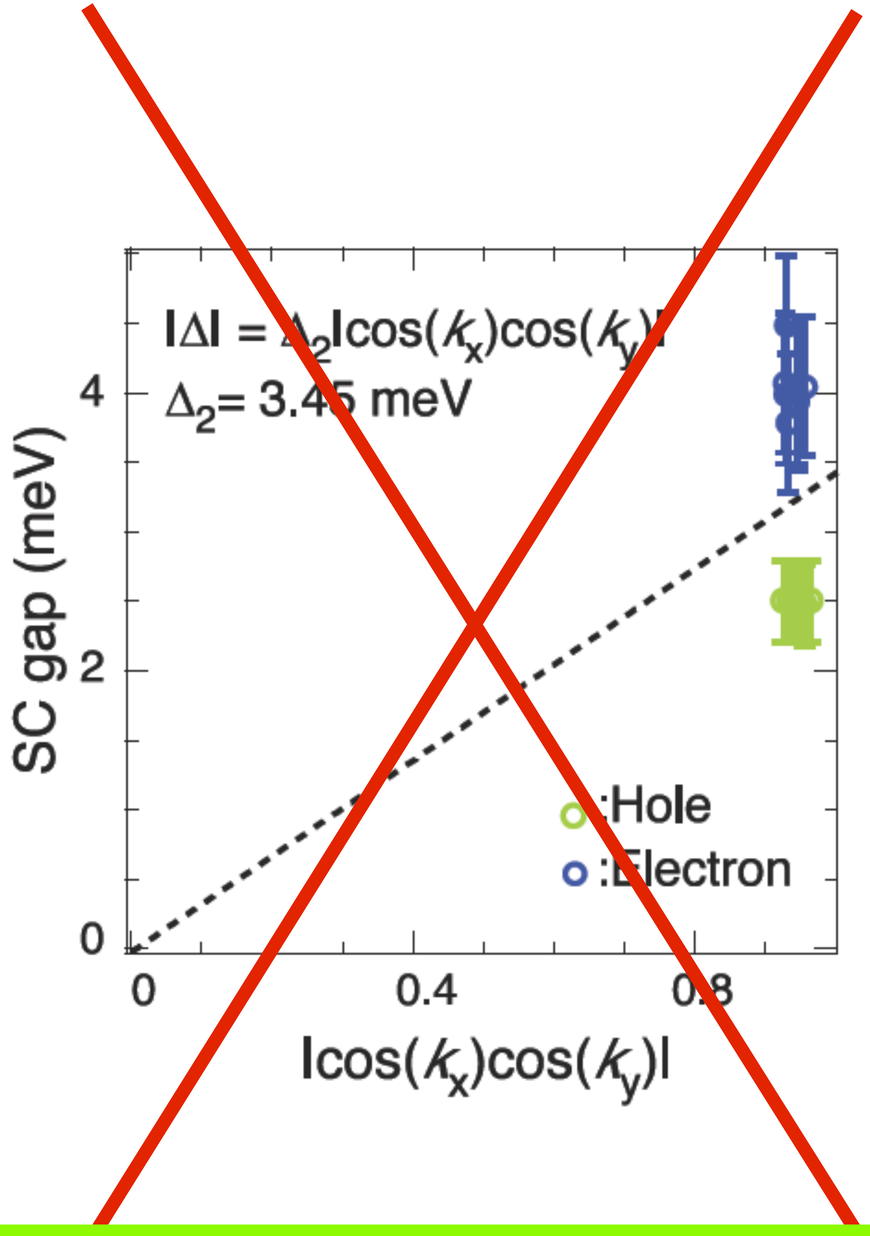
exchange parameters

ferropnictides	ferrochalcogenides
$J_1 > 0$	$J_1 < 0$
J_3 negligible	J_3 non-negligible

H. Miao, *et al. arXiv:* 1107.0985 (2011)

superconducting gap function





exchange parameters

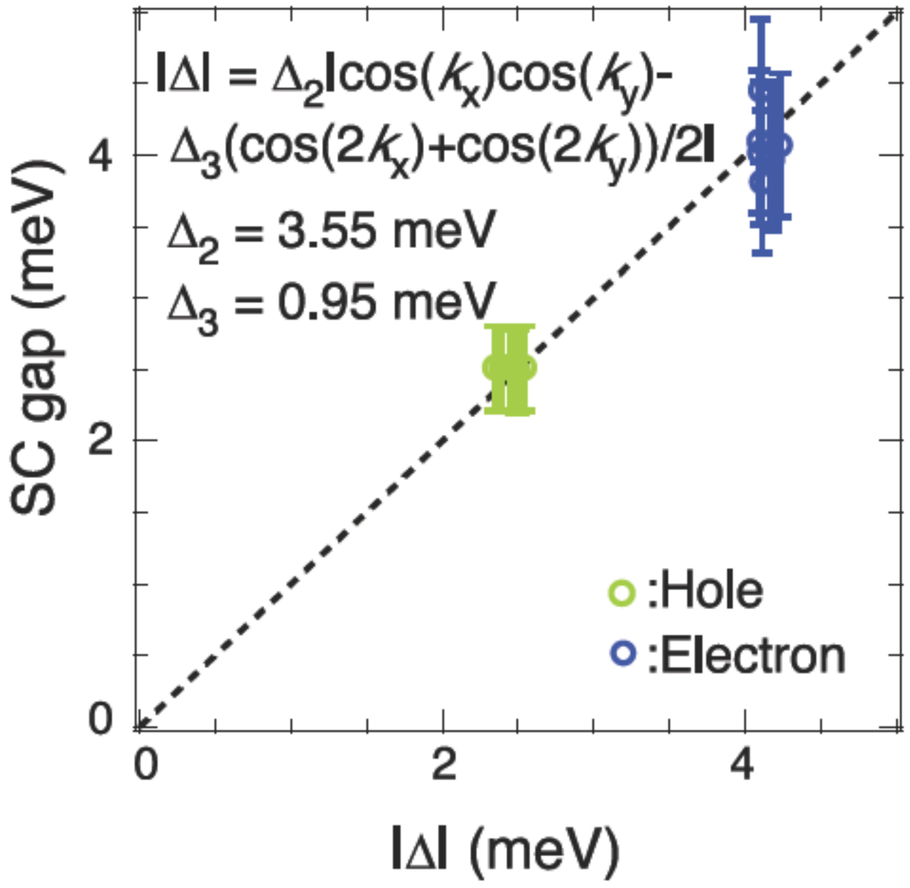
ferropnictides	ferrochalcogenides
$J_1 > 0$	$J_1 < 0$
J_3 negligible	J_3 non-negligible (~ 7 meV)

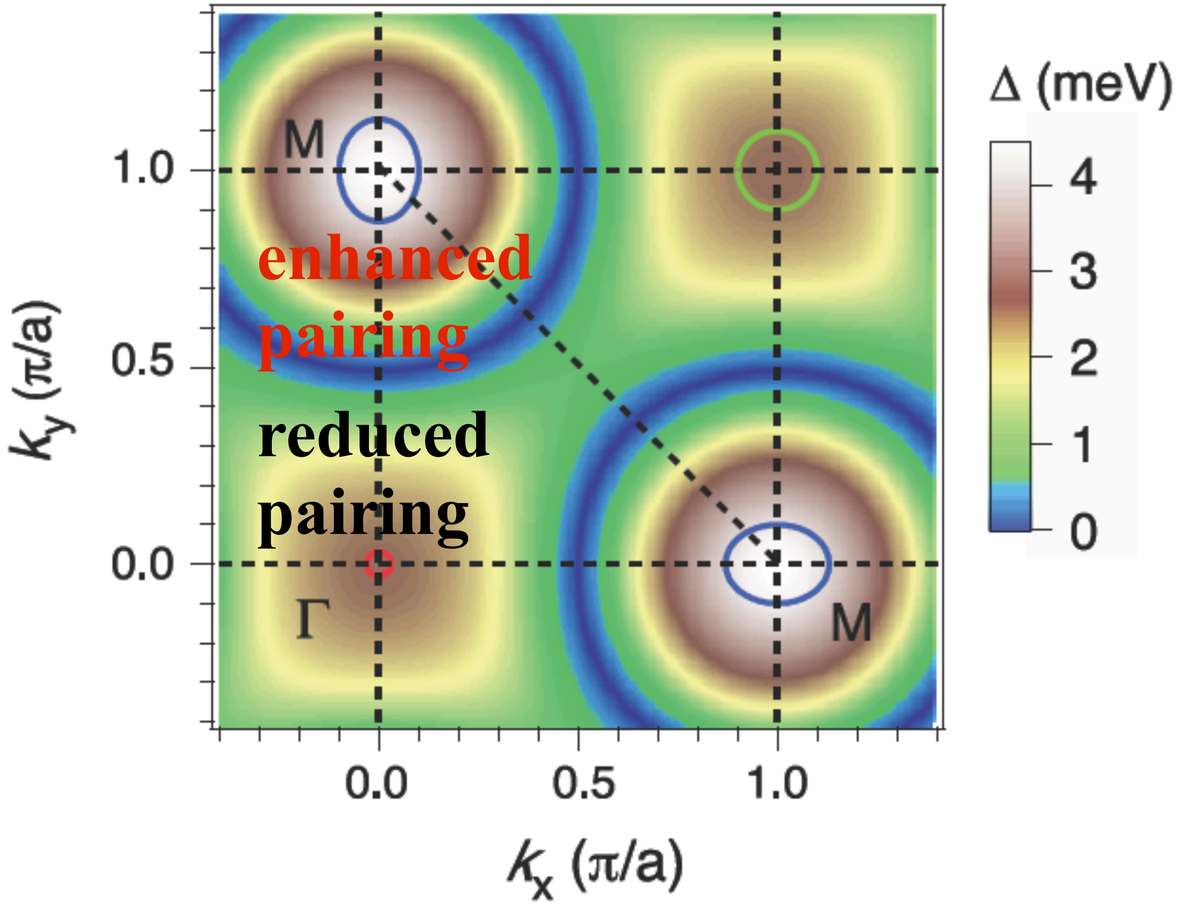
H. Miao, *et al. arXiv:* 1107.0985 (2011)

O. J. Lipscombe, *et al. Phys. Rev. Lett.* **106,** 057004 (2011)

superconducting gap function

$$|\Delta(k_x, k_y)| = |\Delta_2 \cos(k_x)\cos(k_y) - \Delta_3[\cos(2k_x) + \cos(2k_y)]/2|$$





H. Miao, *et al. arXiv:* 1107.0985 (2011)

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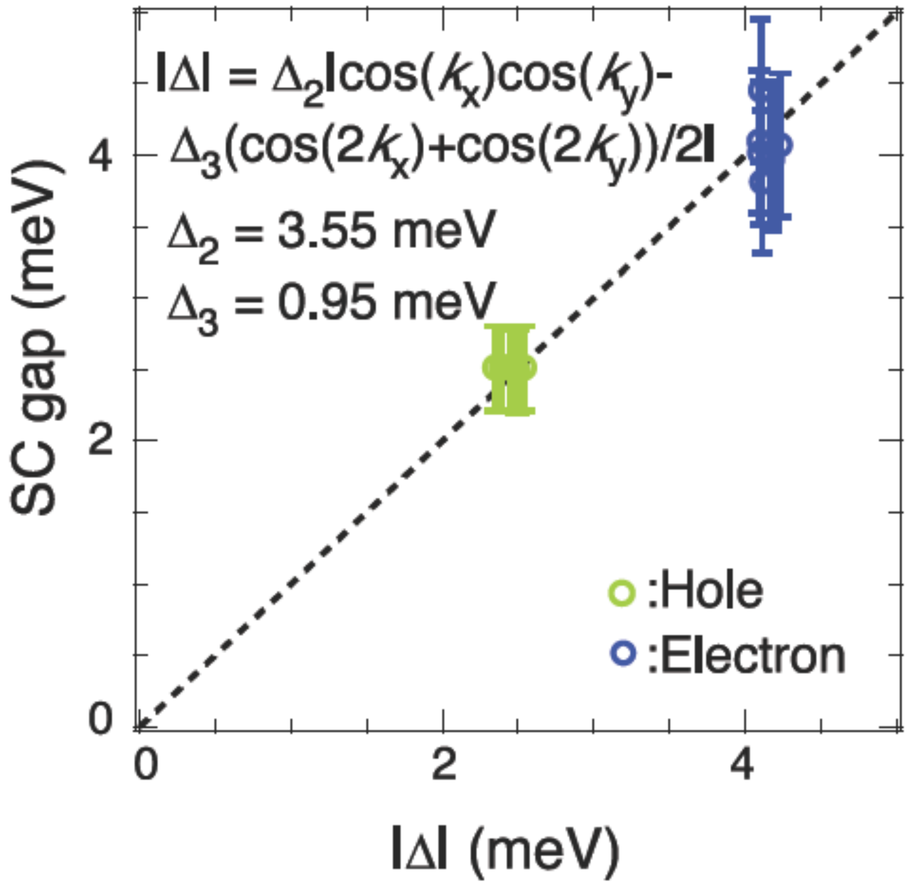
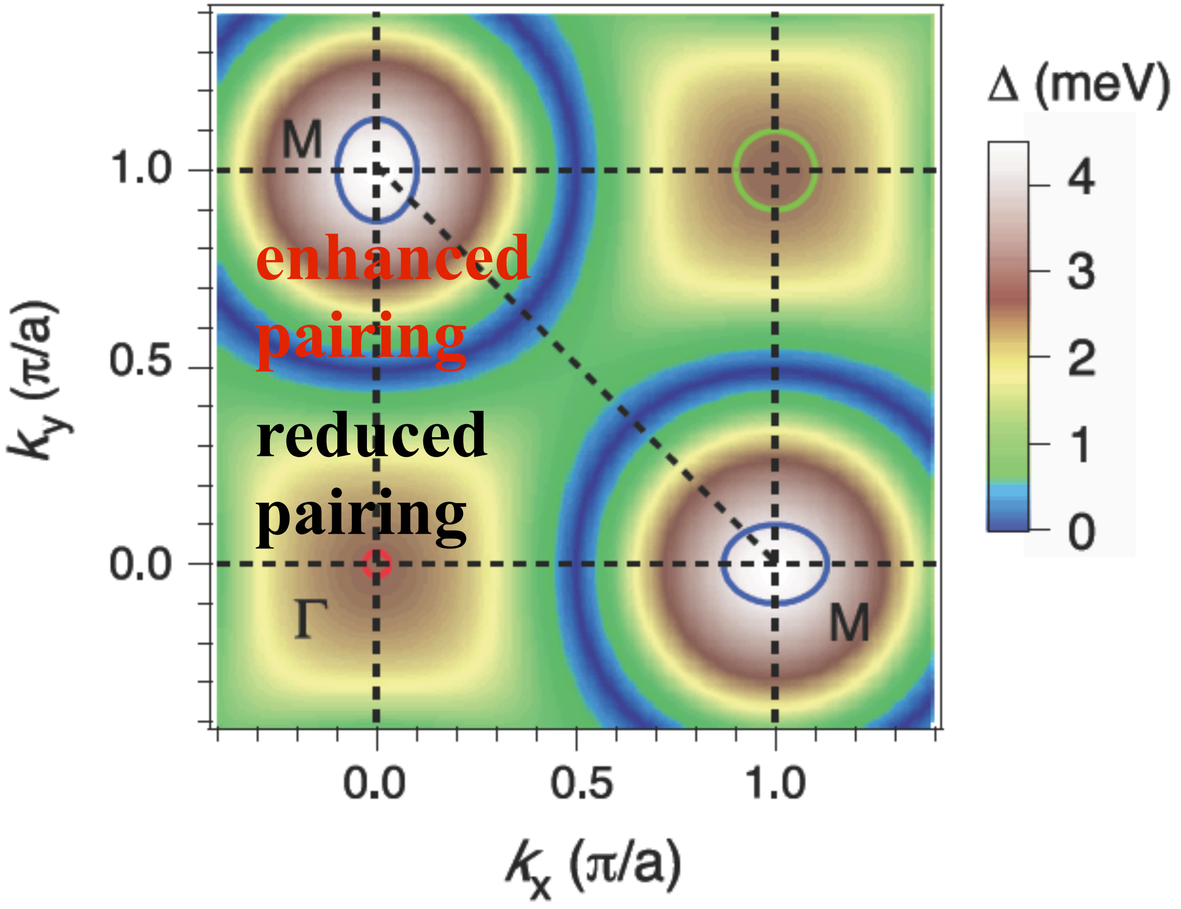


$\Delta_2/\Delta_3 \approx J_2/J_3 = 22/7$



H. Miao, *et al. arXiv:* 1107.0985 (2011)

O. J. Lipscombe, *et al. Phys. Rev. Lett.* **106,** 057004 (2011)

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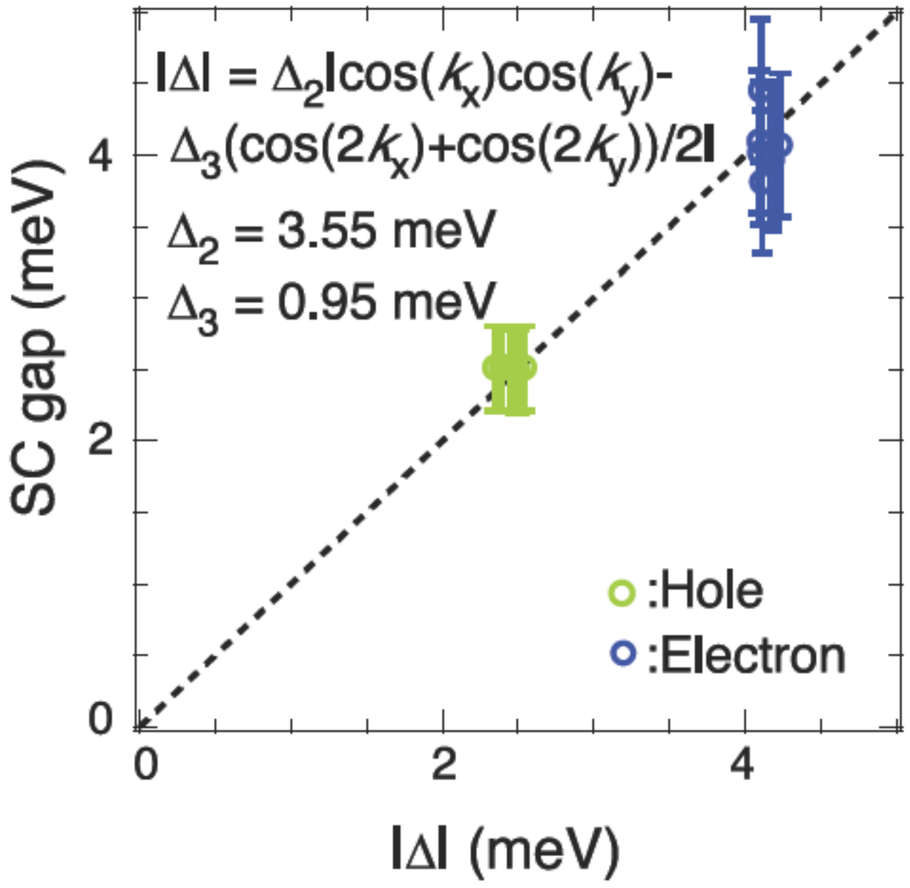

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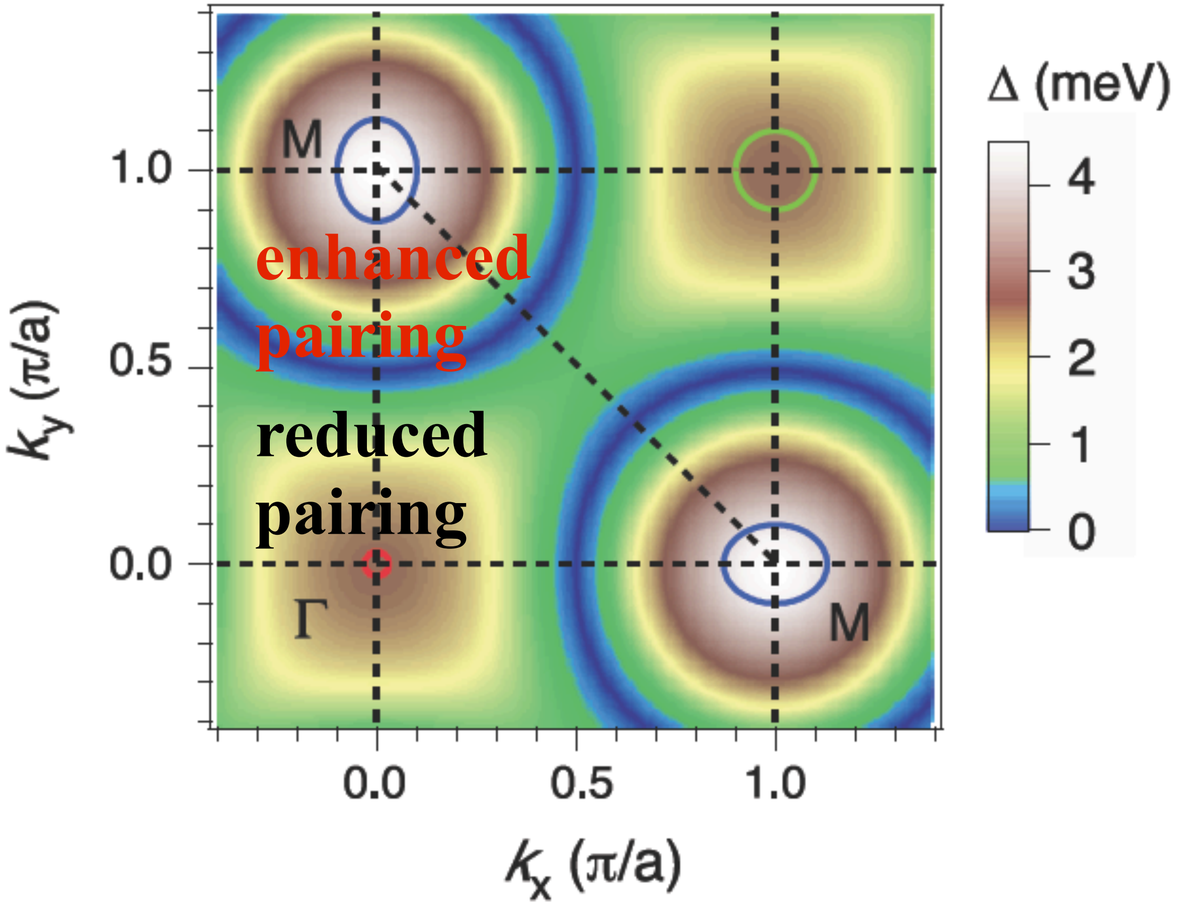

for $K_{0.8}Fe_{1.6}Se_2$, $J_3 \sim 9$ meV

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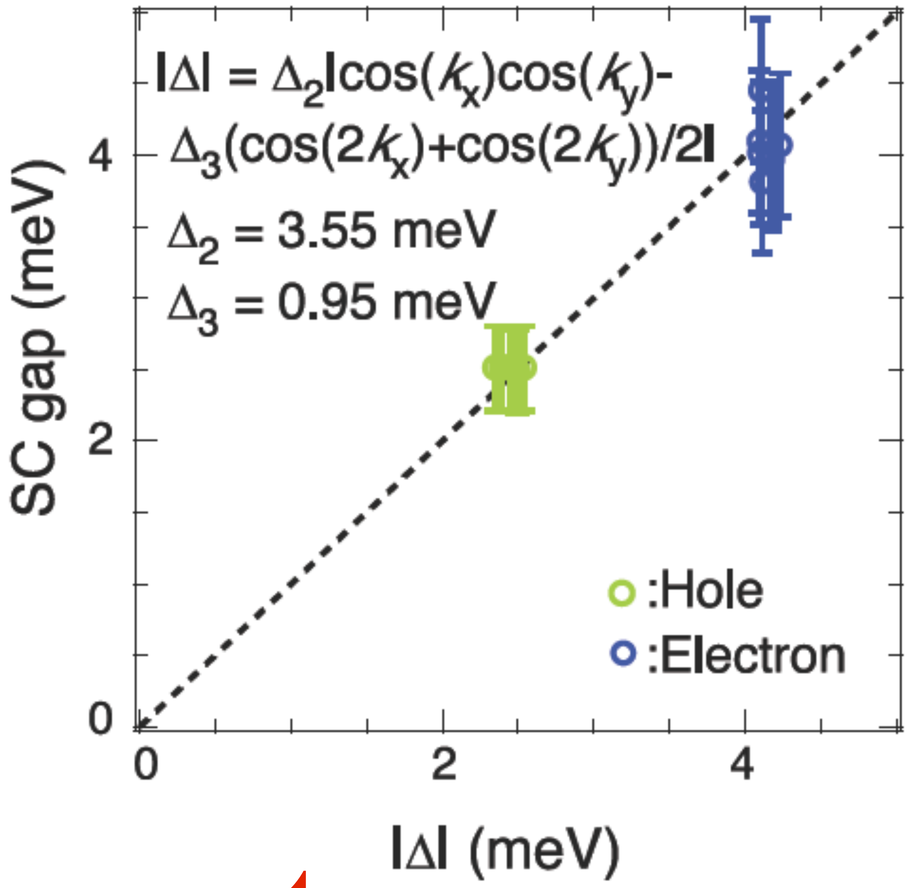
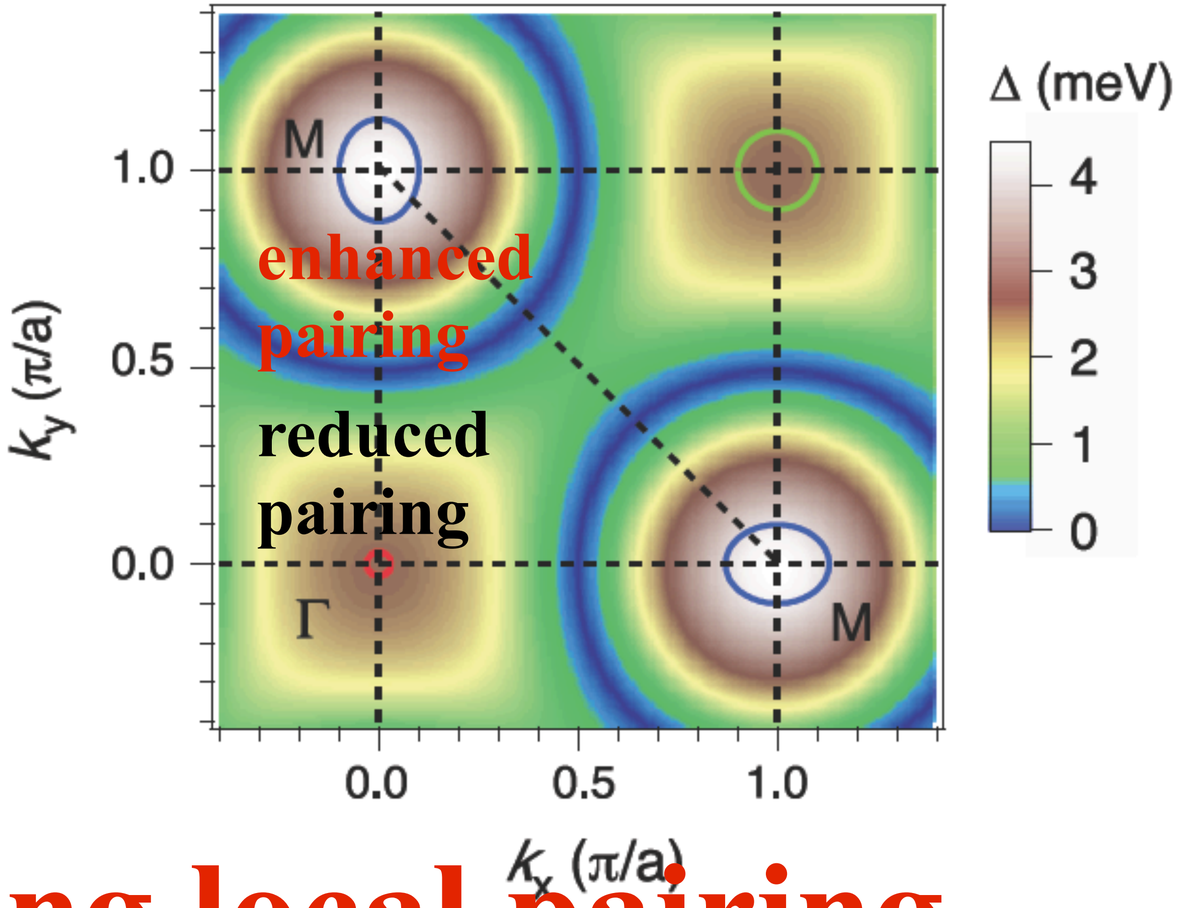


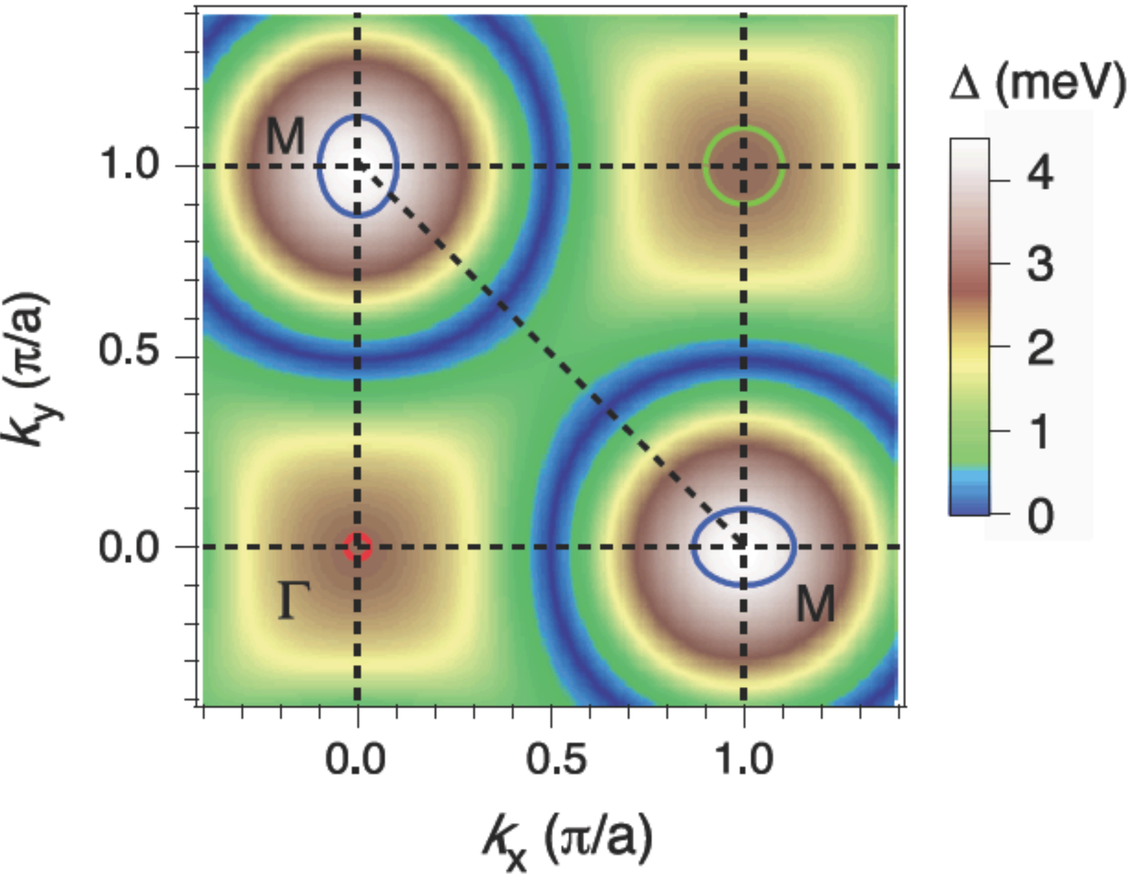


strong coupling local pairing

H. Miao, *et al. arXiv:* 1107.0985 (2011)

O. J. Lipscombe, *et al. Phys. Rev. Lett.* **106,** 057004 (2011)

node?



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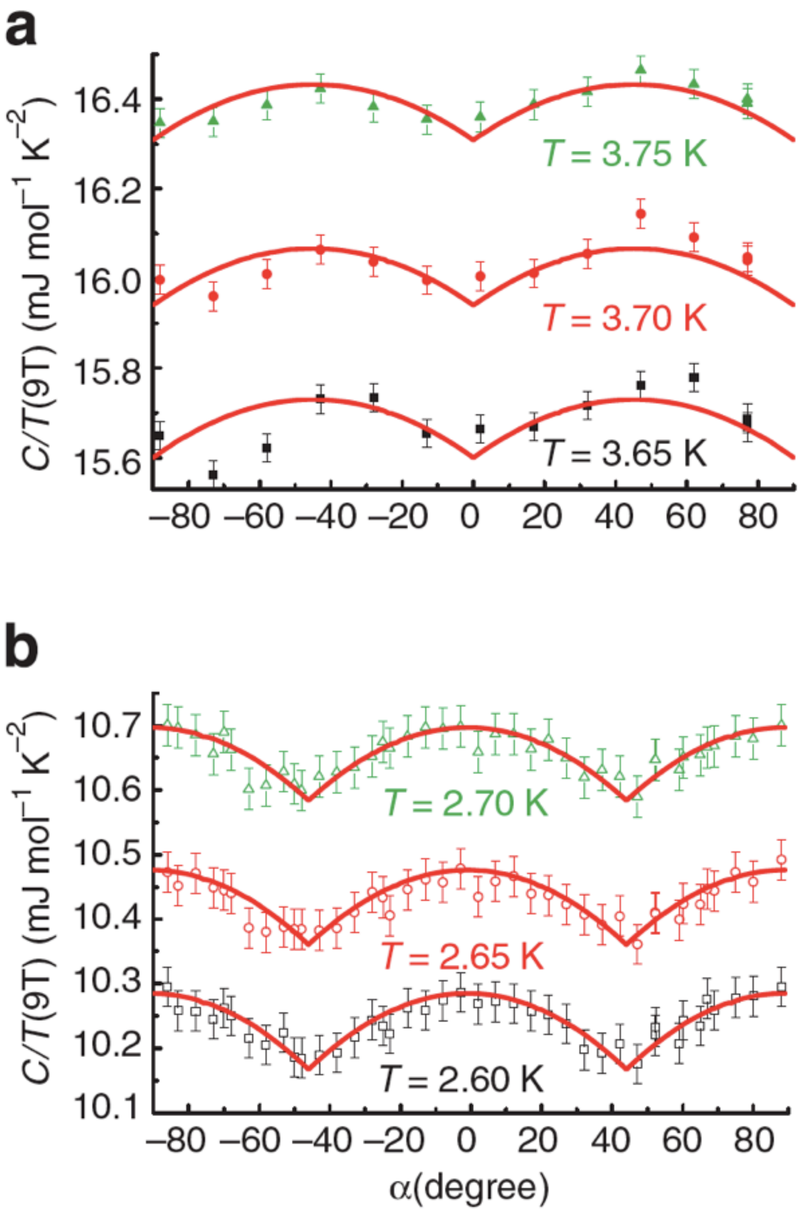
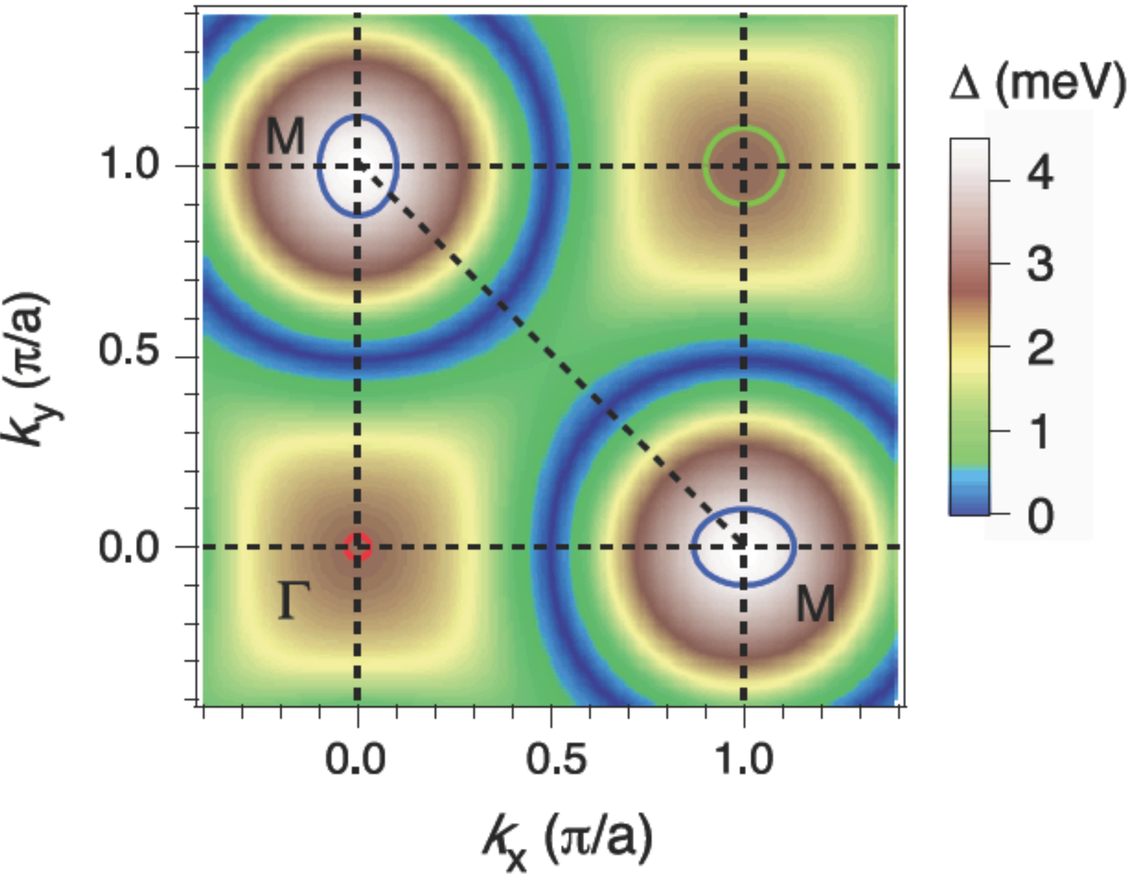


B. Zeng, *et al. Nat. Commun* **1**, 112 (2010)

node?

k_z effect?



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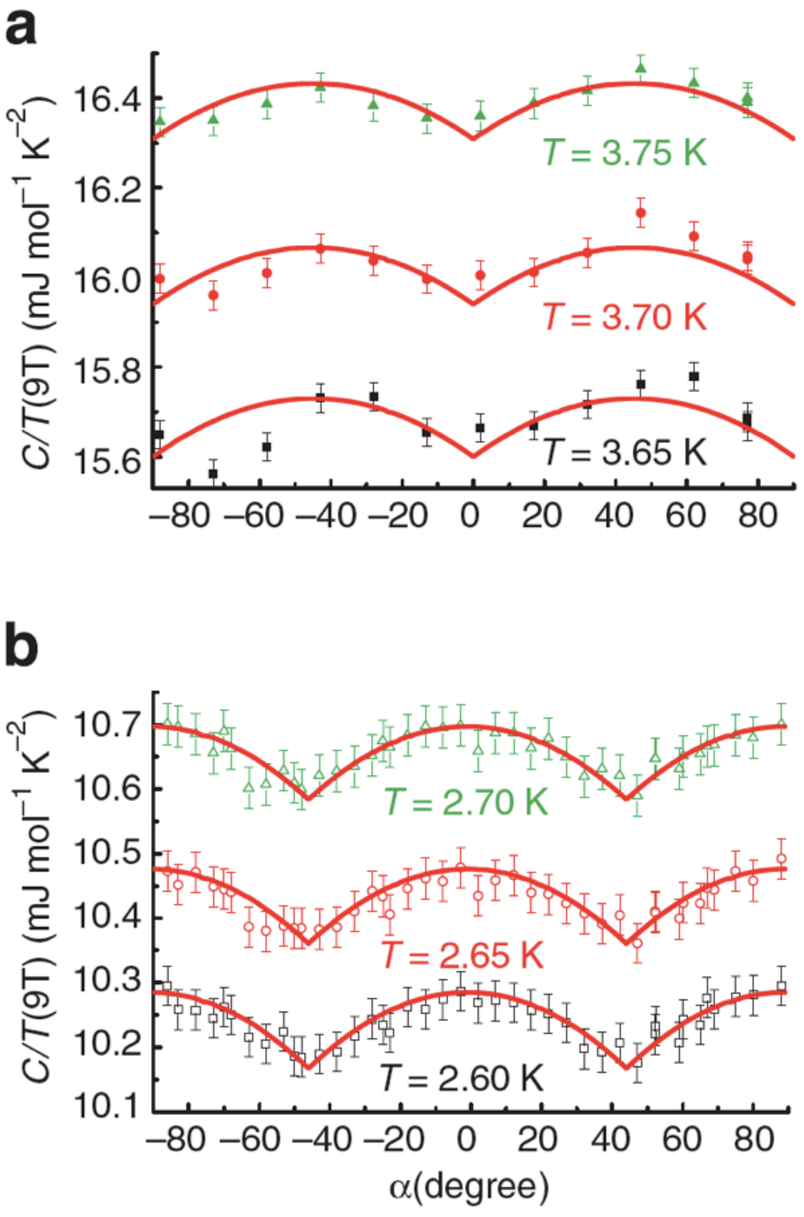

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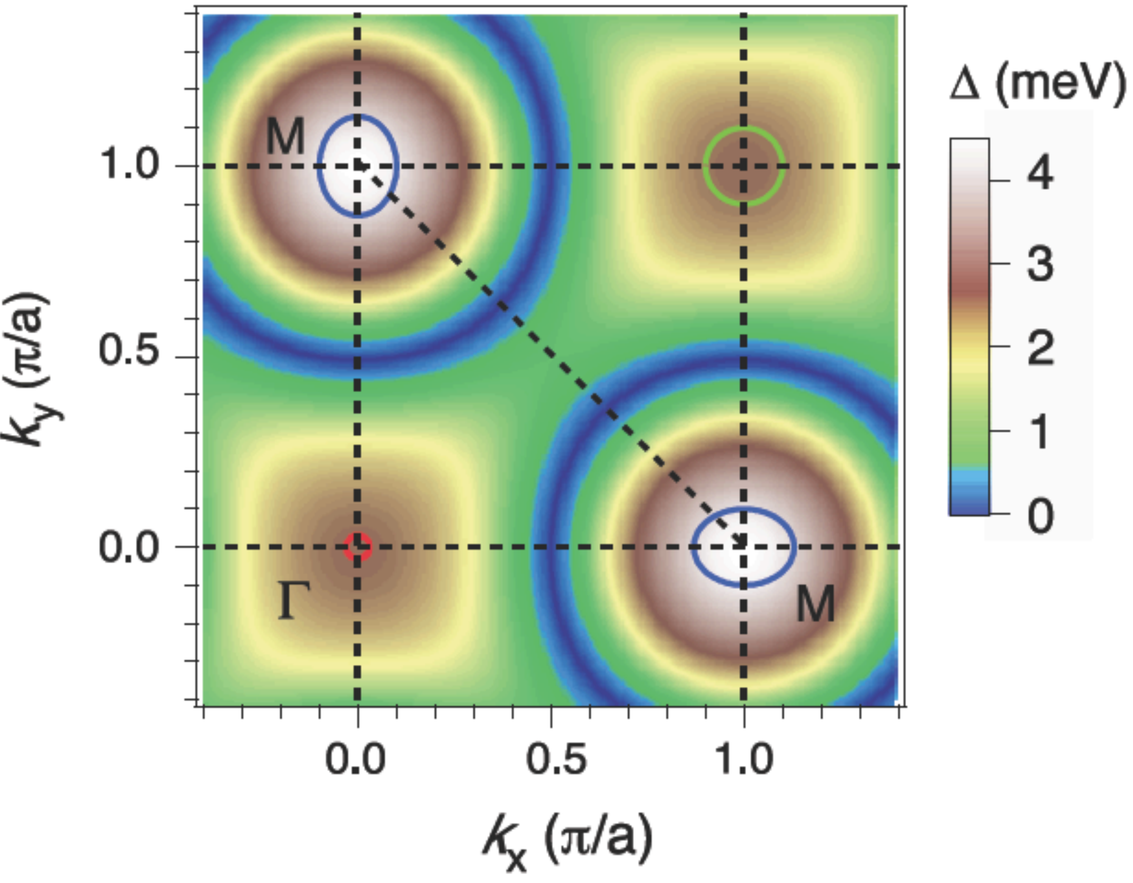
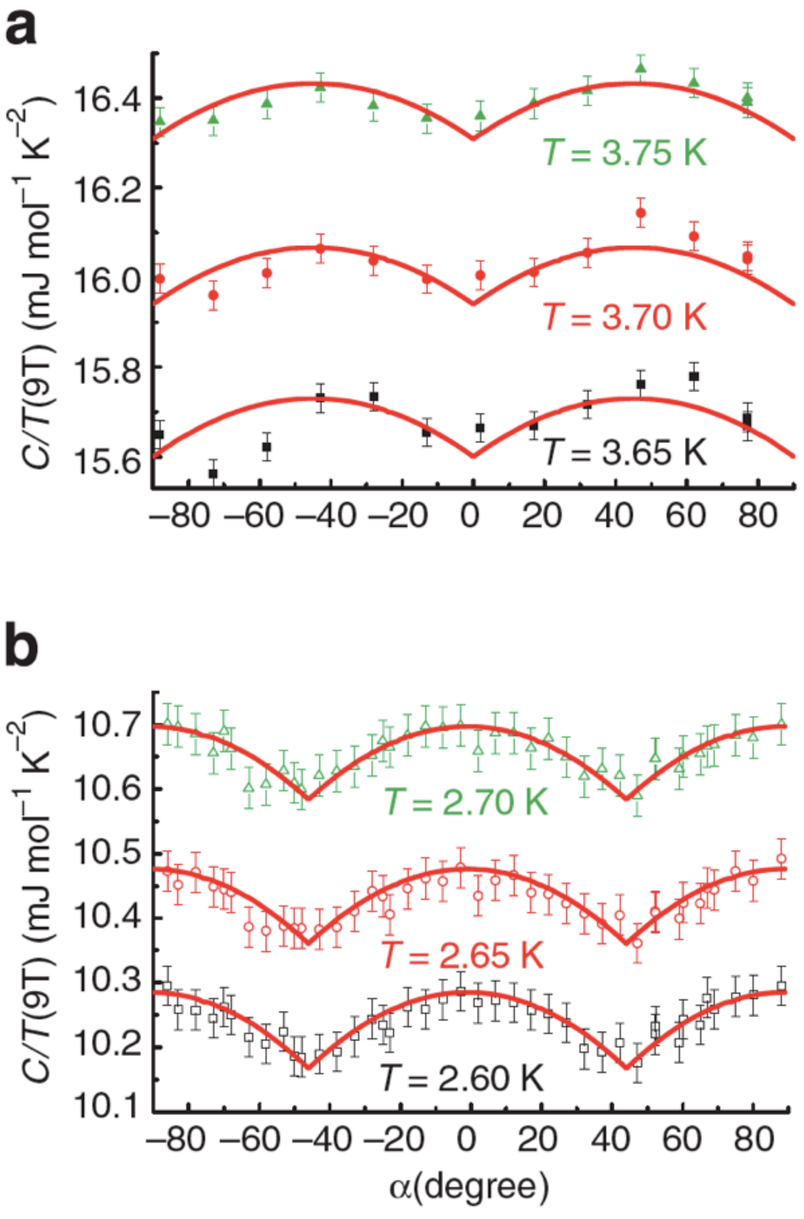
node?

k_z effect?

unlikely:
quasi 2D system





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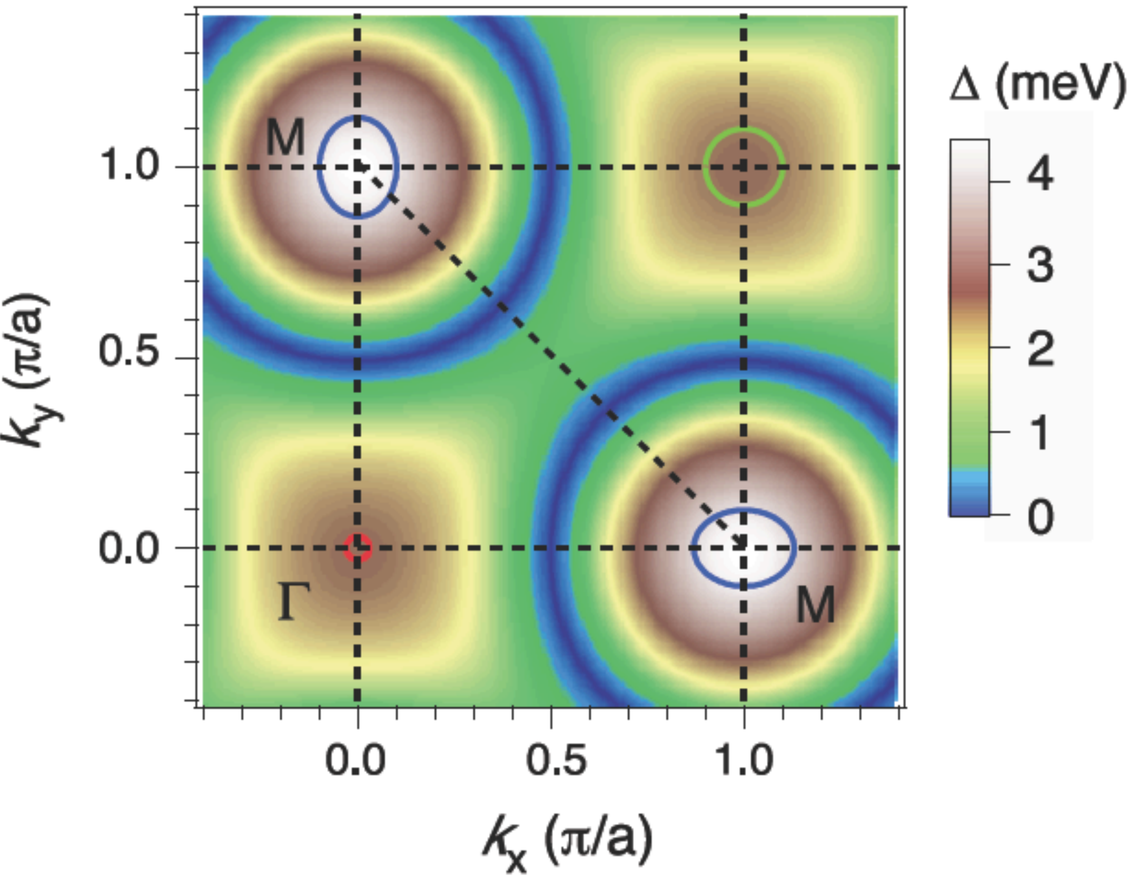

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unlikely:
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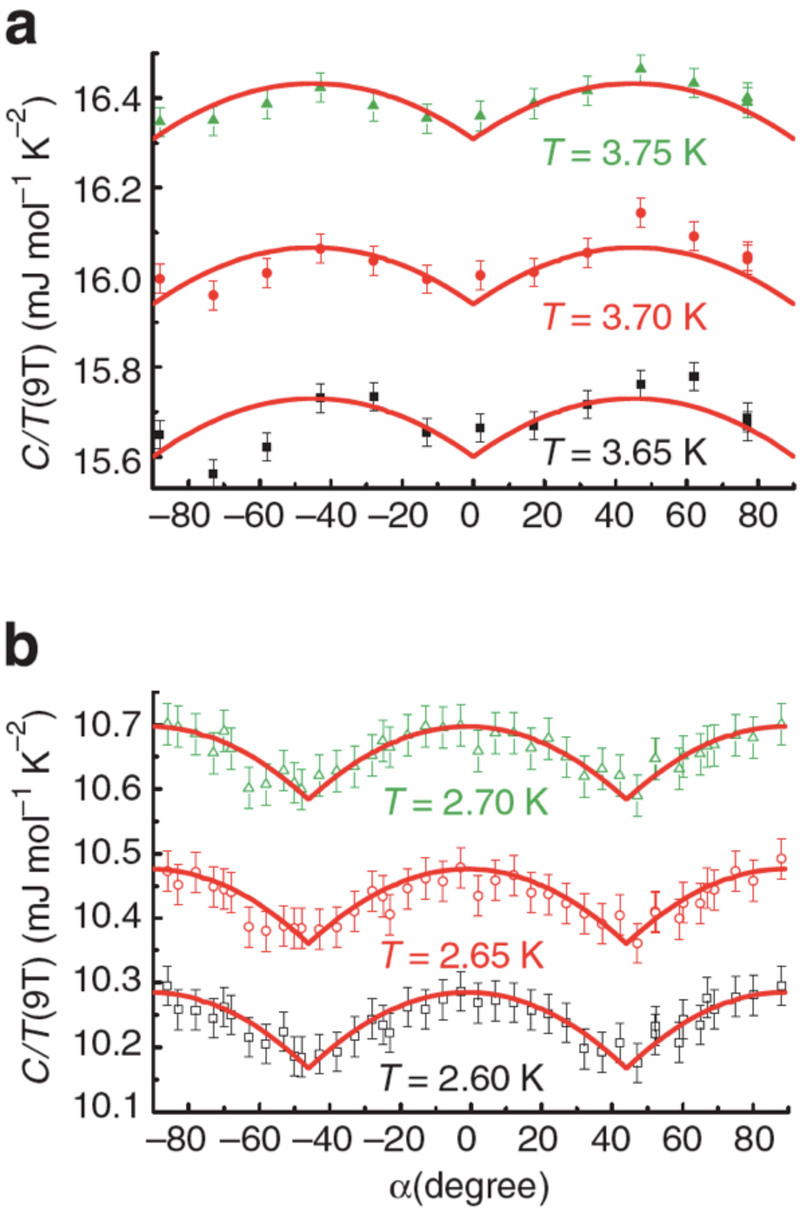
cleaved surface?



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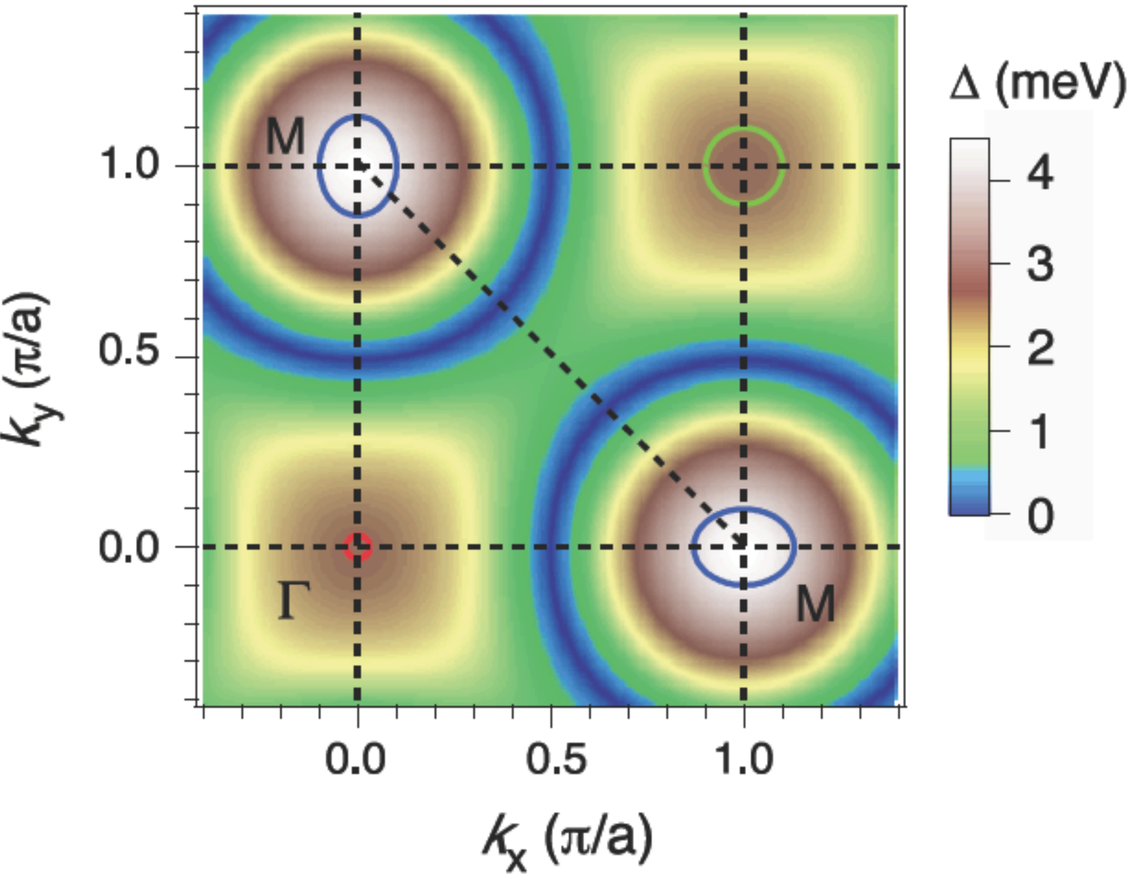
node?



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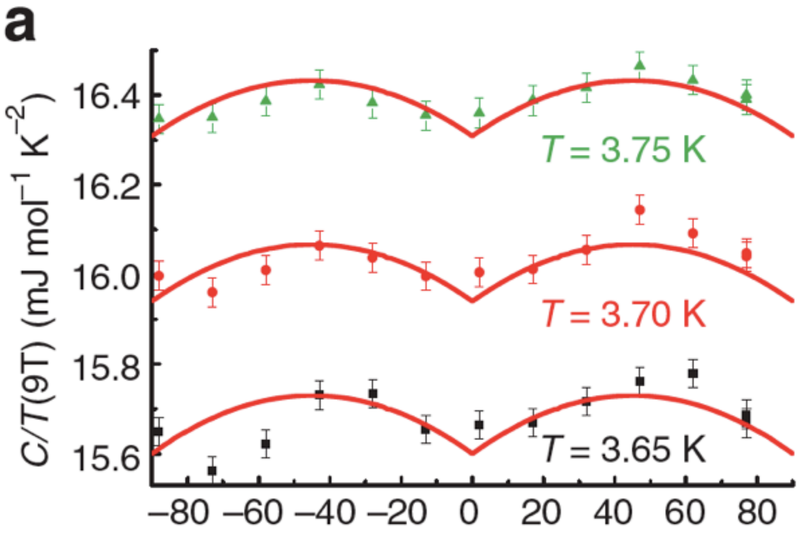

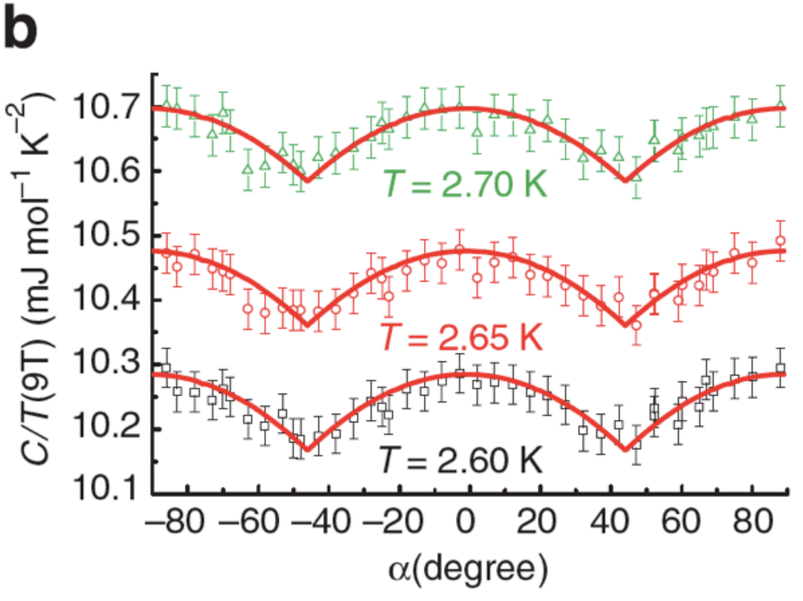

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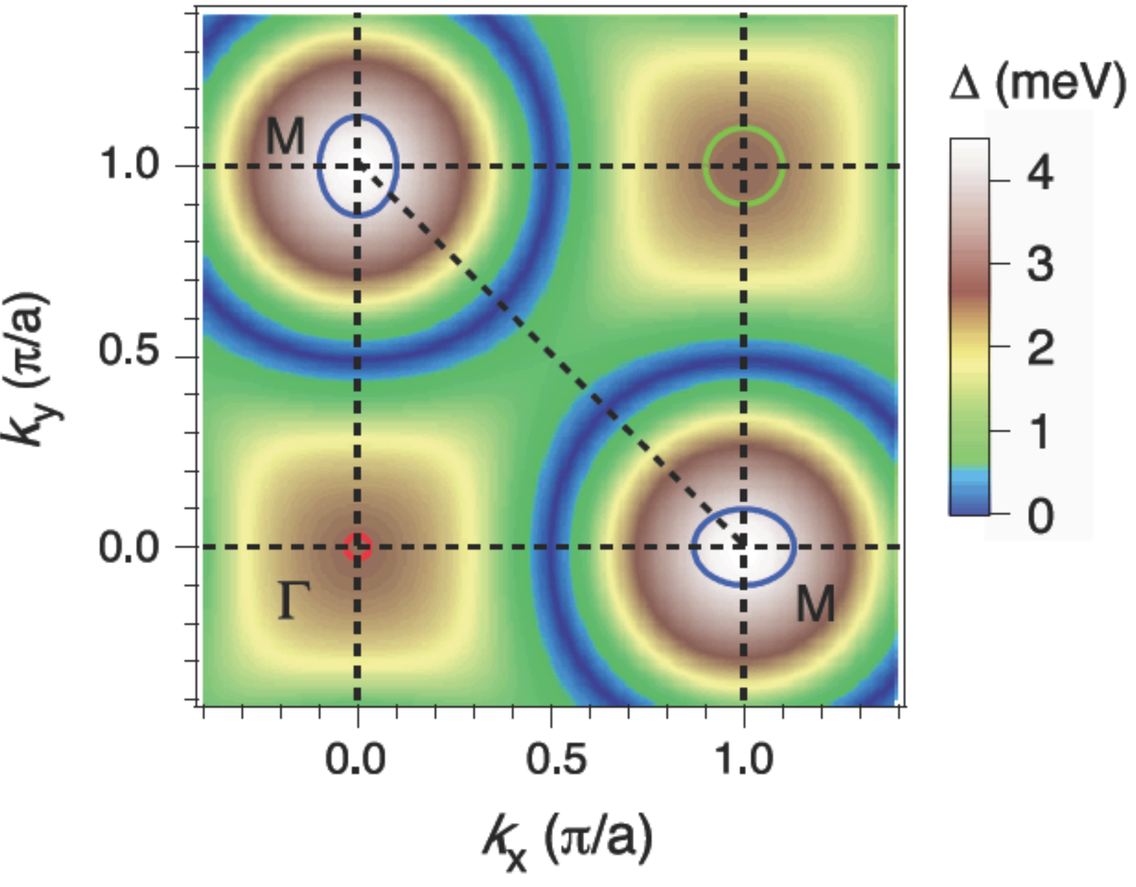

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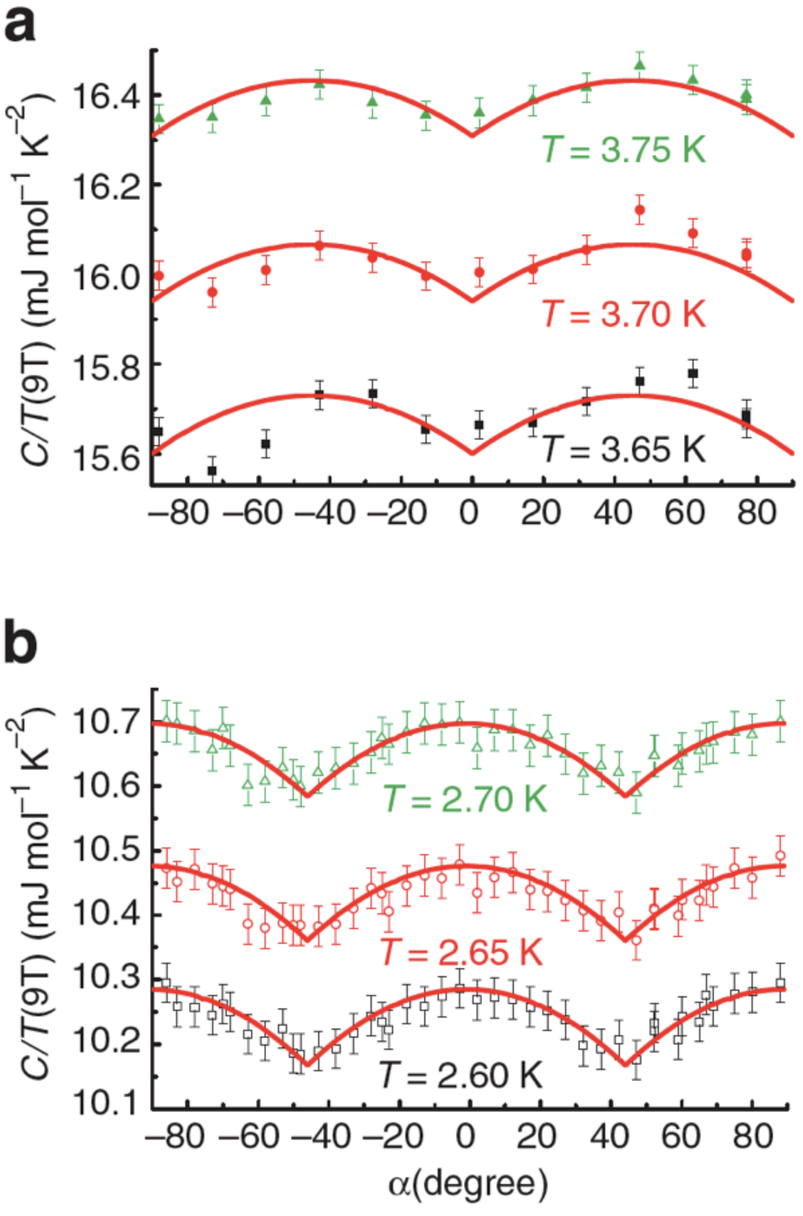

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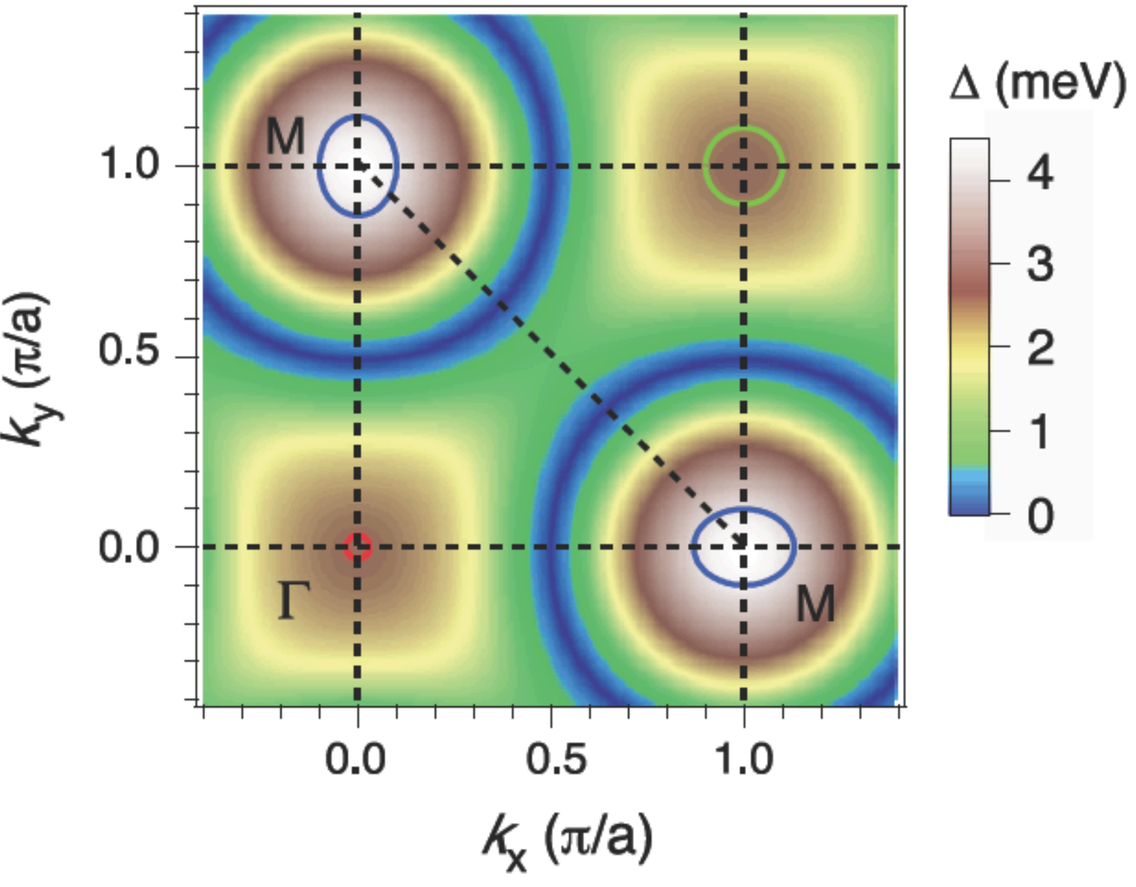

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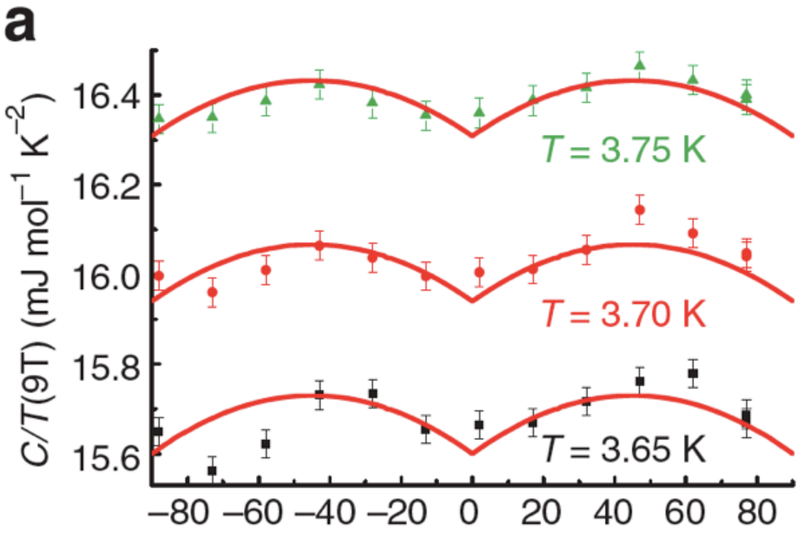
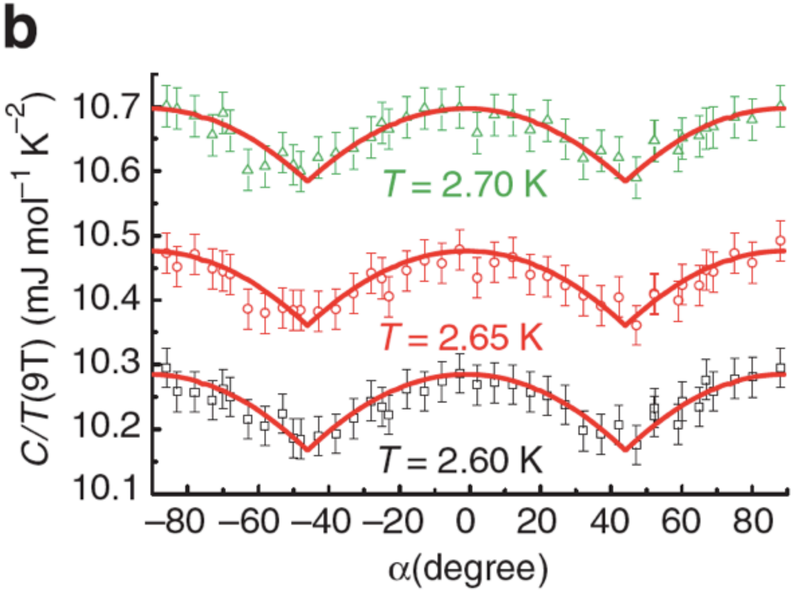
possible





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Summary

1. Three holelike bands are distinguished around Γ point, in which two cross at E_F;

2. Isotropic superconducting gaps are observed on every FS sheets without node;

3. For the first time, the superconducting gap on the electronlike FS is larger than the one on the holelike FSs;

4. Orbital characters for each bands have been carried out through polarization dependent ARPES measurements;

5. J_1-J_2 model derived s± superconducting gap function agrees well with all observed superconducting gaps on different FS sheets;

5. Enhanced pairing on electronlike FS pocket and reduced pairing on holelike ones in the ferrochalcogenides supports the strong coupling local pairing for iron-based superconductors.