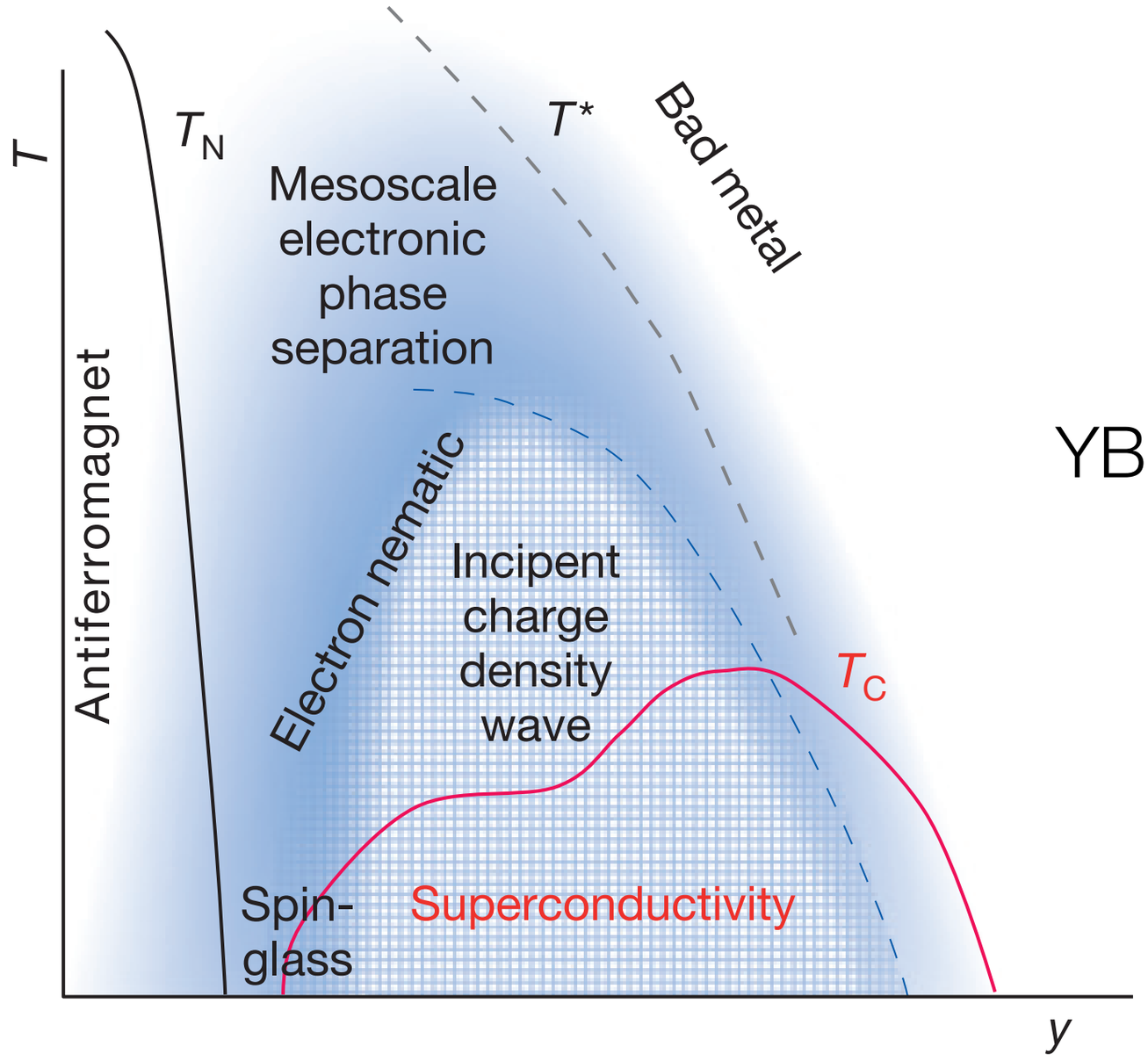
Intertwined order III:
Density waves and superconductivity

Stephen Edkins	experiment	cuprates
Johan Chang	experiment	cuprates
Tom Devereaux	theory	cuprates
Philip Moll	experiment	$Ce(Rh,Ir)In_5$

Ineluctable complexity

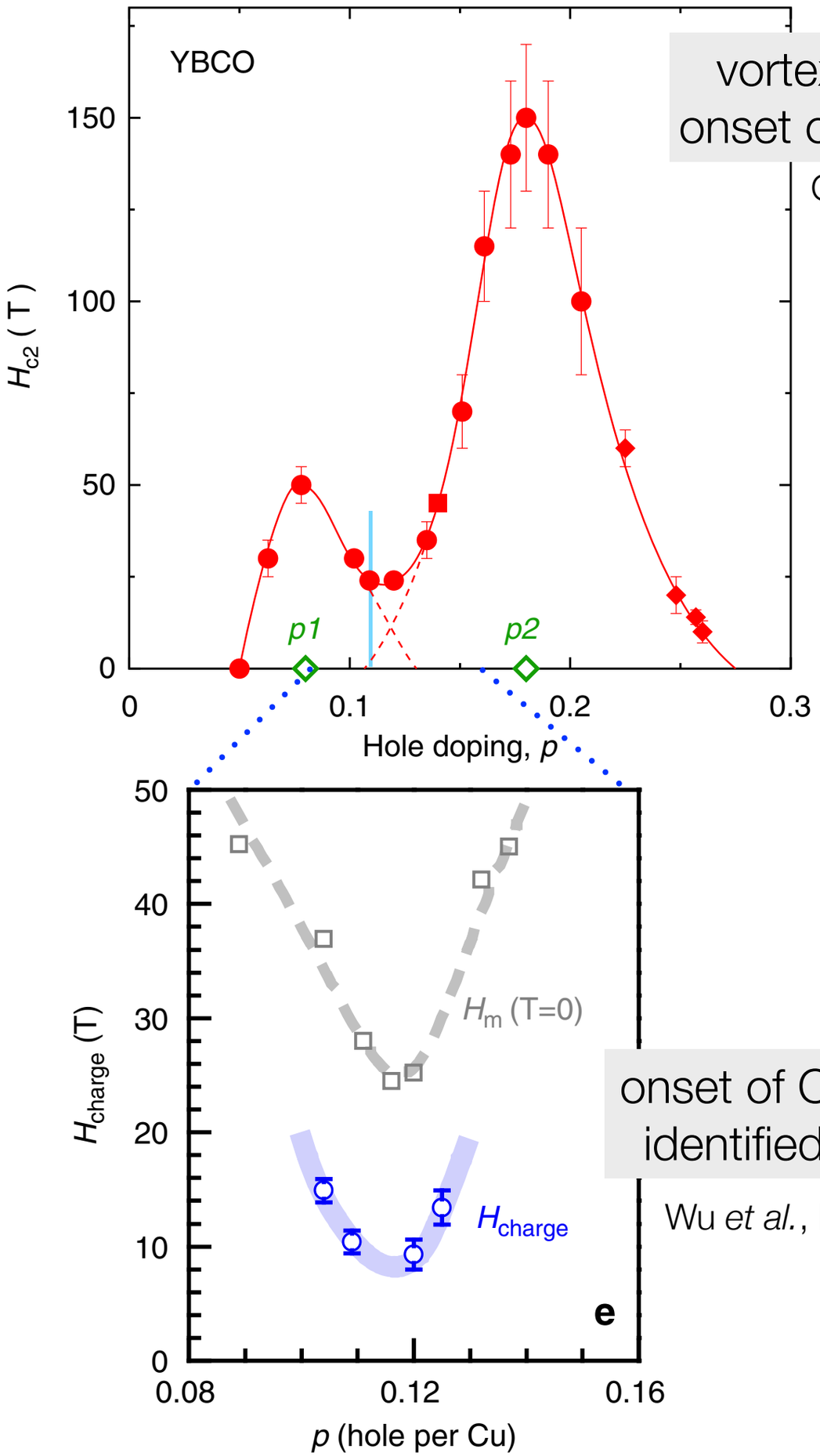


$YBa_2Cu_3O_{6+y}$

Fradkin + Kivelson, Nat. Phys. **8**, 864 (2012)

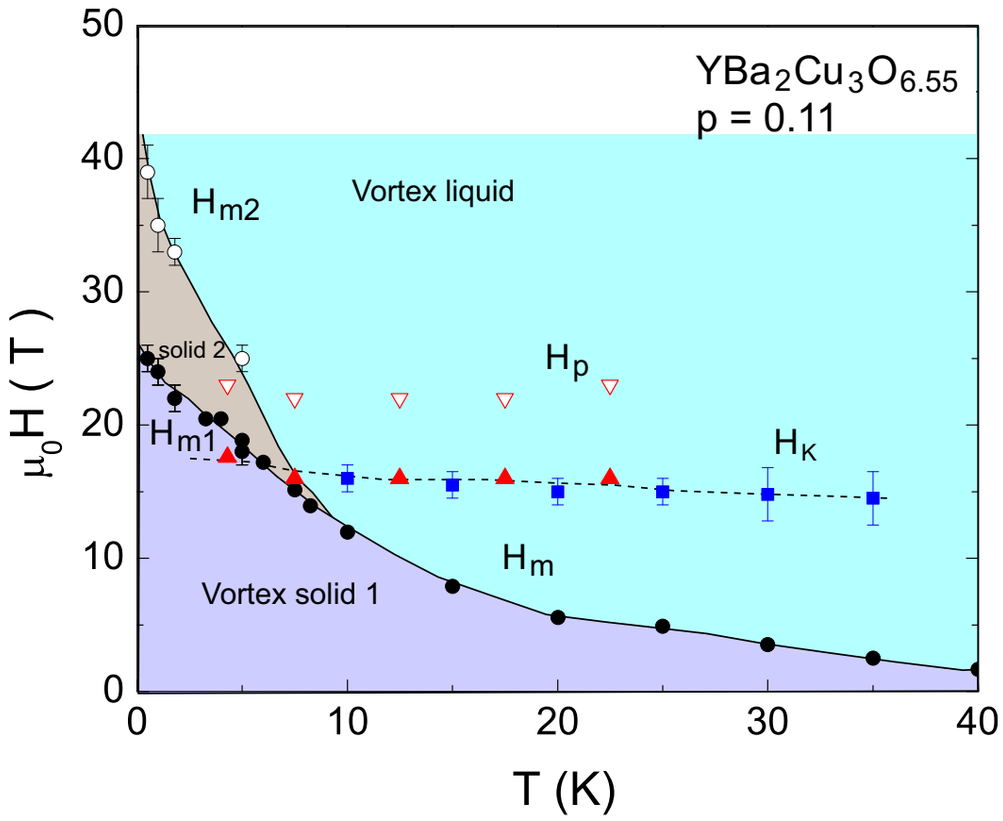
vortex melting
onset of resistivity

Grissonnanche *et al.*, Nat. Commun. **5**, 3280 (2014)



onset of CDW order
identified by NMR

Wu *et al.*, Nat. Commun. **4**, 2113 (2013)



Yu *et al.*, PNAS **113**, 12667 (2016)

CDW order appears to compete with SC

X-rays observe a 2D to 3D transition of CDW

as Johan will explain

3D CDW coexists with vortex liquid

does CDW order compete with SC phase order rather than competing with pairing?

What does theory say about CDW order?

Monday - Steve White - stripes in nn Hubbard model

What happens if you go to 3-band Hubbard model?

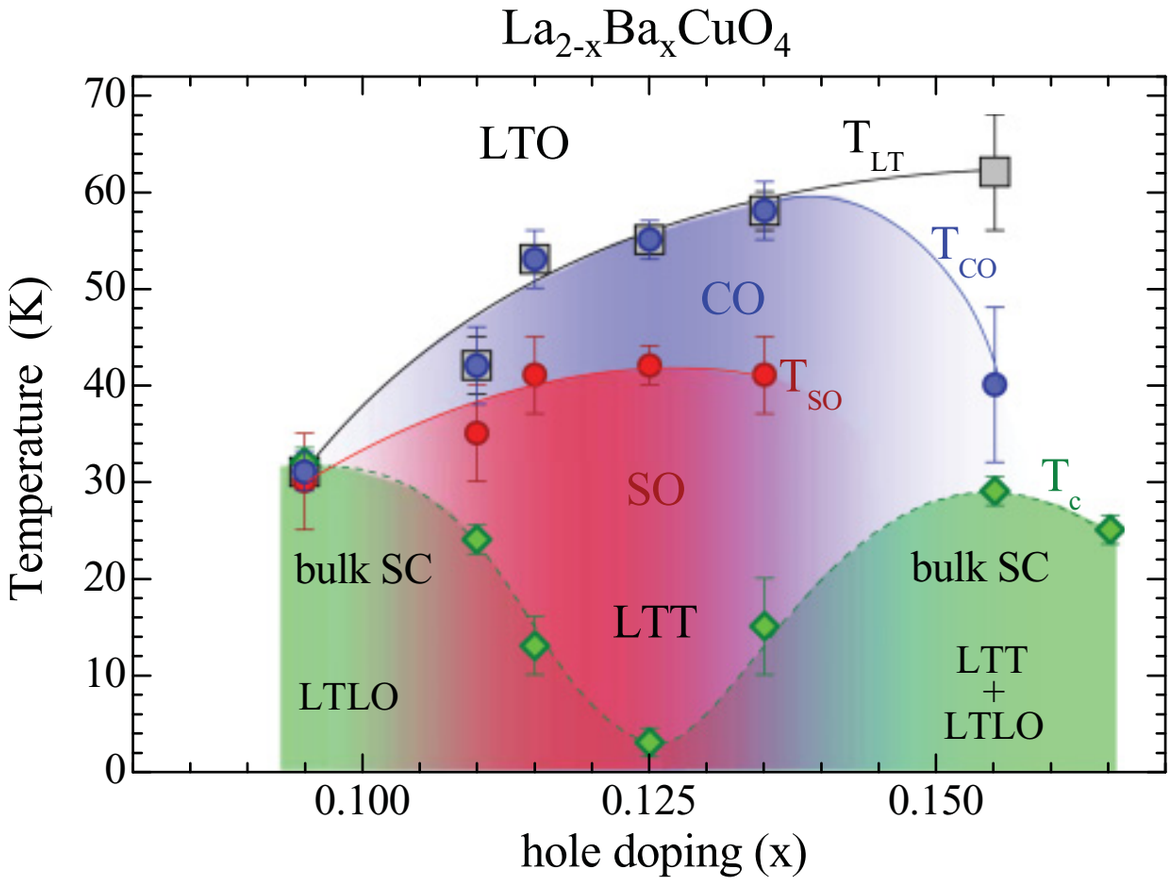
Tom will explain

Ground state: DMRG

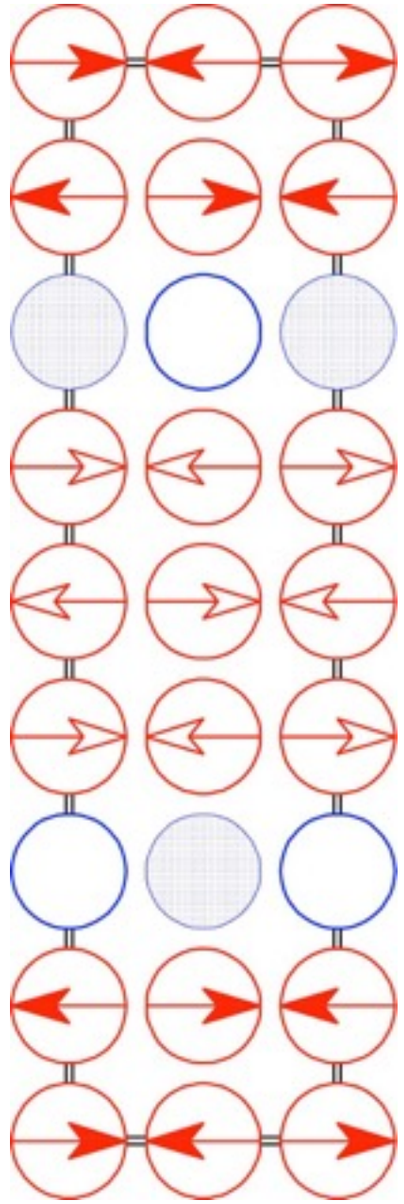
Excitations: DQMC - but only at high T >> T*

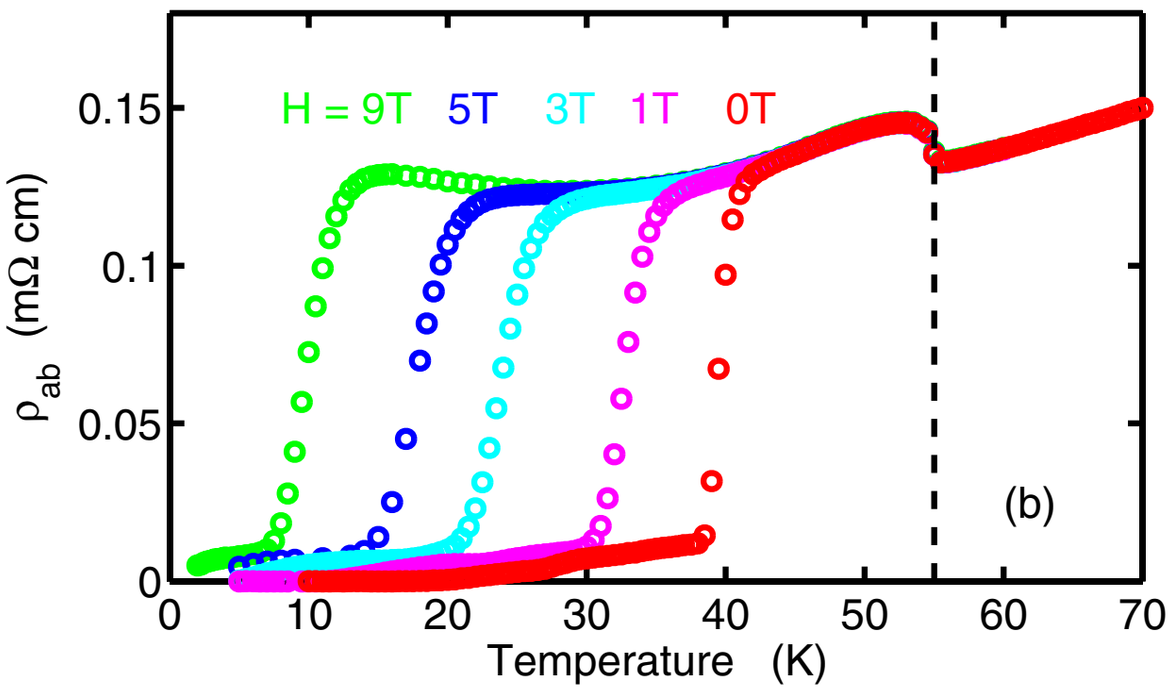
Do spin correlations only appear below T*,
or to they become more coherent below T*

Competition between CDW and 3D SC



Hücker *et al.*, PRB (2011)

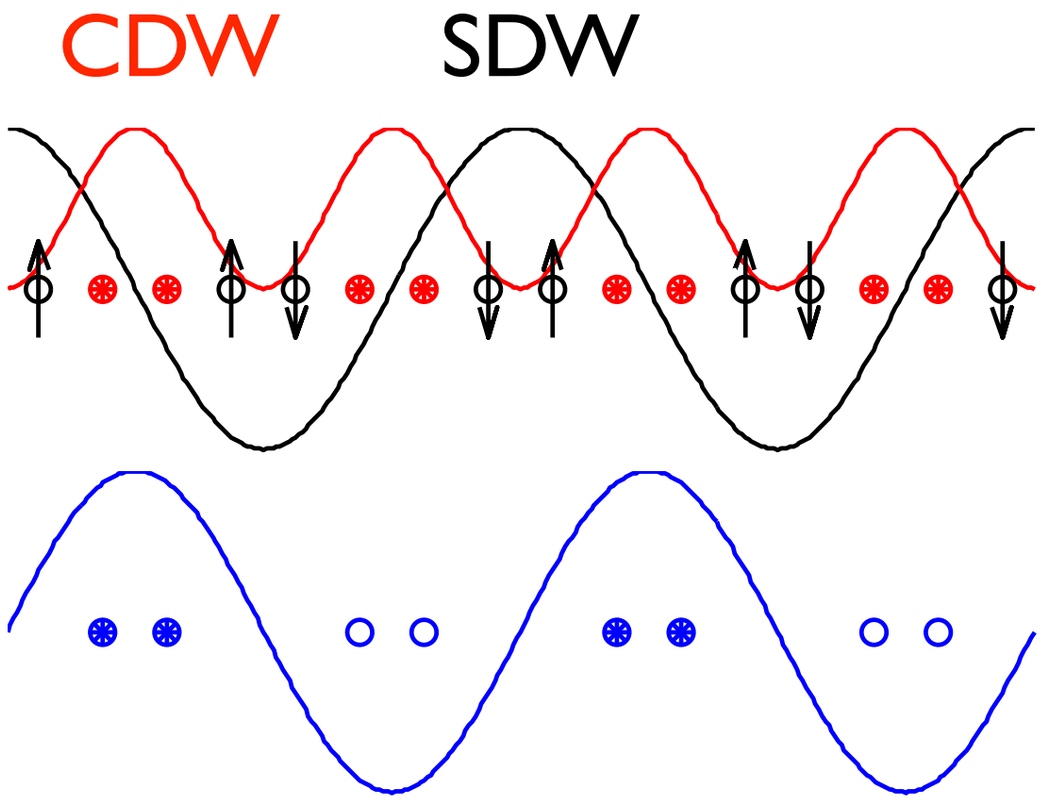




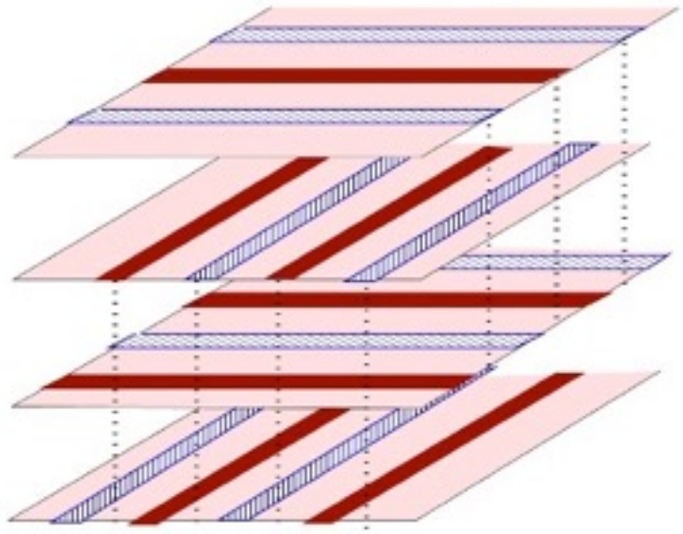
x = 1/8

Q. Li *et al.*, PRL (2007)

2D SC and Pair-Density-Wave Superconductor



Intertwined superconductivity
and antiferromagnetism



Frustration of interlayer coupling:
Himeda *et al.*, PRL (2002)
Berg *et al.*, PRL (2007)

P.A. Lee, PRX (2014)

PDW state is exotic.

Can we get direct evidence for the PDW state?

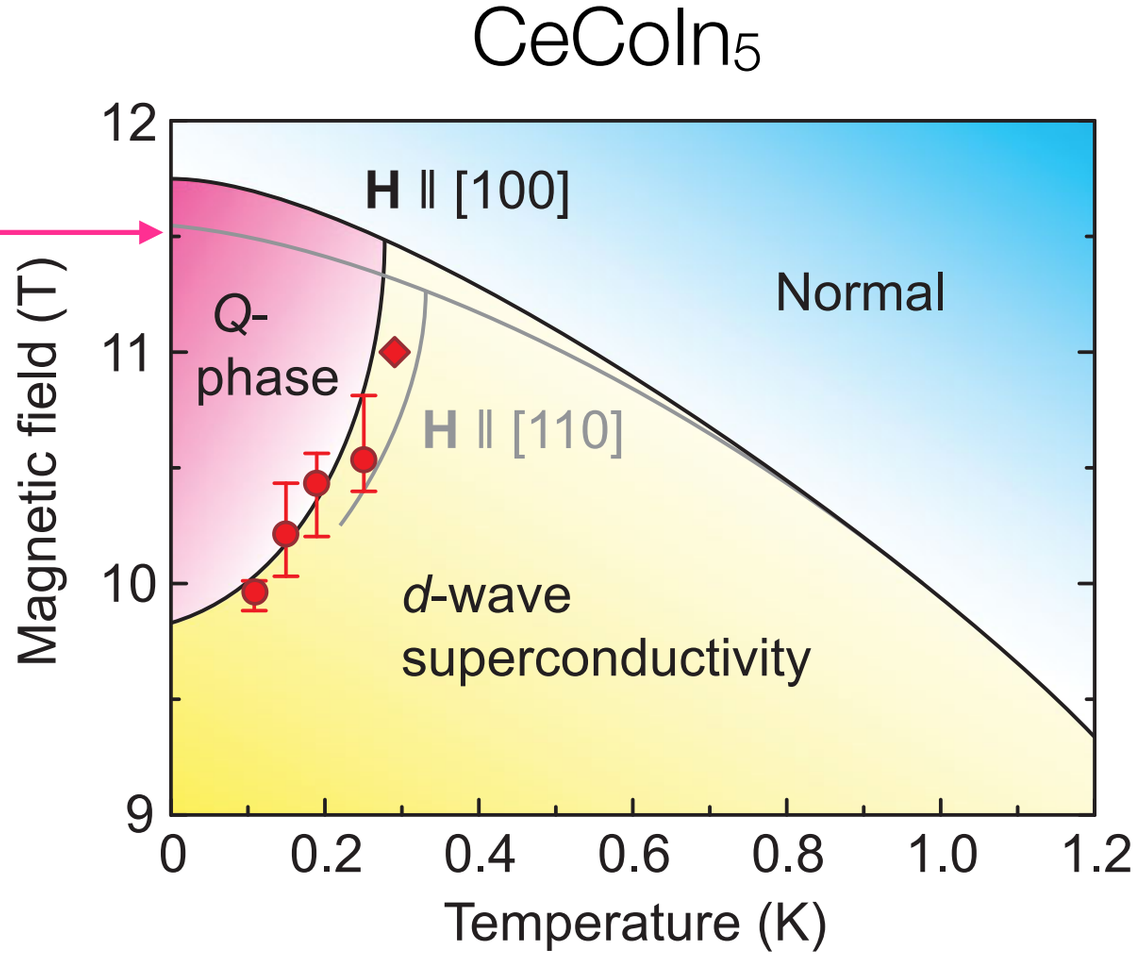
As Steve will describe,

scanning Josephson tunneling microscopic imaging

offers great promise

Does the PDW state exist in other systems?

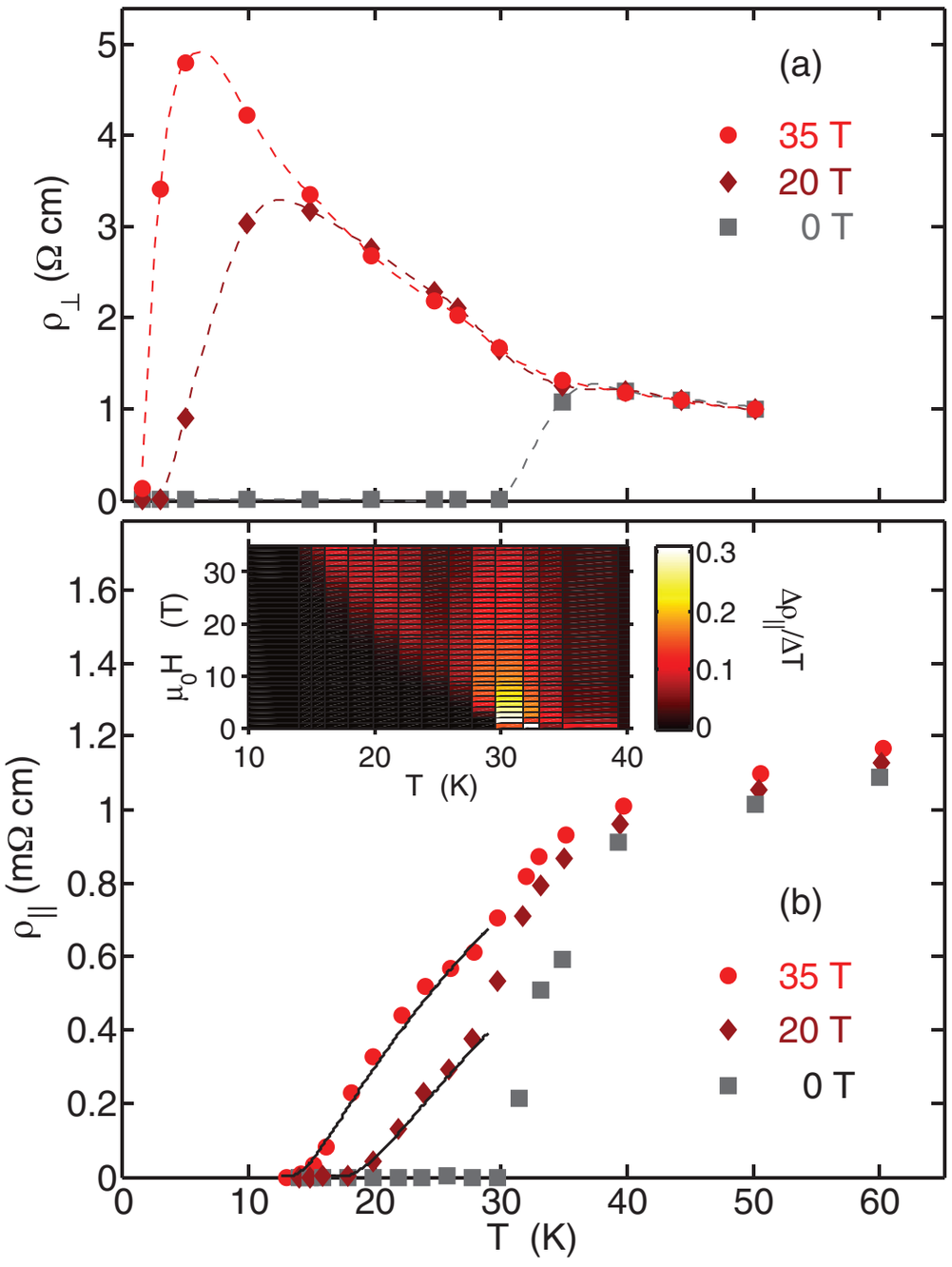
Possible *p*-wave PDW in the Q phase



D.Y. Kim *et al*., PRX **6**, 041059 (2016)

$La_{2-x}Ba_xCuO_4$ x = 0.095

Decoupling of SC layers in a magnetic field



Stegen *et al*., PRB (2013)

Philip will show

more extreme SC anisotropy in $CeIrIn_5$

field-induced anisotropy in $CeRhIn_5$

On to the talks …