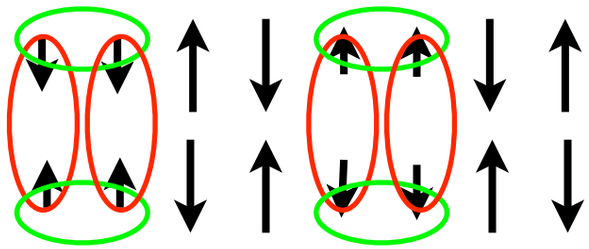
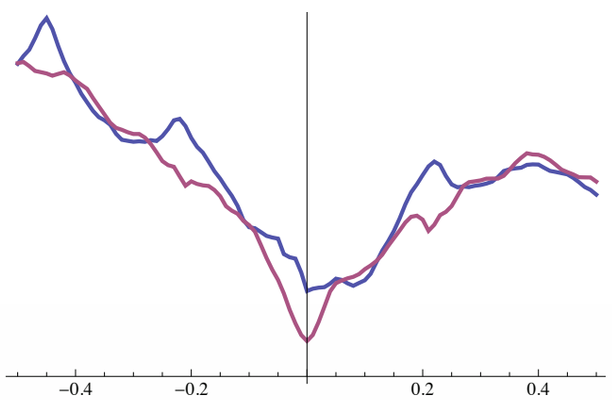
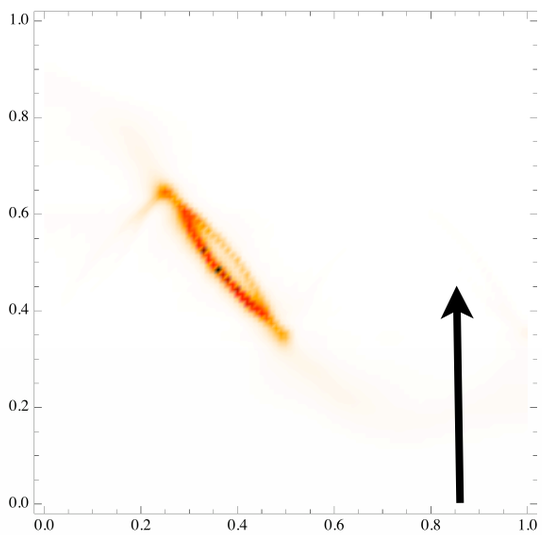
Mean field theory of a striped pseudogap state

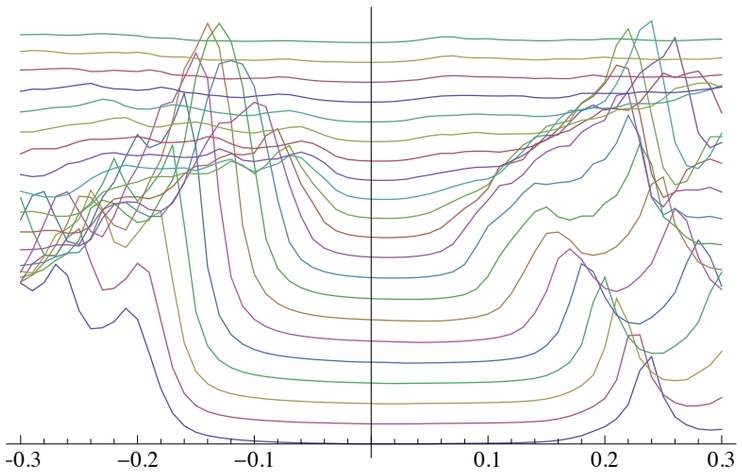
Mats Granath, Univ. of Gothenburg, Sweden
Brian M. Andersen, Univ. of Copenhagen, Denmark

KITP, July 14, 2009.



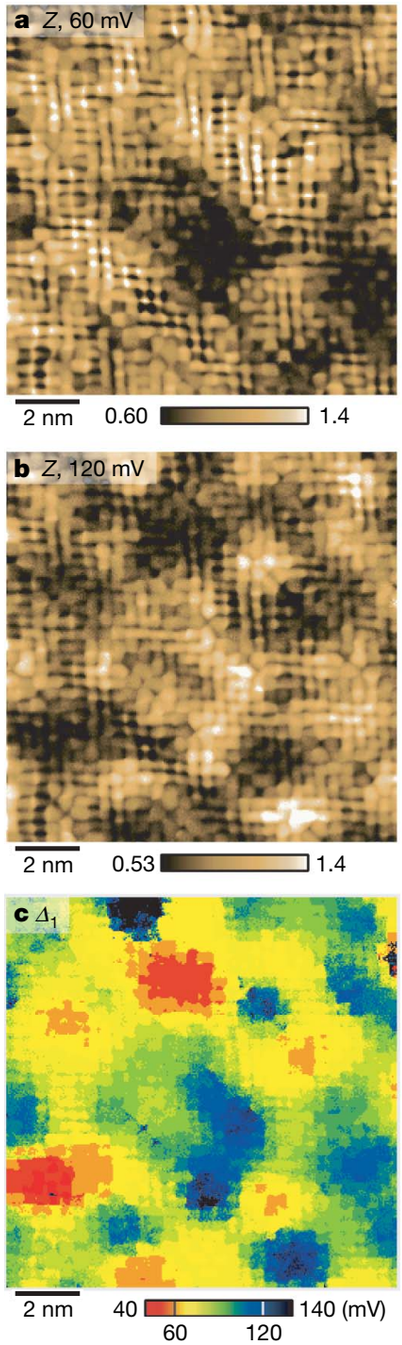




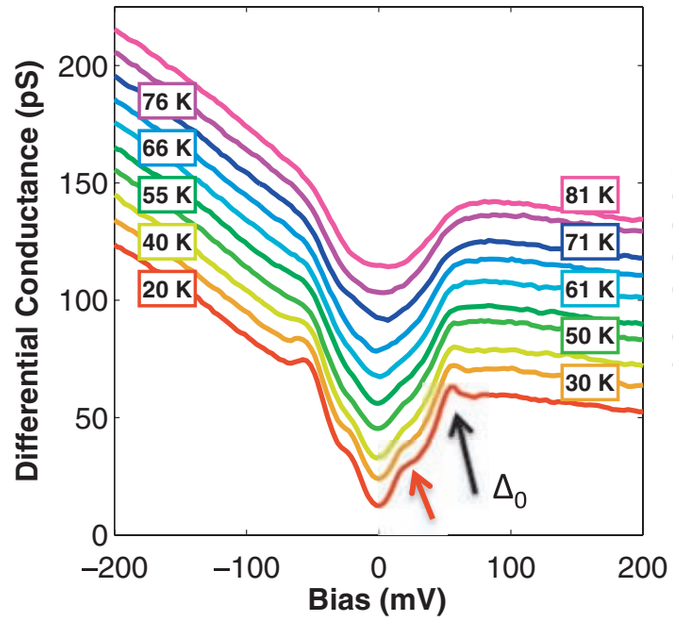


Stripes/Pseudogap/Fermi arc, Related?

STM

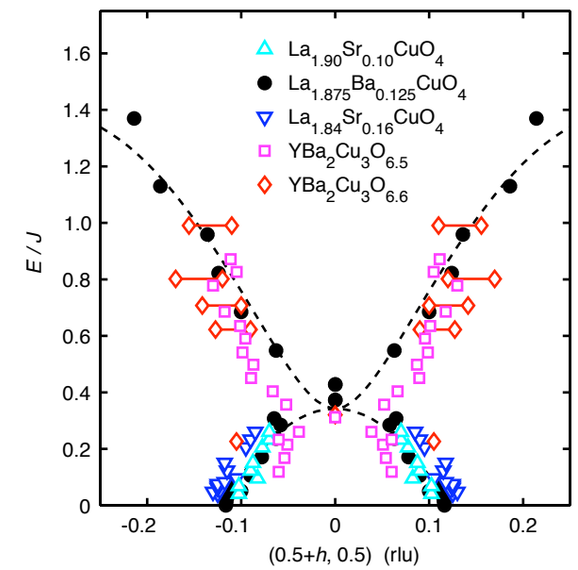


Kohsaka et al, Nature 2008.
BSCCO U45



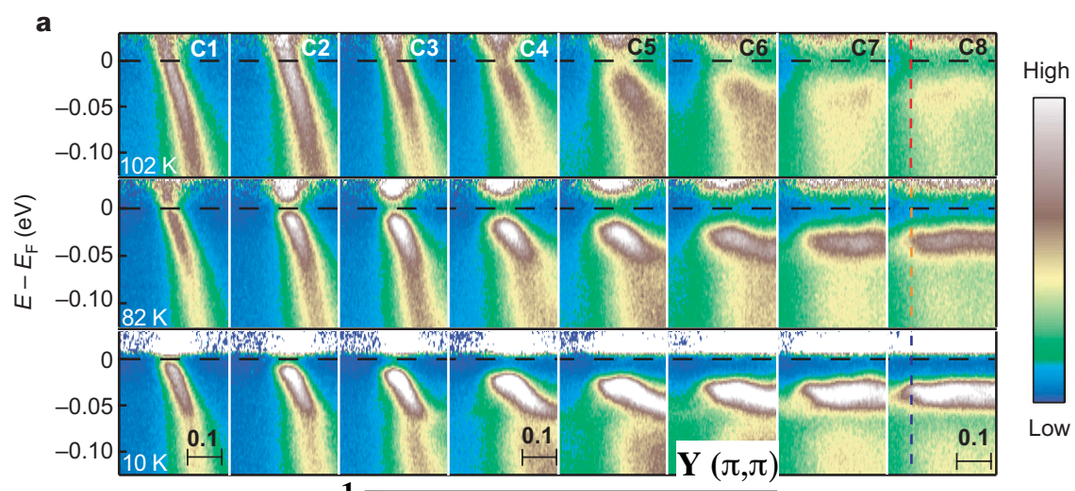
Pushp et al, Science 2009.
BSCCO U61

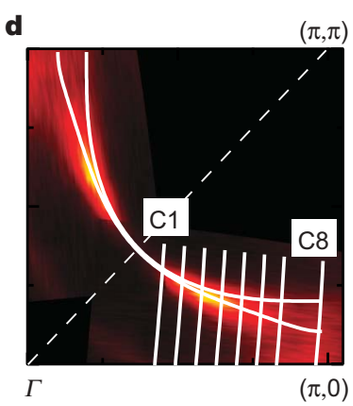
Neutrons



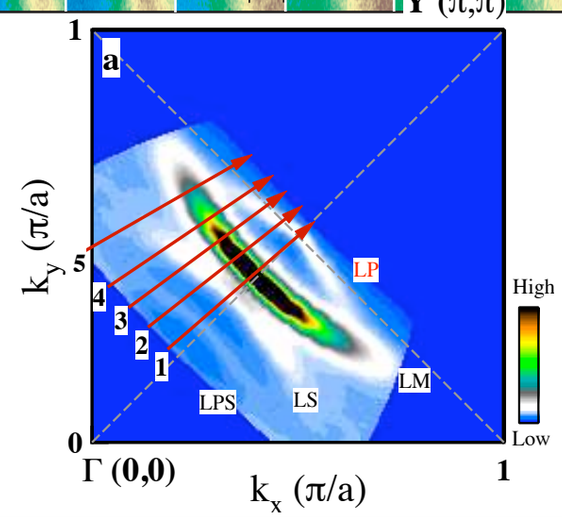
Tranquada review

ARPES





Lee et al, Nature 07.
BSCCO U92



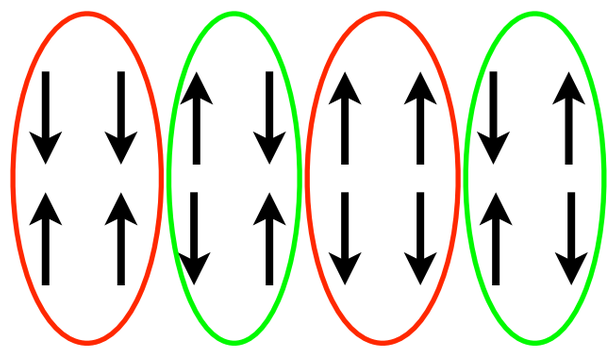
J. Meng et al, arXiv 09
La-BSCCO U18

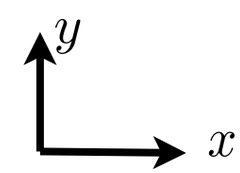
Can we capture some of this phenomenology in a mean field stripe model?

Stripes in mean field

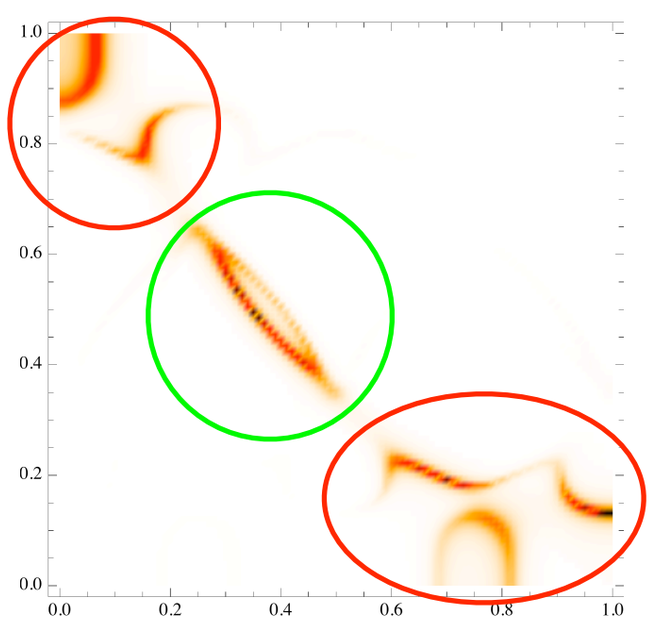
$$m\sigma \sum_{x,y} (-1)^y V(x) n_{x,y,\sigma} = m\sigma \sum_{k_x,k_y,q} V_q c^\dagger_{k_x,k_y,\sigma} c_{k_x-q,k_y-\pi,\sigma}$$

$(-1)^y V(x)$:





$A(k, \epsilon_F)$



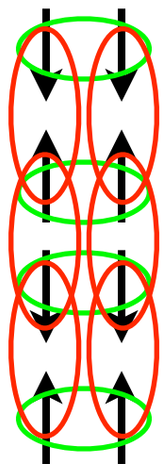
m=0.25t, approx 20% doping

Antinodal states have more weight on the "charge stripes" (higher hole density) and vice versa for nodal states

The Antinodal states are robust (in gap states of AF order)

With pairing on stripes

Single particle caricature of a spin gapped state on hole rich stripes?

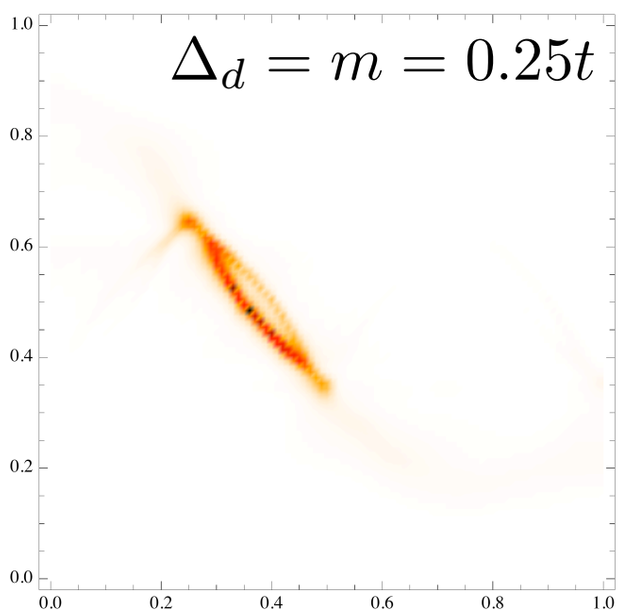


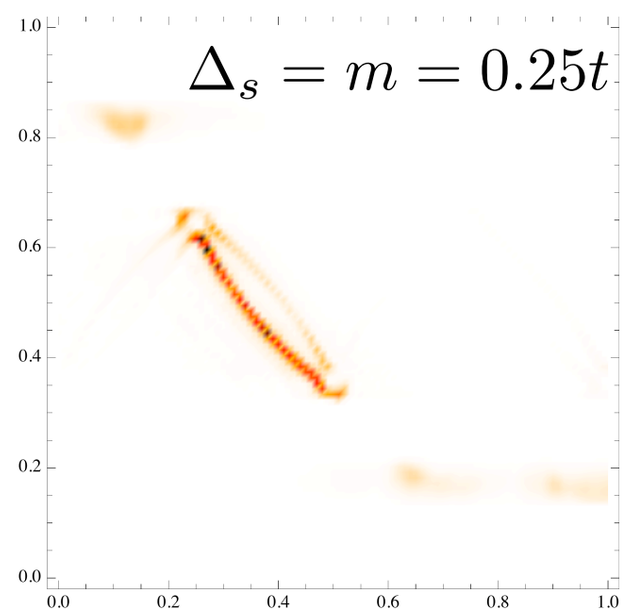
$$\Delta_d e^{i\phi_j}\left(c^\dagger_{x,y,\uparrow}c^\dagger_{x+1,y\downarrow} - c^\dagger_{x,y,\uparrow}c^\dagger_{x,y+1\downarrow}\right) + H.C.$$

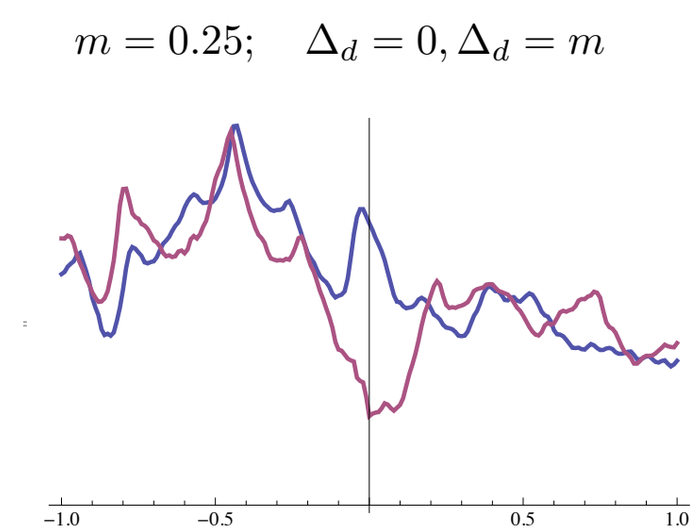
$$\boldsymbol{\Delta}_s e^{i\phi_j} c^\dagger_{x,y,\uparrow}c^\dagger_{x,y\downarrow}$$

ϕ_j random phase, uncorrelated between stripes (1D superconductor along stripe)

Antinodal gap







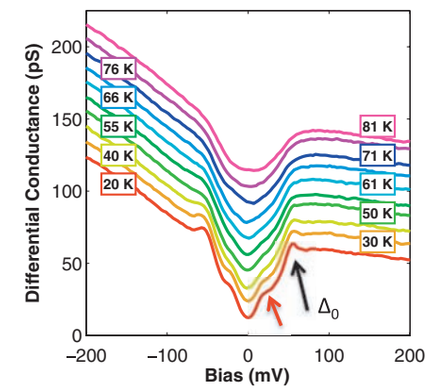
Pseudogap/"Fermi arc" from striped pairing (not smeared d-wave node)

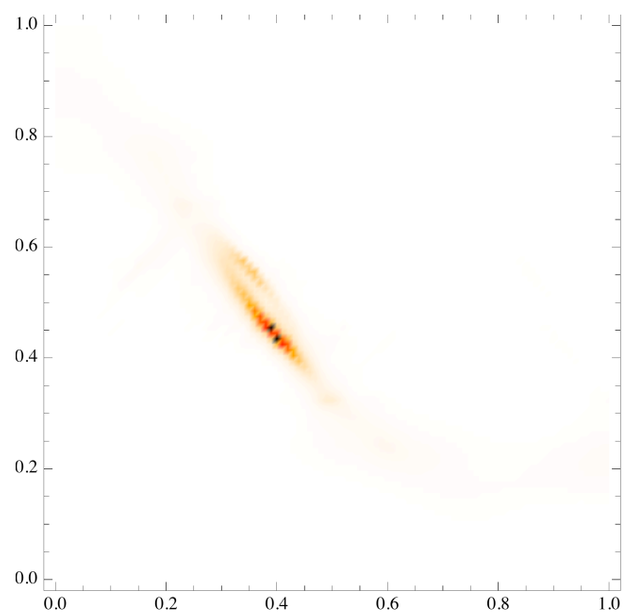
Superconducting state

In a state with glassy stripe order only the q=0 pairing component is expected to order

$$\Delta_0(\cos k_x - \cos k_y)$$

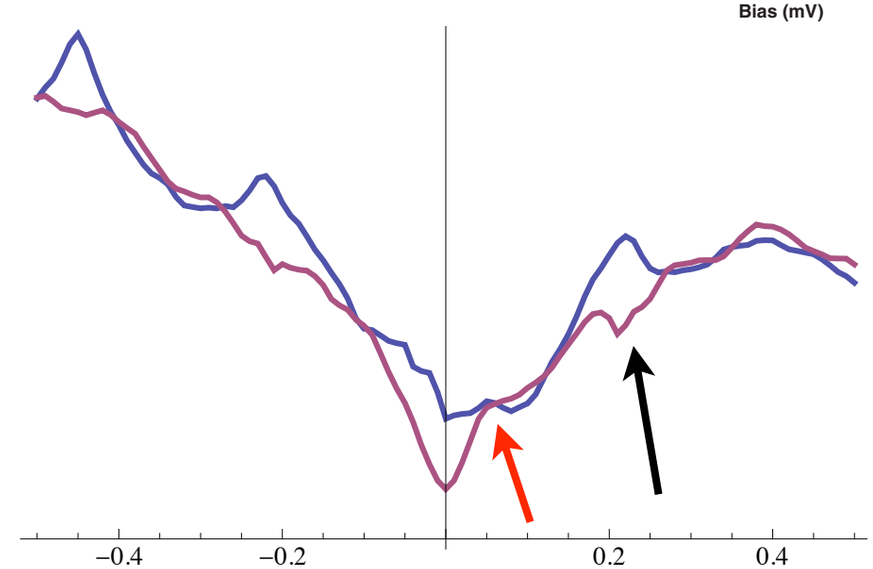
Also keeping the phase disordered pairing on stripes





Point node

(Up to stripe reflections)



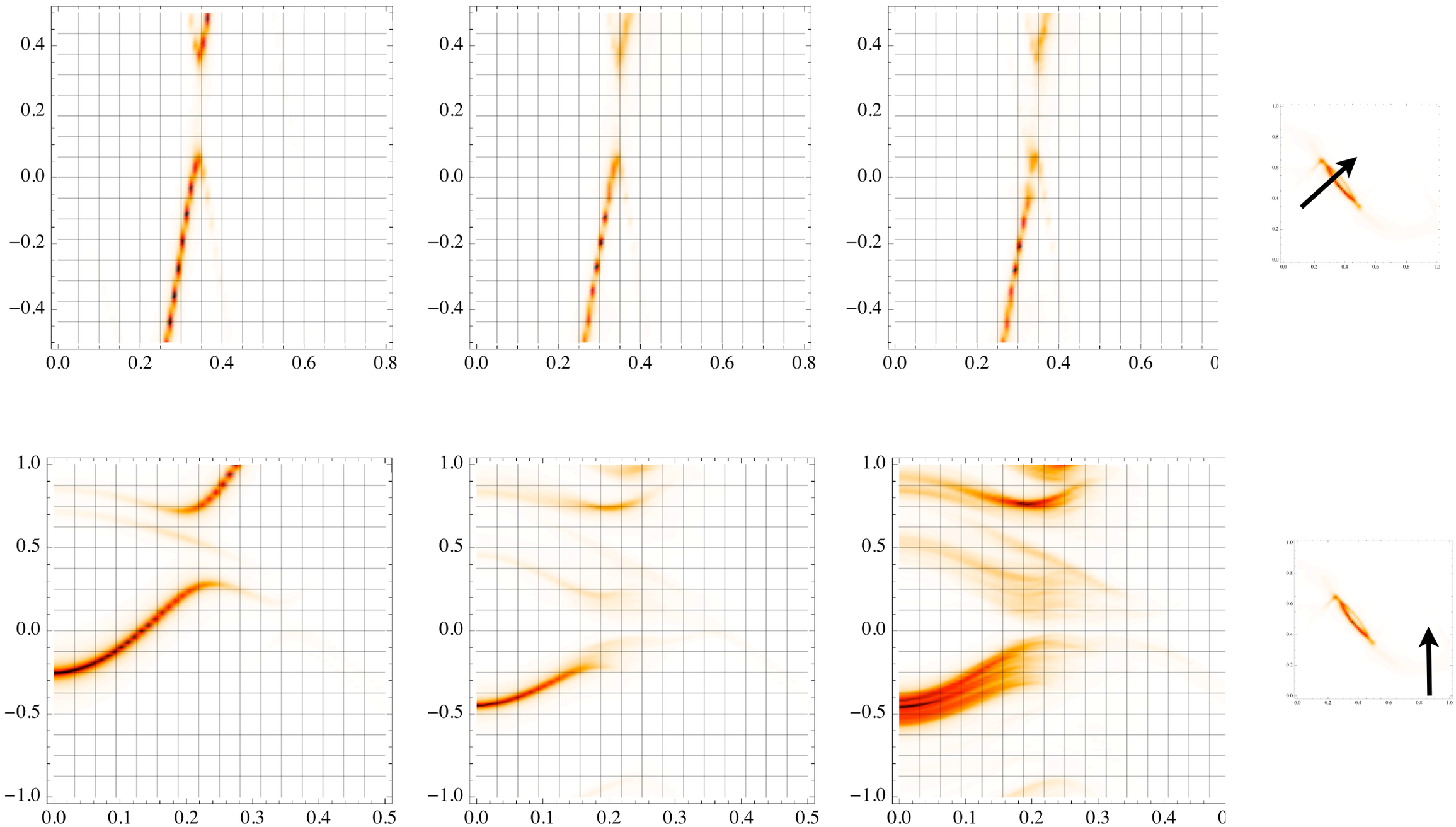
DOS in sc phase (red) exhibiting a sub-gap kink.

From gapping the pocket

Spectral weight cuts

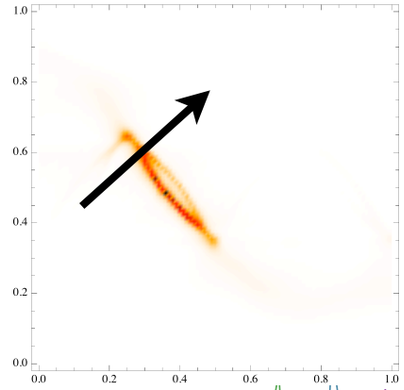
Only stripe order | Pseudogap state | SC state

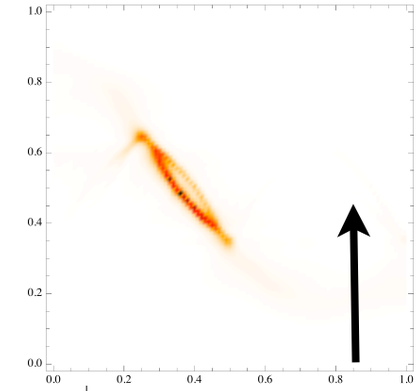
band dispersing through E_F



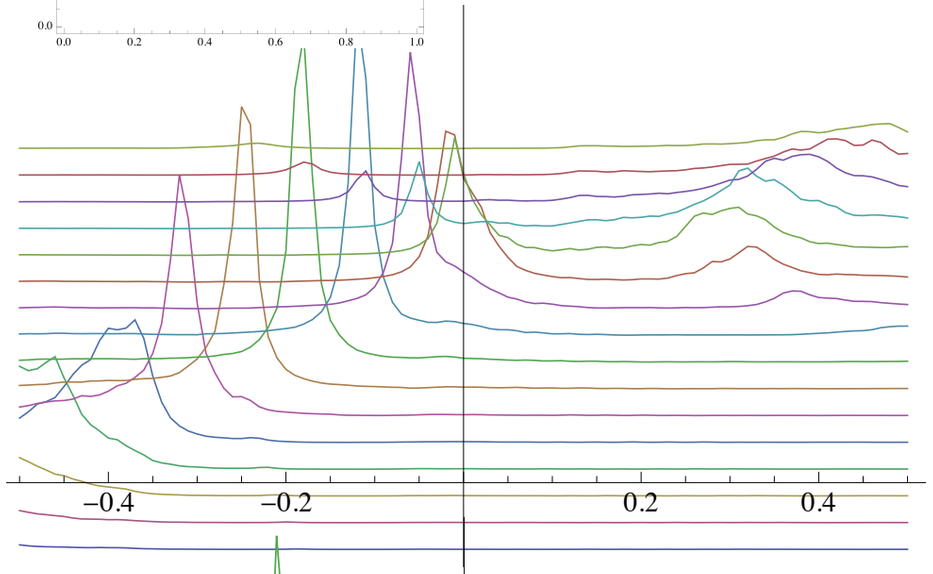
Momentum selective gap from "real space pairing"
(no simple momentum dependence of the pairing)

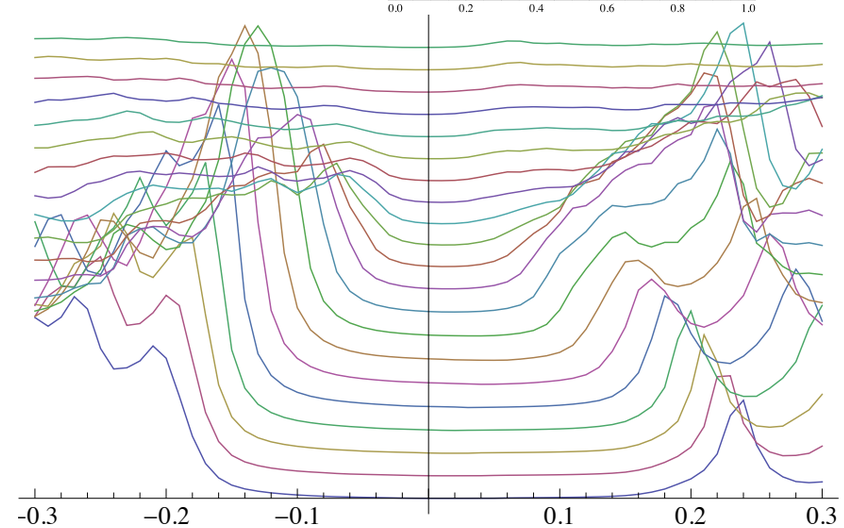
Energy distribution curves



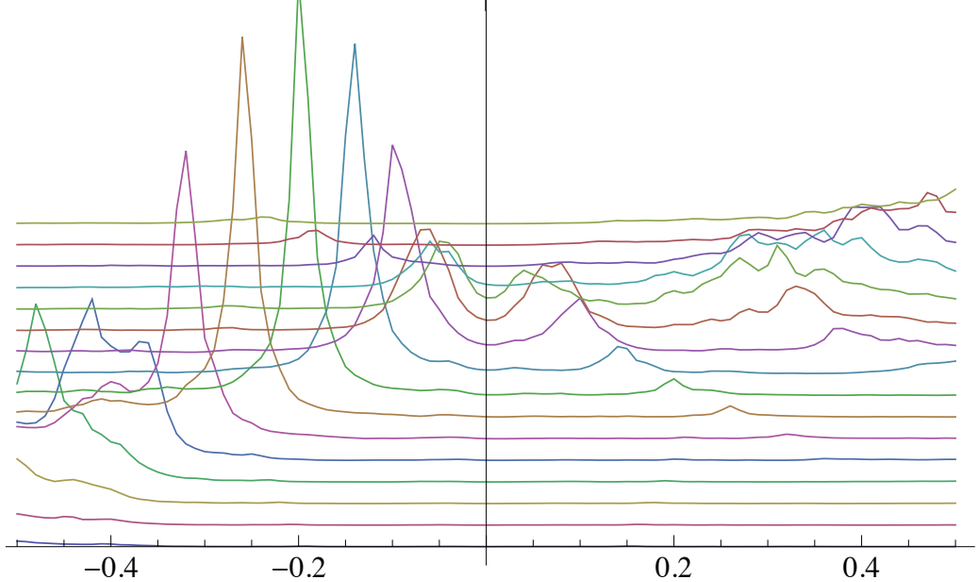


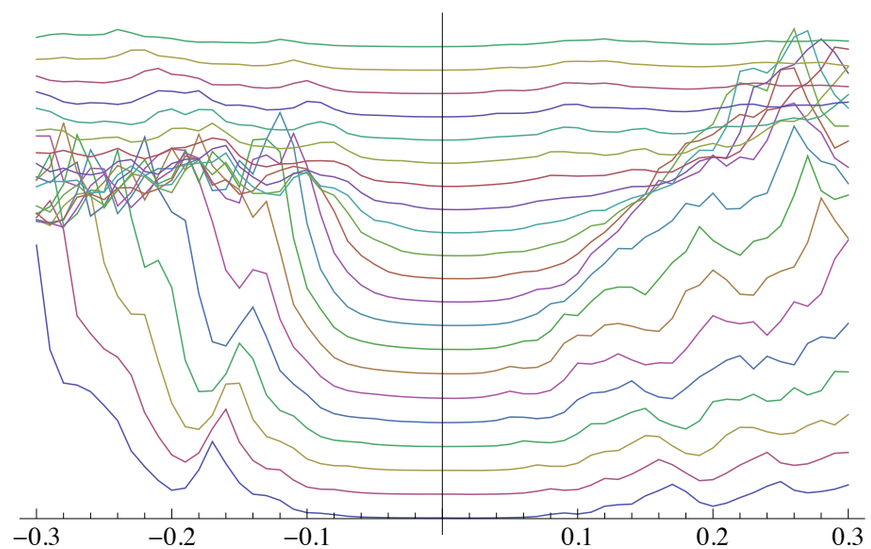
above Tc



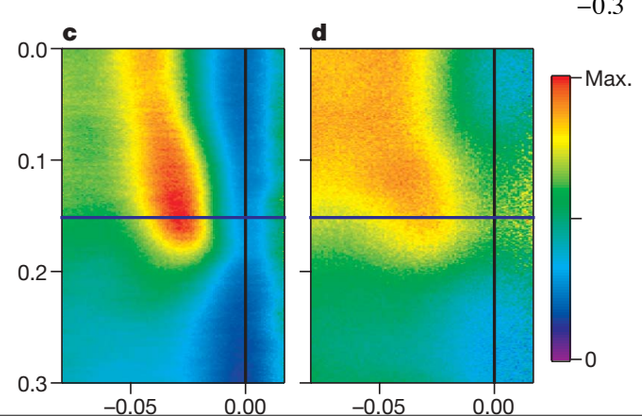


below Tc





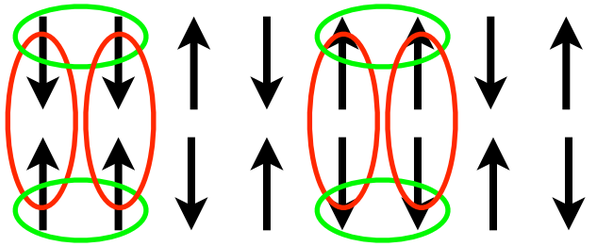
particle-hole
symmetric pseudogap



Yang et al, Nature 2008

(Other) Striped superconductor

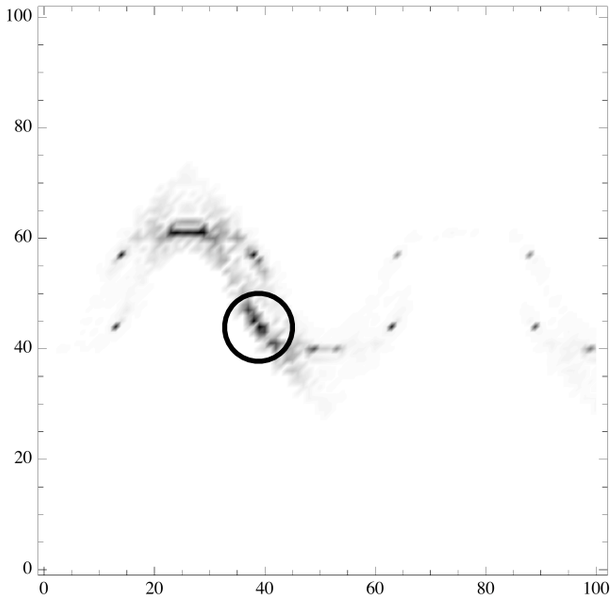
Locking the phase uniformly.

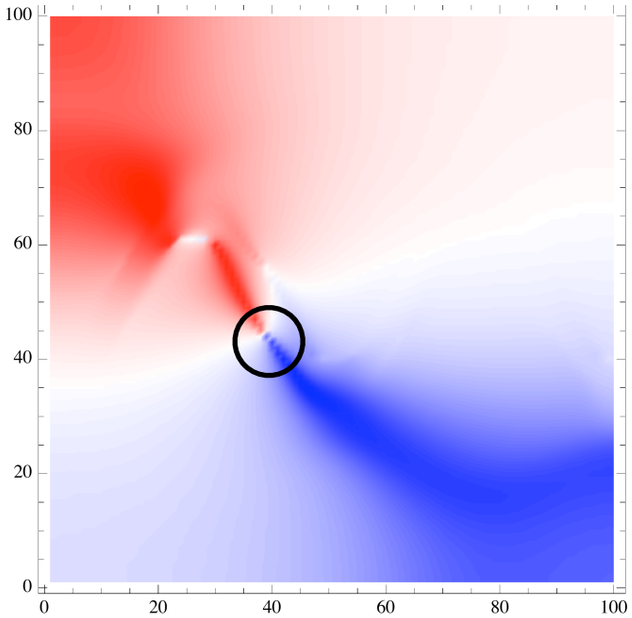


$$< c^\dagger_{k_x,k_y,\uparrow} c^\dagger_{-k_x-q,-k_y,\downarrow} > \quad q = 0, \pm\pi/2, \pi$$

Only point nodes (no Fermi surface)

$$\int_{-\delta}^{\delta} A(k, \epsilon_f - w)$$





$$\Delta_{q=0}$$

Reduced superfluid density in the q=0 component,
reduced Josephson coupling between different stripe directions (LTT phase of LBCO?)

Summary

- Stripe order + pairing on stripes => antinodal pseudogap / nodal Fermi surface
- does not rely on d-wave like paring (it is not a broadened node)
- subgap peak in DOS in SC state due to gapping of the nodal FS

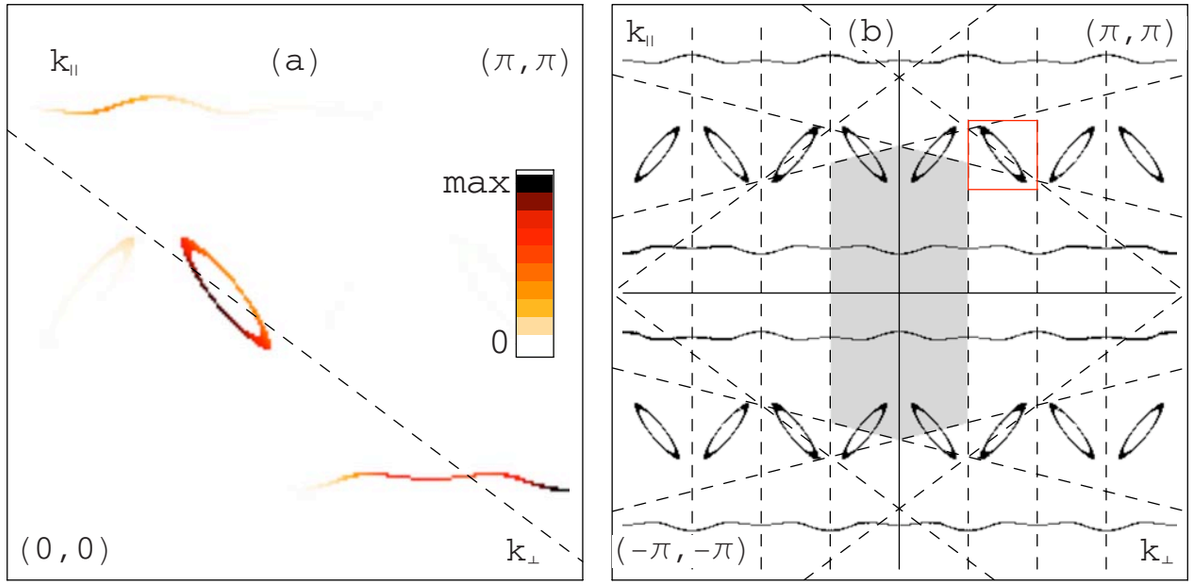
Outlook

- Glassy stripes (including variations in pairing amplitude), should be OK
- **Fluctuating stripes? can we still get the pseudogap?**

(T^* as onset of stripe correlations and striped pair correlations)

Earlier work, M.G. PRB 2008

Ordered



Disordered SDW