Theory for the elementary excitations in hole- and electron-doped cuprates: The kink in ARPES and its relation to the resonance peak

Dirk Manske[1] and Ilya Eremin[2]

[1] ETH Zürich (Switzerland) and Max-Planck-Institute for Solid State Research, Stuttgart (Germany)

[2] TU Braunschweig and Max-Planck-Institute for the Physics of Complex Systems, Dresden (Germany)

Kink feature in high-T_c cuprates:

- why only observed in hole-doped cuprates?
- are the various kinks fingerprints of spin fluctuations?
- how to understand the anisotropy in **k**-space and d-wave pairing simultaneously?

Are the kinks related to the resonance peak and characteristic for other unconventional superconductors like Sr_2RuO_4?

Anisotropic spin excitations in high-T_c cuprates:

Fermi-liquid theory? stripe scenario?

new experiments on fully untwinned YBCO

earlier data on partially twinned YBCO by Mook *et al.* (Nature, 2000) reveal 1D excitations

Keimer's new results (Nature 2004):

- INS data show 2D magnetic fluctuations
- but strong anisotropy
  $\longrightarrow$ one-dimensional width and amplitude anisotropy (dependent on excitation energy)

Resonance peak below T_c in high-T_c cuprates:

feedback effect of superconductivity?

why is the resonance peak only observed in hole-doped cuprates with a constant ratio for ω_{res}/T_c?

what is the dispersion of the resonance peak? (are bilayer effects important?)

Is a Schrieffer-Scalapino-Wilkins-like analysis for high-T_c cuprates possible?

[see D. Manske *et al.*, PRB **67**, 134520 (2003)]

Aim:

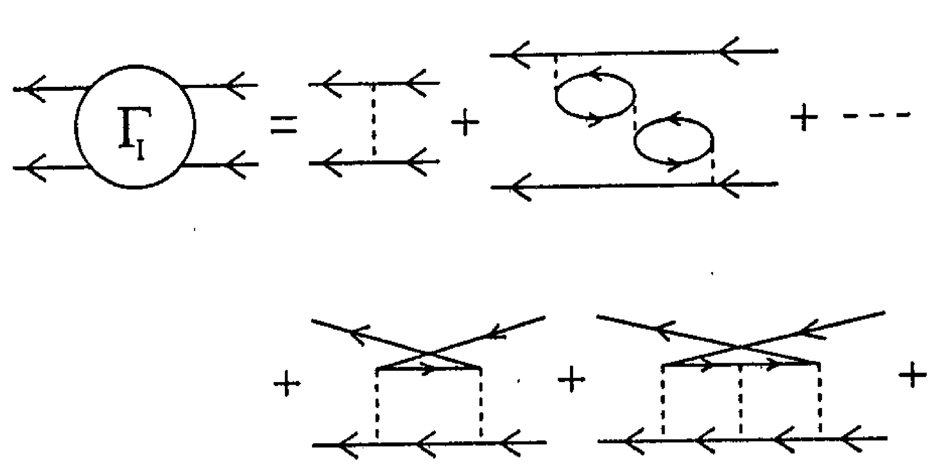
Generalized Eliashberg equations for spin fluctuation-mediated Cooper-pairing (FLEX approximation) $\longrightarrow$

- understanding of the kink features and d-wave
- understanding of the resonance peak, its dispersion, and the strong magnetic anisotropy

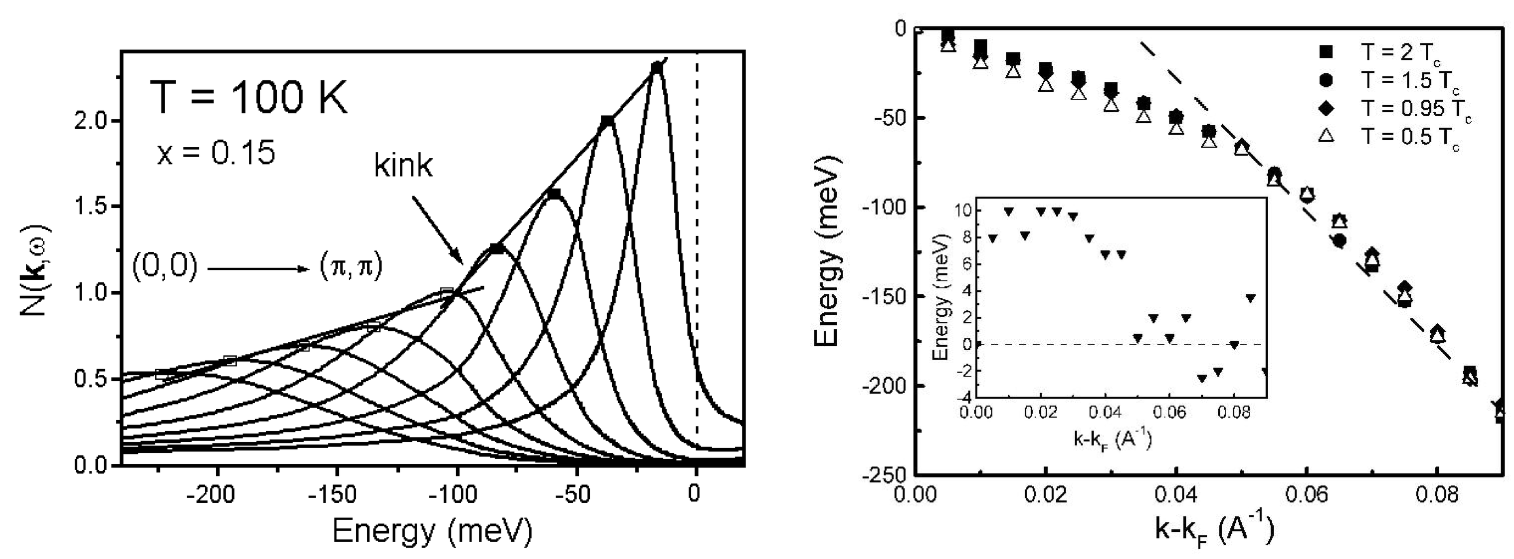
Microscopic theory for Cooper-pairing

Bethe-Salpeter equation (solved self-consistently using the Hubbard model):

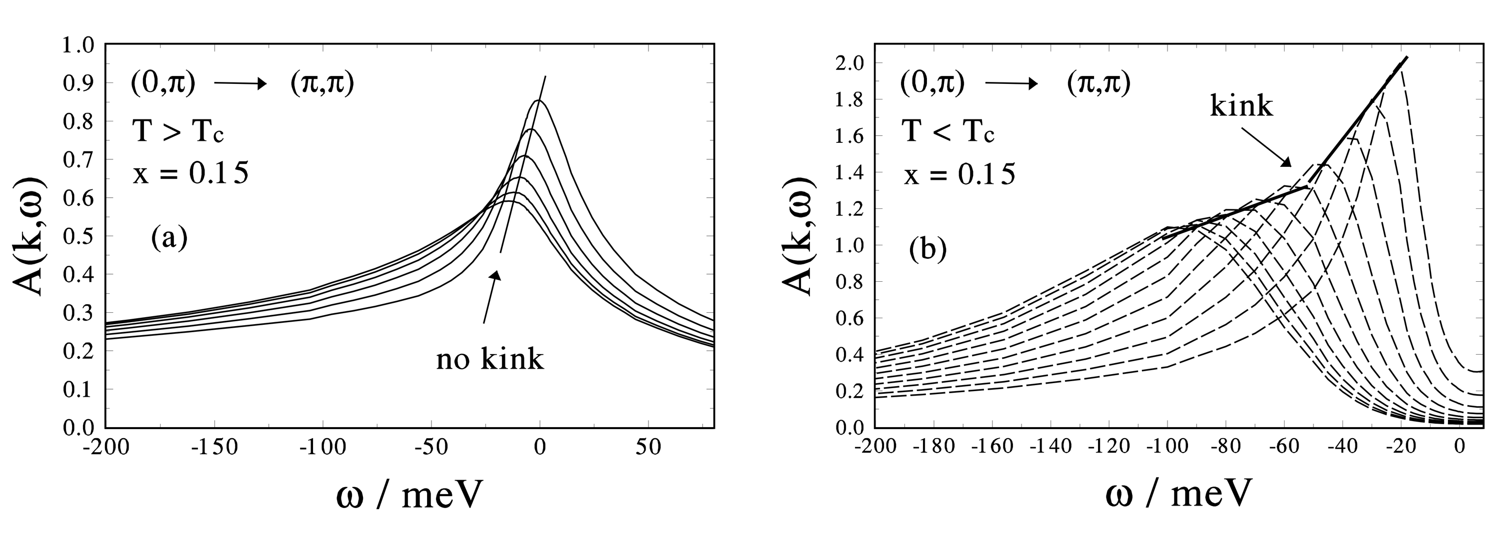
$$H = -\sum_{\langle ij\rangle\,\sigma} t_{ij}\left(c^+_{i\sigma}c_{j\sigma} + c^+_{j\sigma}c_{i\sigma}\right) + U\sum_i n_{i\uparrow}n_{i\downarrow}$$



leads to a kink in the nodal direction (above and below T_c, PRL 2001):



antinodal direction: kink occurs only below T_c (feedback effect, PRB 2003)



kinks occur due to a renormalized energy dispersion $\omega_{\mathbf{k}} = \epsilon_{\mathbf{k}} + \mathrm{Re}\ \Sigma(\mathbf{k},\omega)$

$\Rightarrow$ fingerprints of spin fluctuations!

anisotropy in **k**-space and d-wave symmetry can be explained, but:

$\Rightarrow$ isotope effect (Lanzara *et al.*) $\rightarrow$ **contribution of phonons?**

Results for the resonance peak and magnetic anisotropy

spin excitation (calculated self-consistently)

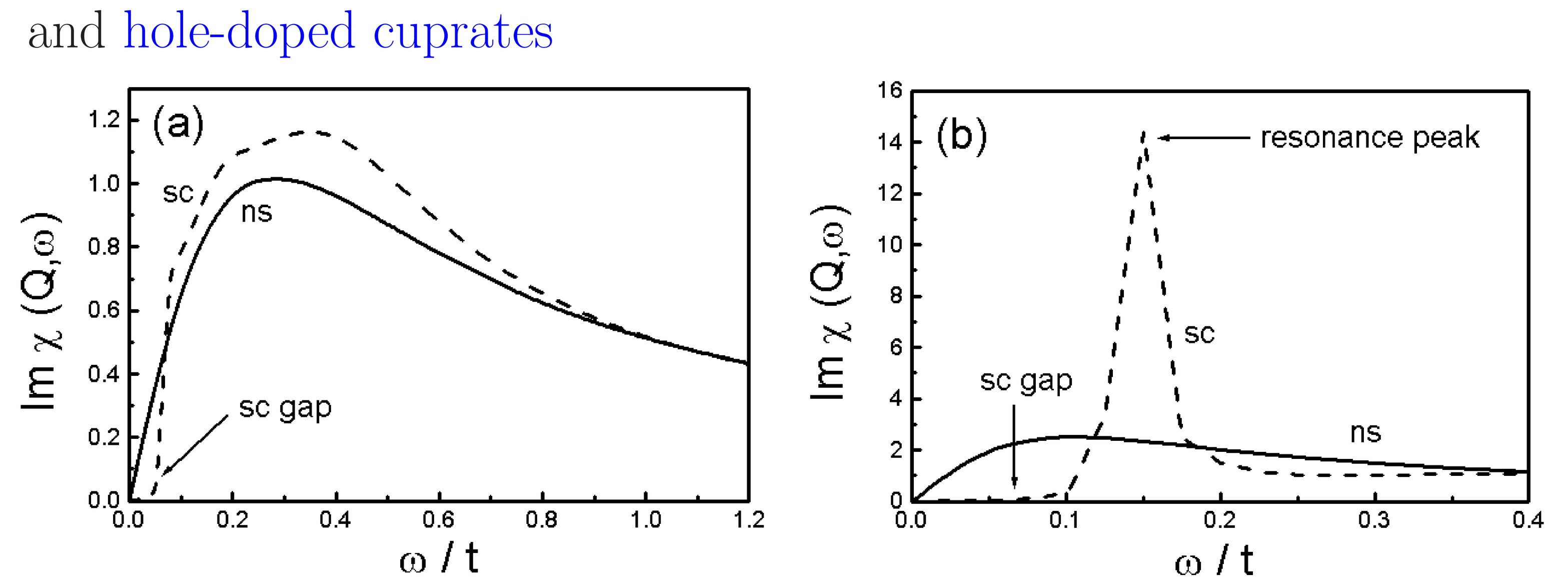
$$\mathrm{Im}\,\chi(\mathbf{Q},\omega) = \frac{\mathrm{Im}\,\chi_0(\mathbf{Q},\omega)}{(1-U\,\mathrm{Re}\,\chi_0(\mathbf{Q},\omega))^2 + U^2\,(\mathrm{Im}\,\chi_0(\mathbf{Q},\omega))^2}$$

may become resonant if

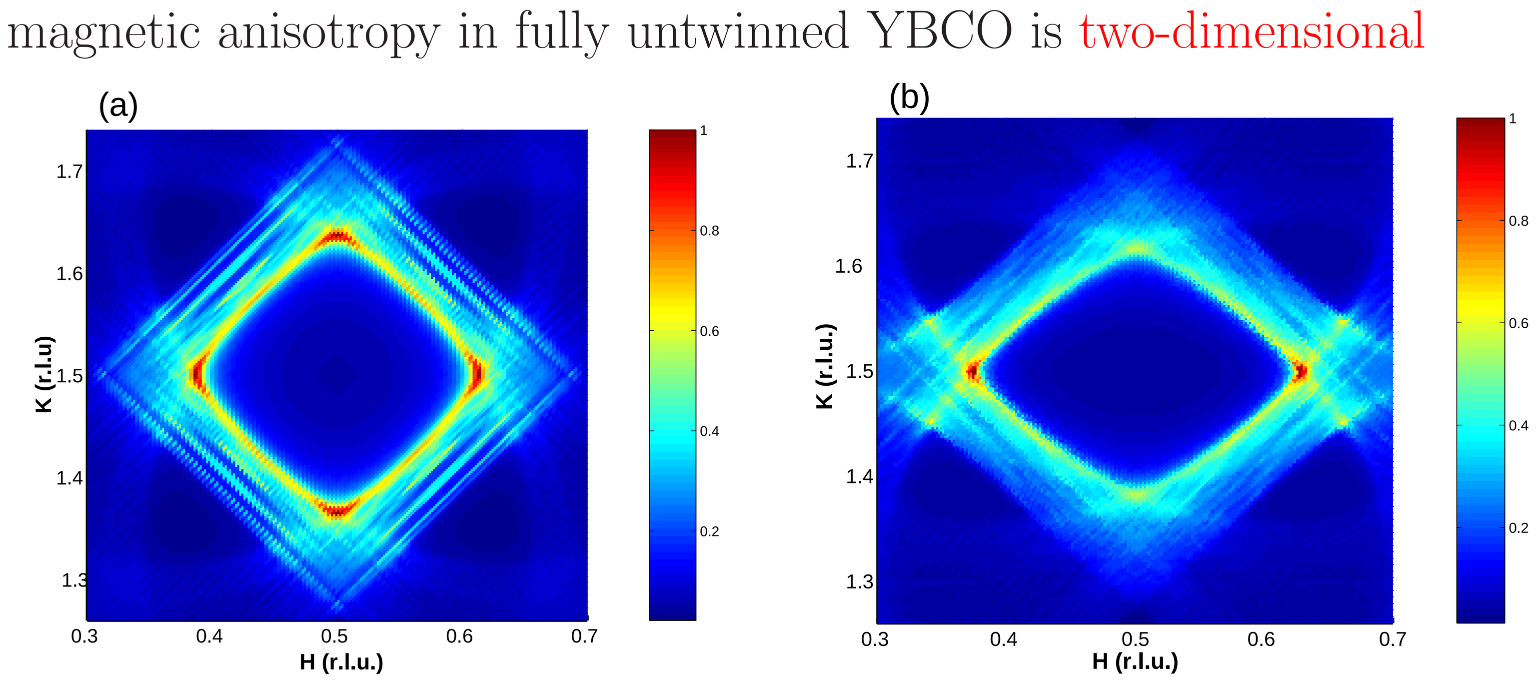
$$\frac{1}{U_{cr}} = \mathrm{Re}\ \chi_0(\mathbf{q}=\mathbf{Q},\omega=\omega_{res})$$

is (nearly) fulfilled.

- results for electron- (no resonance peak, only feedback effect!) and hole-doped cuprates



- we find a parabolic dispersion of the resonance peak and a constant ratio for ω_{res}/T_c in hole-doped cuprates
- magnetic anisotropy in fully untwinned YBCO is two-dimensional



tetragonal case: ring-like excitations, 4 incommensurate peaks

orthorombic case ($t_x \neq t_y$): 2 peaks are suppressed

$\Rightarrow$ alternative explanation to the stripe scenario