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

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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 \(\text{Sr}_2\text{RuO}_4\)?

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 \textit{et al.} (Nature, 2000) reveal 1D excitations
- Keimer’s new results (Nature 2004):
  - INS data show 2D magnetic fluctuations
  - but strong anisotropy
    \(\rightarrow\) 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 \(\omega_{\text{res}}/T_c\)?
- 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 \textit{et al.}, \textit{PRB} \textbf{67}, 134520 (2003)]

Aim:

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

\[ H = - \sum_{\langle ij \rangle \sigma} t_{ij} (c_{i\sigma}^+ c_{j\sigma} + c_{j\sigma}^+ c_{i\sigma}) + U \sum_i n_{i\uparrow} n_{i\downarrow} \]

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)

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 \(\omega_{\text{res}}/T_c\) 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

Microscopic theory for Cooper-pairing

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

\[ \text{Im} \chi(Q, \omega) = \frac{\text{Im} \chi_0(Q, \omega)}{(1 - U \text{Re} \chi(Q, \omega))^2 + U^2 (\text{Im} \chi(Q, \omega))^2} \]

may become resonant if

\[ \frac{1}{U_{cr}} = \text{Re} \chi_0(Q = Q, \omega = \omega_{\text{res}}) \]

is (nearly) fulfilled.

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