A theory of the underdoped cuprates


Competing orders in the underdoped cuprates, Eun Gook Moon and S. Sachdev, *to appear*
Phenomenological quantum theory of competing orders 

Competition between superconductivity (SC) and spin-density wave (SDW) order

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Competition between superconductivity (SC) and spin-density wave (SDW) order

- Upper-critical field, $H_{c2}$, decreases as SDW is enhanced with decreasing doping ($r$)

Phenomenological quantum theory of competing orders

Competition between superconductivity (SC) and spin-density wave (SDW) order


- SDW order is more stable in the metal than in the superconductor: $r_{cm} > r_c$. 
Phenomenological quantum theory of competing orders

Competition between superconductivity (SC) and spin-density wave (SDW) order

- For doping with \( r_c < r < r_{cm} \), SDW order appears at a quantum phase transition at \( H = H_{sdw} > 0 \).

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Competition between superconductivity (SC) and spin-density wave (SDW) order

Neutron scattering on La$_{1.9}$Sr$_{0.1}$CuO$_4$

Phenomenological quantum theory of competing orders

Competition between superconductivity (SC) and spin-density wave (SDW) order


Neutron scattering on La_{1.855}Sr_{0.145}CuO_{4}

J. Chang et al., arXiv:0902.1191
Phenomenological quantum theory of competing orders

Competition between superconductivity (SC) and spin-density wave (SDW) order


Neutron scattering on YBa$_2$Cu$_3$O$_{6.45}$

D. Haug *et al.*, arXiv:0902.3335
Phenomenological quantum theory of competing orders

Competition between superconductivity (SC) and spin-density wave (SDW) order

Quantum oscillations without Zeeman splitting

Spin density wave theory in hole-doped cuprates

Increasing SDW order

Spin density wave theory in hole-doped cuprates

Fermi pockets in hole-doped cuprates

Begin with SDW ordered state, and focus on fluctuations in the orientation of the SDW order parameter $\vec{\phi}$, by using a unit-length bosonic spinor $z_{\alpha}$

$$\vec{\phi} = z_{\alpha}^* \vec{\sigma}_{\alpha\beta} z_{\beta}$$
Increasing SDW order $d$-wave pairing of the electrons is associated with:

- **Strong $s$-wave** pairing of $g_{\pm}$
- **Weak $p$-wave** pairing of $f_{\pm\nu}$. 
Field-doping phase diagram has all the key features of the phenomenological theory of competing orders.
Finite temperature “pseudogap”

Because $r_{cm} > r_c$, for $T > T_c$ there is local SDW order which is disordered by thermal fluctuations.