Ising version of t-J model: Implications for underdoped cuprates

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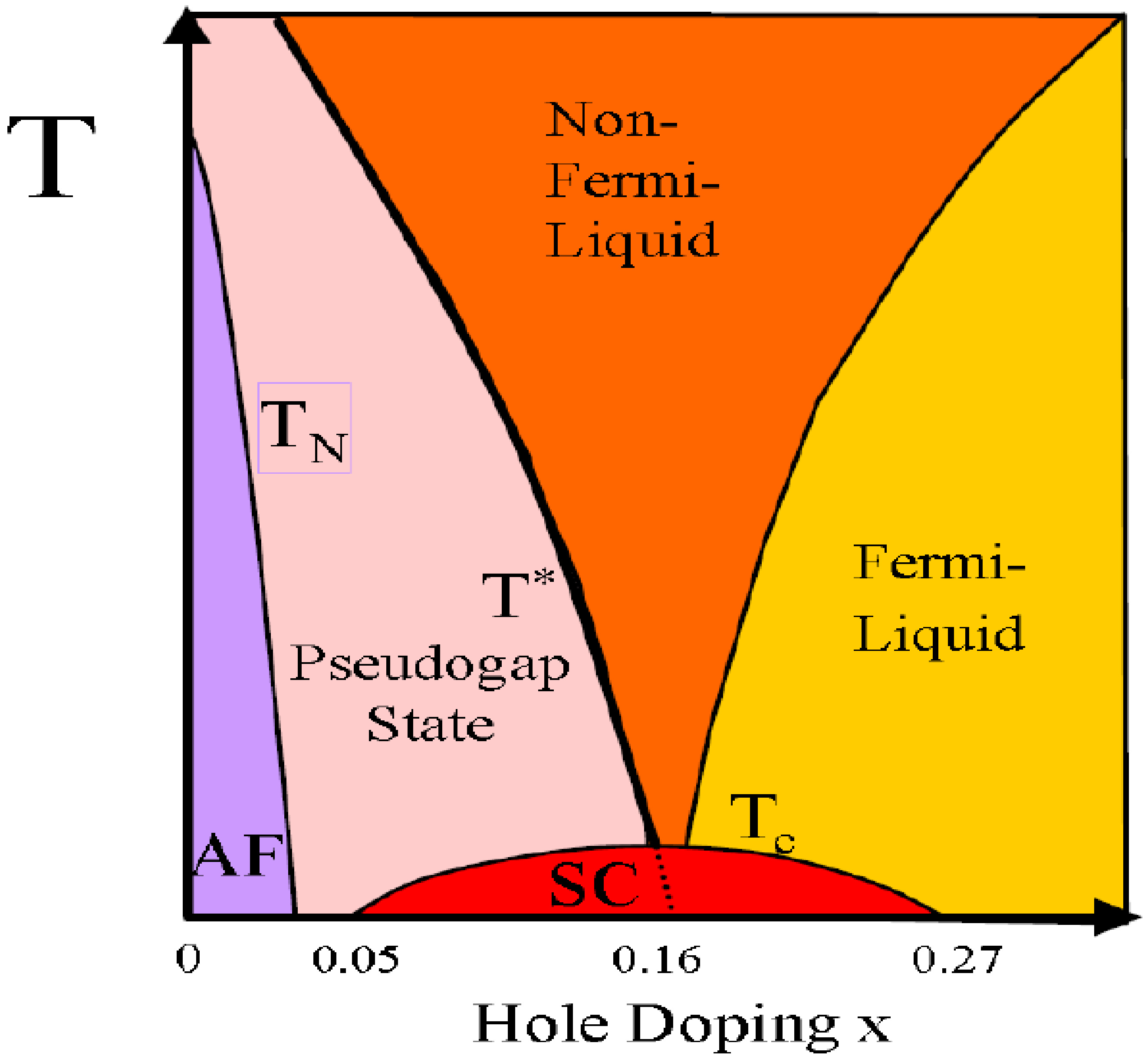
OUTLINE

Cuprate Phase Diagram

Doped Ising Model

Magnetic Correlations in Lightly Doped Cuprates



T
Non-
Fermi-
Liquid
T N
T*
Pseudogap
State
Fermi-
Liquid
Tc
AF
SC
0
0.05
0.16
0.27
Hole Doping x

t–J model (SU(2) globally invariant)

$$H_{t-J} = -\sum_{ij\sigma} t_{ij}\tilde{c}_{i\sigma}^{\dagger}\tilde{c}_{j\sigma} + J\sum_{\langle ij\rangle}\left(\boldsymbol{Q}_i\boldsymbol{Q}_j - \frac{1}{4}\tilde{n}_i\tilde{n}_j\right)$$

where $\tilde{c}_{i\sigma} = Pc_{i\sigma}P = c_{i\sigma}(1-n_{i,-\sigma})$ is the projected electron operator (to exclude the on-site double occupancy),

$$\boldsymbol{Q}_i = \sum_{\sigma,\sigma'} c_{i\sigma}^{\dagger}\boldsymbol{\tau}_{\sigma\sigma'}c_{i\sigma'}$$

t–J_z model. (SU(2) globally invariant at $J_z = 0$)

$$H_{t-J_z} = -\sum_{ij\sigma} t_{ij}\tilde{c}_{i\sigma}^{\dagger}\tilde{c}_{j\sigma} + J_z\sum_{\langle ij\rangle}\left(Q_i^z Q_j^z - \frac{1}{4}\tilde{n}_i\tilde{n}_j\right)$$

Slave spin-dopon repr:

Ribeiro, Wen, Phys. Rev. Lett. (2005), v.95, 057001:

$$\tilde{c}_{i\uparrow}=\frac{1}{\sqrt{2}}[S^+S^-d_\downarrow - S^-d_\uparrow]$$

Ferraz, Kochetov, Uchoa, Phys. Rev. Lett. (2007), v.98, 069701:

$$\vec{S}_i \cdot \vec{s}_i + \frac{3}{4}n_i=0$$

$$H_{tJ} = \sum_{ij\sigma} T_{ij} d^\dagger_{i\sigma} d_{j\sigma} + J \sum_{ij} \vec{S}_i \cdot \vec{S}_j + \lambda \sum_i \vec{S}_i \cdot \vec{s}_i$$

$$T_{ij} = 2t_{ij} + (3\lambda/4 - \mu)\delta_{ij}$$

$$\lambda \to +\infty$$

Ising version of t-J model

Maska, Mierzejewski, Ferraz,Kochetov,
J.Phys.C 21 , 045703 (2009)

Maska, Mierzejewski, Kochetov, Vidmar,
Bonca, Sushkov, Phys. Rev. B85 (2012) 245113

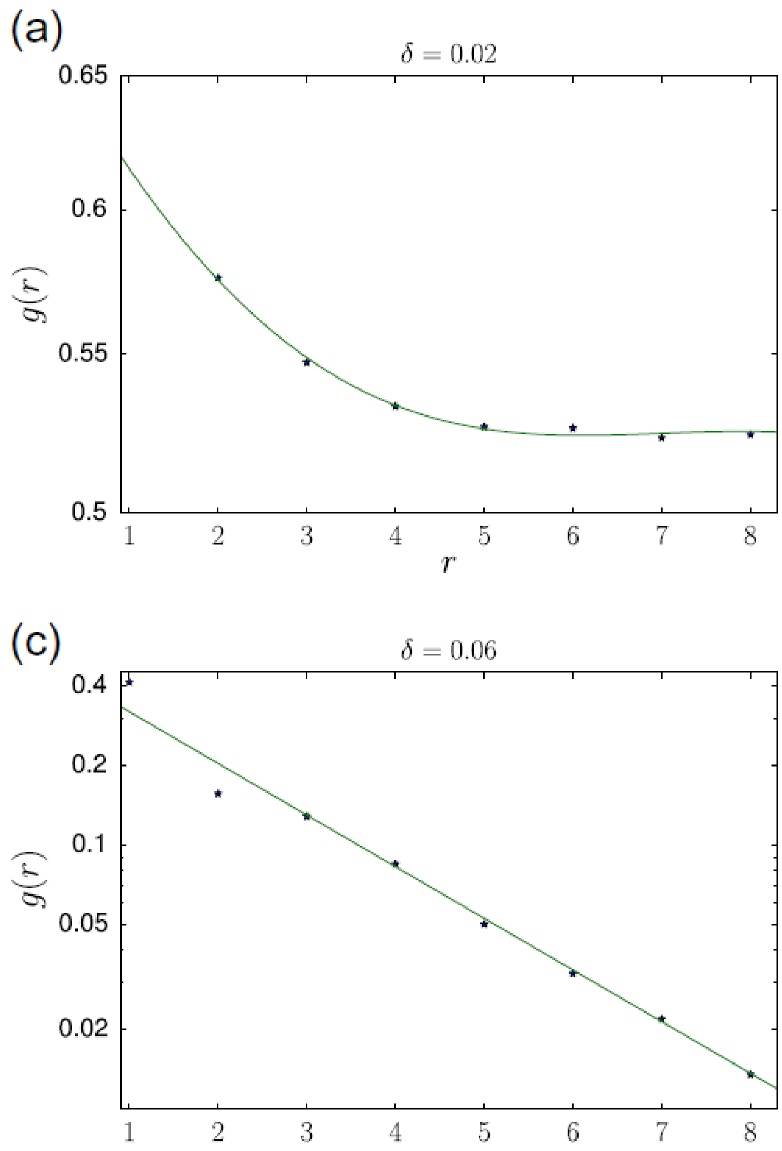
$$H_{t-J}^{Ising} = \sum_{ij\sigma} t_{ij} d_{i\sigma}^{\dagger} d_{j\sigma} + J \sum_{\langle ij \rangle} \left[\left(S_i^z S_j^z - \frac{1}{4} \right) \right.$$

$$+ \lambda \sum_i \left(S_i^z M_i^z + \frac{1}{4} n_i^d \right), \quad \lambda \to +\infty.$$

(Z_2 global symmetry at ∀ t ,J)

No double occupancy constraint and magnetic correlations in cuprates

Maska, Mierzejewski, Kochetov, Phil. Mag. V.95 (2015), 583



Distance dependence of the spin–spin correlation function $g(r)$ for different hole contrentations δ

The long-range AF order vanishes at hole concentration below 6 %, which remains in a perfect agreement with experimental data on high-temperatures superconductors. This is very impressive result, as many other techniques give much higher values of concentration, at which AF disappears. The main mechanism responsible for the destruction of the long-range AF order has its origin in the interplay of the hole mobility and minimization of the spin-spin exchange energy.

This strong competition is strictly related to the constraint of no double occupancy.