COLLÈGE DE FRANCE
1530

Chaire de Physique de la Matière Condensée

Cuprates supraconducteurs : où en est-on ?

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Cycle 2010-2011
Cours 4 – 23/11/2010

Today's seminars:
a neutron scattering festival !

- Yvan Sidis, LLB, CEA&CNRS

Dynamique de spins dans les oxydes de cuivre supraconducteurs à haute température critique : apport de la spectroscopie neutronique

- Philippe Bourges, LLB, CEA&CNRS

Ordre et excitations magnétiques dans la phase pseudogap des cuprates supraconducteurs : existence de boucles de courants ?

Lecture 4

Resonating Valence Bond (RVB) Theories:

- *Key ideas*
- *Early predictions*
- *Today's significance vs. known phenomenology*
- *Limitations*

Early predictions of RVB approaches:

- d-wave pairing
- Pseudogap

(for spin degrees of freedom)

Early hints:

Possibility of orbital currents violating Time-reversal invariance (flux-phases)

(cf. today's seminar by P. Bourges)

Mostly on blackboard today !

- For references and (considerable) more details, see:
- P.A.Lee, N.Nagaosa and X.G.Wen, Reviews of Modern Physics, 78 (2006) 17.
- P.A. Lee, Rep. Prog. Phys. 71 (2008) 012501

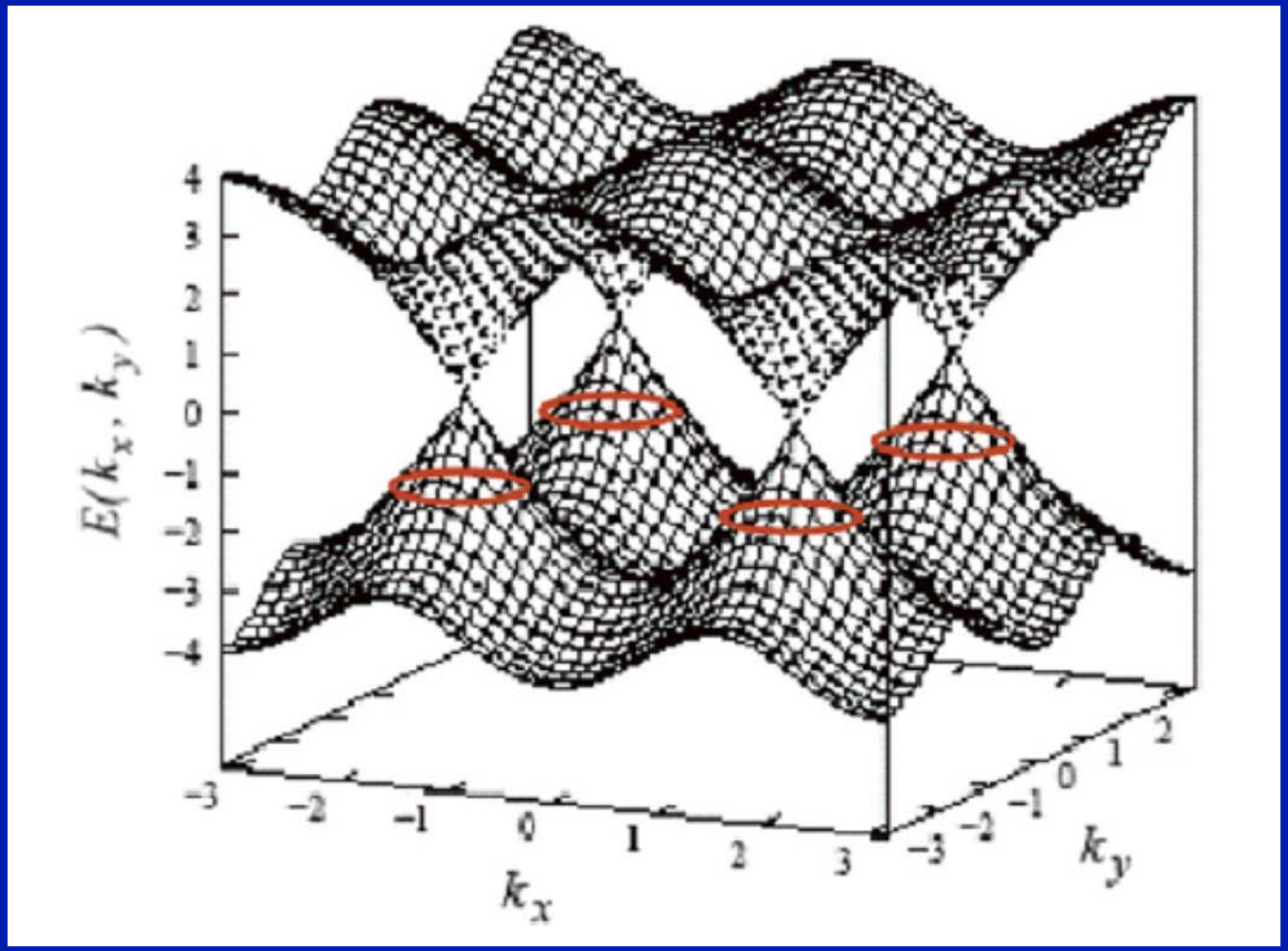

Figure 7. The energy dispersion of the staggered flux phase. Note the massless Dirac spectrum at the nodal points $(\pm\frac{\pi}{2}, \pm\frac{\pi}{2})$. The figure shown is for the special case of π-flux. In general, the nodal spectra becomes anisotropic. With doping Fermi pockets are formed when the Fermi energy crosses the energy spectrum.

SU(2) symmetry at half-filling

$$L_1 = \frac{\tilde{J}}{2}\sum_{\langle ij\rangle} \mathrm{Tr}[U_{ij}^{\dagger}U_{ij}] + \frac{\tilde{J}}{2}\sum_{\langle ij\rangle,\sigma} (\Phi_{i\sigma}^{\dagger}U_{ij}\Phi_{j\sigma} + \mathrm{c.c.})$$
$$+ \sum_{i\sigma} f_{i\sigma}^{*}(\partial_\tau - i\lambda_i)f_{i\sigma} + \sum_i b_i^{*}(\partial_\tau - i\lambda_i + \mu_B)b_i$$
$$- \sum_{ij,\sigma} t_{ij} b_i b_j^{*} f_{i\sigma}^{*} f_{j\sigma},$$

where

$$U_{ij} = \begin{pmatrix} -\chi_{ij}^{*} & \Delta_{ij} \\ \Delta_{ij}^{*} & \chi_{ij} \end{pmatrix}.$$

$$\Phi_{i\uparrow} = \begin{pmatrix} f_{i\uparrow} \\ f_{i\downarrow}^{*} \end{pmatrix}, \quad \Phi_{i\downarrow} = \begin{pmatrix} f_{i\downarrow} \\ -f_{i\uparrow}^{*} \end{pmatrix}.$$

Redundancy of Description of a spin by fermions

At half-filling $b=\mu_B=0$ and the mean-field solution corresponds to $\lambda_i=0$. The Lagrangian is invariant under

$$\Phi_{i\sigma} \rightarrow W_i \Phi_{i\sigma}, \tag{47}$$

$$U_{ij} \rightarrow W_i U_{ij} W_j^{\dagger}, \tag{48}$$

Relating the π-flux phase and d-wave state by SU(2) symmetry

$$U_{ij}^{\pi\text{-flux}} = -\chi[\tau^3 - i(-1)^{i_x+j_y}]$$

$$U_{i,i+\mu}^{d} = -\chi(\tau^3 + \eta_\mu \tau^1), \quad (\eta_x = +1\ ,\ \eta_y = -1)$$

$$U_{ij}^{SF} = W_i^{\dagger} U_{ij}^{d} W_j,$$

where

$$W_j = \exp\left[i(-1)^{j_x+j_y} \frac{\pi}{4} \tau^1 \right].$$

SU(N) large-N :

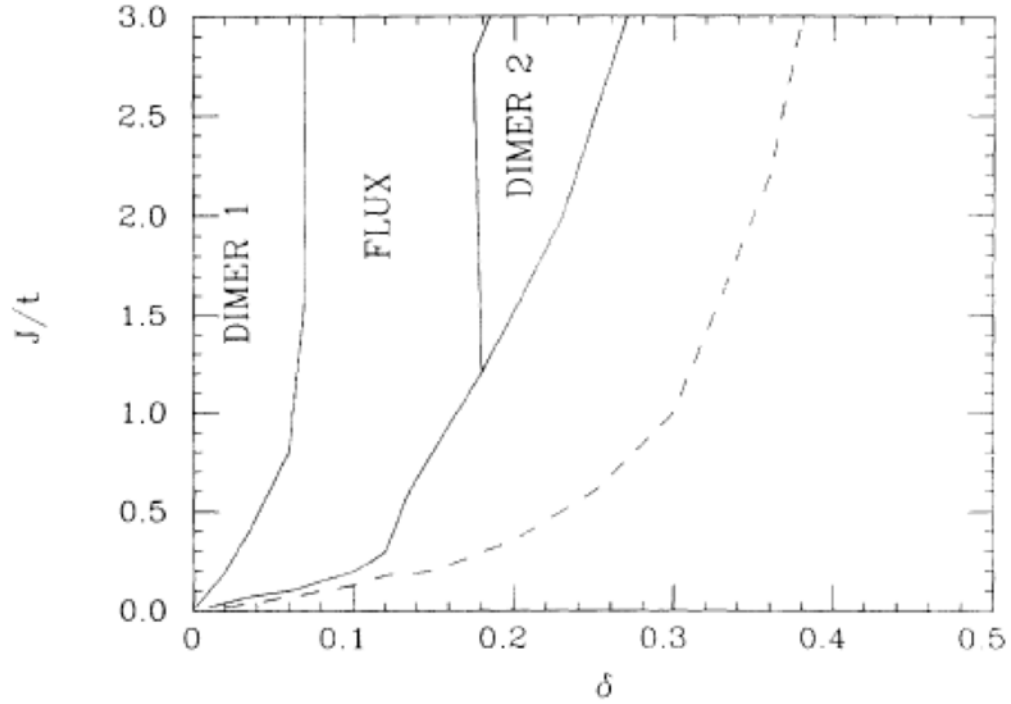

FIG. 1. Phase diagram for various values of J/t as a function of doping δ. The dashed line is the phase separation line. $J/t = 0.02$ is the minimum value here considered.

Grilli, Castellani, Kotliar, PRB 1992