

Oscillations quantiques dans
les supraconducteurs à haute
température critique:

Collaborations



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M. Nardone

S. Lepault



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and *T. Carrington*

A. Bangura

J. Fletcher

R. A. Cooper



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St. Andrews

A. P. Mackenzie



D. Bonn

R. Liang

W. Hardy



L. Taillefer

N. Doiron-Leyraud

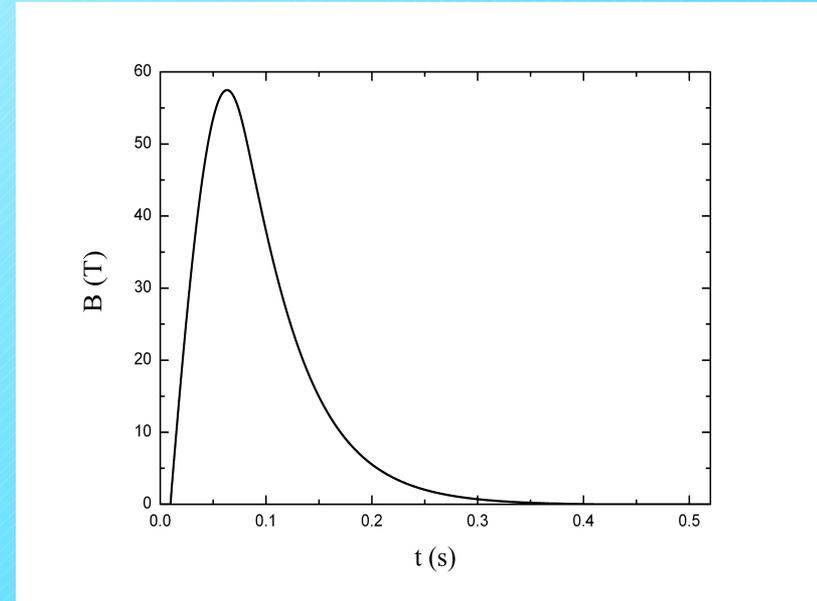
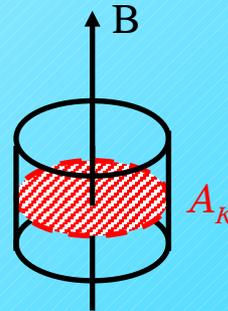
D. LeBœuf

J-B. Bonnemaïson

Mesures d'oscillations quantiques:

- Sonde volumique
- Conséquence de la quantification des niveaux d'énergie en niveaux de Landau en présence de champ magnétique
- Oscillations périodiques en fonction de l'inverse du champ magnétique
- Mesure directe des aires extrémales de la surface de Fermi (pas d'information sur leurs nombres, ni leur localisation dans l'espace des k)

Relation d'Onsager :
$$F = \frac{\phi_0}{2\pi^2} A_k$$



Oscillations de l'aimantation :
Effet de Haas-van Alphen (dHvA)

Oscillations de la résistivité :
Effet Shubnikov-de Haas (SdH)

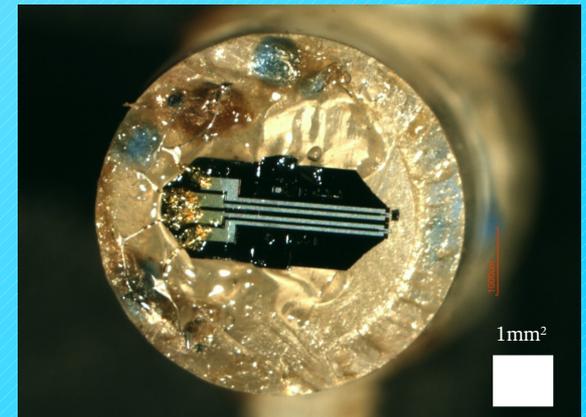
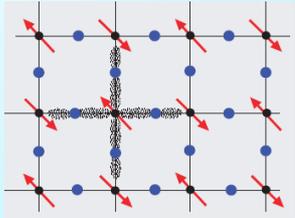
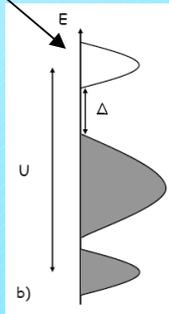
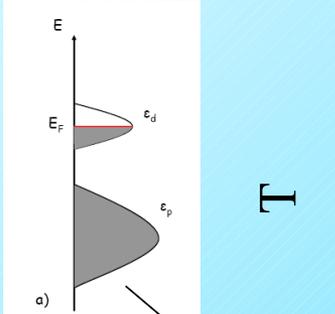


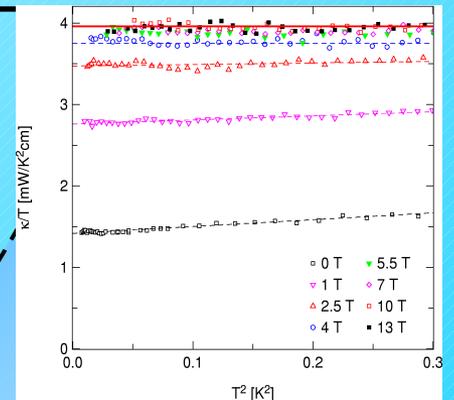
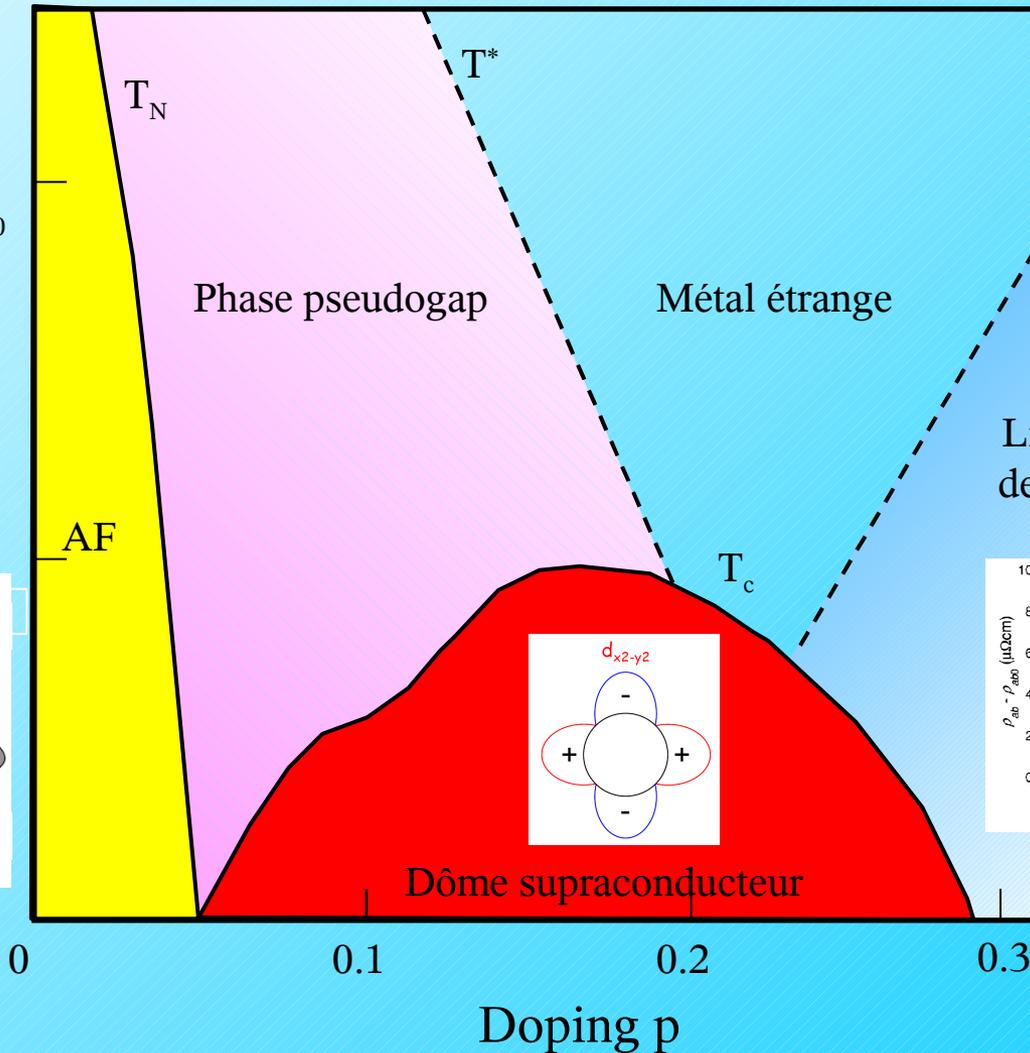
Diagramme de phase générique :



Orenstein et al., science 2000

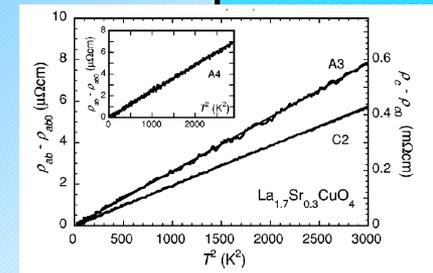


Isolant de Mott



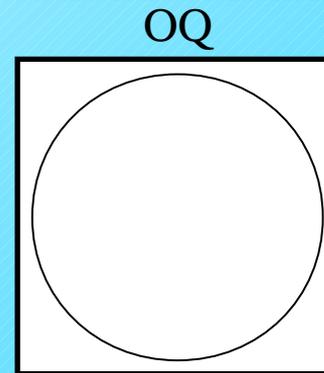
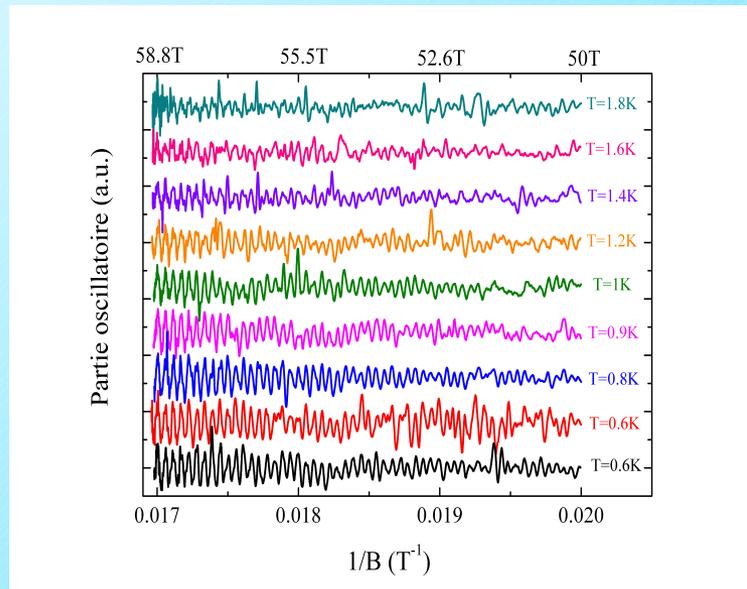
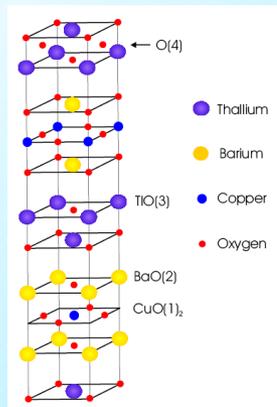
C. Proust et al, PRL (2002)

Liquide de Fermi



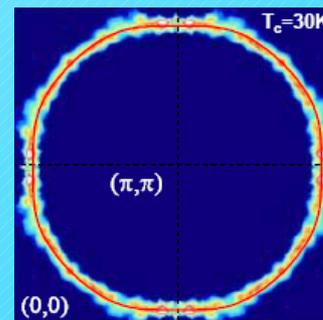
Nakamae et al., PRB (2003)

Surface de Fermi de $Tl_2Ba_2CuO_{6+\delta}$:



$$k_F = 7.42 \pm 0.05 \text{ nm}^{-1}$$

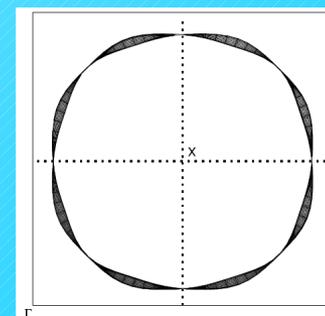
ARPES



Platé *et al.*, PRL (2005)

$$k_F = 7.28 \pm 0.22 \text{ nm}^{-1}$$

AMRO



Hussey *et al.*, Nature (2003)

$$k_F = 7.35 \pm 0.1 \text{ nm}^{-1}$$

$$F = 18100 \pm 50 \text{ T}$$

Relation
d'Onsager

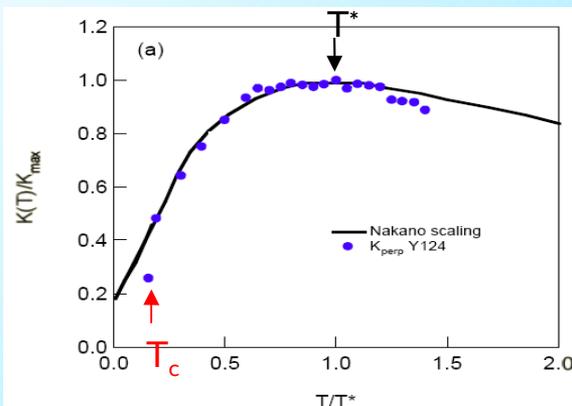
$$A_k = 172.8 \pm 0.5 \text{ nm}^{-2}$$

~65% of 1st Brillouin zone

Vignolle *et al.*, Nature (2008)

La surface de Fermi des cuprates sur-dopés est constituée d'une large orbite de trou en accord avec les calculs de structure de bande.

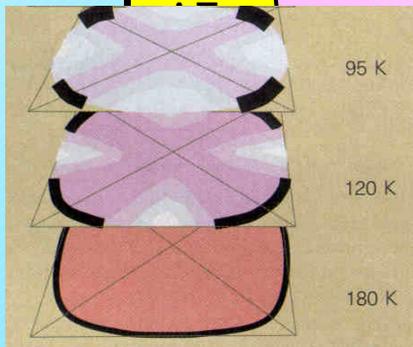
Diagramme de phase générique :



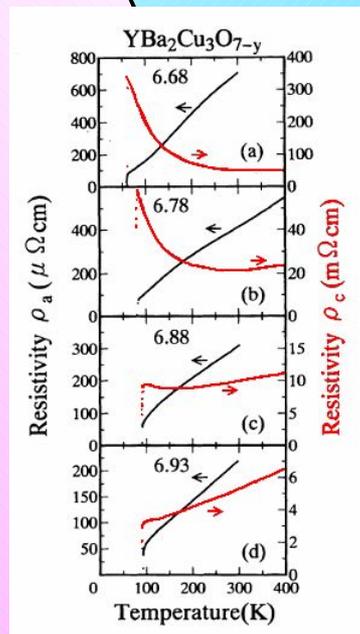
Alloul *et al.*, PRL (1989)
Warren *et al.*, PRL (1989)

T

Phase pseudogap



M. Norman *et al.*, Nature (1998)



Takenaka *et al.*, PRB (1994)

Dôme supraconducteur

Métal étrange

Liquide de Fermi

T_c

0

0.1

0.2

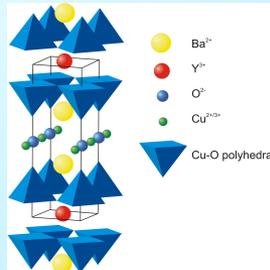
0.3

Dopage p

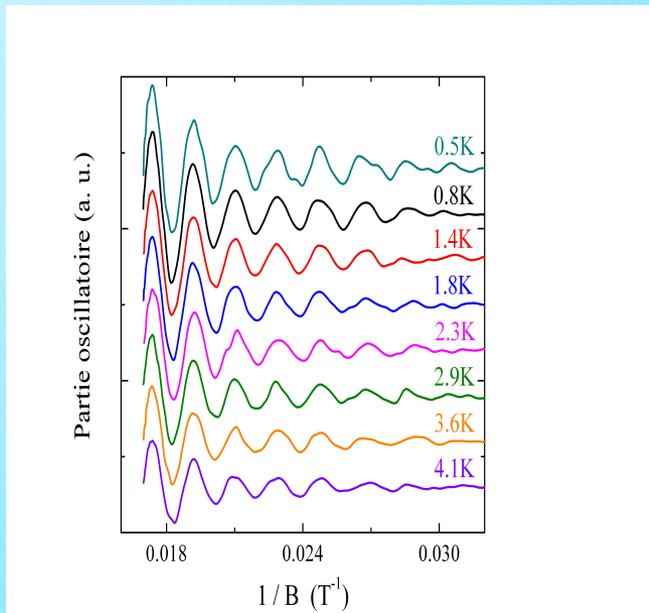
Osillations Quantiques dans les cuprates sous-dopées :



(Ruixing Liang, D.A. Bonn, W.N. Hardy)



• $y=6.51$: $T_c = 57.5$ K, $p = 0.1$



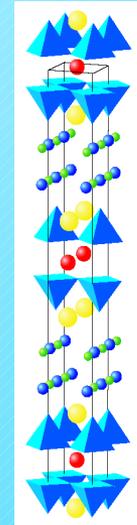
Jaudet *et al.*, PRL (2008)

Frequency : $F = 540 \pm 4$ T

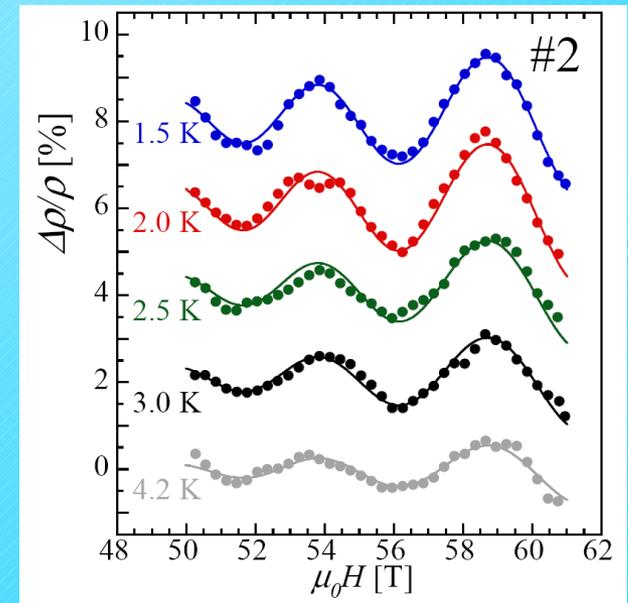
→ $A_k = 5.15 \pm 0.04$ nm²
 ~ 1.9 % of 1st Brillouin zone



(N. Hussey, S. Adachi)



• $T_c = 80$ K, $p \sim 0.14$



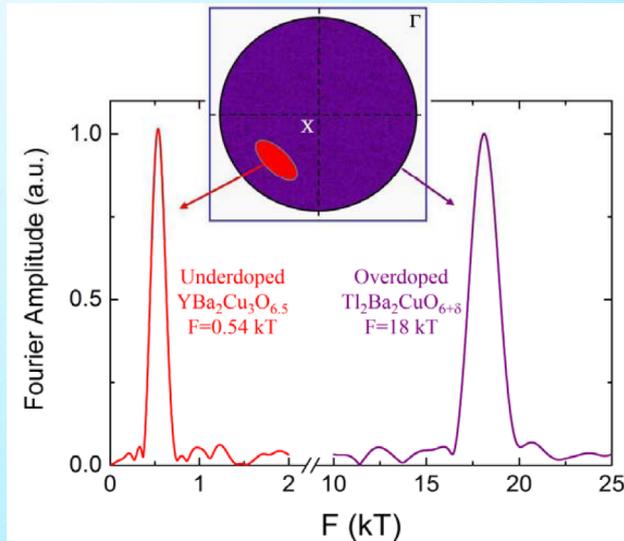
Bangura *et al.*, PRL (2008)

Yelland *et al.*, PRL (2008)

Frequency : $F = 620 \pm 30$ T

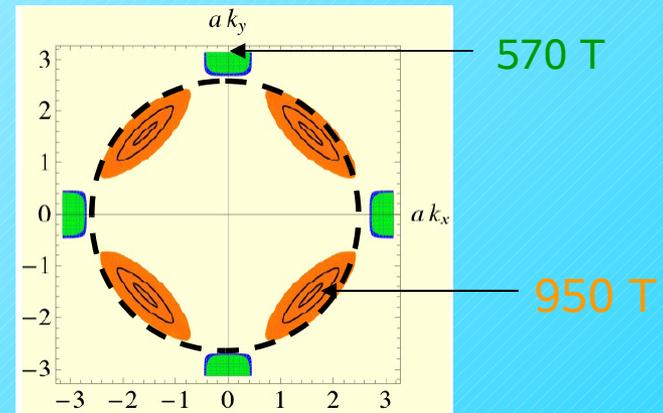
→ $A_k = 6.3 \pm 0.28$ nm²
 ~ 2.4 % of 1st Brillouin zone

Indice de la présence d'une poche d'électron:

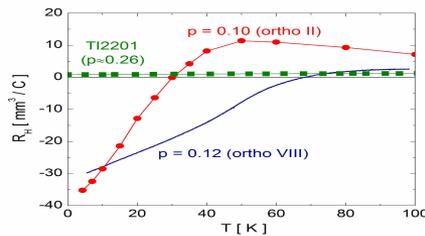


Jaudet *et al.*, Physica B (2008)

Reconstruction de la surface de Fermi
au vecteur d'onde $Q(\pi, \pi)$:



X. Jia et al, arXiv: 0806.3793

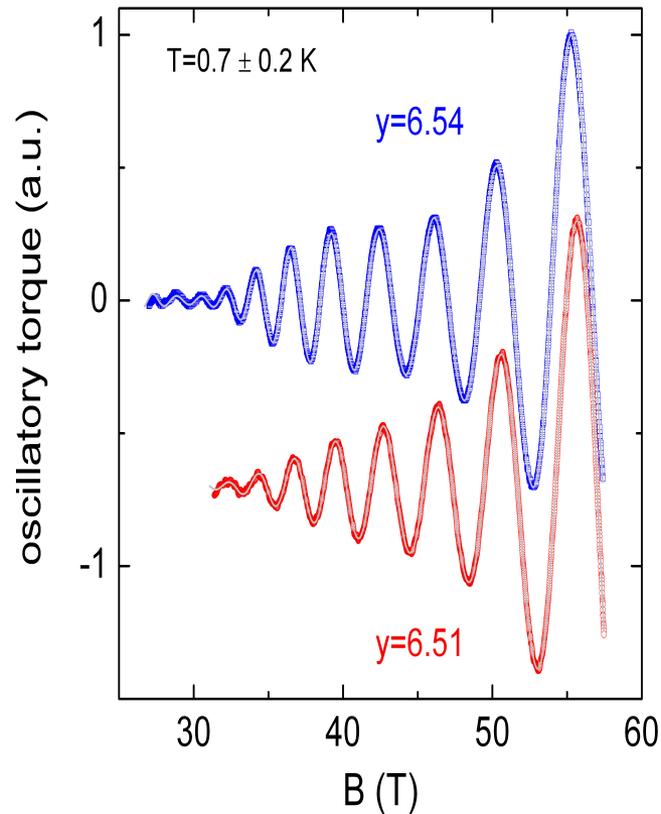


Mackenzie *et al.*, PRB (1996)

LeBoeuf *et al.*, Nature (2007)

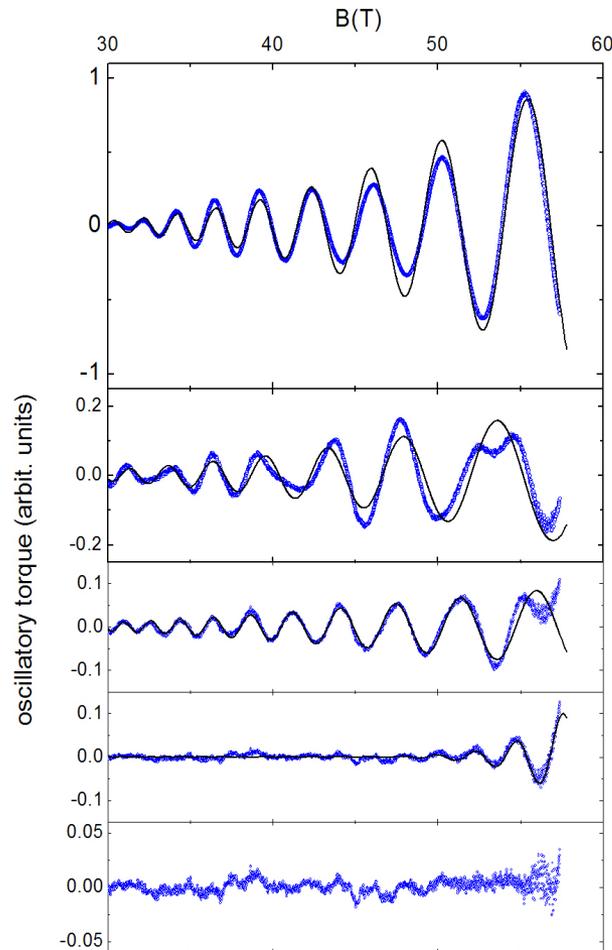
Il reste à détecter une fréquence
supplémentaire correspondant
à la poche de trou.

A la recherche d'une fréquence additionnelle:



Mesures de couple magnétique moyenné sur dix tirs.

Ajustement à la théorie Lifshitz Kosevitch:



- data
- fit $F_1 = 540$ T

- data-fit F_1
- fit $F_2 = 450$ T

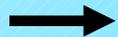
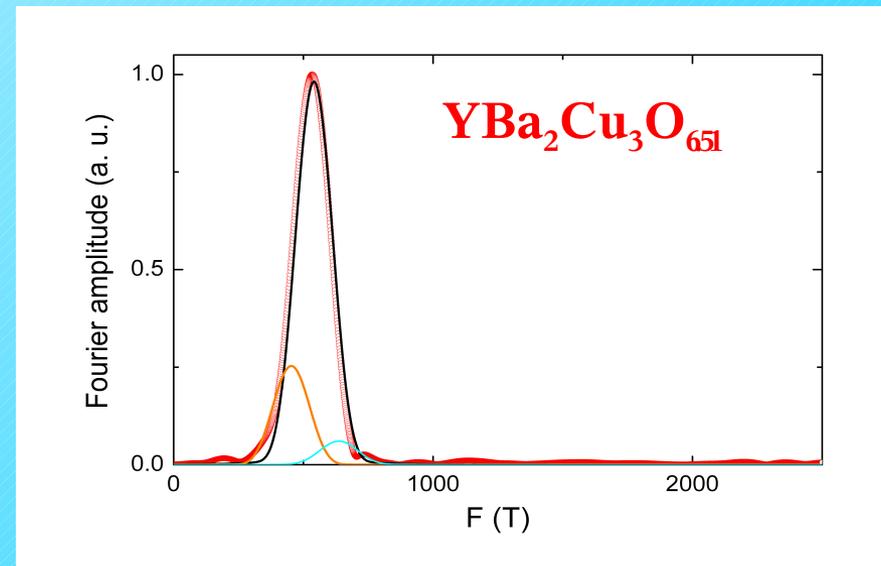
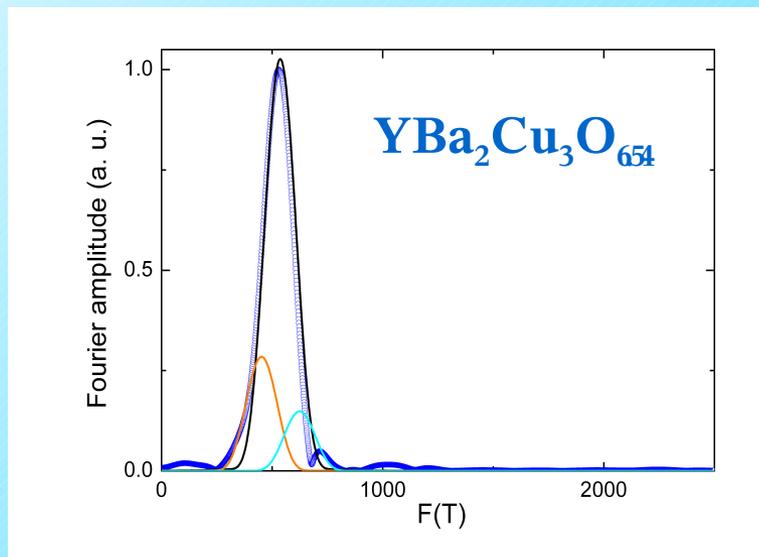
- data-fit F_1 -fit F_2
- fit $F_3 = 630$ T

- data-fit F_1 -fit F_2 -fit F_3
- fit $F_4 = 1120$ T

- residual

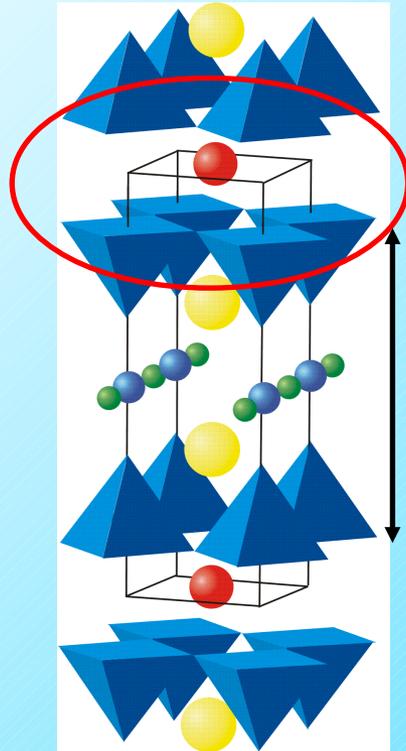
Transformée de Fourier:

| F_1 | F_2 | F_3 | F_4 |
|----------------|----------------|----------------|-----------------|
| 540 ± 15 T | 450 ± 15 T | 630 ± 40 T | 1130 ± 20 T |



Présence de plusieurs fréquences proches
mais pas fréquence correspondantes à la poche de trou.

Bi-layer splitting et gondolement :

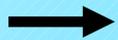
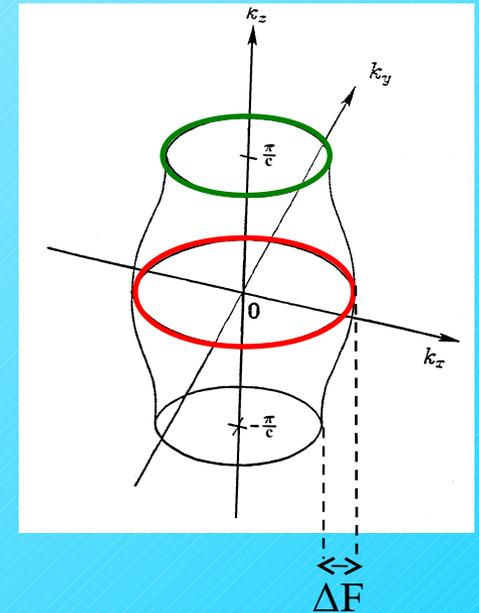


➔ **Bilayer splitting**

t_{\perp} ➔ **Gondolement dans un cas quasi-2D simple:**

$$\Delta F = 90T \Leftrightarrow t_{\perp} = 1.3 \text{ meV}$$

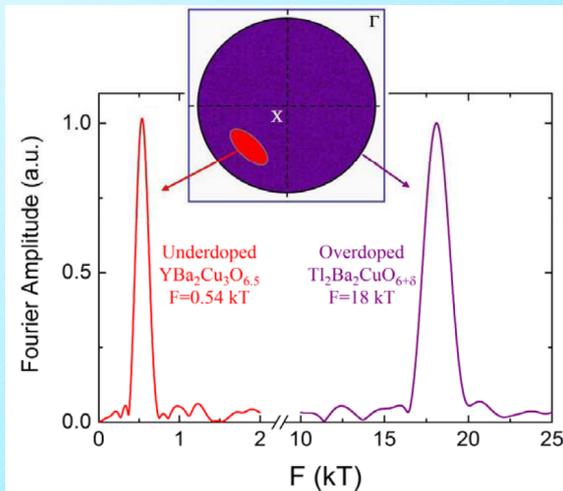
Yamaji, JPSJ(1998)



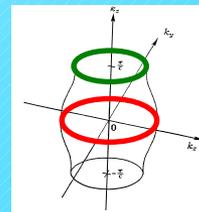
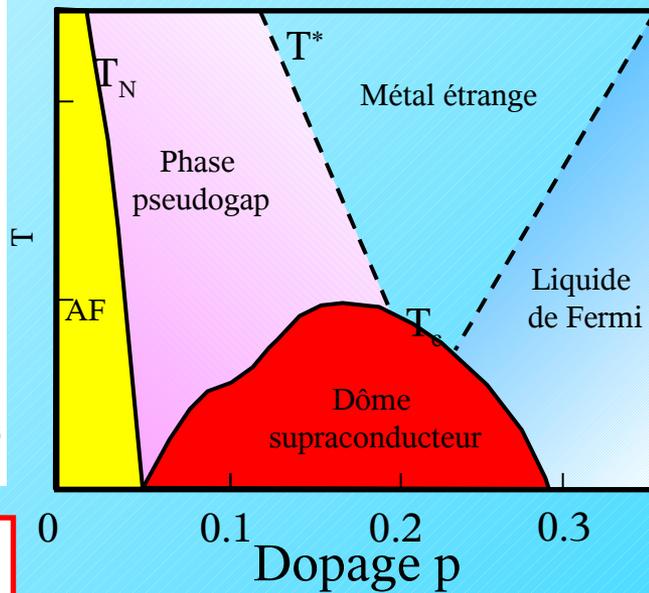
Surface de Fermi 3D dans les cuprates sous-dopées à basse température.

Conclusion:

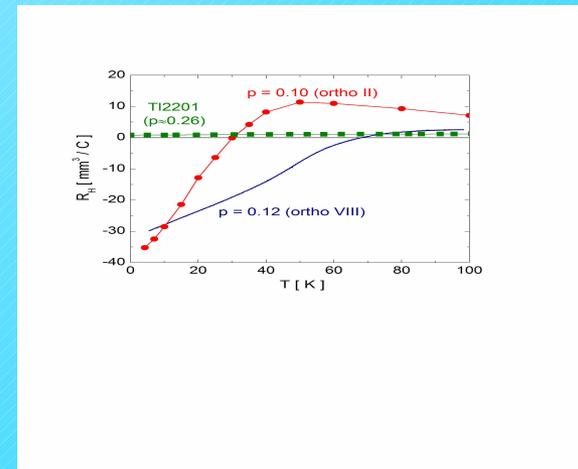
Ces mesures suggèrent que la phase pseudogap est caractérisée par:



Un changement de topologie de la surface de Fermi en fonction du dopage.



Une surface de Fermi 3D à basse température.



Une reconstruction de la surface de Fermi.

