

Evidencia Experimental de Estados de Cristal Líquido Electrónico

Referencias generales:

- E. Fradkin, Les Houches Lectures
- E. Fradkin, S. Kivelson, M. Lawler, J. Eisenstein, Review sobre orden nemático
- Las referencias mas nuevas están en las transparencias

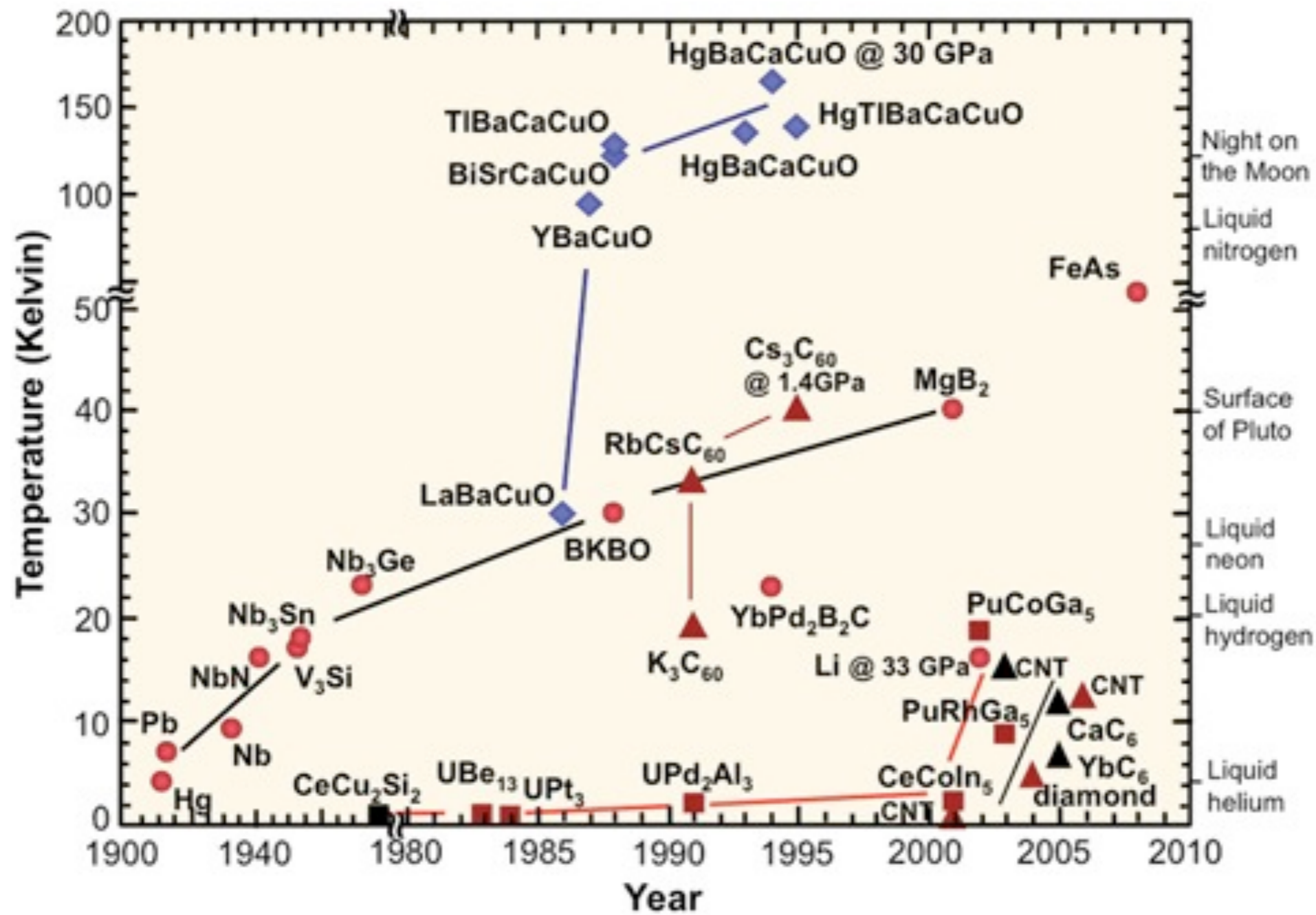
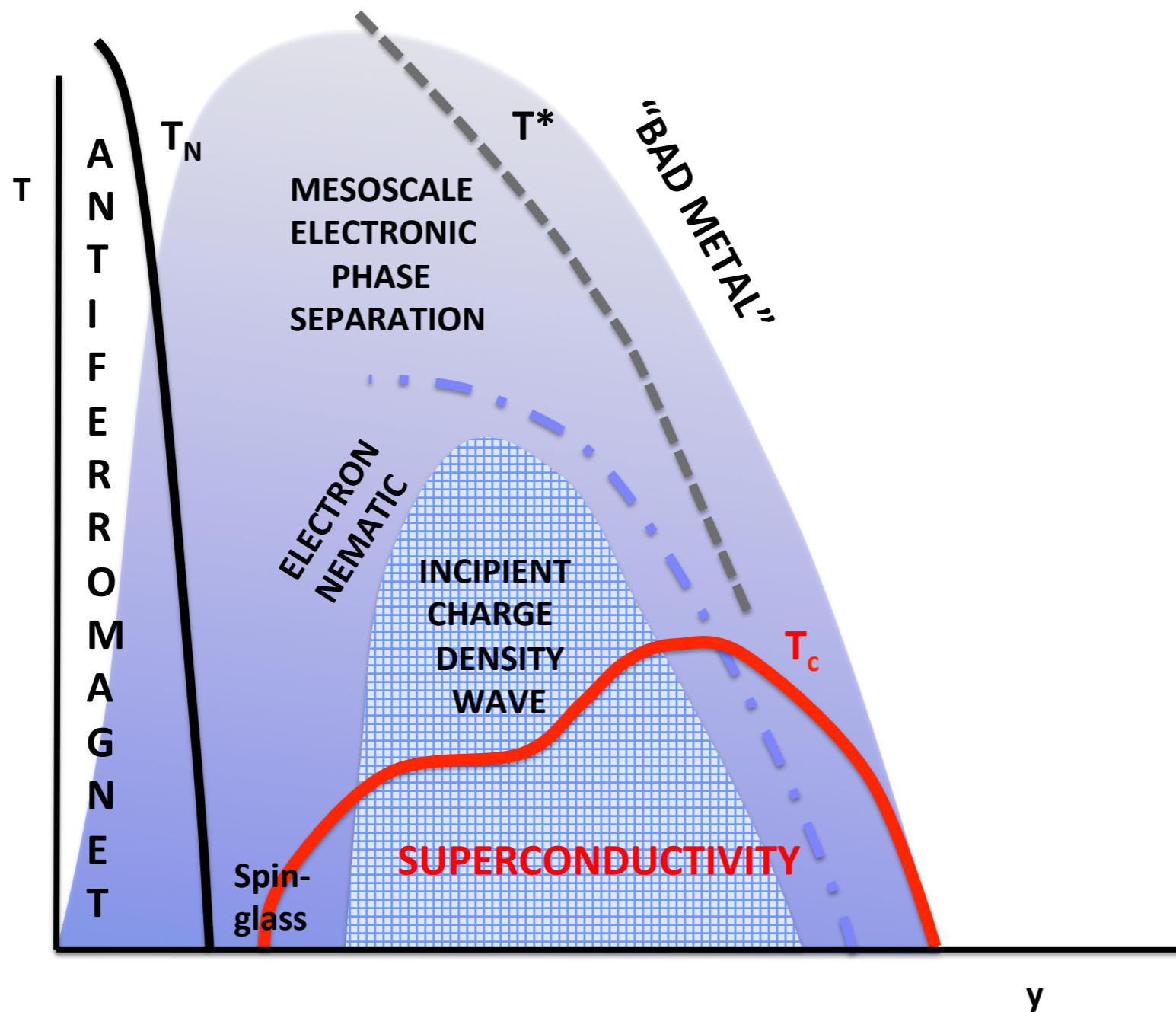
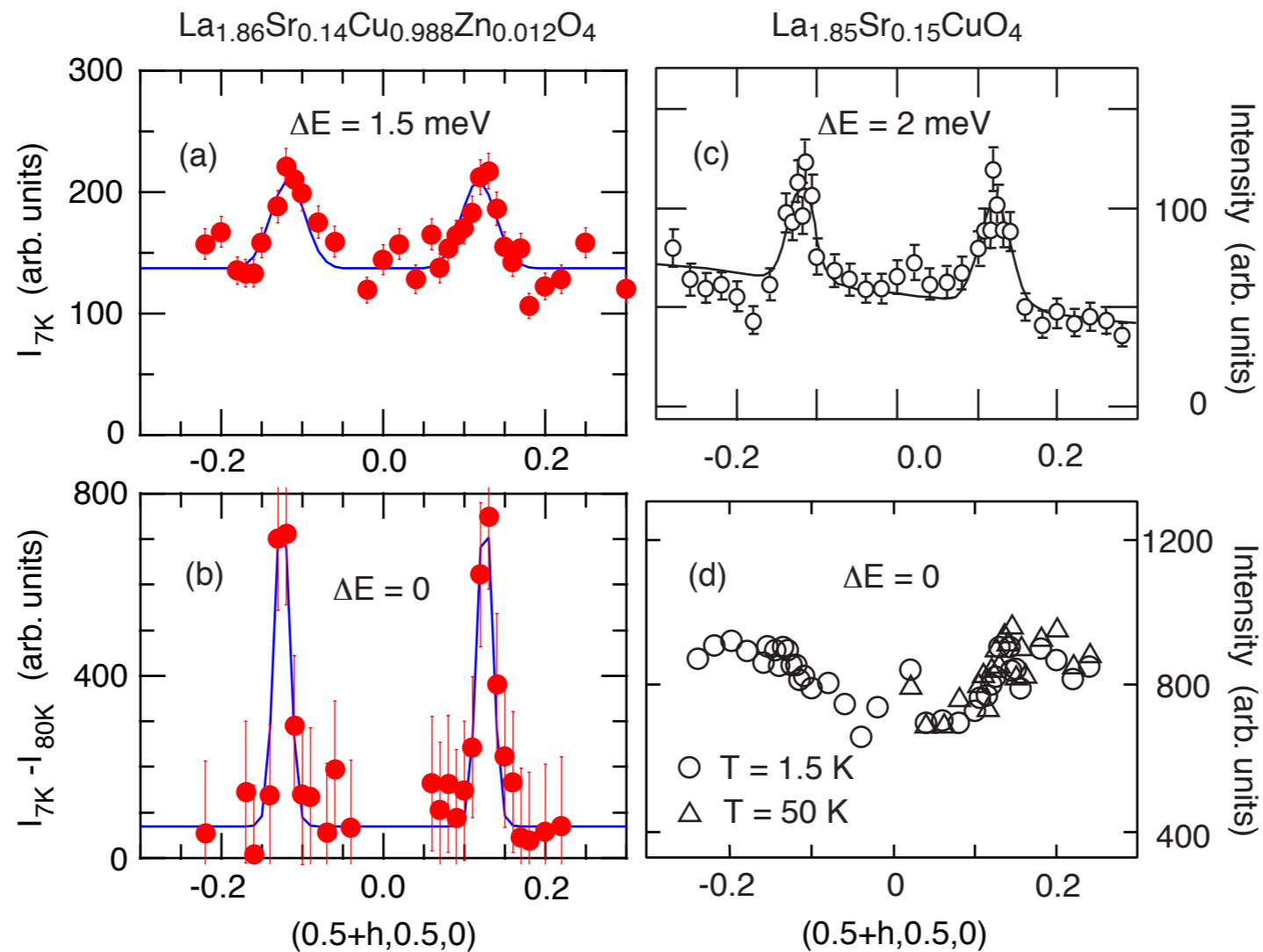


Diagrama de Fase Esquemático de YBCO

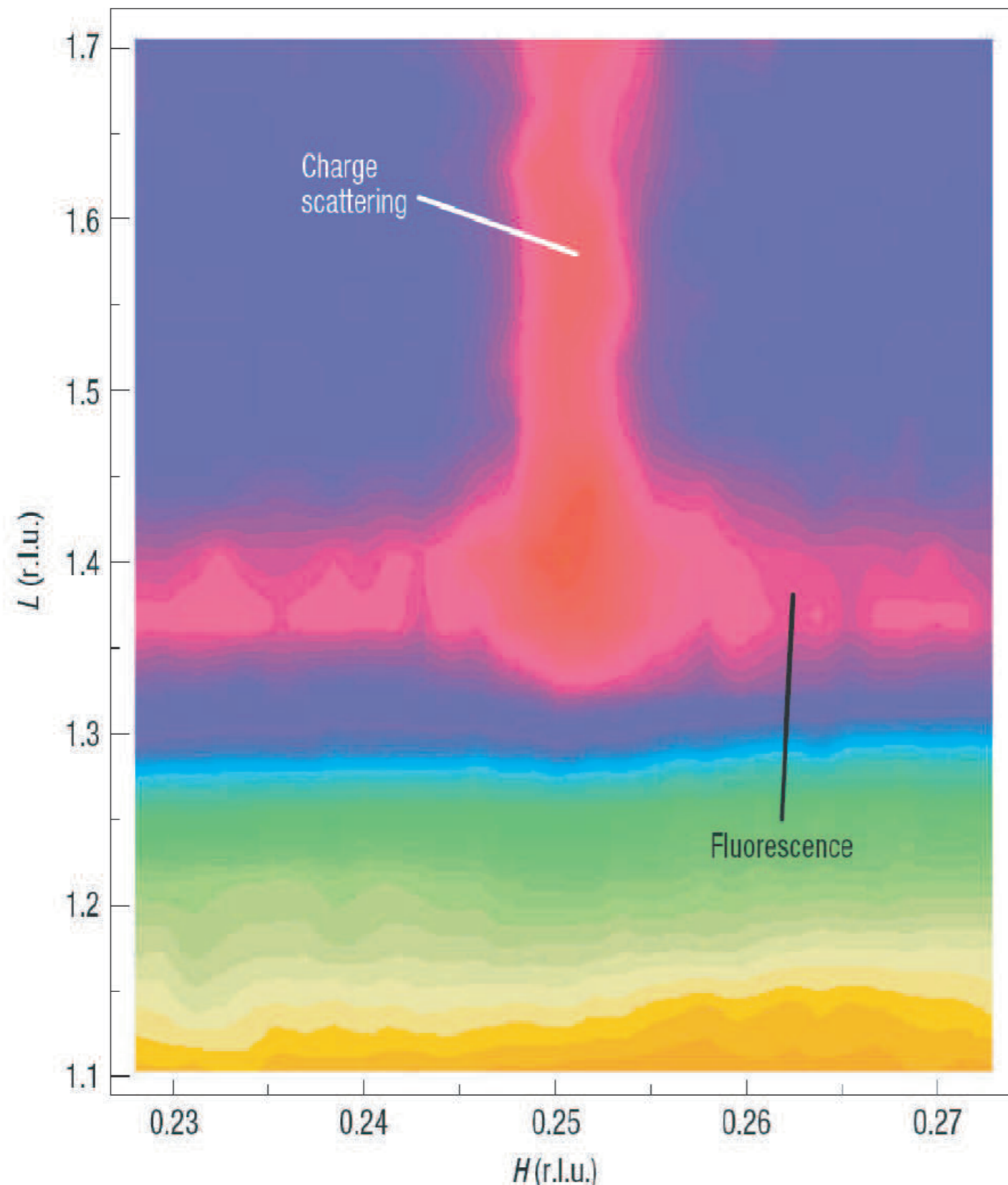


Fases Smécticas ('Stripes') de Spin ('ISDW')



Scattering inelástico de neutrones en LSCO (Tranquada et al) (1995): orden 'fluctuante' y orden estático. Para detalles ver mi Reviews of Modern Physics de 2003

Fase Sméctica de Carga ('CDW')



RIXS (scattering inelástico resonante de rayos X) en LBCO
P. Abbamonte et al,
Nature Physics 1, 155
(2005)

Orden de Carga Sméctico ('CDW') en YBCO (Difracción de Rayos X, Hayden, 2012) J. Chang et al, Nature Physics 8, 871 (2012)

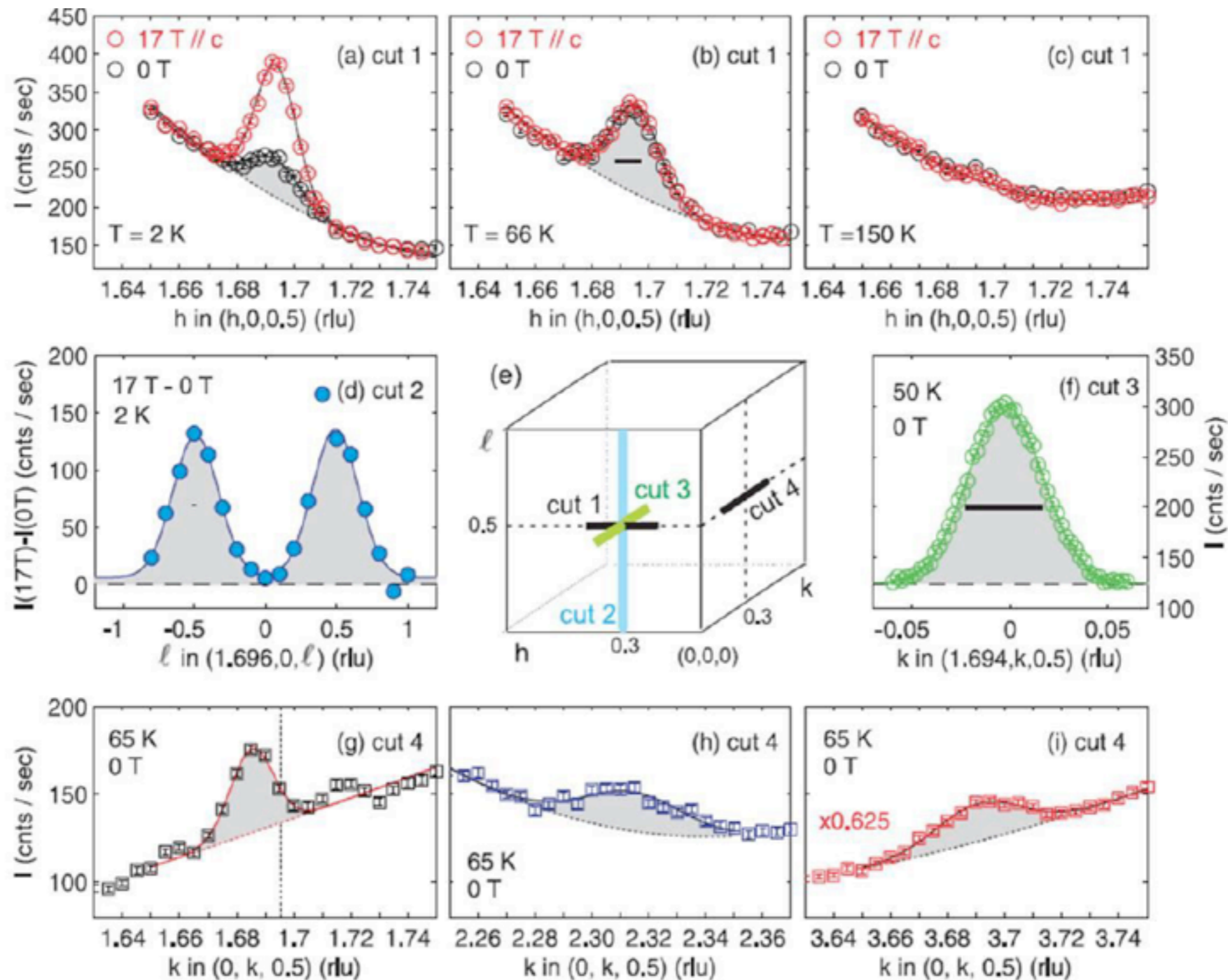


Figure 1 | Incommensurate charge density wave order

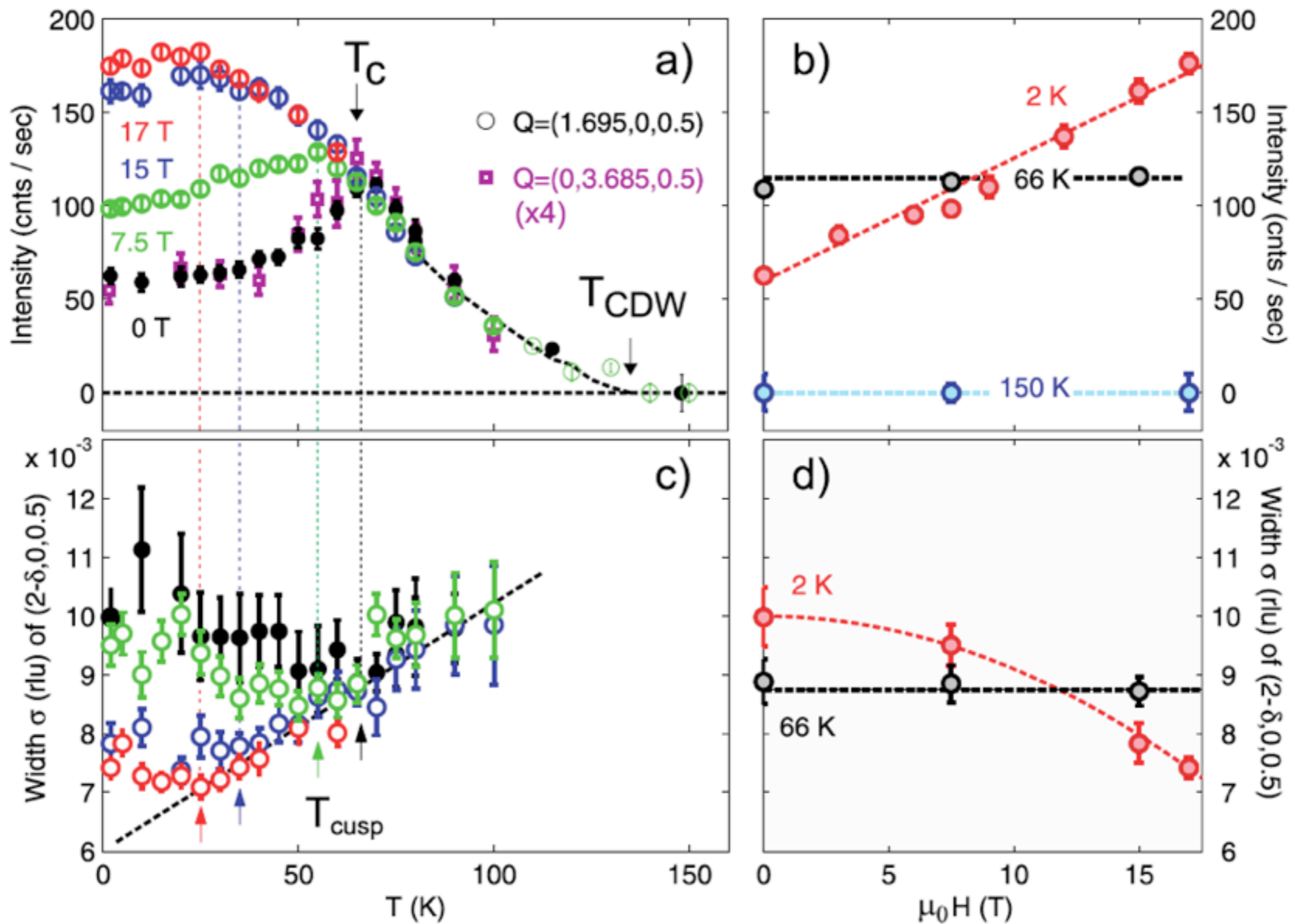


Figure 2 | Competition between charge-density-wave order and superconductivity.

Transición de fase termodinámica en YBCO en campos magnéticos altos (C. Proust, 2012) D. LeBoeuf et al, Nature Physics 9, 79 (2012)

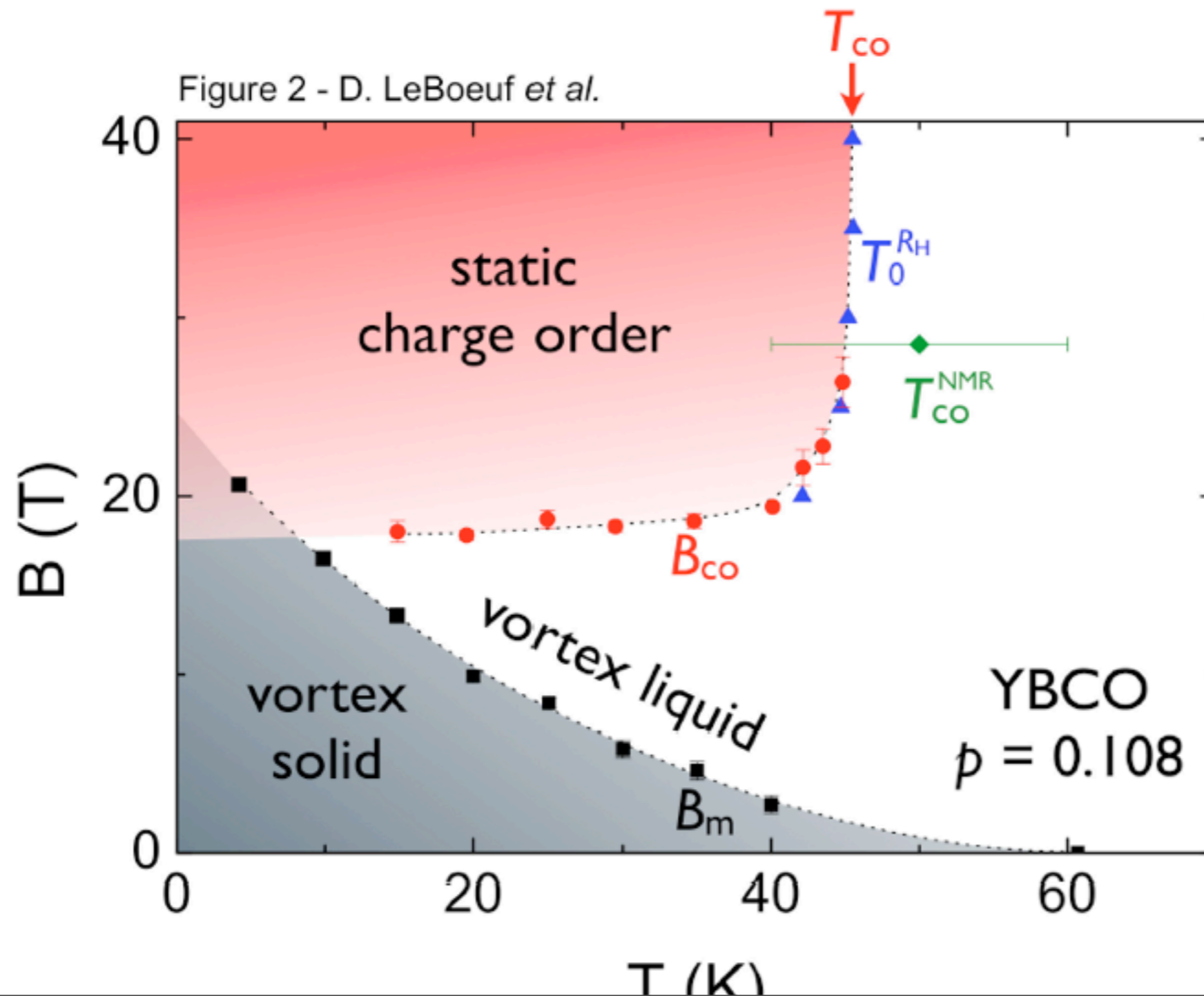
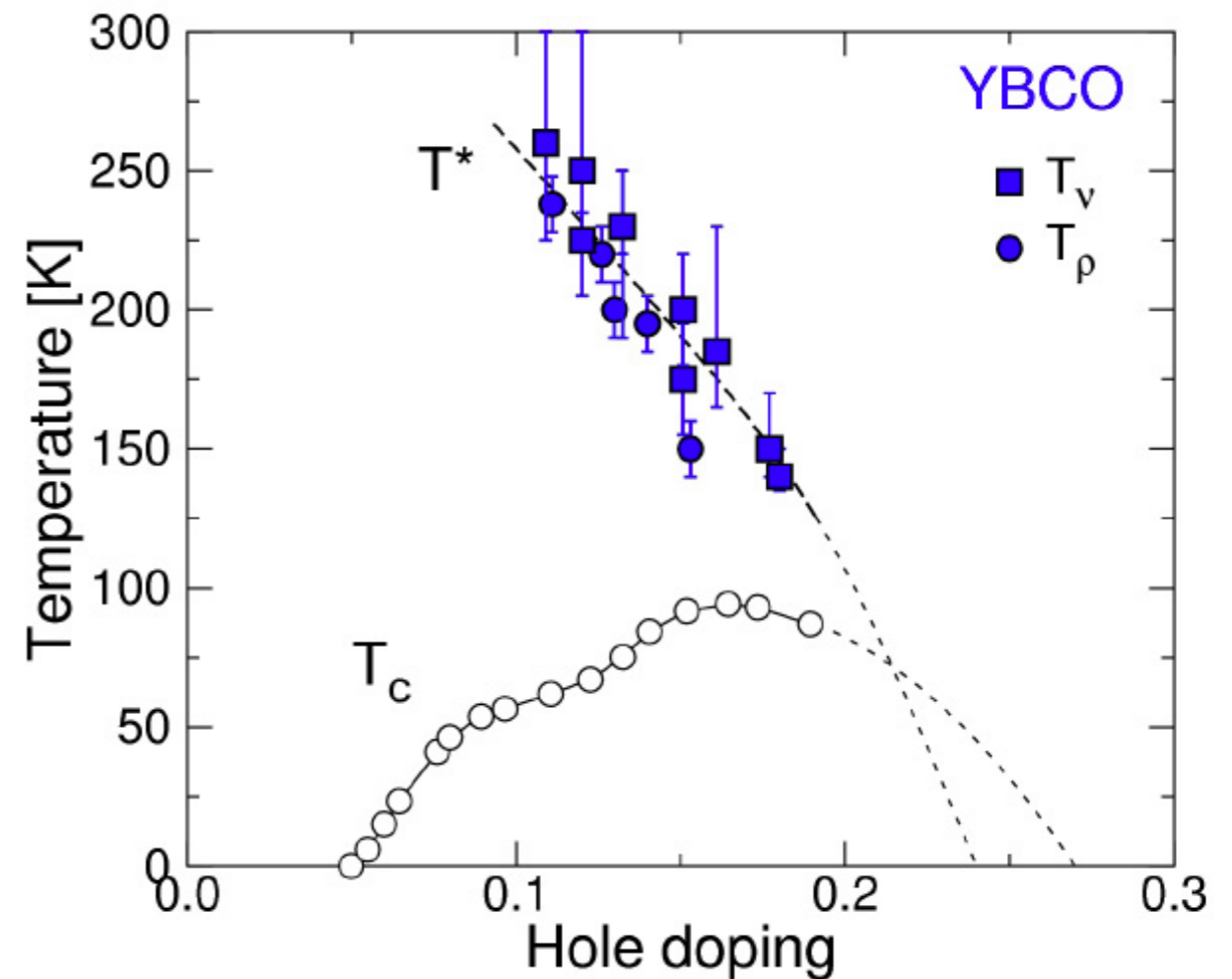
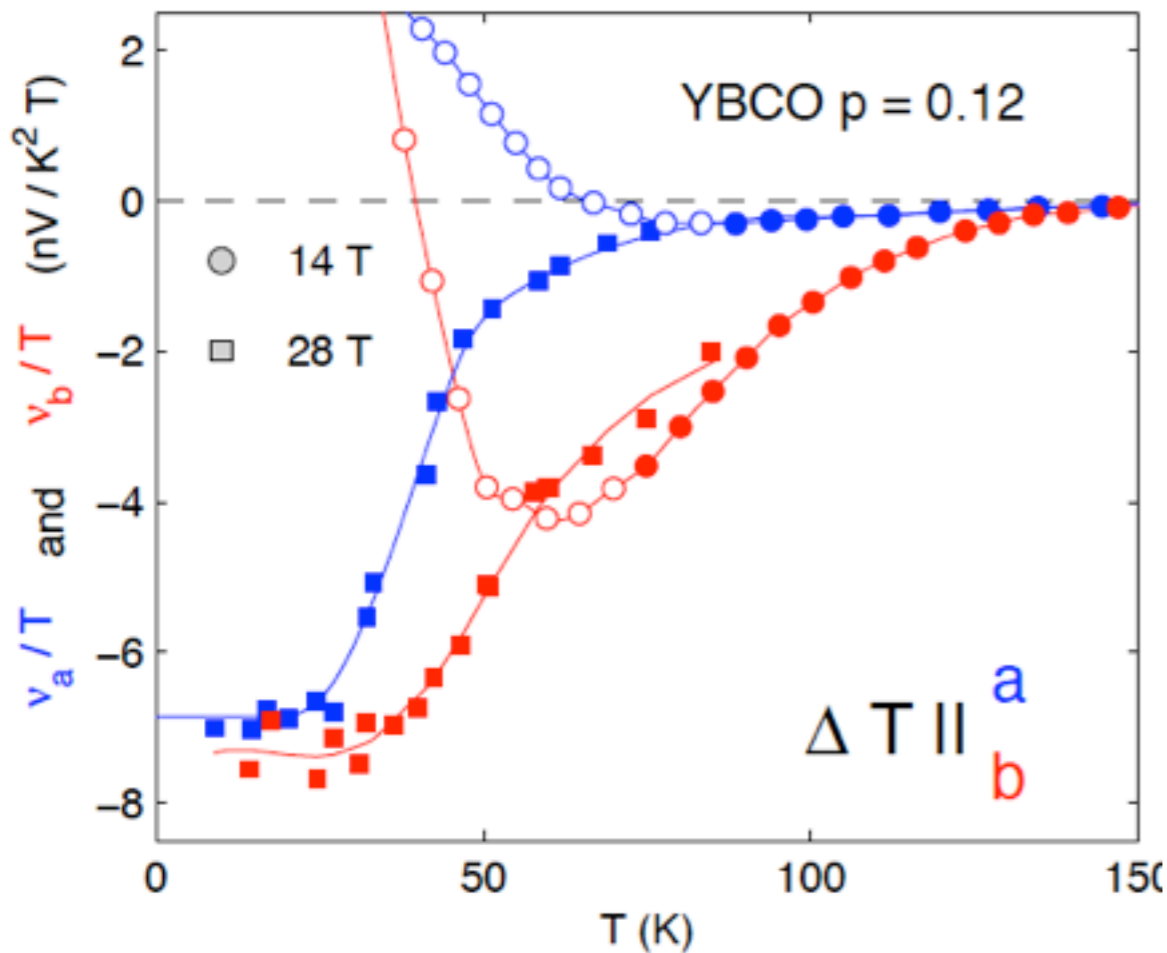


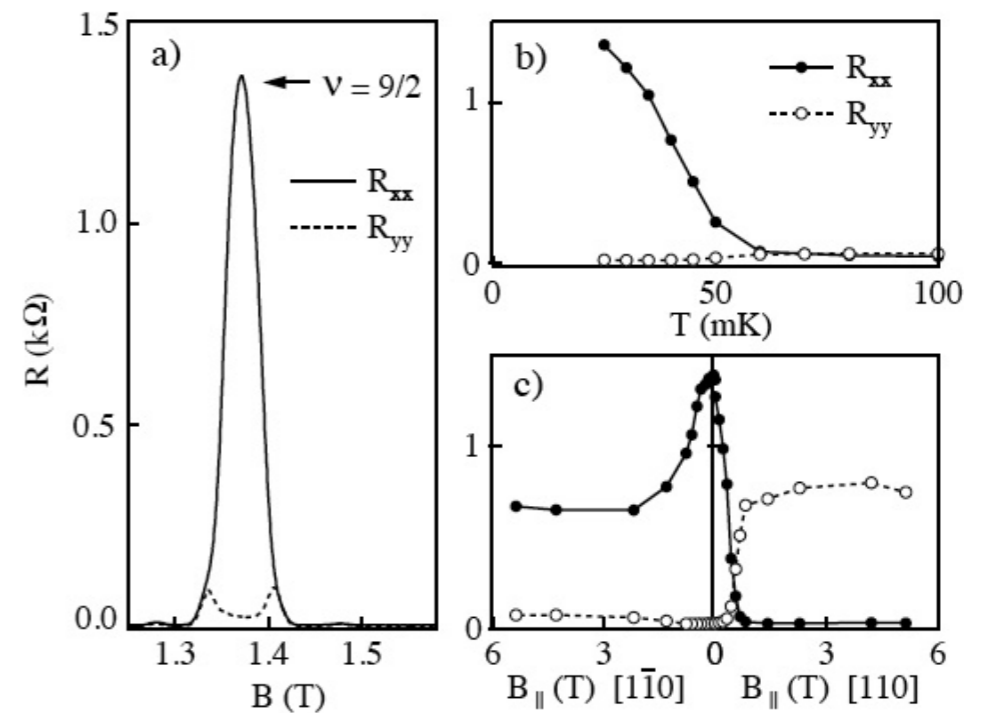
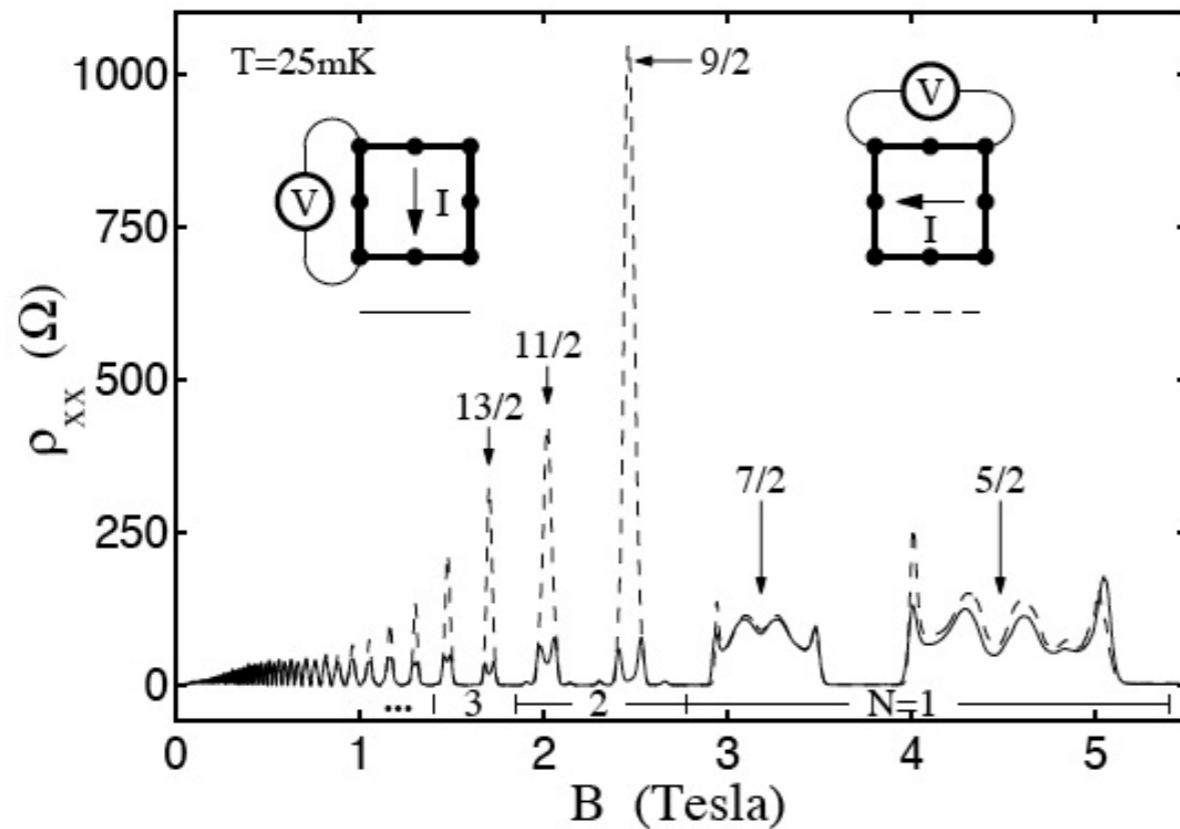
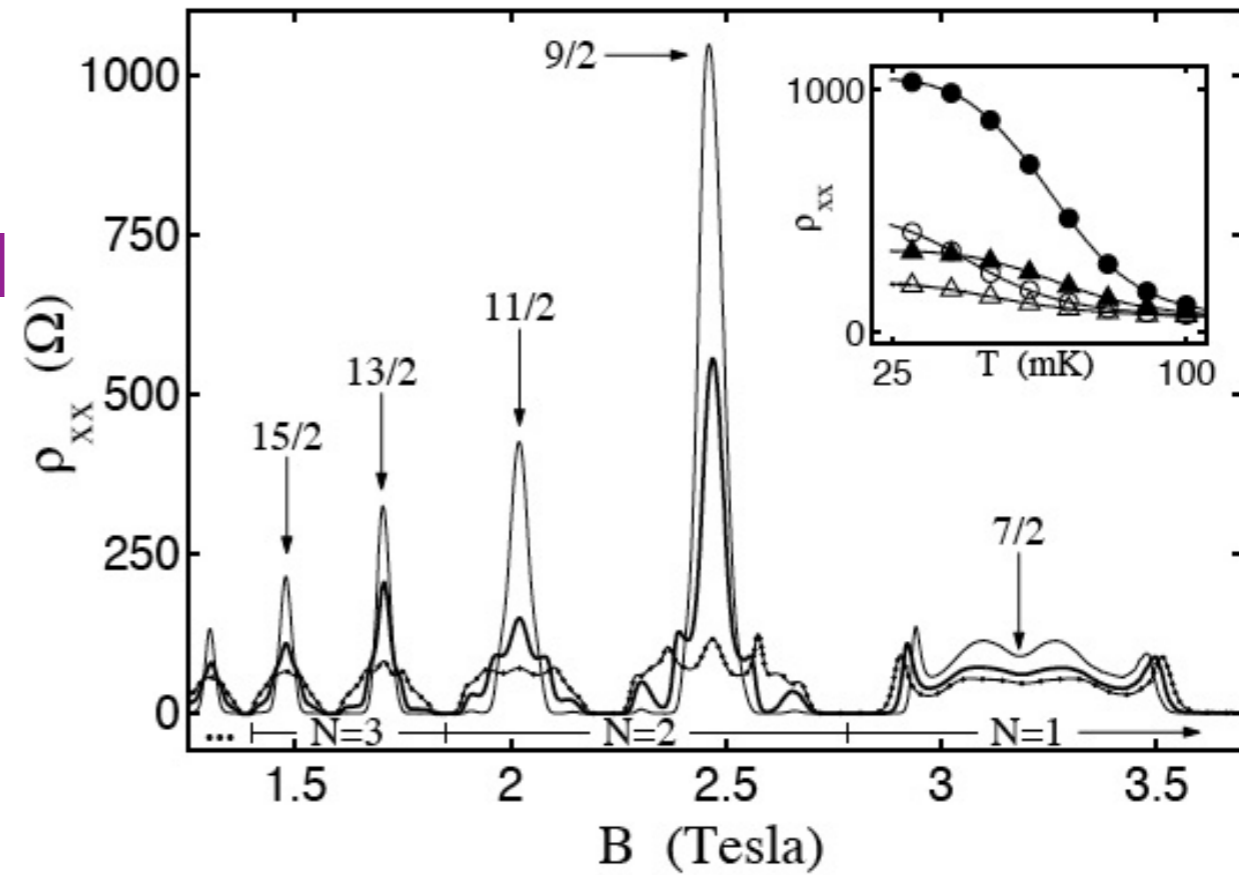
Diagrama de fase de YBCO a partir de mediciones de la anisotropía del tensor termoeléctrico de Nernst (Taillefer et al, 2011)
 R. Daou et al, Nature 463, 519 (2010)

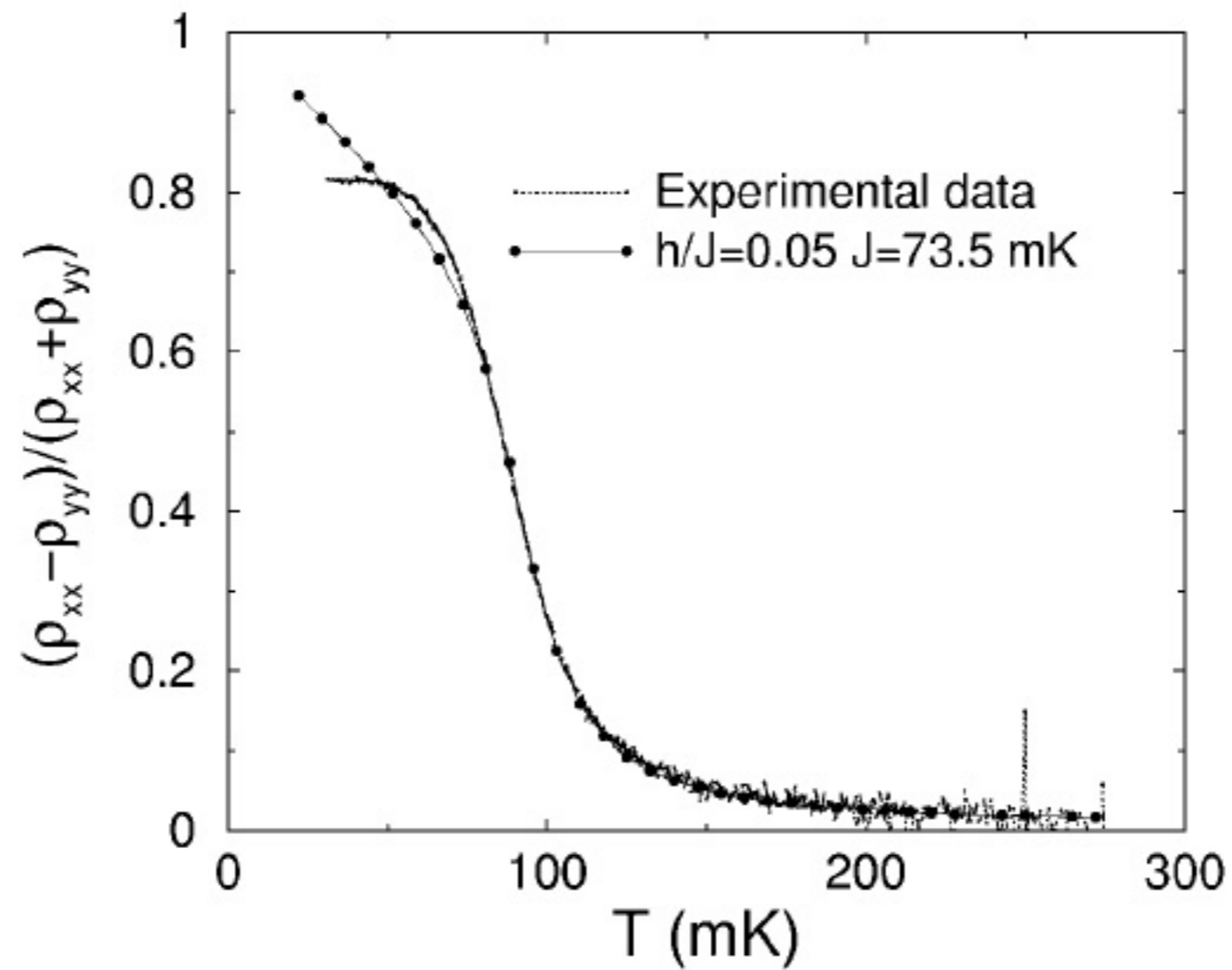
$$\nu_a = \frac{\alpha}{H} \frac{V_b}{\Delta T_a} \quad \text{and} \quad \nu_b = \frac{\alpha}{H} \frac{V_a}{\Delta T_b}$$

$$\begin{pmatrix} j_e \\ j_Q \end{pmatrix} = \begin{pmatrix} \sigma & \alpha \\ T\alpha & \kappa \end{pmatrix} \begin{pmatrix} E \\ -\nabla T \end{pmatrix}$$



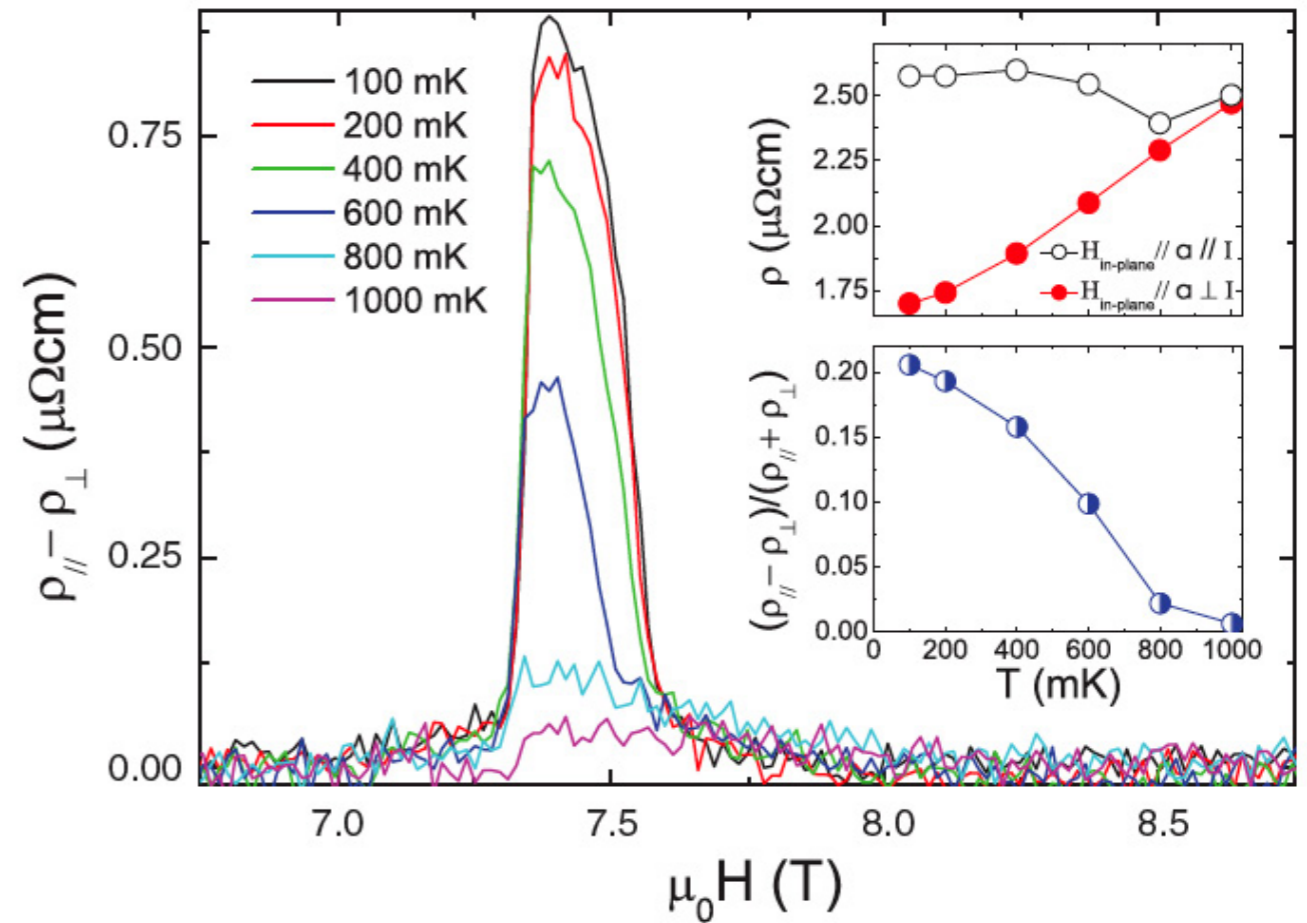
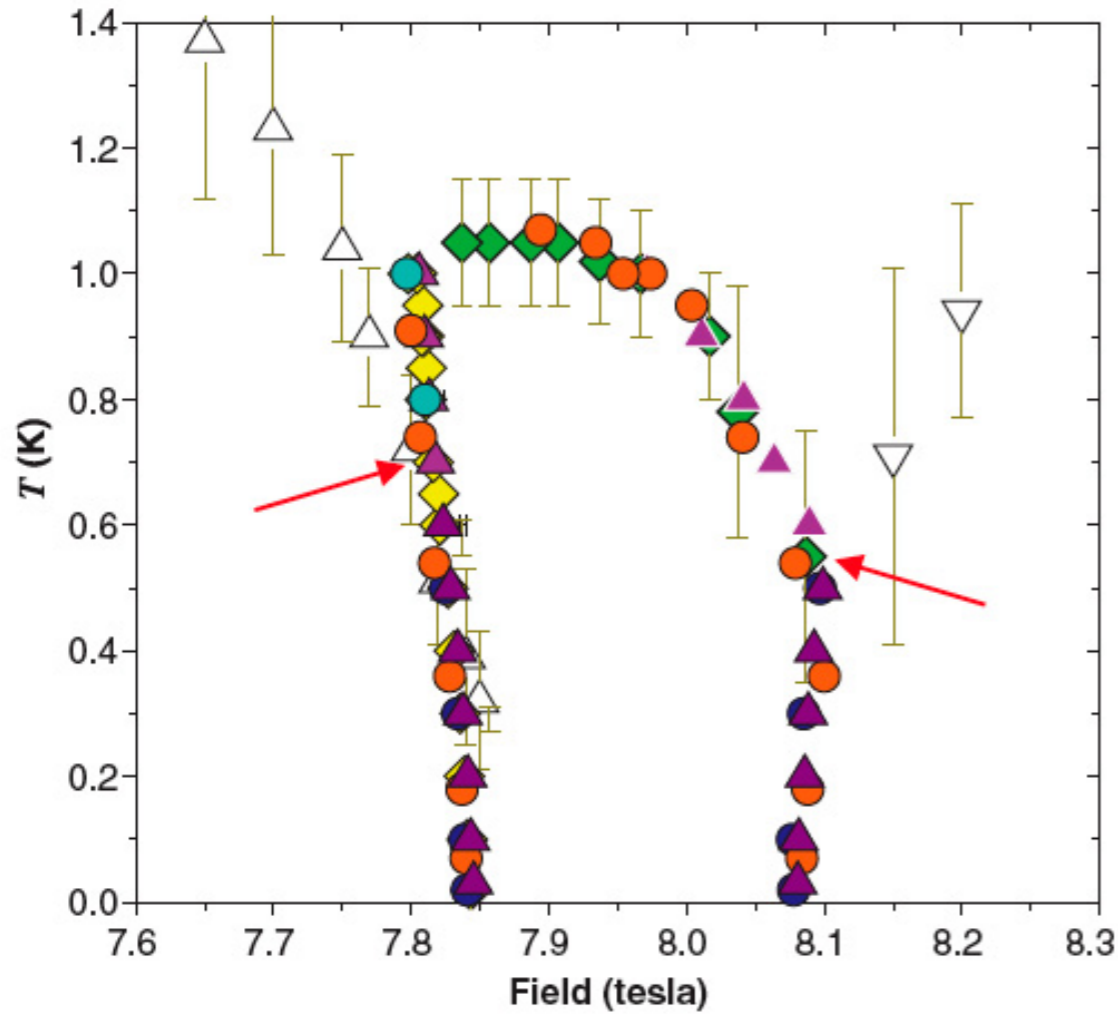
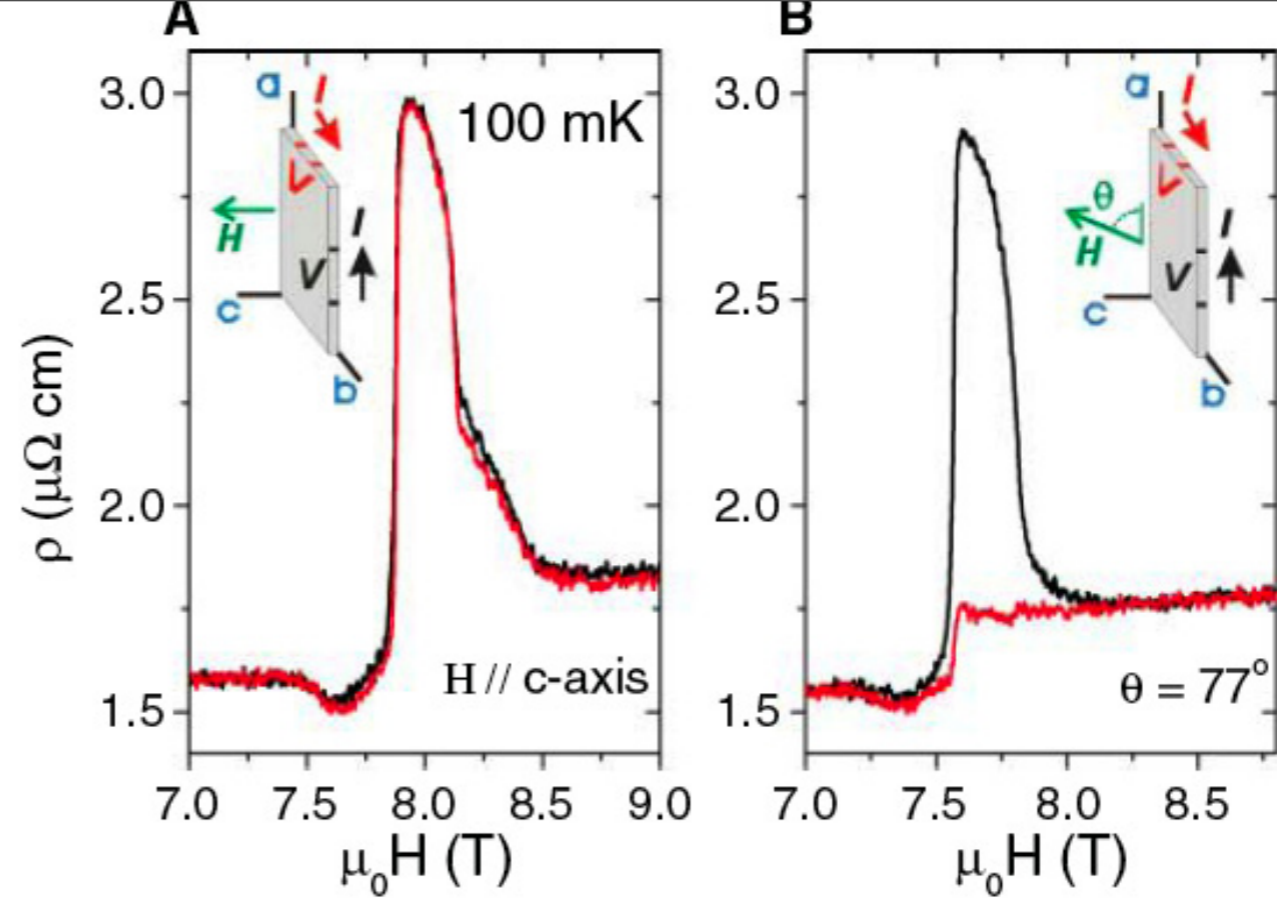
Estado nemático compresible
 del 2DEG en campos
 magnéticos fuertes, en el nivel
 de Landau $N=2$
 (Eisenstein et al 1998)
 (ver review)





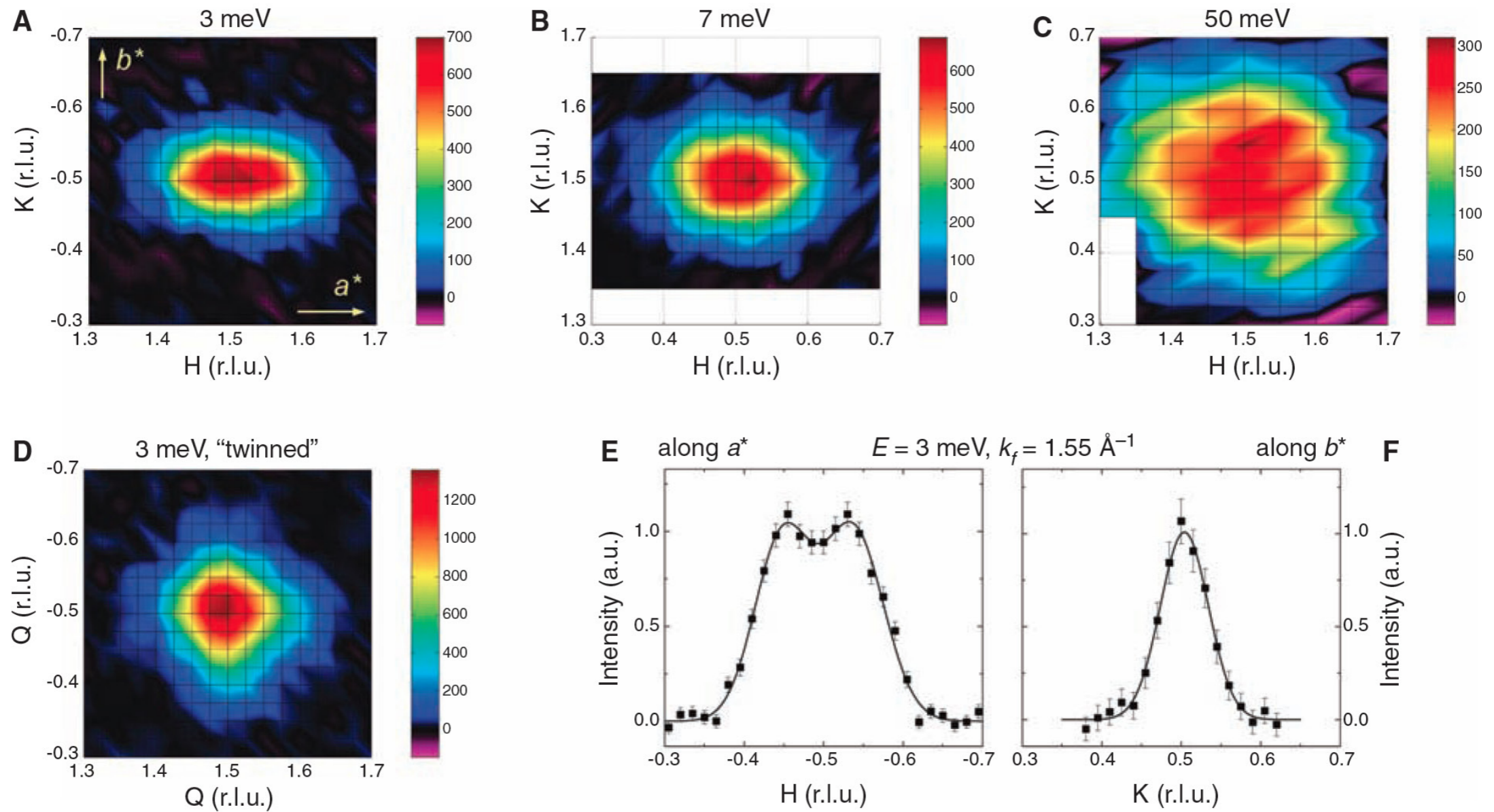
E. Fradkin, S. Kivelson, E. Manousakis, K. S. Nho
Phys Rev. Lett. 84, 1982 (2000)

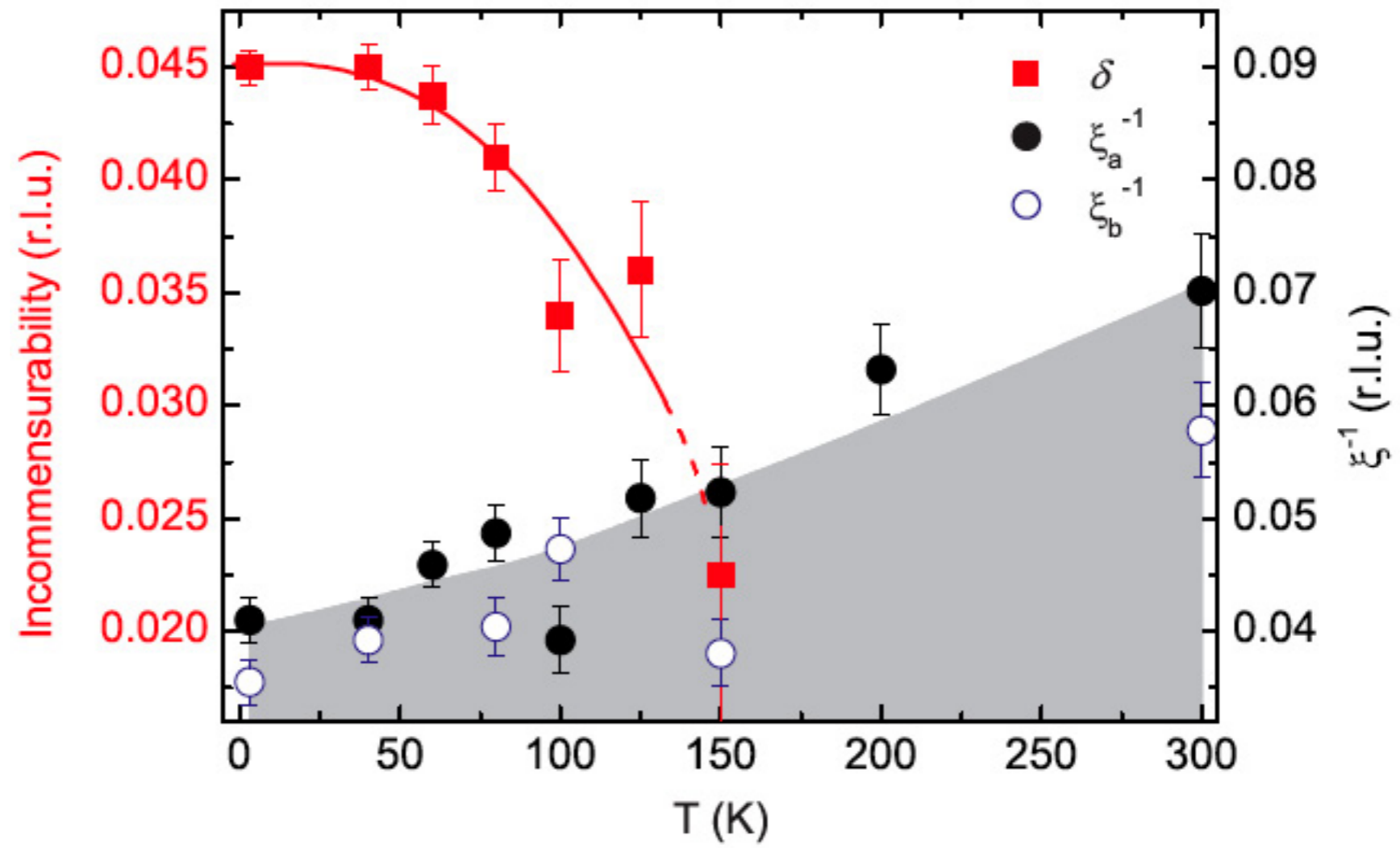
Estado nemático en $\text{Sr}_3\text{Ru}_2\text{O}_7$ en campos magnéticos (Borzi, Grigera, Mackenzie et al, 2007) (ver review)



Franjas “fluctuantes” como estado nemático

YBCO, $y=0.45$ (Keimer et al. 2008) (neutrones)
V. Hinkov et al, Science 319, 597 (2007)





Orden nemático local e inhomogeneidad electrónica en las imágenes de STM en BSCCO (J. C. Davis, 2010)

M. J. Lawler et al, Nature 466, 347 (2010)

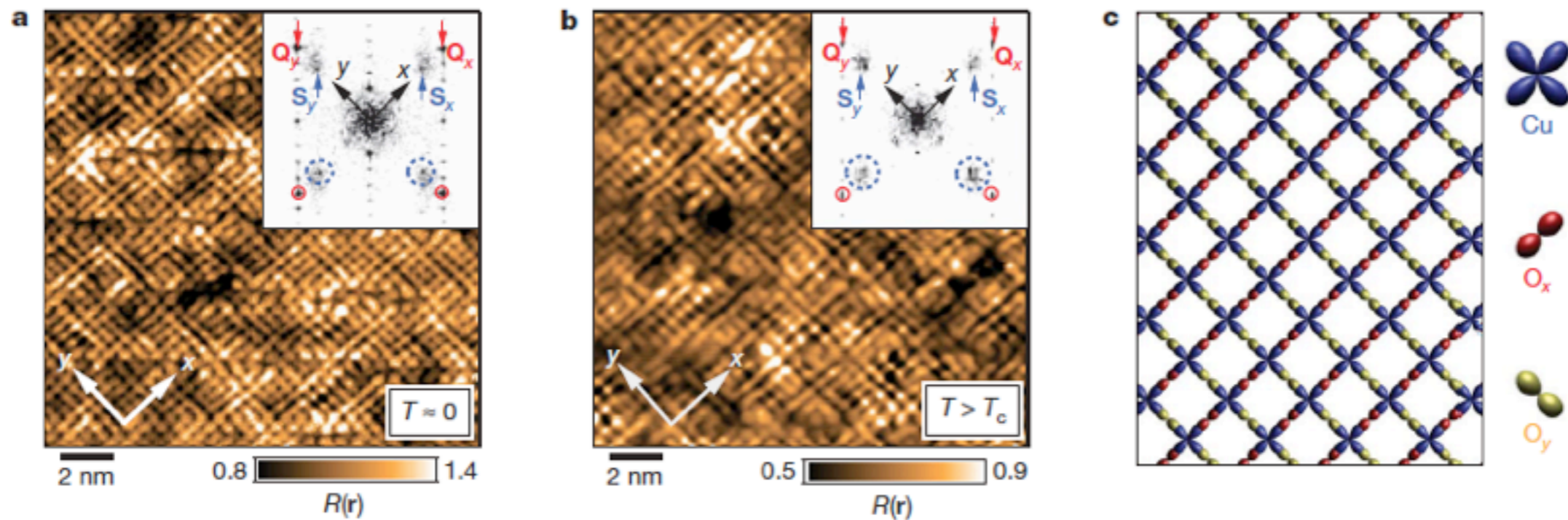
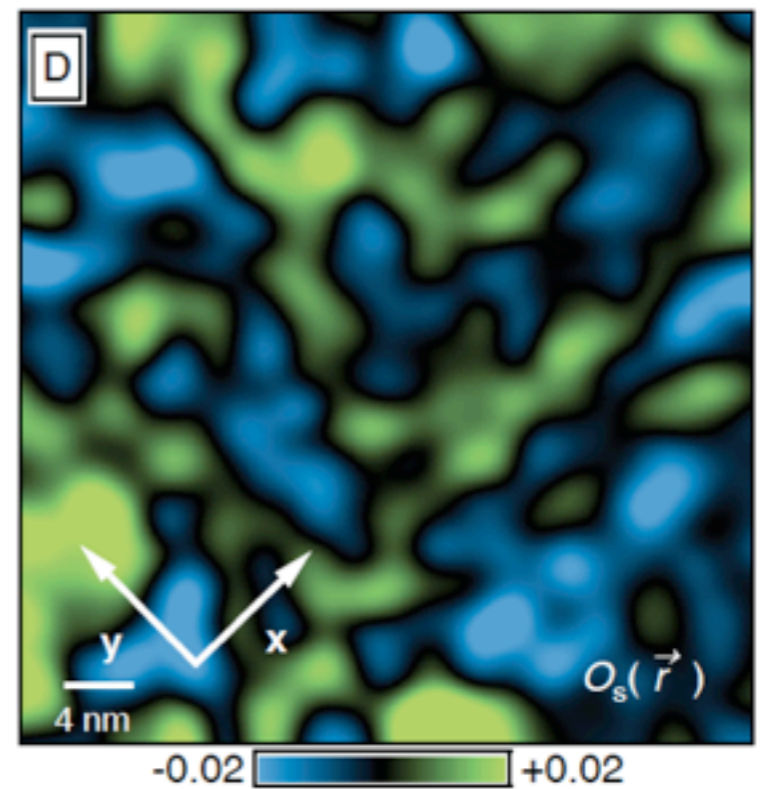
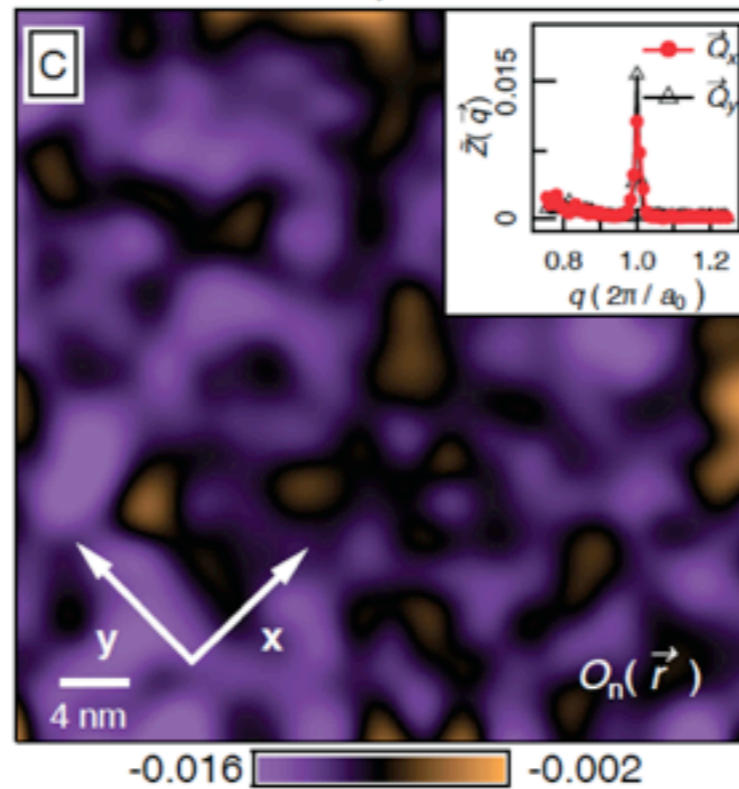
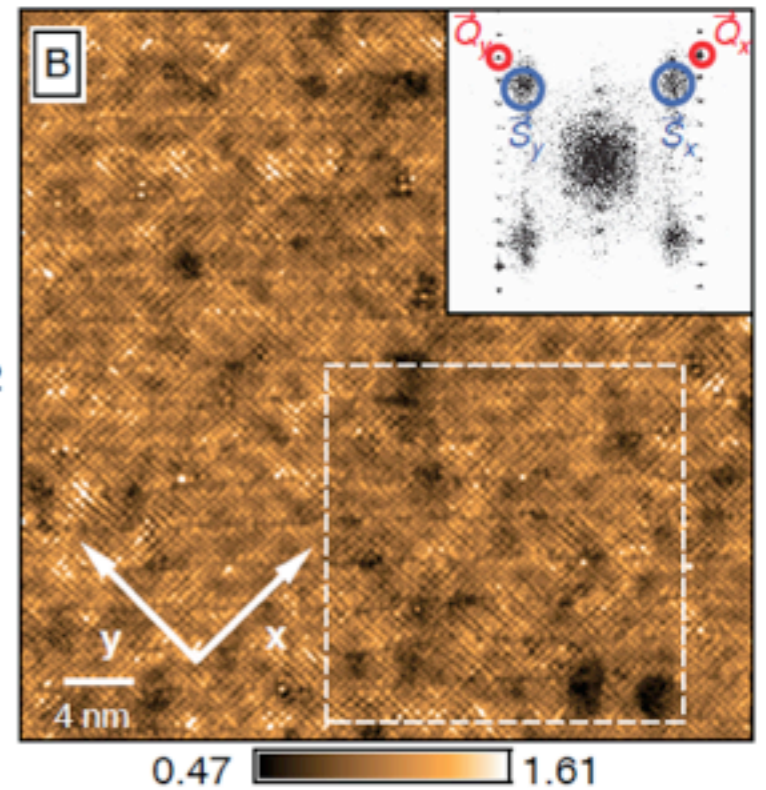
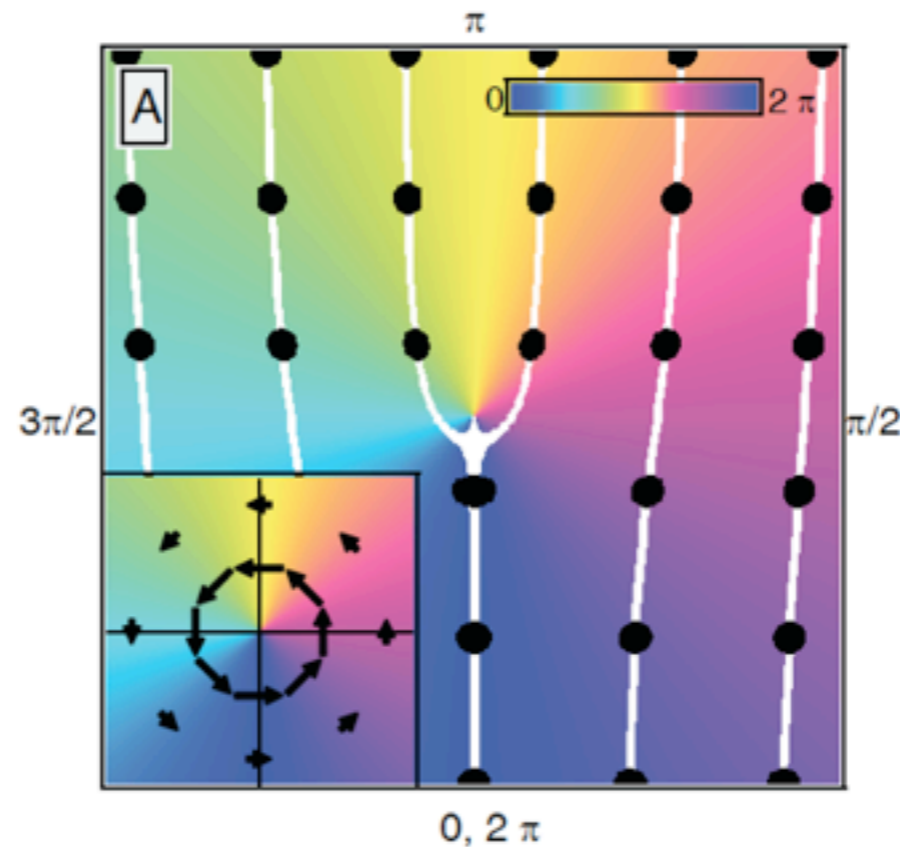


Figure 2 | Imaging the spatial symmetries of the $\omega \approx \Delta_1$ pseudogap states. **a**, Spatial image (R -map⁵) of the $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ pseudogap states $\omega \approx \Delta_1$ at $T \approx 4.3$ K for an underdoped sample with $T_c = 35$ K. The inset shows the Fourier transform upon which the inequivalent Bragg vectors $\mathbf{Q}_x = (1, 0)2\pi/a_0$ and $\mathbf{Q}_y = (0, 1)2\pi/a_0$ are identified by red arrows and circles. The inequivalent wavevectors $\mathbf{S}_x = (\sim 3/4, 0)2\pi/a_0$ and $\mathbf{S}_y = (0, \sim 3/4)2\pi/a_0$ are identified by blue arrows and circles. **b**, Spatial image (R -map⁵) of the $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ pseudogap states $\omega \approx \Delta_1$ at $T \approx 55$ K for the same sample with $T_c = 35$ K. Again, the inset shows the Fourier transform with the inequivalent Bragg

vectors $\mathbf{Q}_x = (1, 0)2\pi/a_0$ and $\mathbf{Q}_y = (0, 1)2\pi/a_0$ identified by red arrows and $\mathbf{S}_x = (\sim 3/4, 0)2\pi/a_0$ and $\mathbf{S}_y = (0, \sim 3/4)2\pi/a_0$ identified by blue arrows and circles. The phenomenology of the $\omega \approx \Delta_1$ pseudogap states, especially their broken spatial symmetries, appear indistinguishable whether in the superconducting phase (a) or in the pseudogap phase (b). **c**, A schematic representation of how electronic contributions from multiple sites within the CuO_2 unit cell could lead to global electronic nematicity in the copper oxides. Here the two O sites are labelled using different colours to represent the inequivalent electronic structure at those locations within each unit cell.

Orden nemático en BSCCO extraído de datos de STM (J.C. Davis et al, 2010)
 Mesaros et al, Science 333, 426 (2011)



$$O_n[M] = \frac{1}{2} [\tilde{M}(Q_y) - \tilde{M}(Q_x) + \tilde{M}(-Q_y) - \tilde{M}(-Q_x)]$$

$$= \text{Re} \tilde{M}(Q_y) - \text{Re} \tilde{M}(Q_x)$$

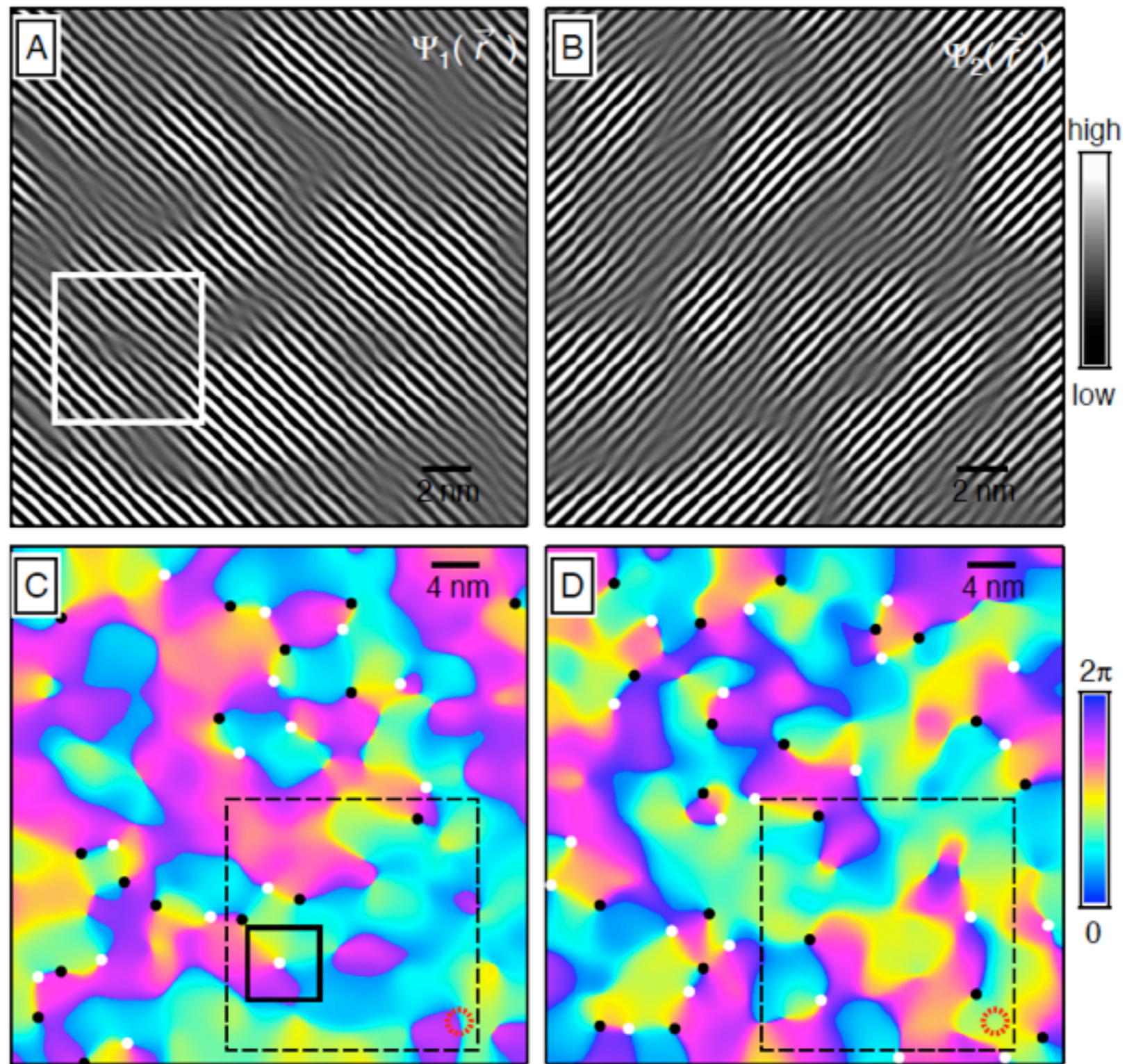
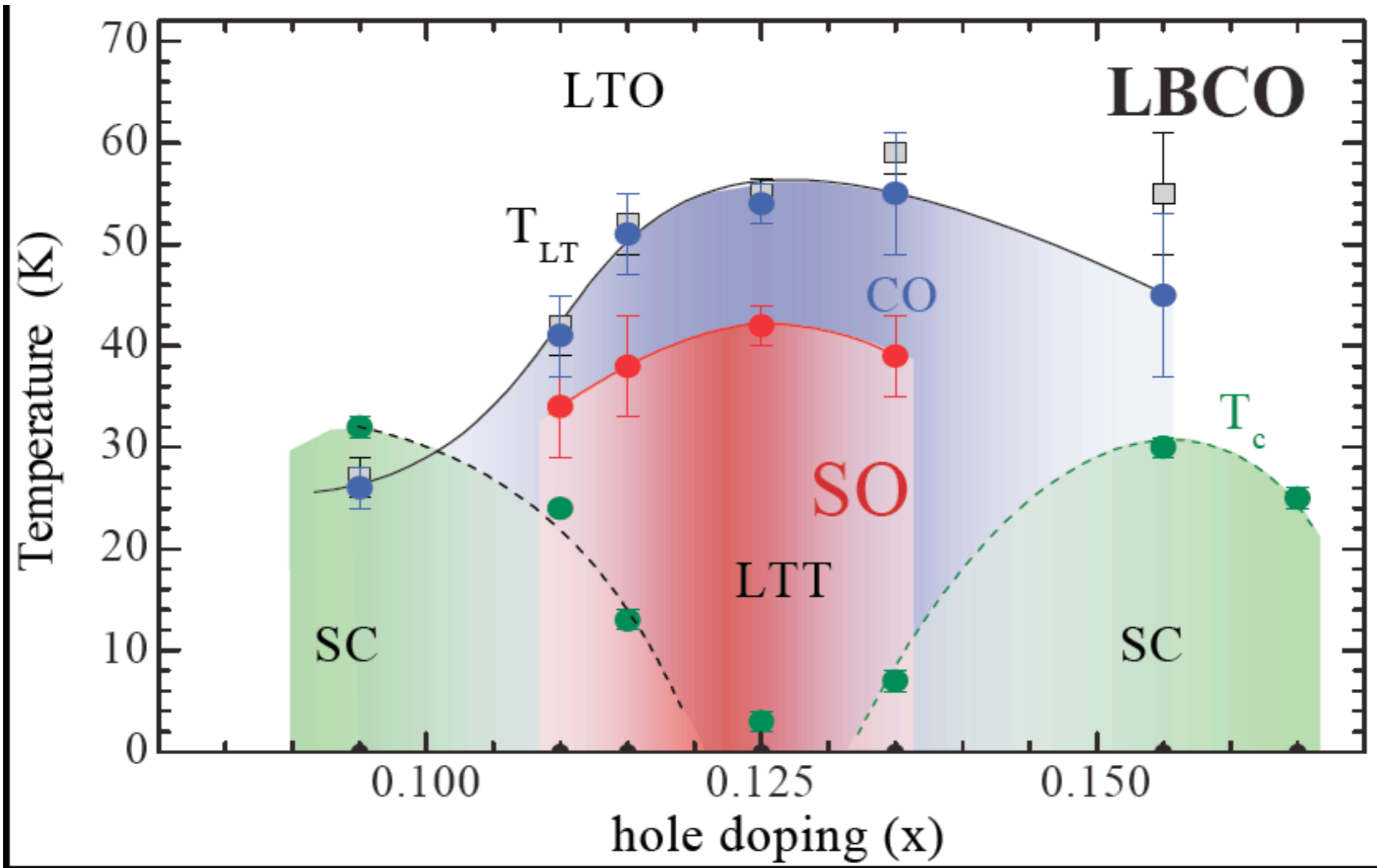
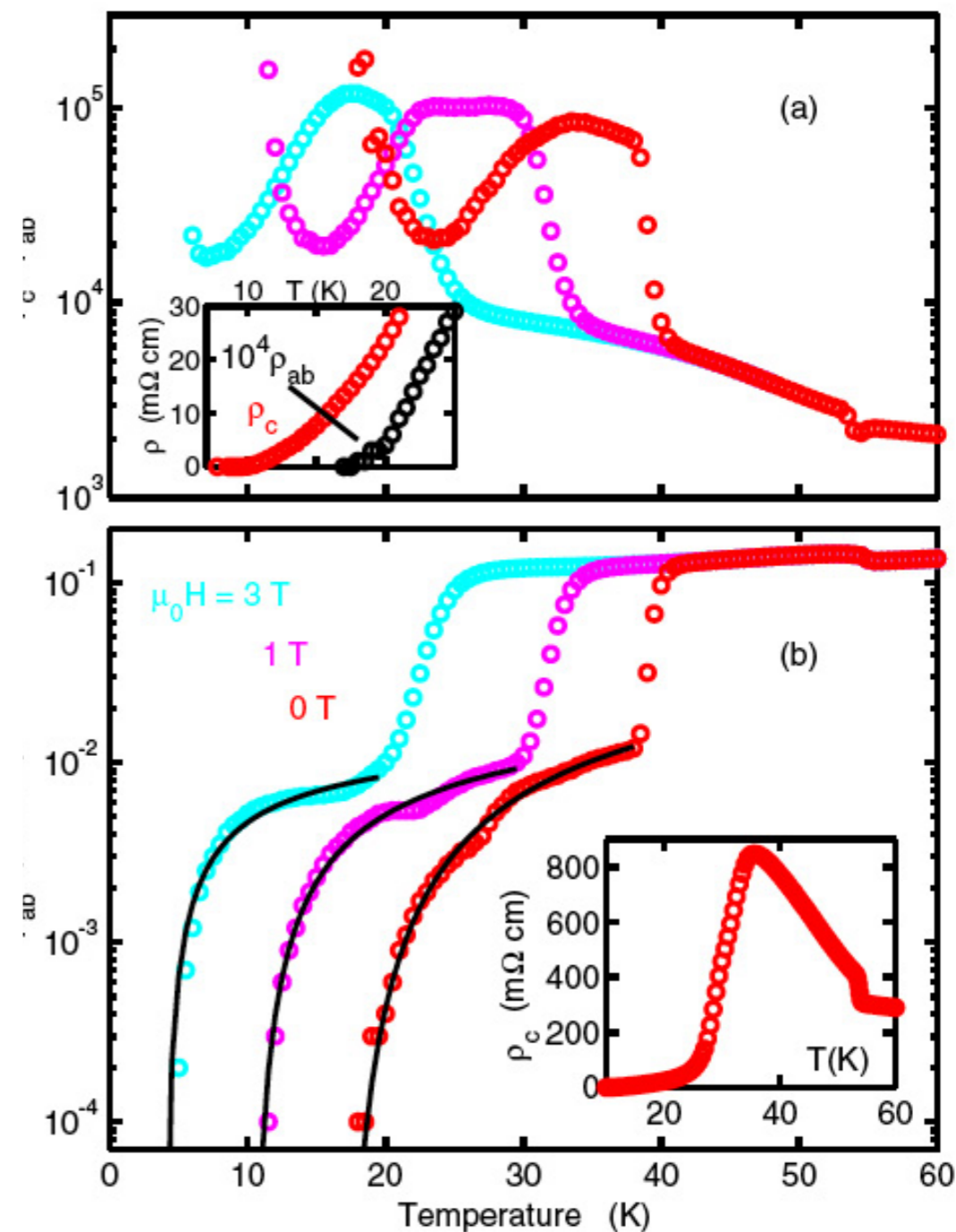
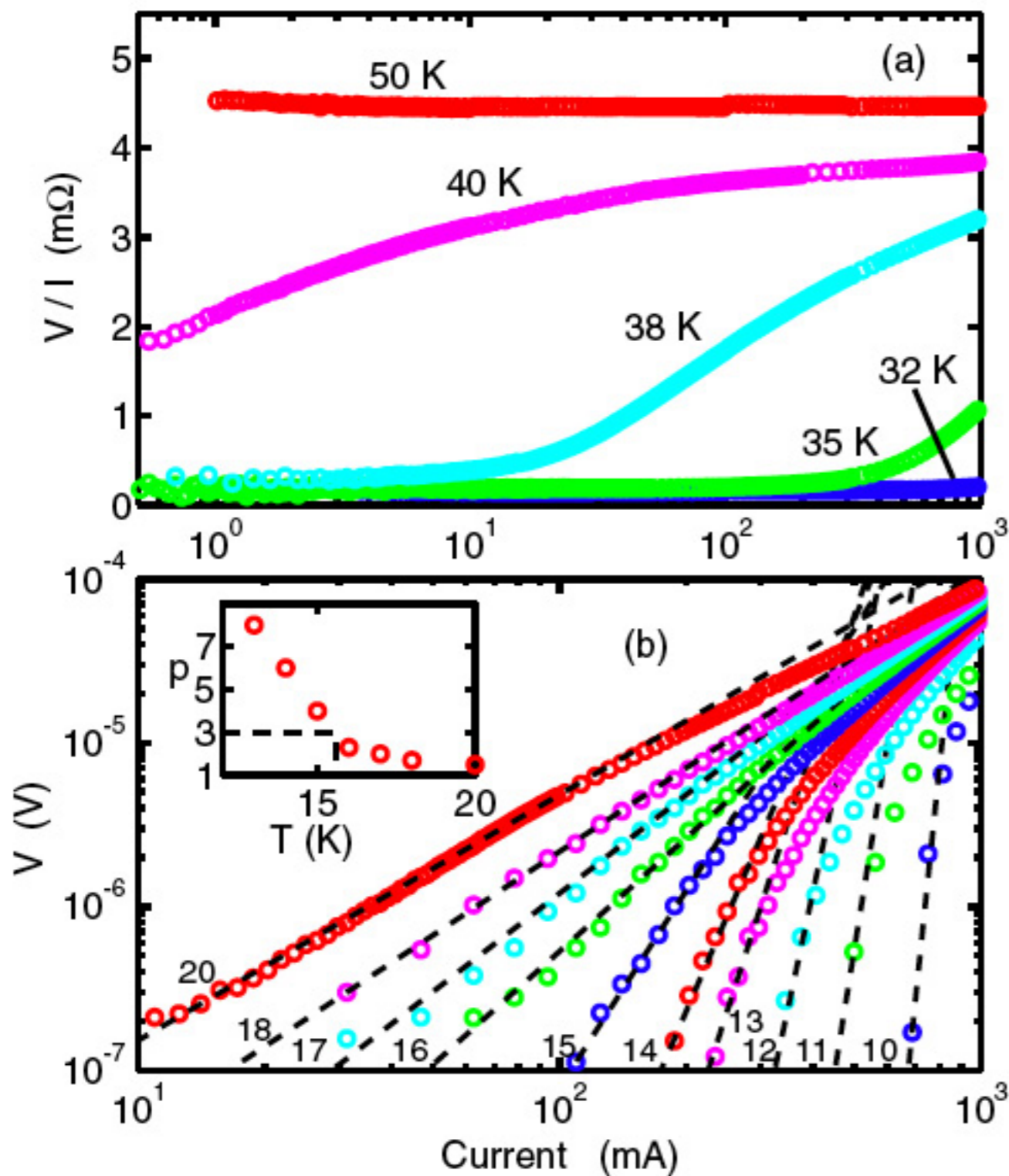


Diagrama de fase de $\text{La}_{2-x}\text{Ba}_x\text{CuO}_4$ (Tranquada, 2007)
C. Homes et al Phys. Rev. B 85, 134510 (2012)

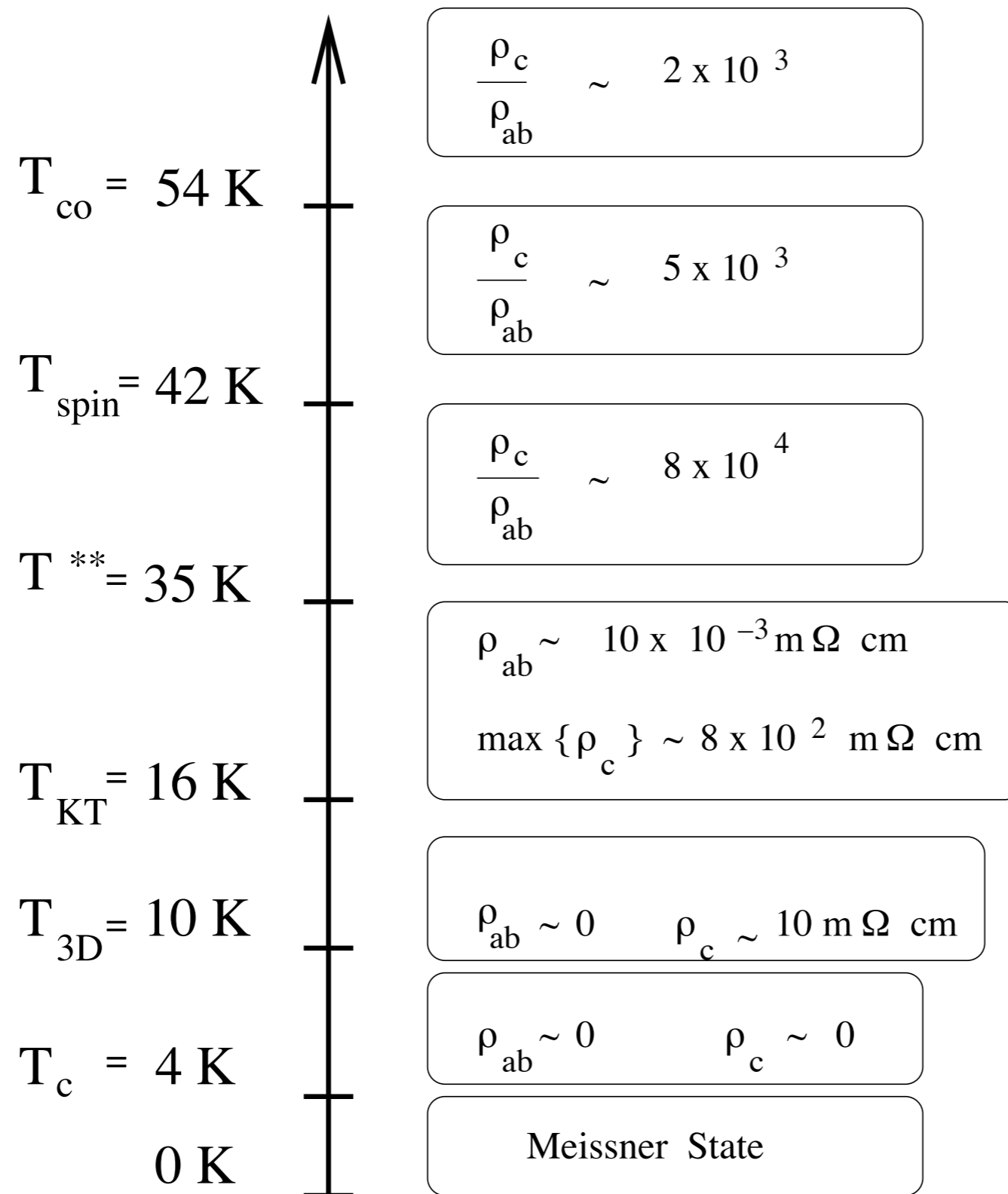


Transporte en $\text{La}_{2-x}\text{Ba}_x\text{CuO}_4$ (Tranquada et al, 2007) Li et al, Phys. Rev. Lett. 99, 067001 (2007)



Desacople dinámico de la superconductividad en los planos de CuO en LBCO

E. Berg et al, Phys. Rev. Lett. 99, 127003 (2007)



Violación de la relación universal de Josephson en LCO dopado con Sr, Nd y Ba (Basov et al 2010)

A. Schafgans et al, Phys. Rev. B 82, 100505(R) (2010)

