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Onset of nematicity in YBCO

Interplay with charge order & superconductivity

Louis Taillefer

Collège de France, Paris, 26 March 2015

Onset of nematicity in YBCO

Interplay with charge order & superconductivity

UNIVERSITÉ DE SHERBROOKE

UBC

O. Cyr-Choinière

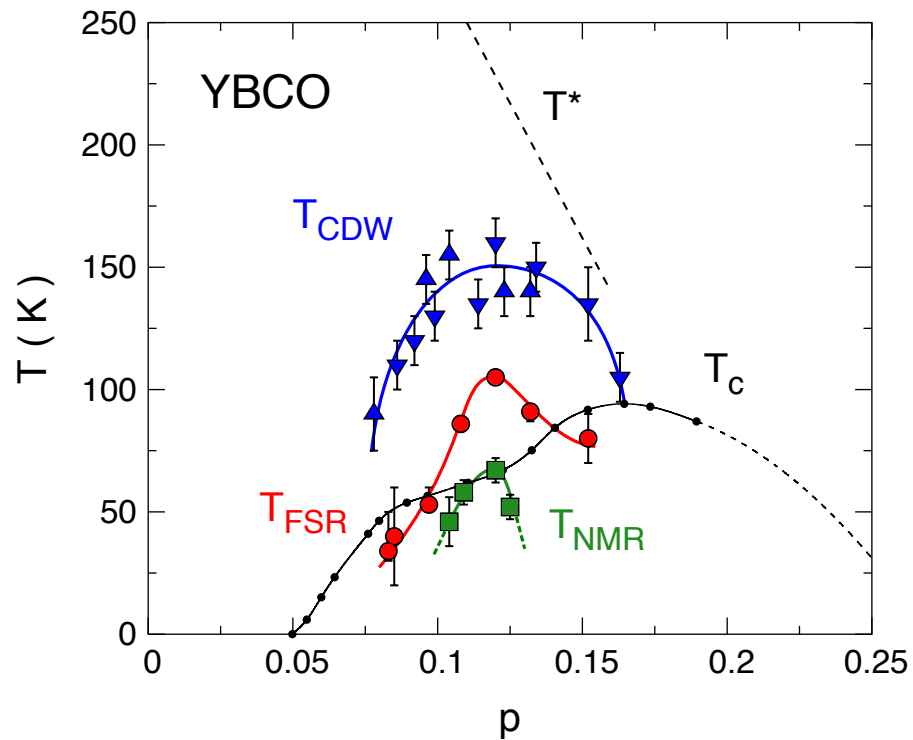**G. Grissonnanche**

S. Badoux

N. Doiron-Leyraud

L. Taillefer

J. Day

R. Liang

W. N. Hardy

D. A. Bonn

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CANADIAN
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RESEARCH
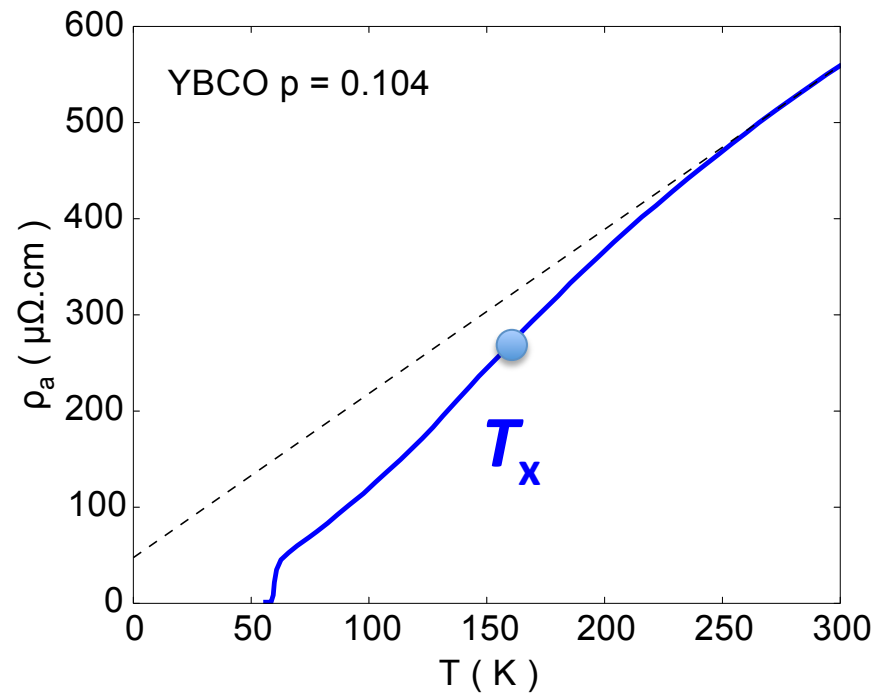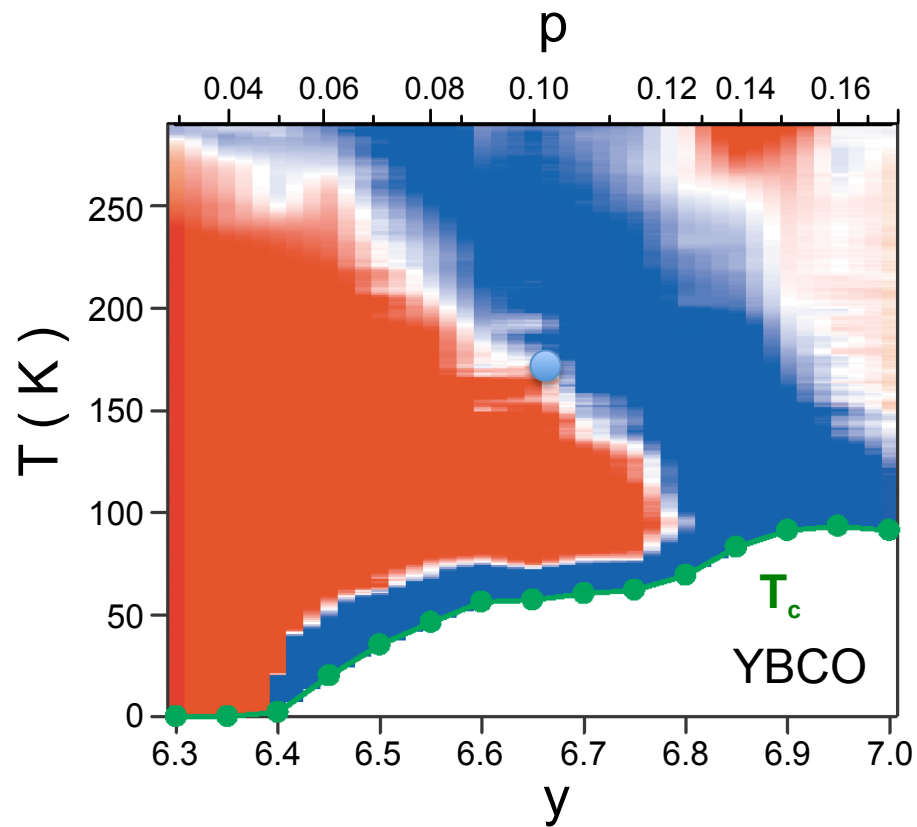
Phases & Questions

1) Superconductivity   – *Why a dome ?*   – *Why peaked at p = 0.16 ?*

2) Pseudogap   – *What is it ?*   – *Crossover or transition ?*

3) Charge order   – *Why a dome ?*   – *Why peaked at p = 0.12 ?*

4) Nematicity   – *Where from?*   – *Crossover or transition ?*
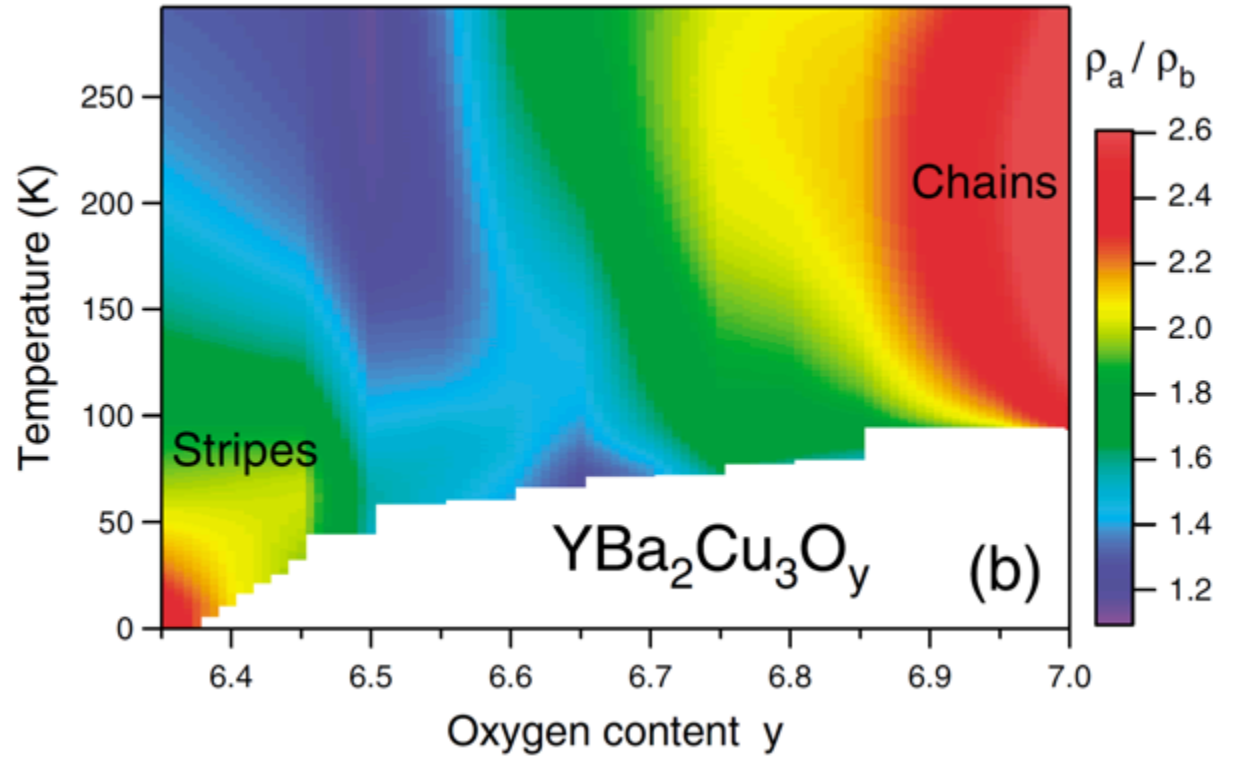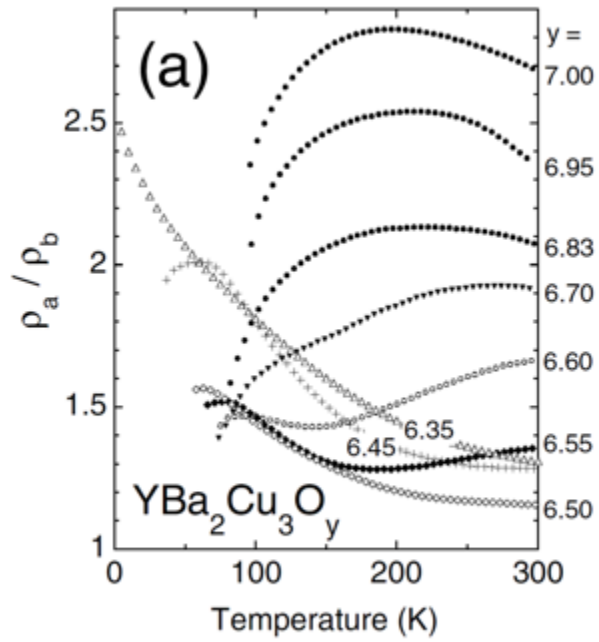
The central line – T_x
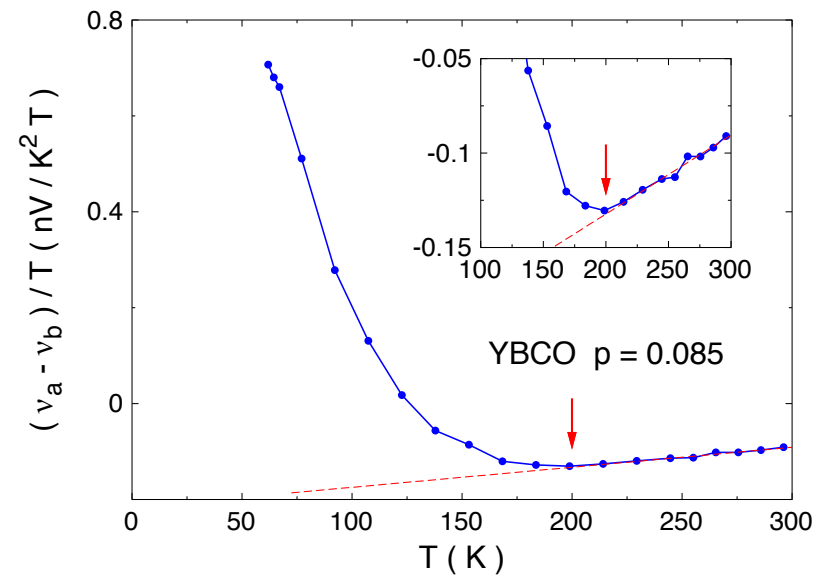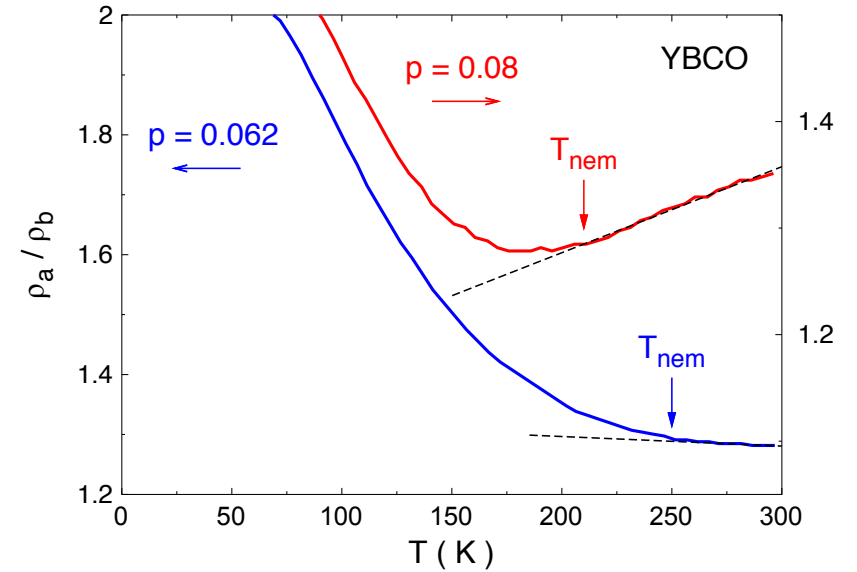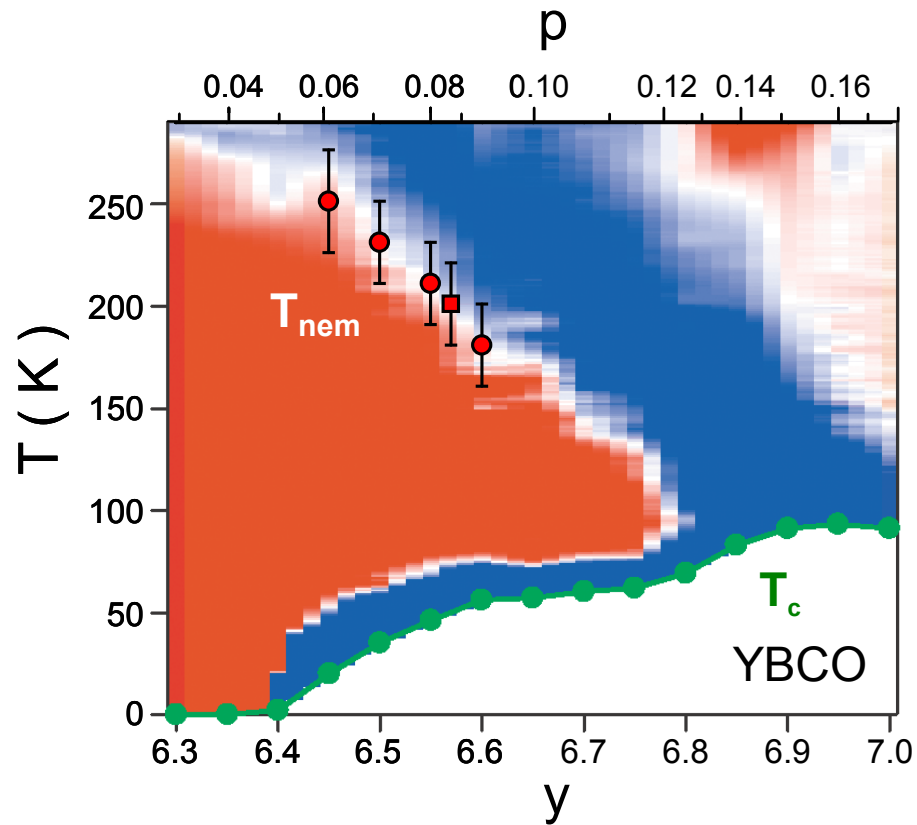

p

YBCO p = 0.104

T_c

YBCO

T_x

Ando *et al.*, PRL **93**, 267001 (2004)
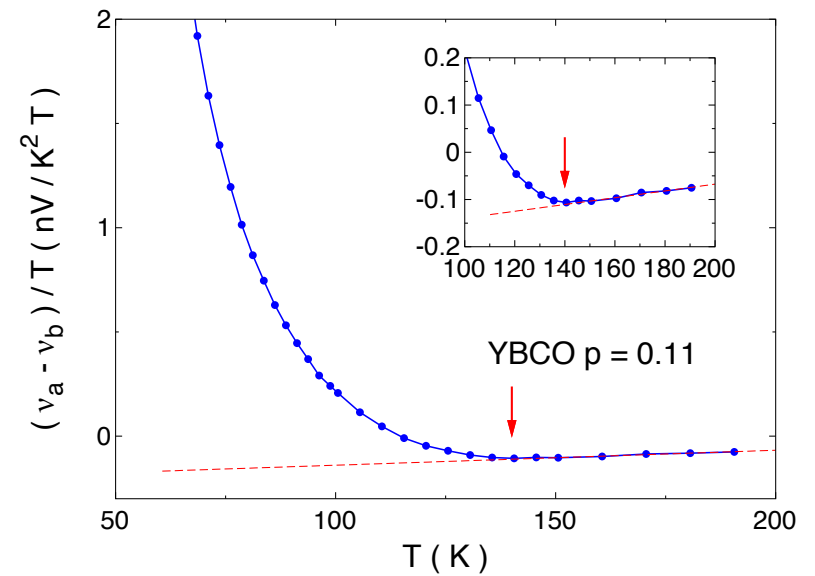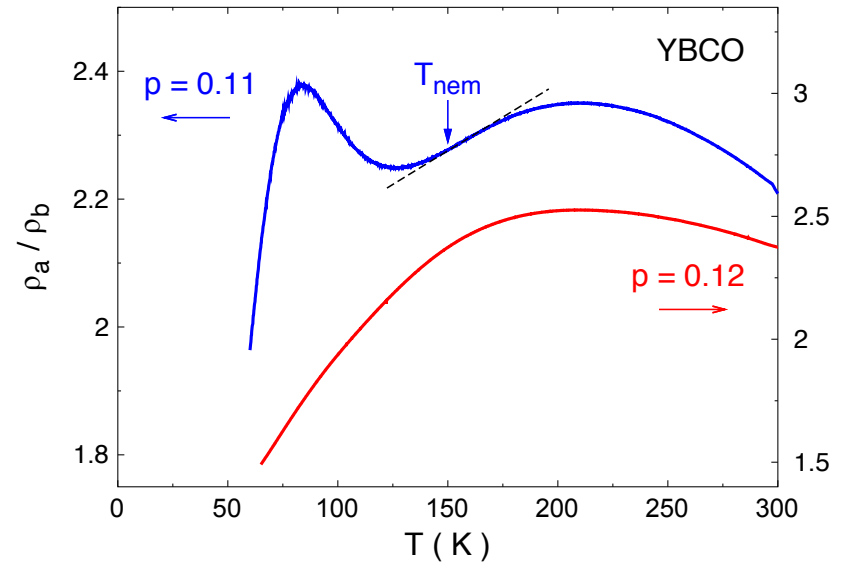
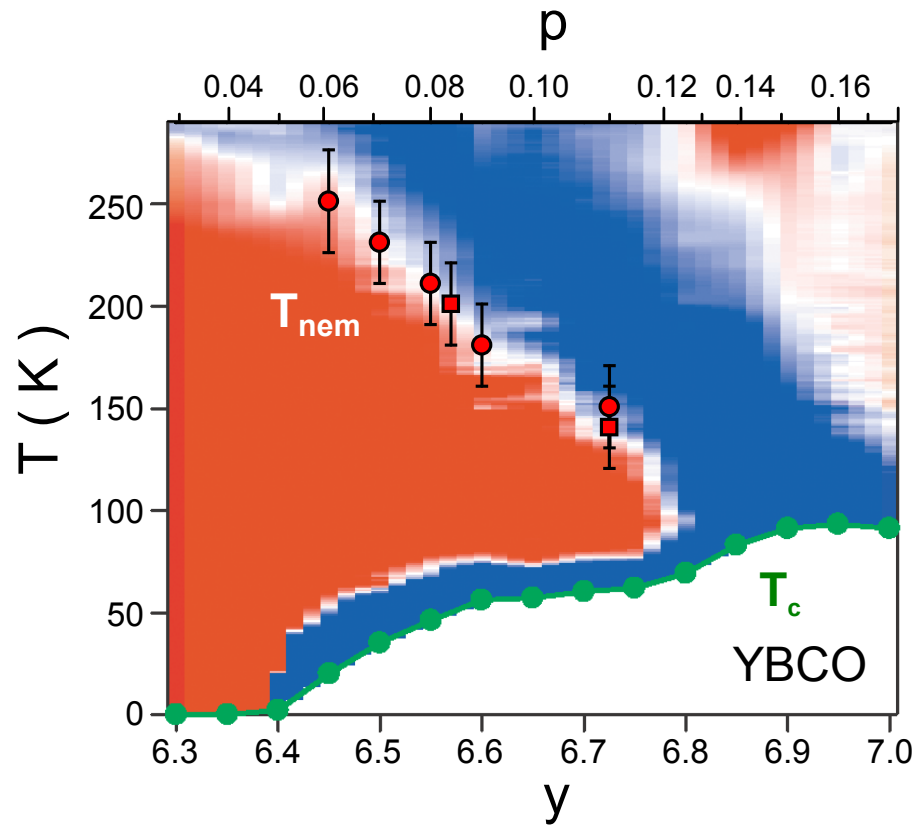# In-plane anisotropy of the resistivty in YBCO

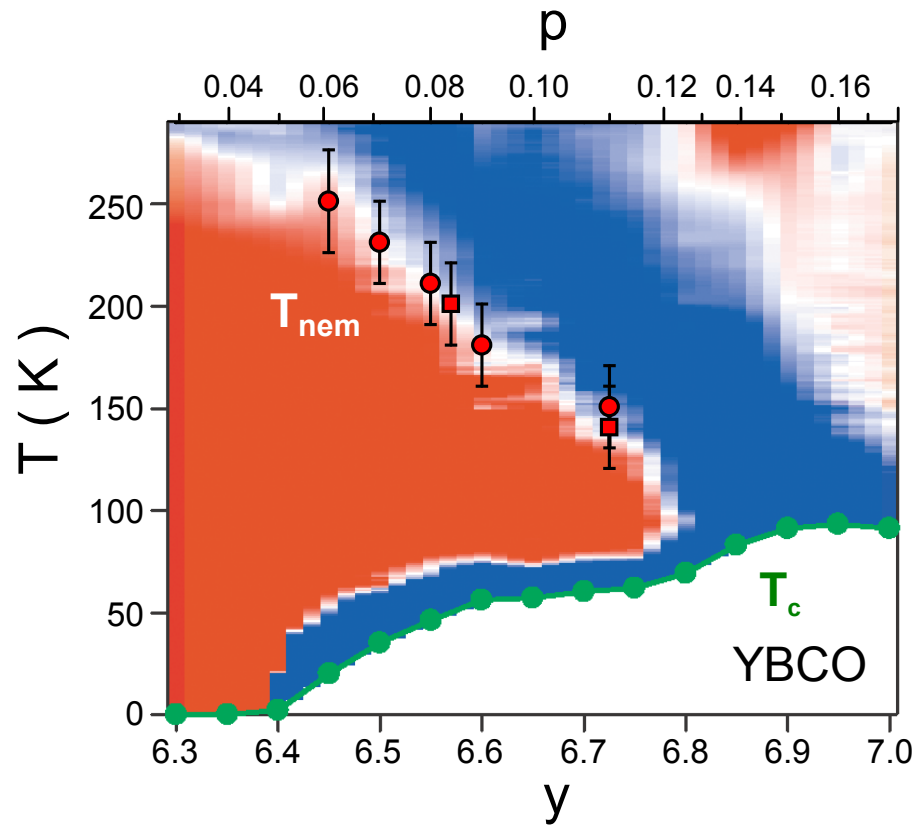Ando *et al.*, PRL **88**, 137005 (2002)

The nematic line – T_{nem}

Cyr-Choinière *et al.,* arXiv:1504.06972 (2015)
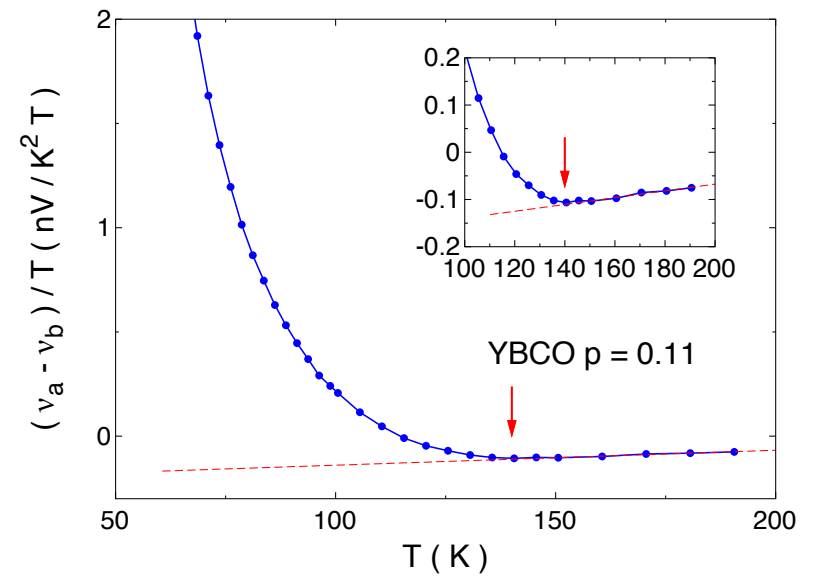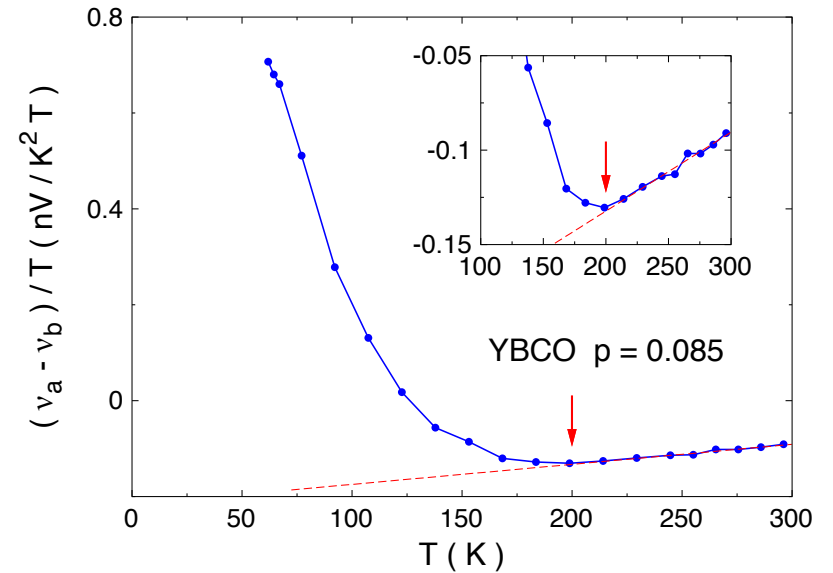
The nemantic line – T_{nem}

Cyr-Choinière *et al.,* arXiv:1504.06972 (2015)

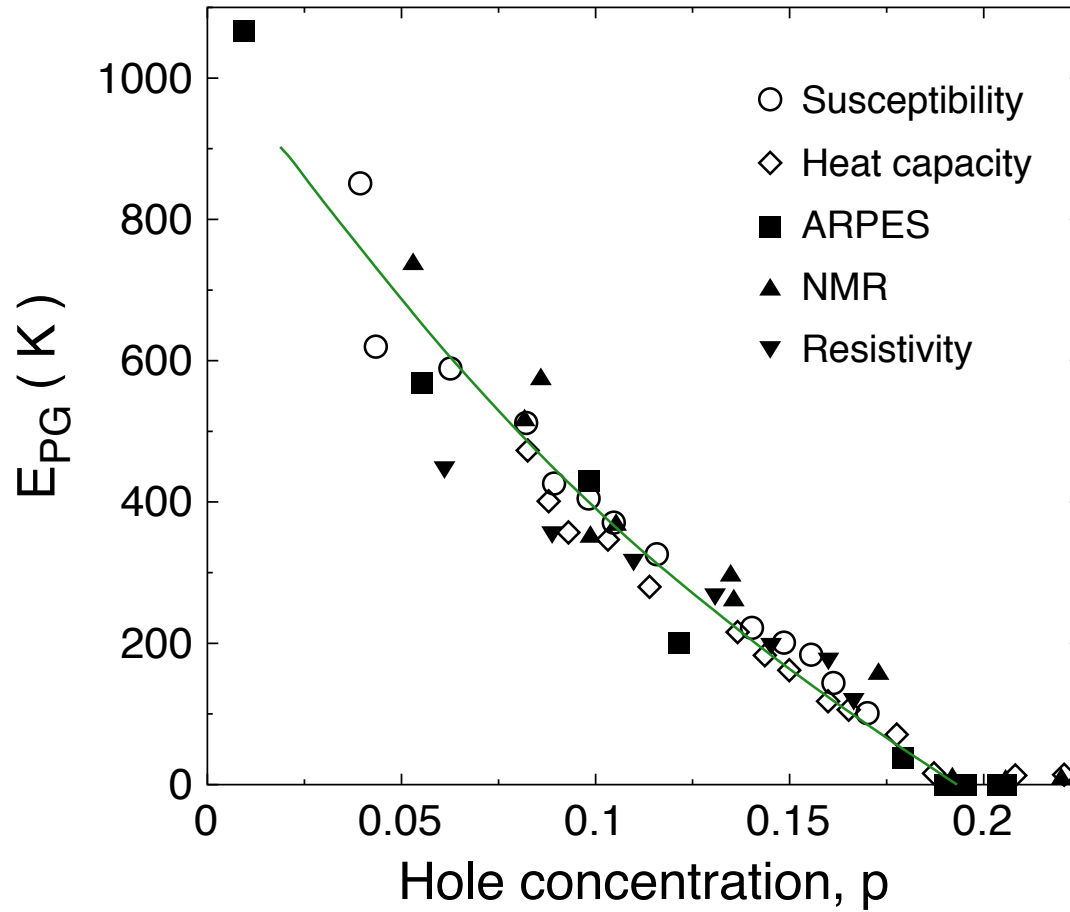# The nematic line   − T_{nem}

$T_x = T_{nem}$

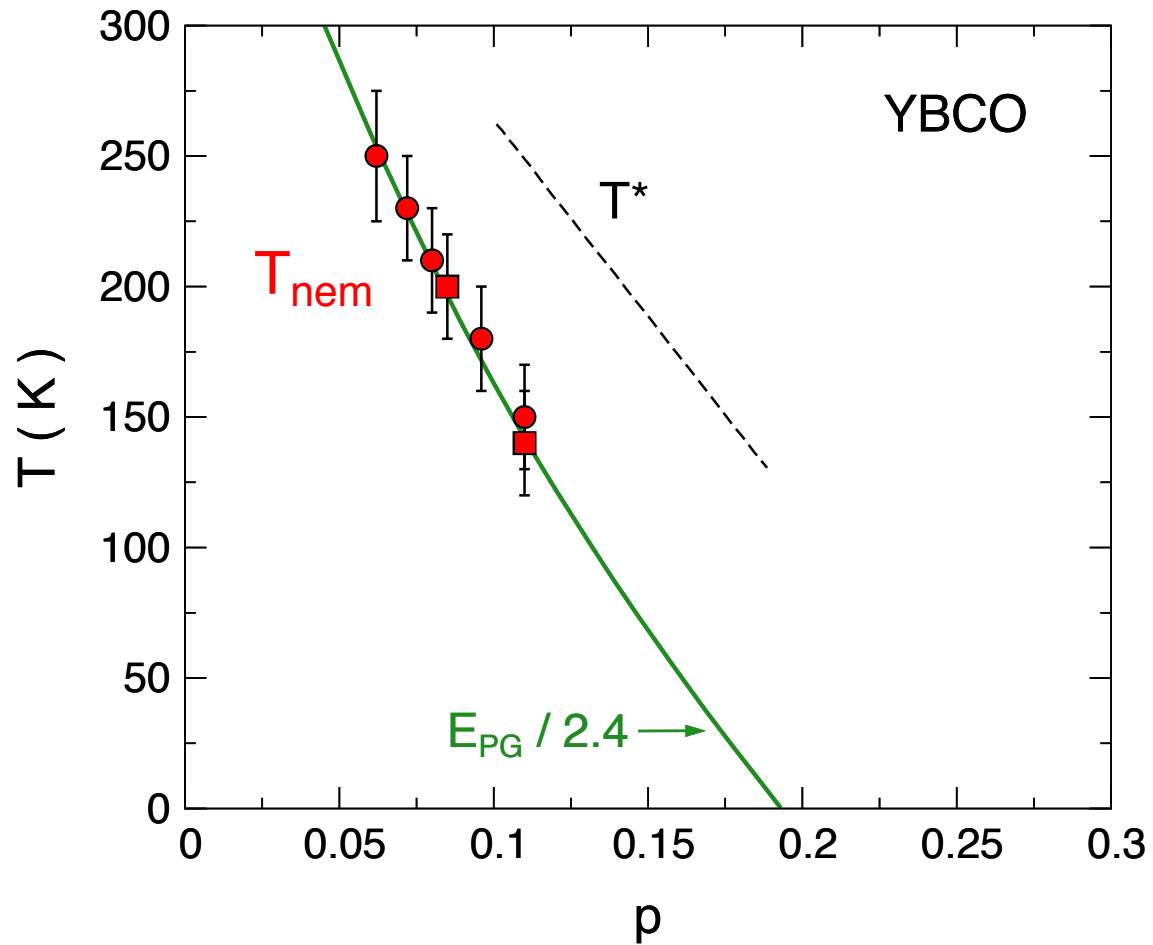Cyr-Choinière *et al.,* arXiv:1504.06972 (2015)

The pseudogap energy – E_{PG}

Tallon & Loram, Physica C **349**, 53 (2001)
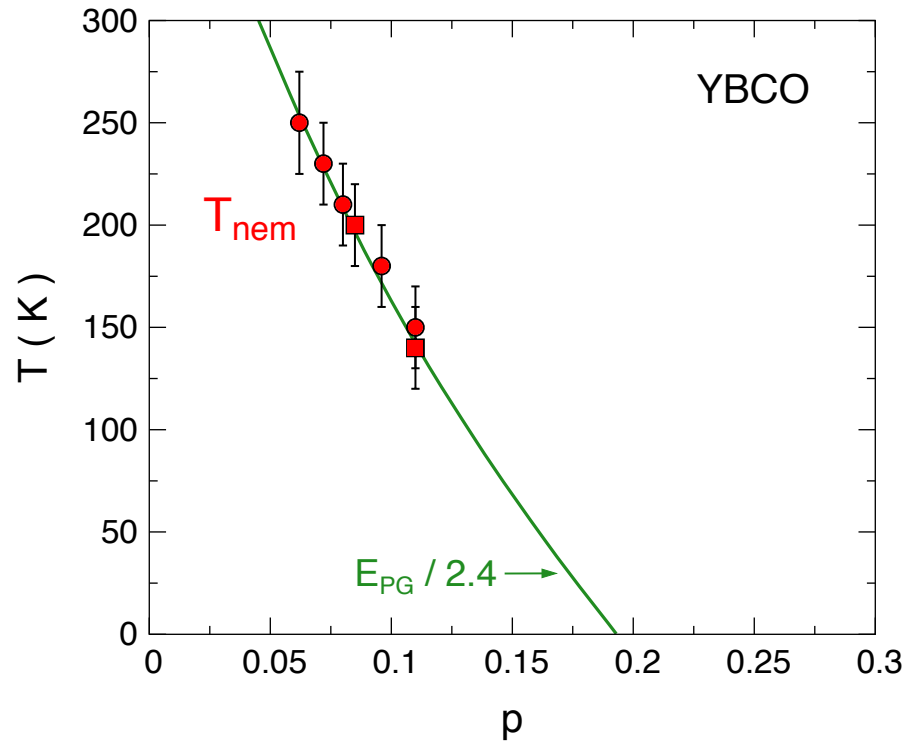
The pseudogap energy − E_{PG}

$$E_{PG} = 2.4\, T_{nem}$$

YBCO

T_{nem}

T*

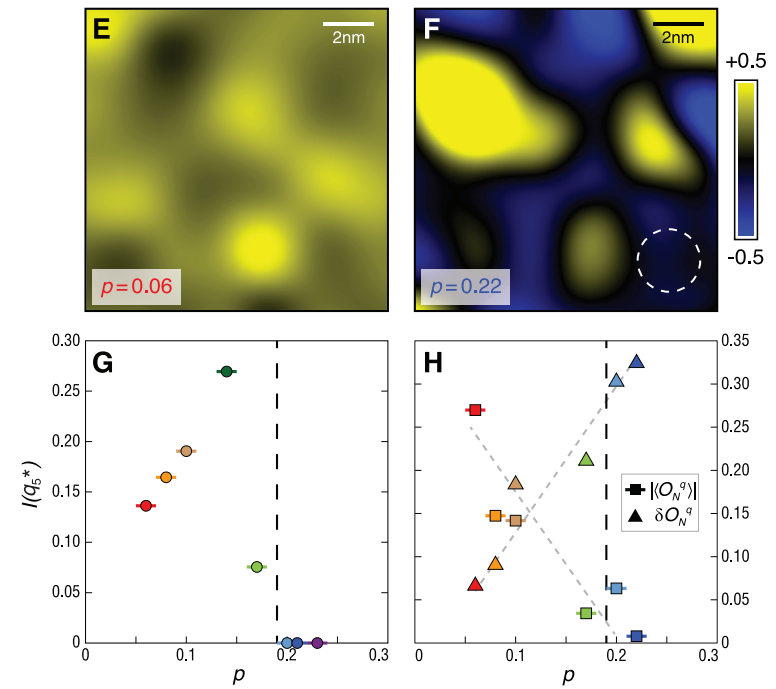$E_{PG}\,/\,2.4\;\longrightarrow$

T (K)

p

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)   Tallon & Loram, Physica C **349**, 53 (2001)

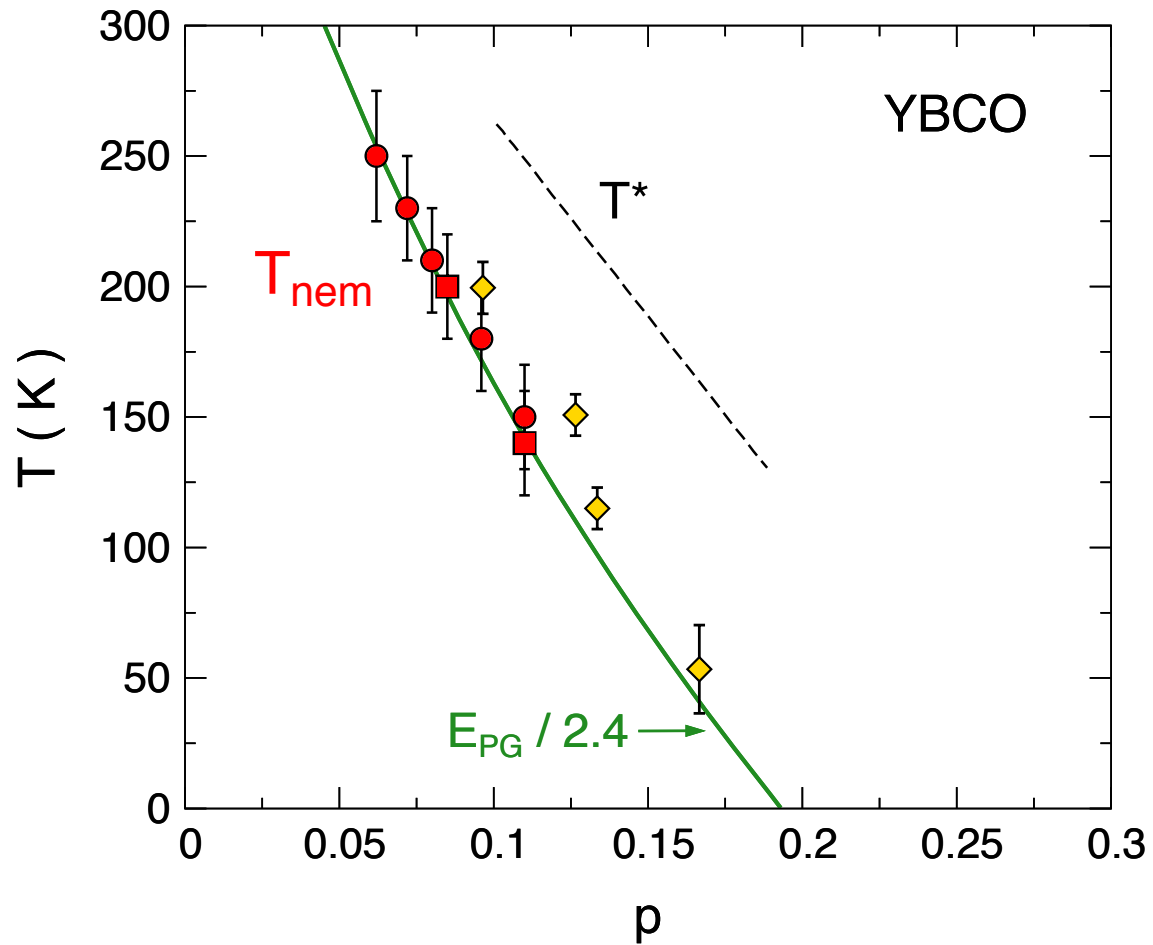# The pseudogap energy – E_{PG}

STM on Bi-2212

Fujita *et al*., Science **344**, 612 (2014)

Tallon & Loram, Physica C **349**, 53 (2001)

Cyr-Choinière *et al*., arXiv:1504.06972 (2015)

Onset of Kerr signal – T_K

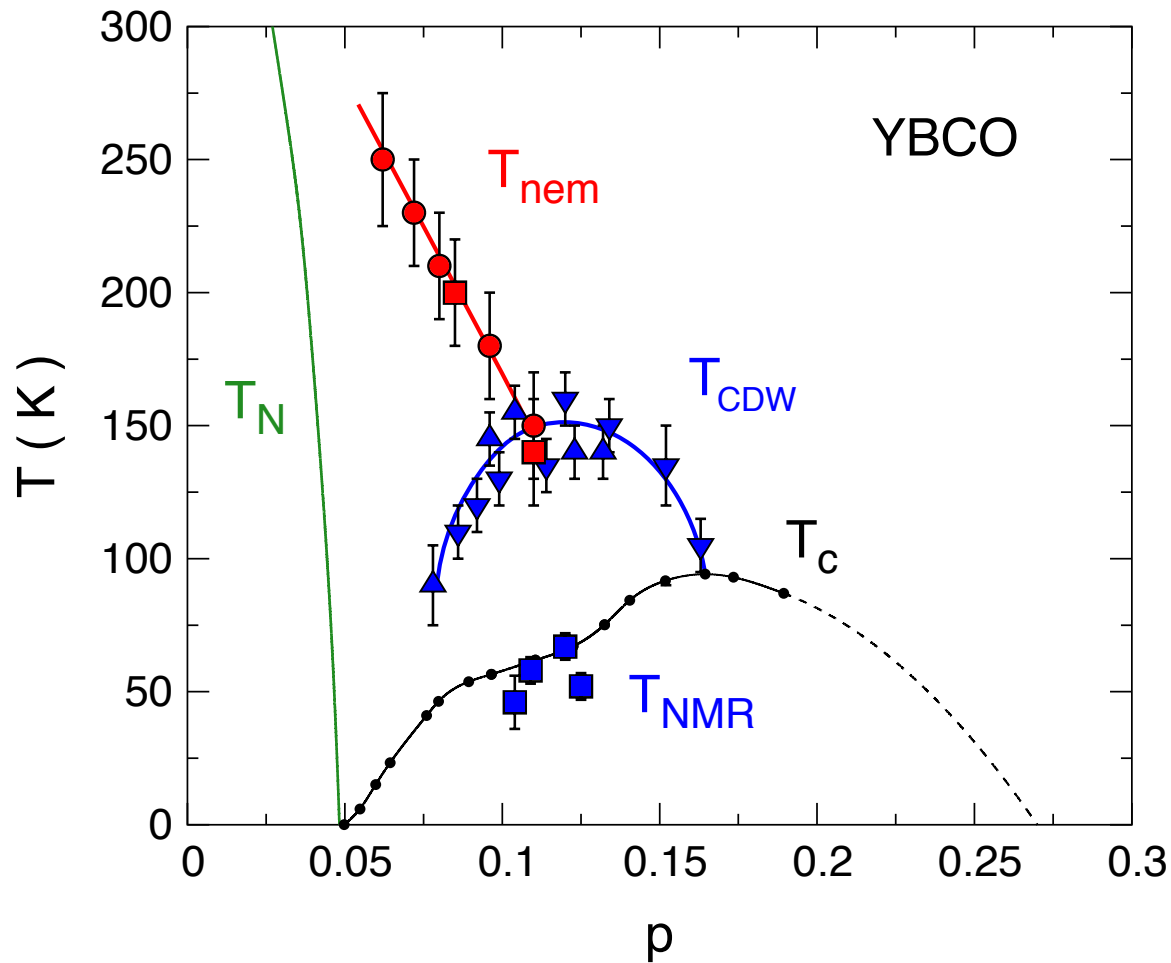Xia *et al.*, PRL **100**, 127002 (2008)

YBCO

T_{nem}

T^*

E_{PG} / 2.4 →

T (K)

p

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)   Tallon & Loram, Physica C **349**, 53 (2001)

Charge order   – T_{CDW}

T_{nem} hits T_{CDW} dome at peak

Hücker *et al.*, PRB **90**, 054514 (2014)

Blanco-Canosa *et al.*, PRB **90**, 054513 (2014)

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)

Wu *et al.*, Nat. Comm. **4**, 2113 (2013)

Suppression of charge order by pressure in YBCO

Restoring the full superconducting dome

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O. Cyr-Choinière

D. LeBoeuf

S. Badoux

S. Dufour-Beauséjour

N. Doiron-Leyraud

L. Taillefer

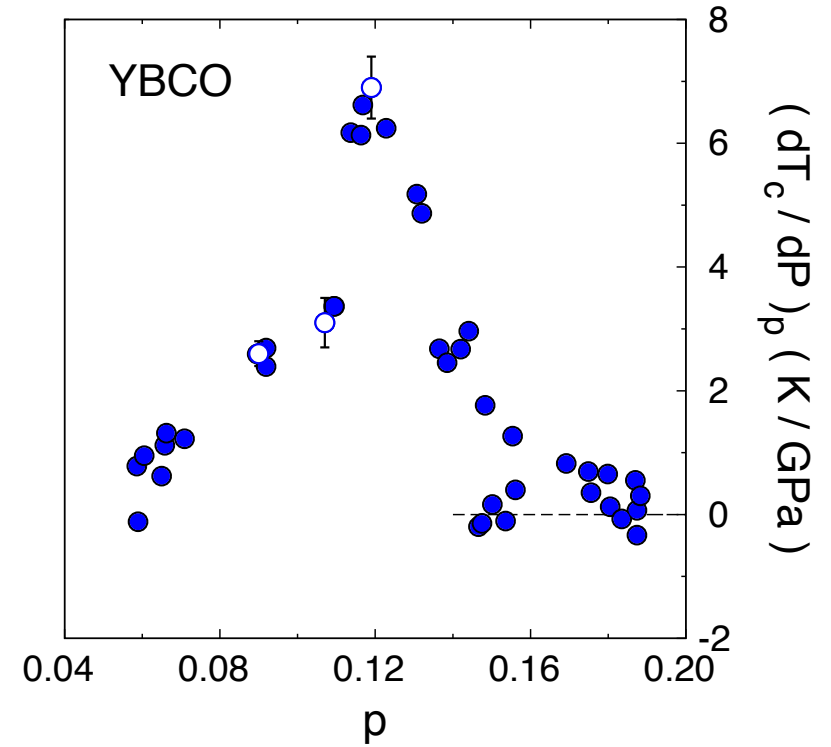R. Liang

W. N. Hardy

D. A. Bonn

T_c in oxygen-ordered YBCO
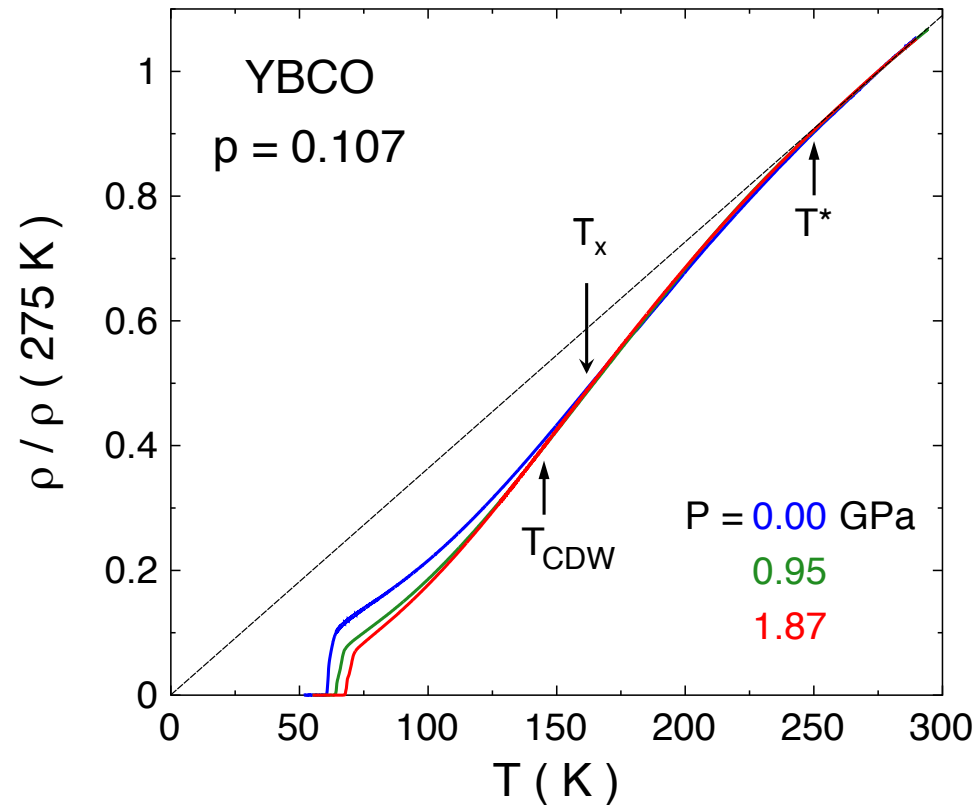
T_c : enhanced by pressure T_x , T^* : unchanged by pressure

Cyr-Choinière *et al.*, arXiv:1503.02033 (2015)

T_c in oxygen-ordered YBCO
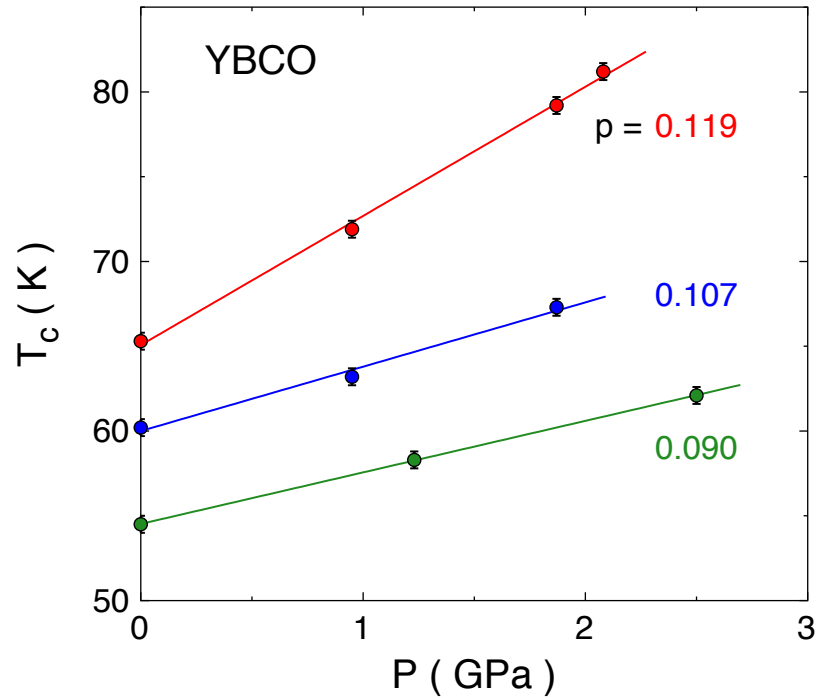
Why is T_c enhanced by pressure ?

dT_c / dP peaks at $p = 0.12$

Cyr-Choinière *et al.*, arXiv:1503.02033 (2015)

T_c in oxygen-ordered YBCO
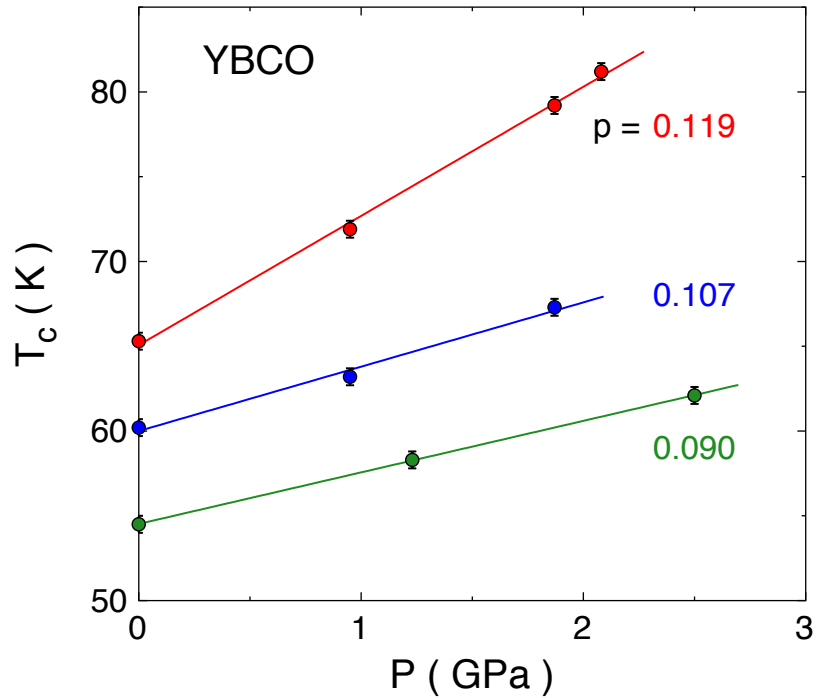
- dT_c / dH peaks at $p = 0.12$

dT_c / dP peaks at $p = 0.12$

Cyr-Choinière *et al.*, arXiv:1503.02033 (2015)
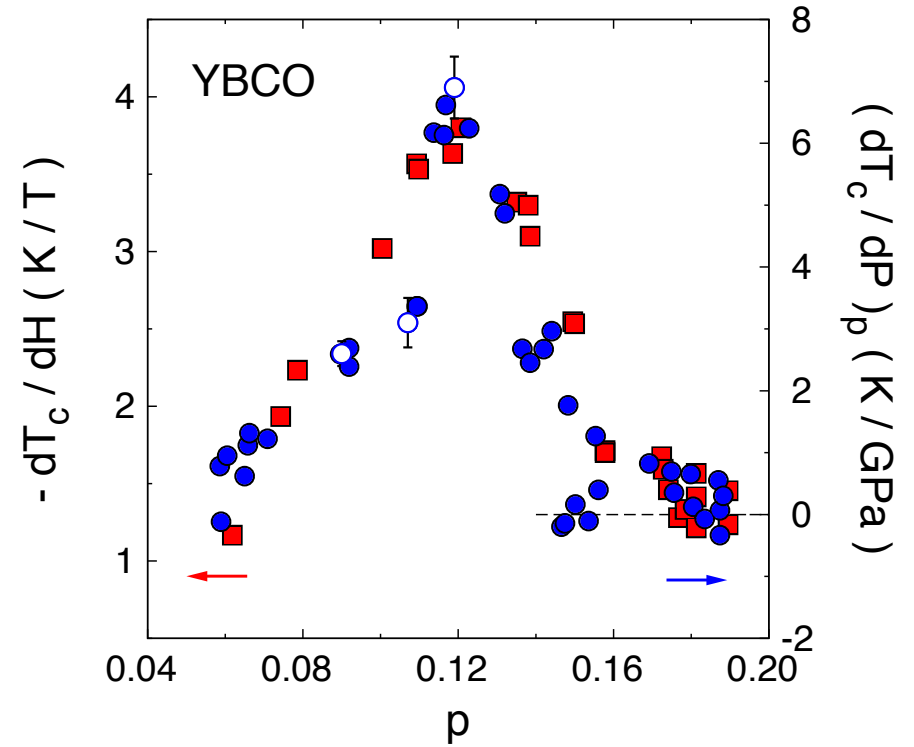
Enhancing T_c by P
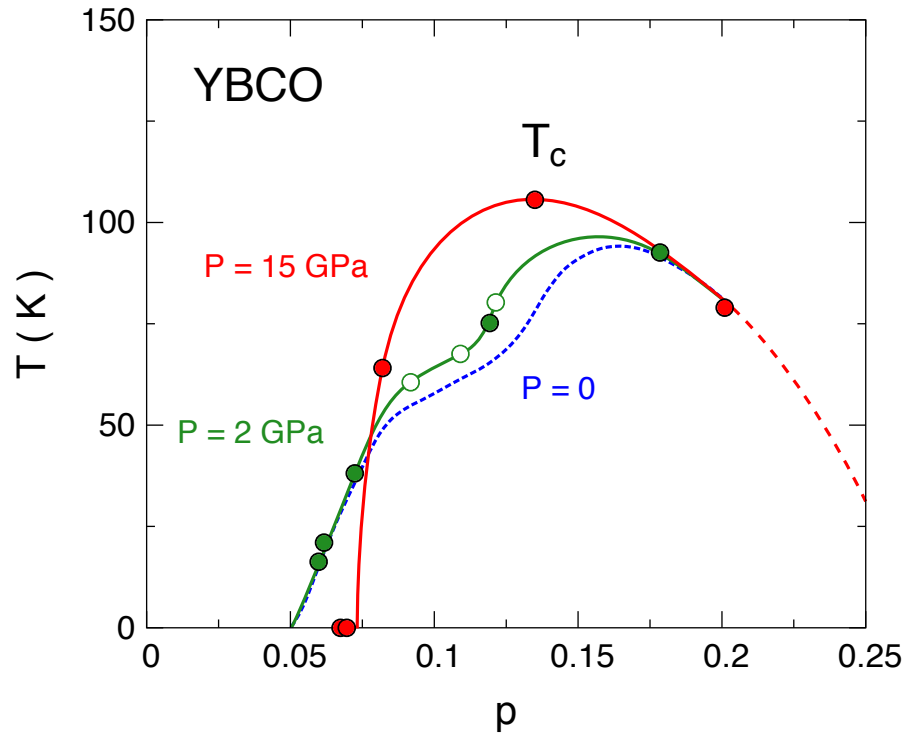
T_c dome restored at P = 15 GPa

dT_c / dP peaks at p = 0.12

Cyr-Choinière *et al.*, arXiv:1503.02033 (2015)
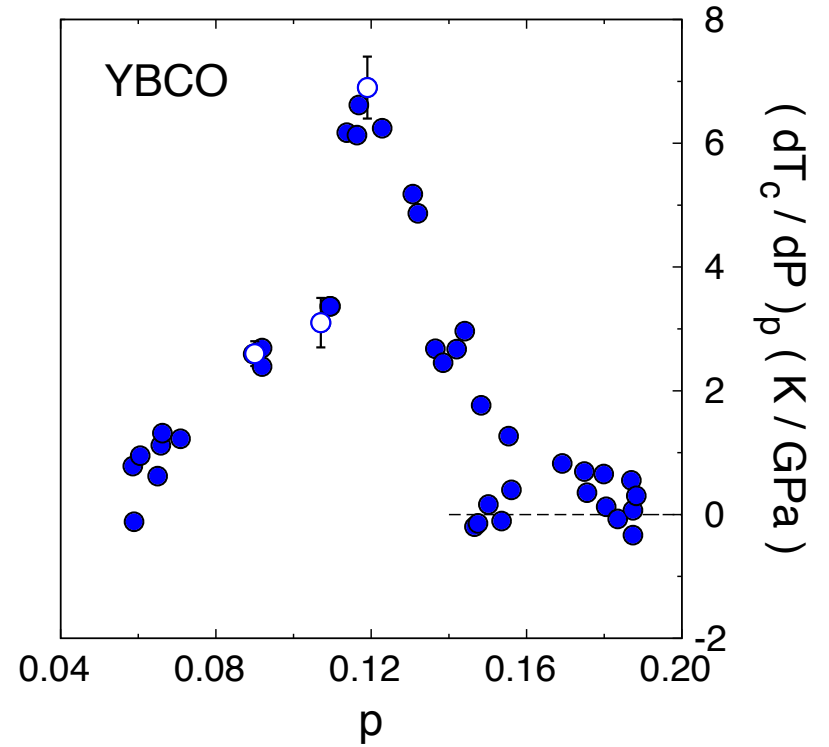
Superconductivity – T_c | T_{nem} hits T_c dome at peak

Cyr-Choinière *et al.*, arXiv:1503.02033 (2015)   Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)
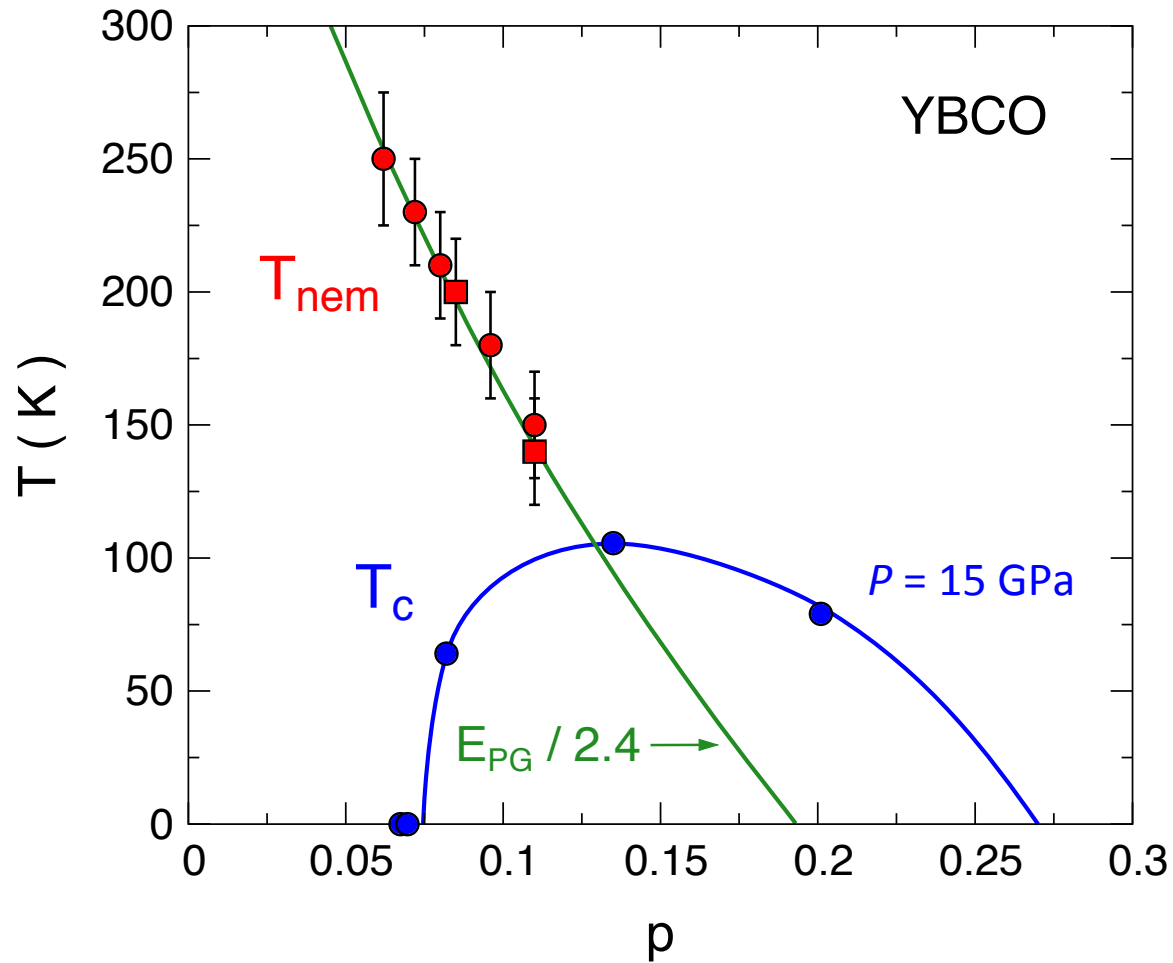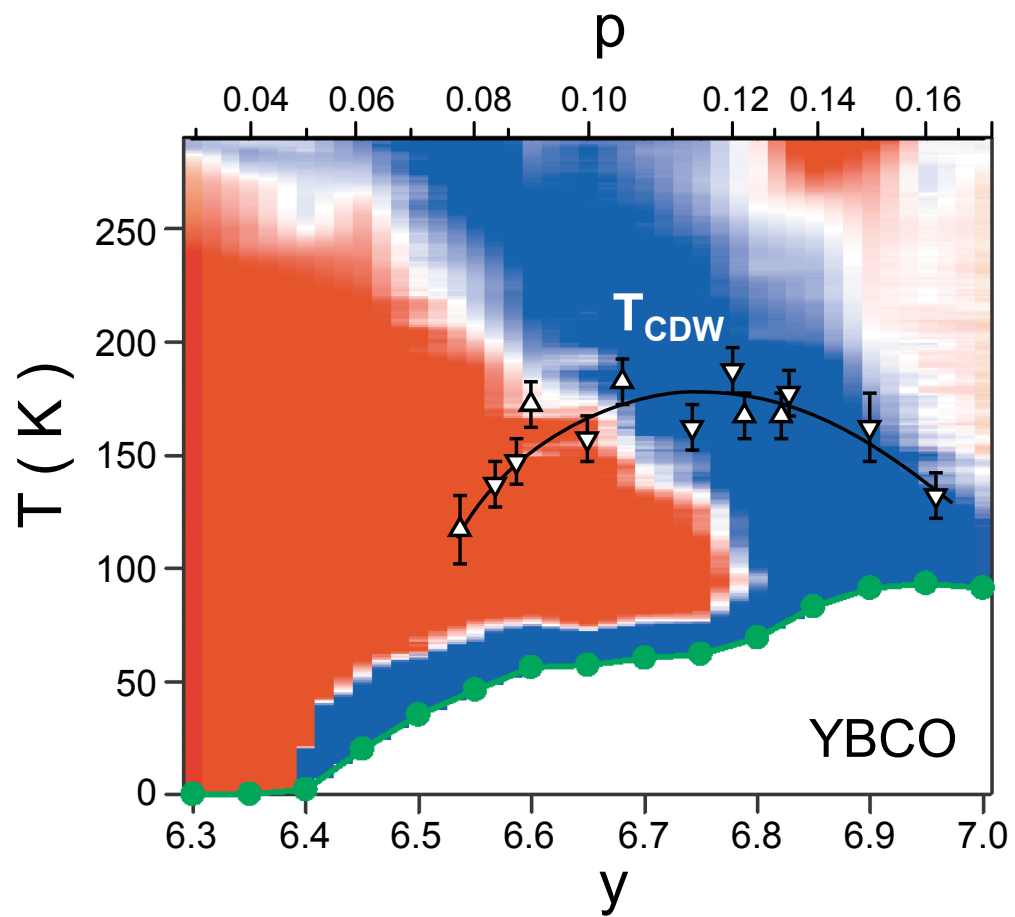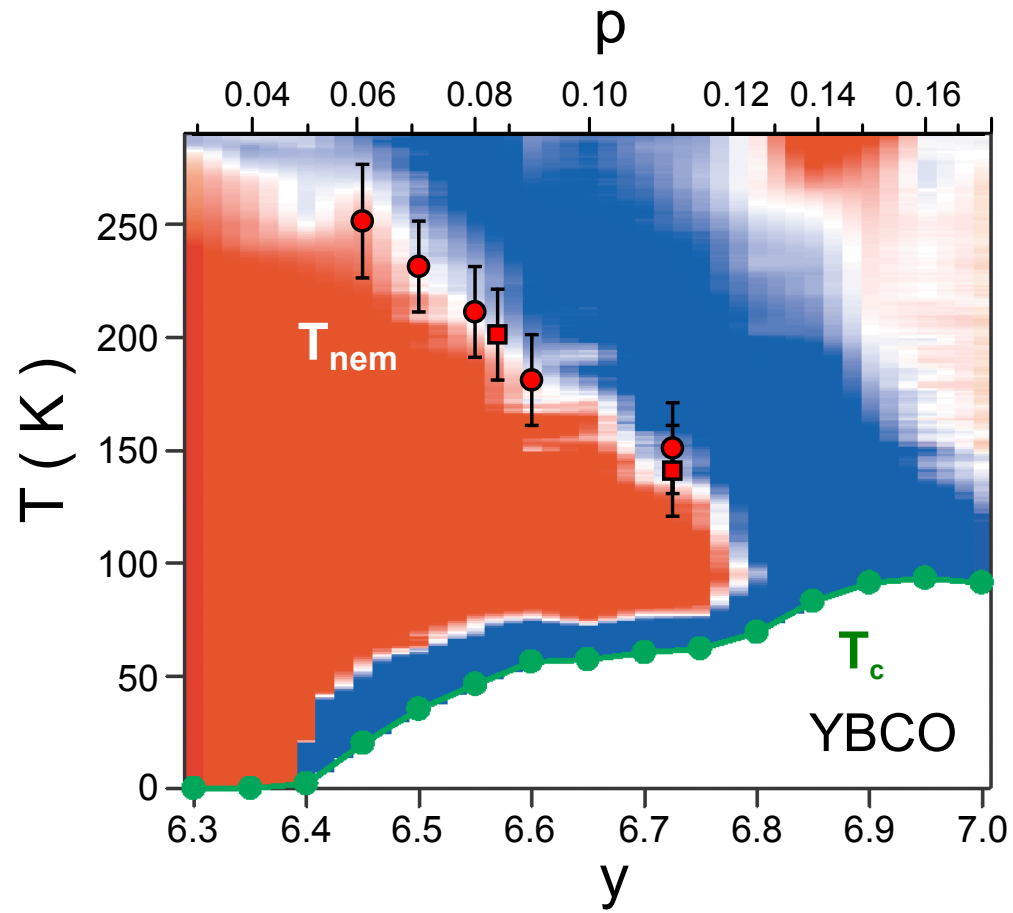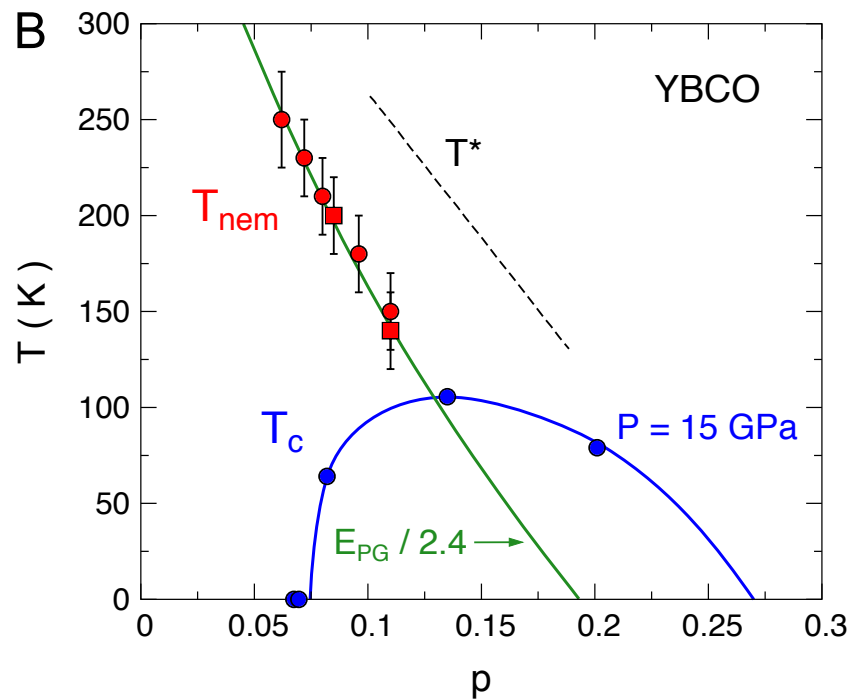
SUMMARY

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)

SUMMARY

$T_x = T_{nem}$

$T_{nem} = E_{PG} / 2.4$

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)
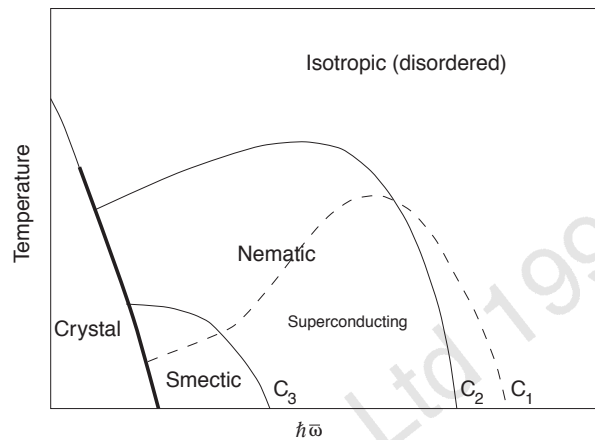
SUMMARY

$T_x = T_{nem}$

$T_{nem} = E_{PG} / 2.4$

A — YBCO phase diagram showing T_N, T_{nem}, T_{CDW}, T_c, T_{NMR} versus p, with axes T (K) and p.

T_{nem} hits T_{CDW} dome at peak

B — YBCO phase diagram showing T_{nem}, T^*, T_c versus p at $P = 15$ GPa, with $E_{PG} / 2.4$ label.

T_{nem} hits T_c dome at peak

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)
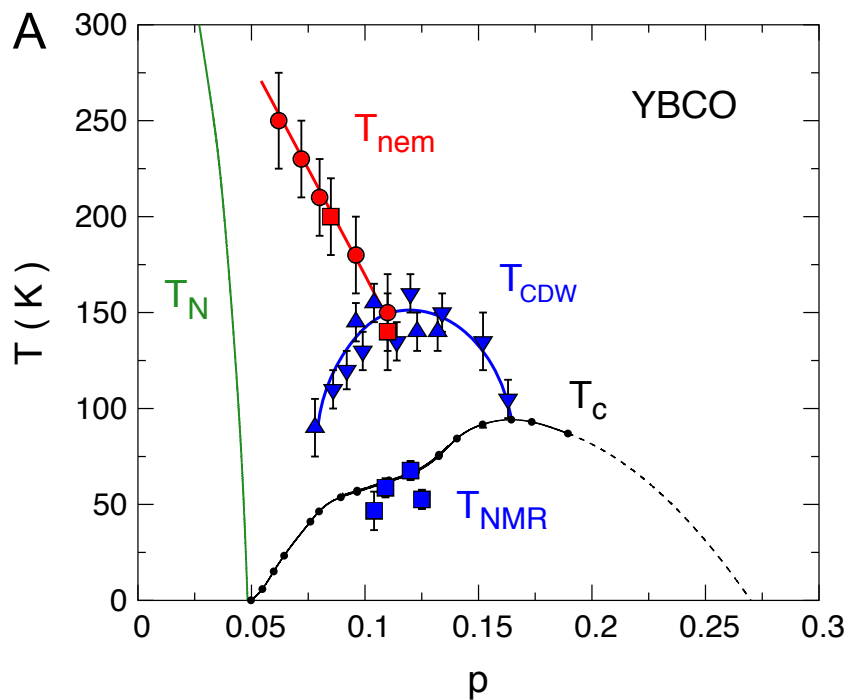
Two scenarios –

Kivelson *et al.*, Nature **393**, 550 (1998)
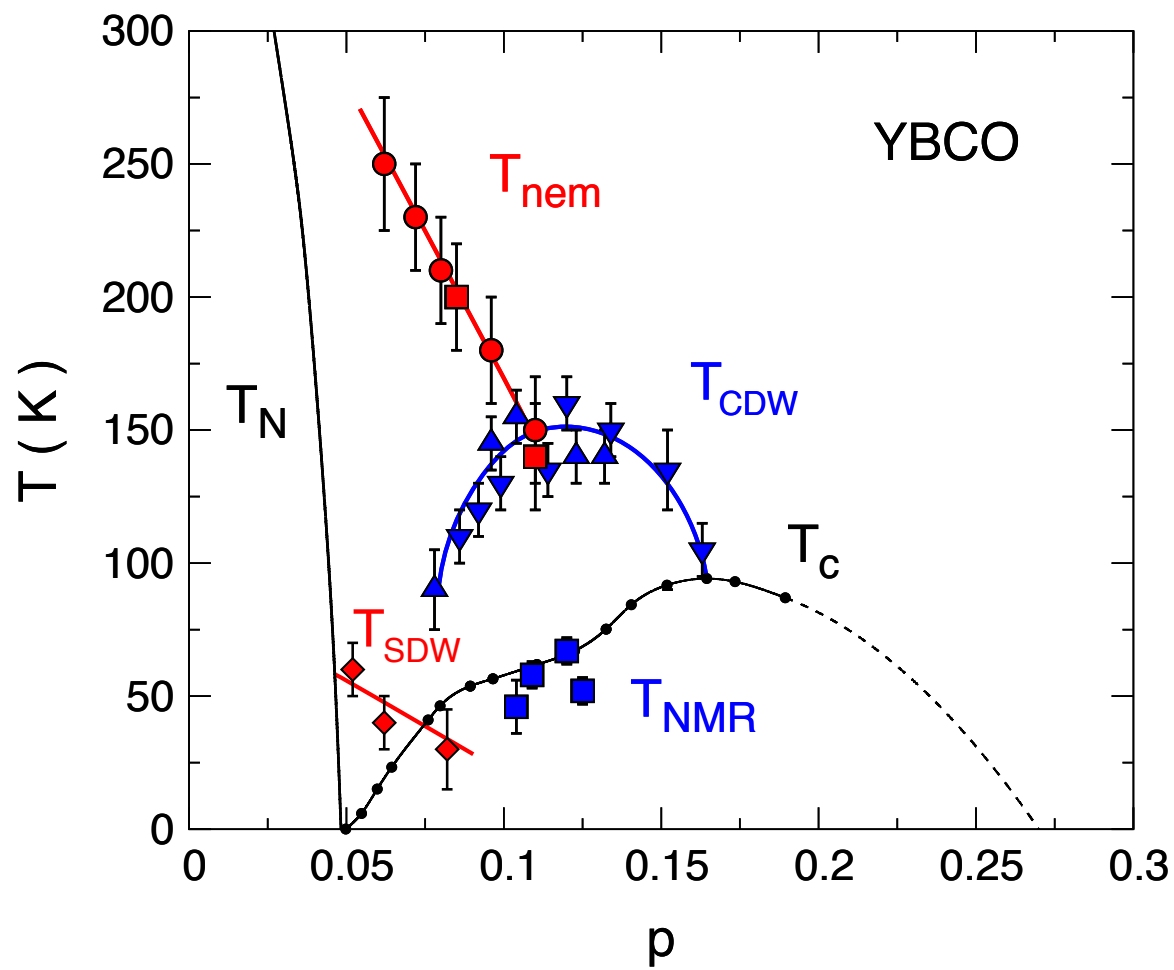
SDW nematicity   *CDW nematicity*
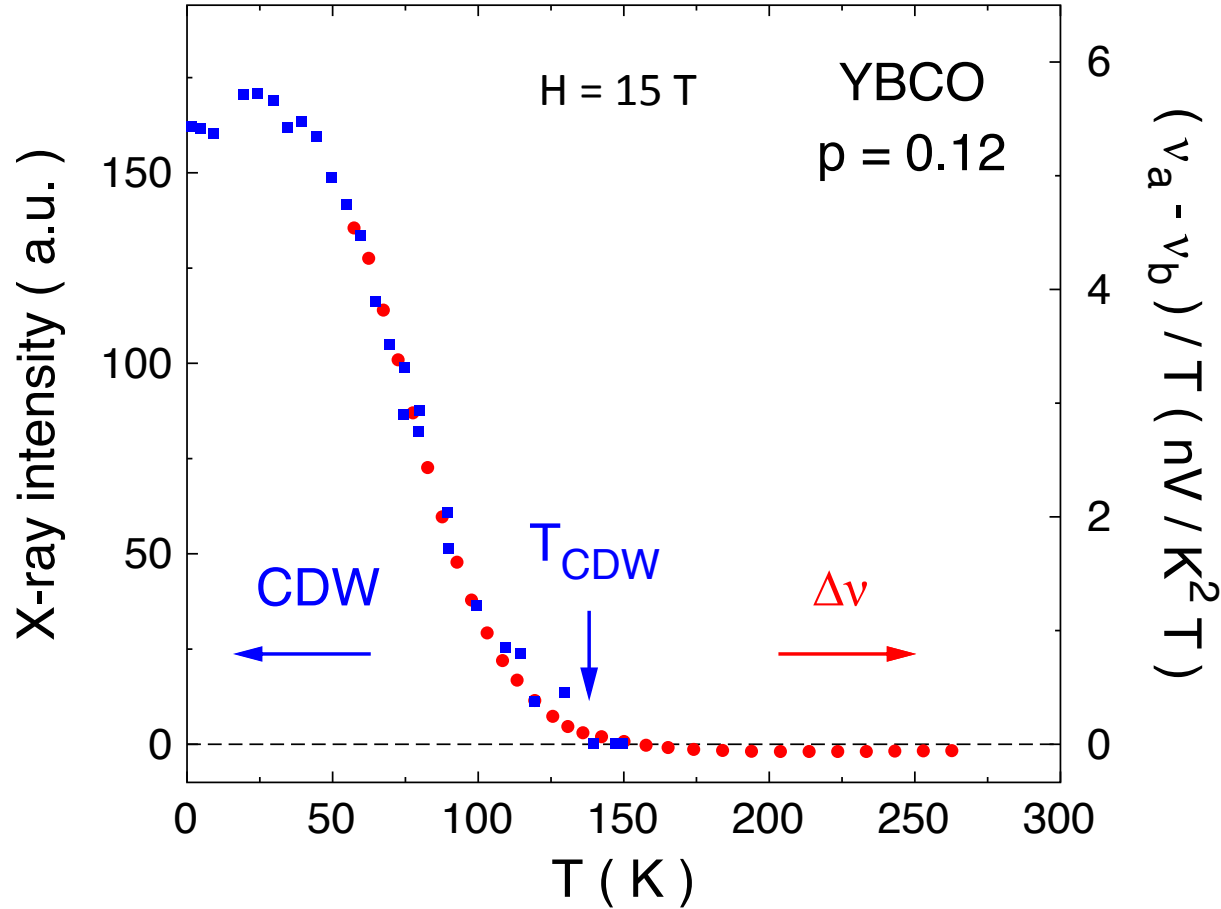
Two scenarios −

SDW scenario

CDW nematicity

X-rays   Nernst
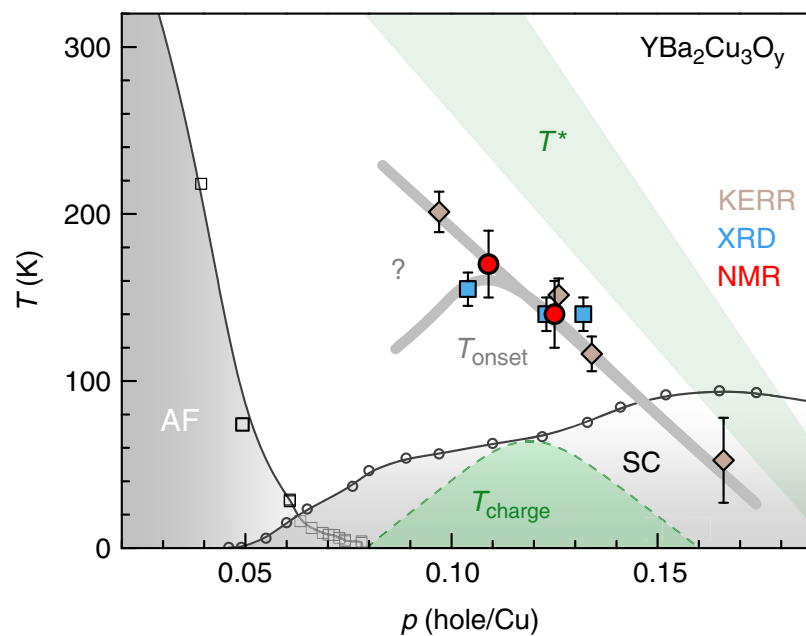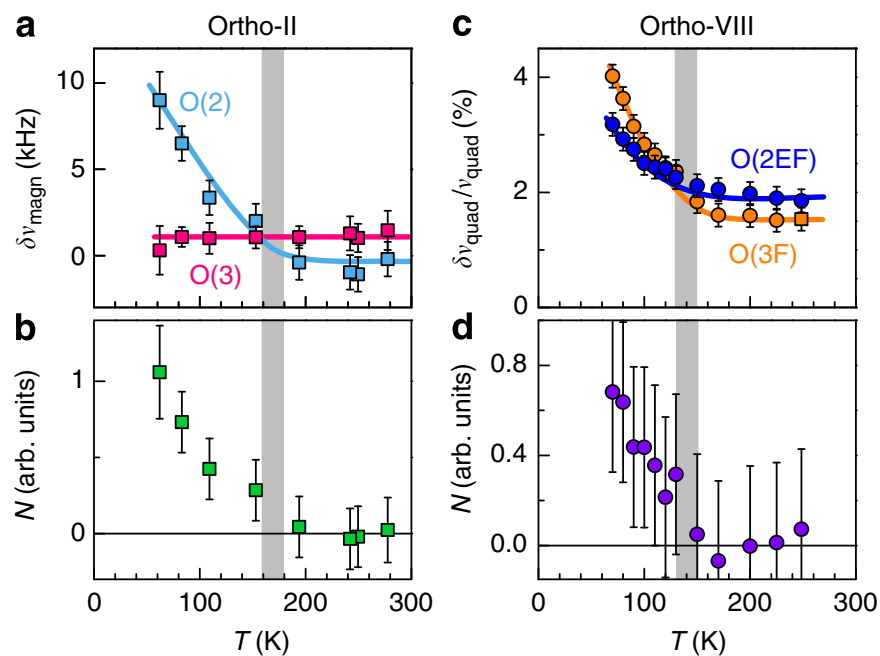
Chang *et al.*, Nat. Phys. **8**, 871 (2012)   Daou *et al.*, Nature **463**, 519 (2010)

Cyr-Choinière *et al.*, arXiv:1504.06972 (2015)
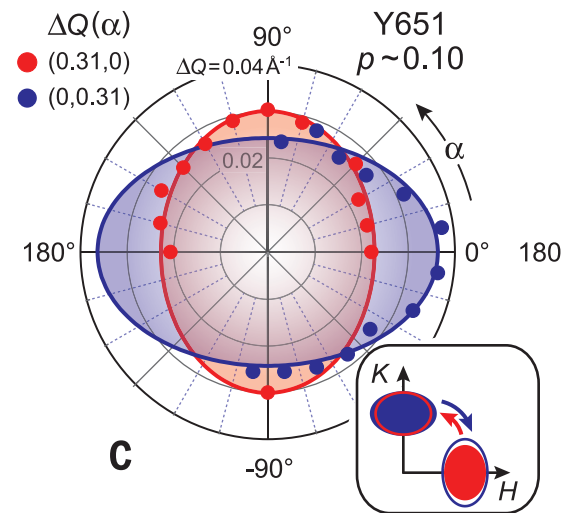
Two scenarios –

CDW nematicity

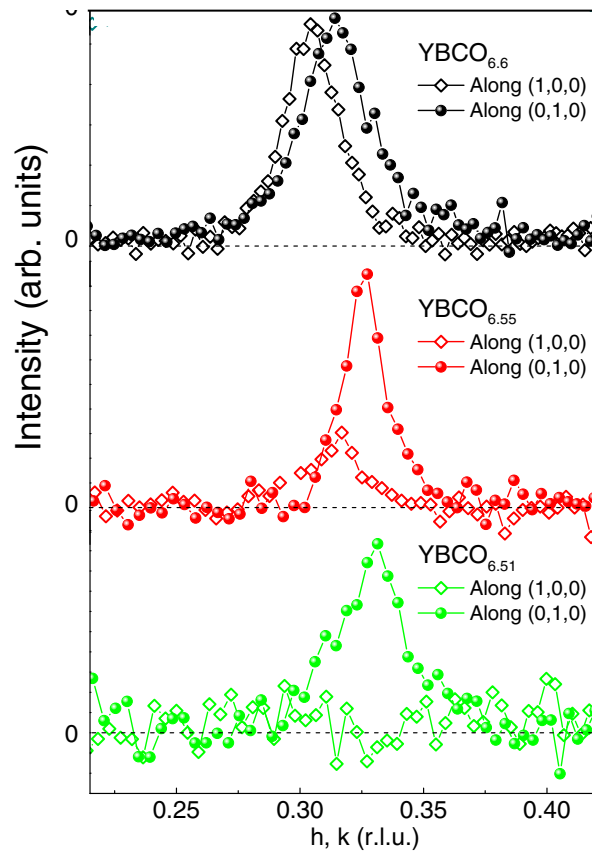**SDW scenario**

NMR

Wu *et al.*, Nat. Commun. **6**, 6438 (2015)

Two scenarios −

CDW nematicity

SDW scenario

RSXS

Blanco-Canosa *et al.*, PRB **90**, 054513 (2014)

Comin *et al.*, Science **347**, 1335 (2015)

Two scenarios –

SDW scenario

SDW nematicity

Neutrons

Hinkov *et al.*, Science **319**, 597 (2008)

Two scenarios −

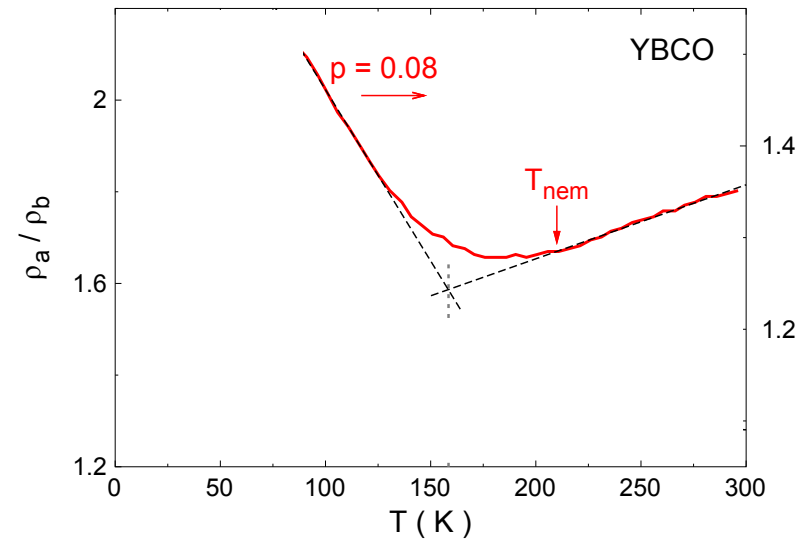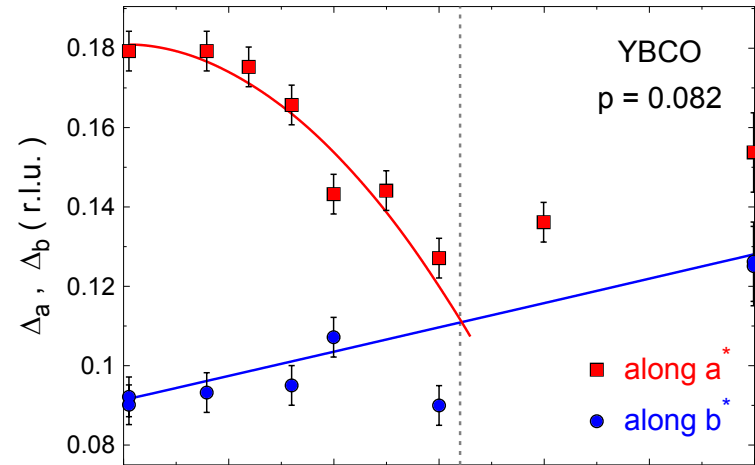## SDW scenario

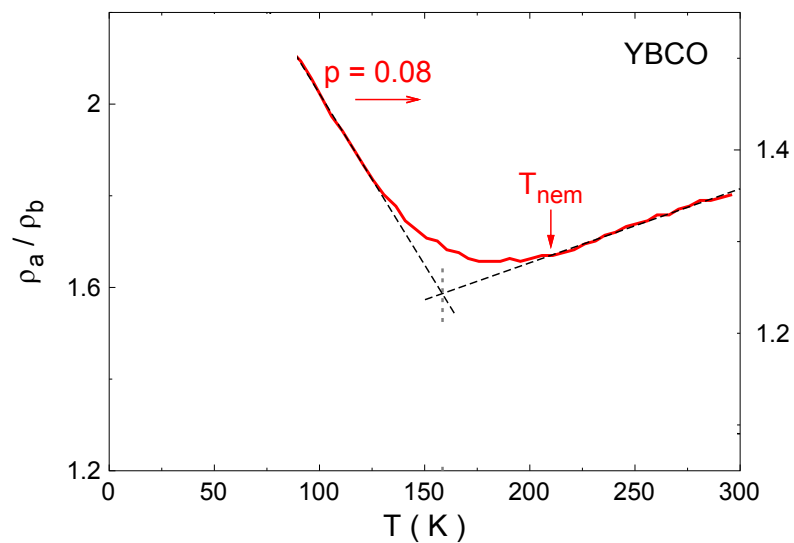## SDW nematicity

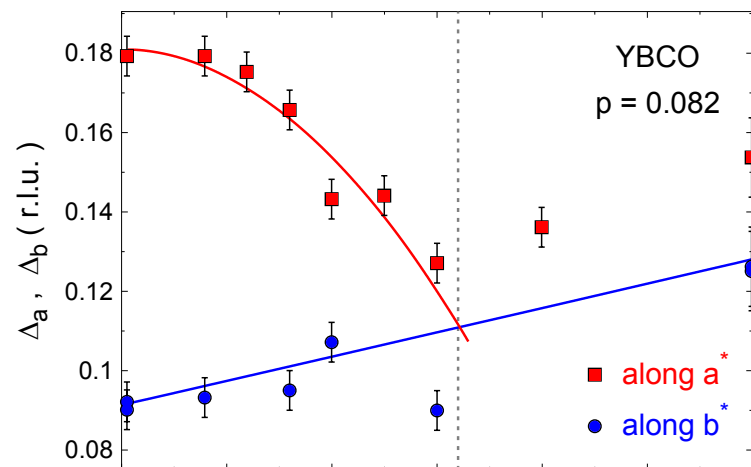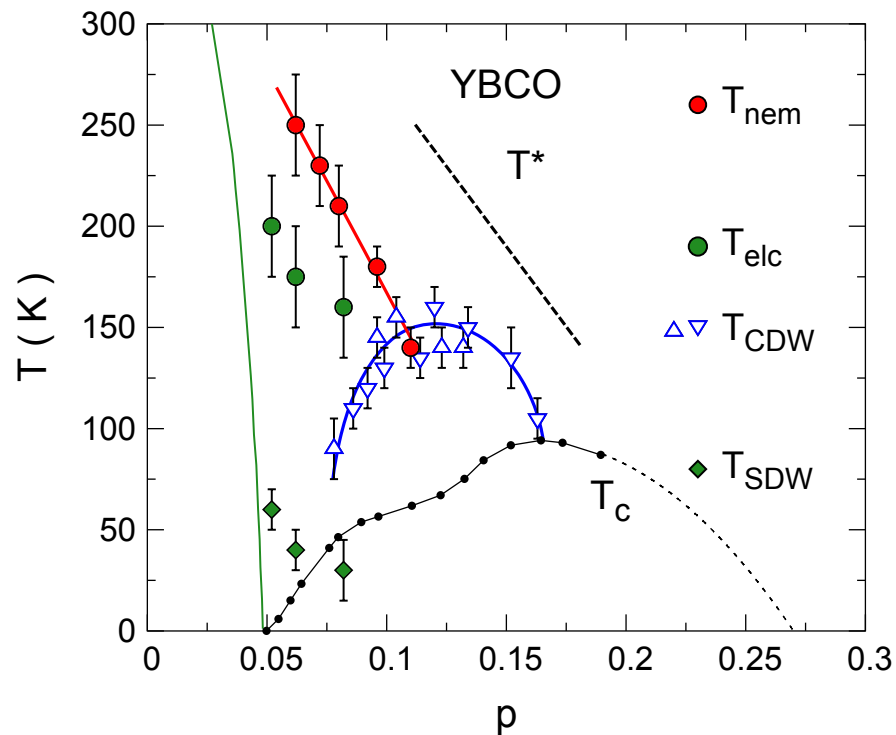Haug *et al.*, NJP **12**, 105006 (2010)

Hinkov *et al.*, Science **319**, 597 (2008)

Two scenarios −

SDW nematicity
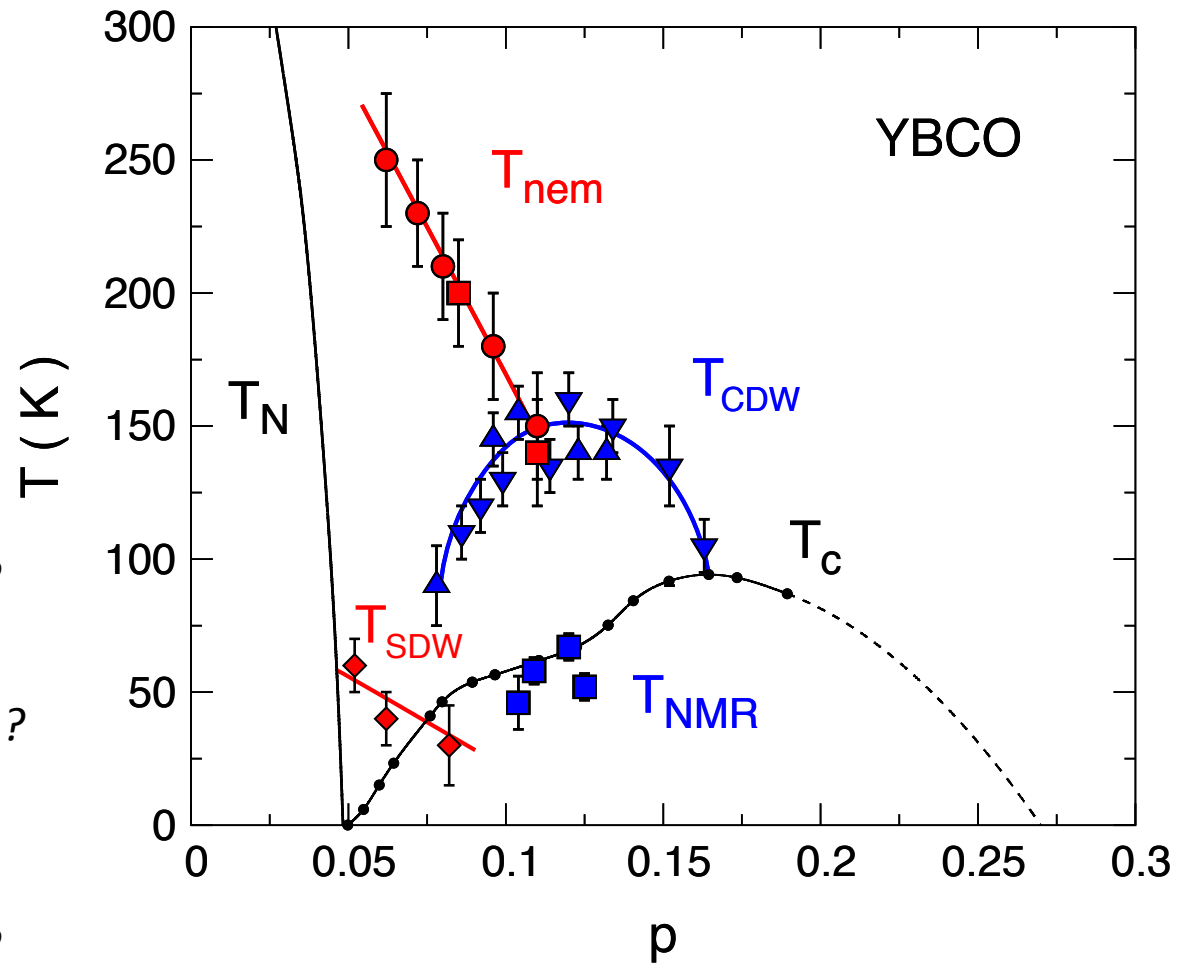
SDW scenario

Hinkov *et al.*, Science **319**, 597 (2008)

Two scenarios –

SDW scenario

Phases & Questions

1) Superconductivity
   - *Why a dome ?*

2) Pseudogap
   - *What is it ?*
   - *Crossover or transition ?*

3) Charge order
   - *Why a dome at p = 0.12 ?*

4) Nematicity
   - *Where from ?*
   - *Crossover or transition ?*

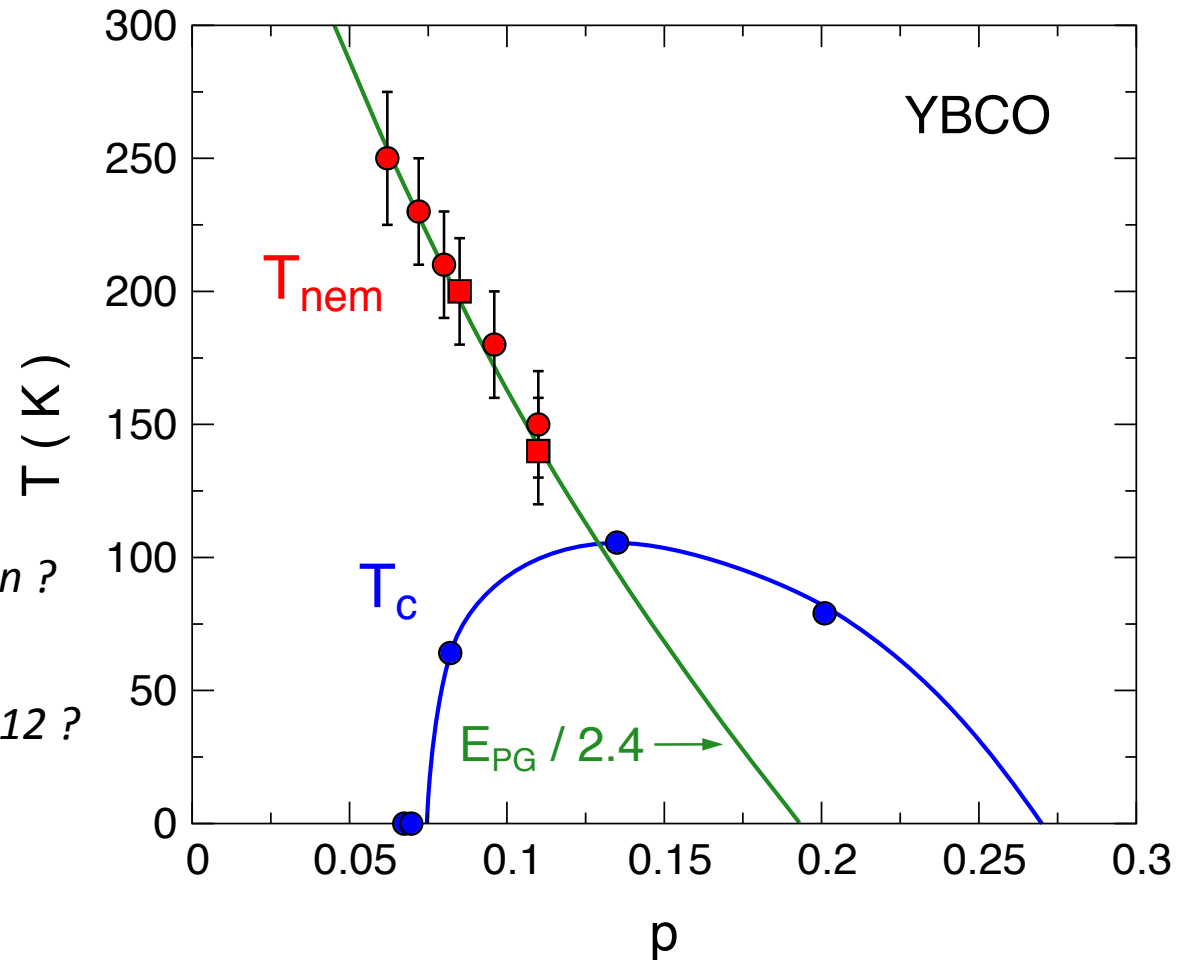*SDW nematicity*   *CDW nematicity*

Two scenarios –

Mott scenario

Phases & Questions

1) Superconductivity
   - *Why a dome ?*

2) Pseudogap
   - *What is it ?*
   - *Crossover or transition ?*

3) Charge order
   - *Why a dome at p = 0.12 ?*

4) Nematicity
   - *Where from ?*

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