

Anisotropy of the : (i) upper critical fields

and the

(ii) paramagnetic Meissner effect (PME)

in $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_4$ single Crystals

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Introduction

(i) Surface superconducting state (SSS)

The nucleation field of a **thin SC sheet** at the surface (H_{c3}) is higher than the nucleation field of a **bulk** SC (H_{c2})

$$H_{c2} < H_{c3}$$

(with the thickness of the order of the Ginzburg-Landau coherence length)

For conventional single band superconductor

$$\gamma = H_{c3} / H_{c2} \approx 1.69$$

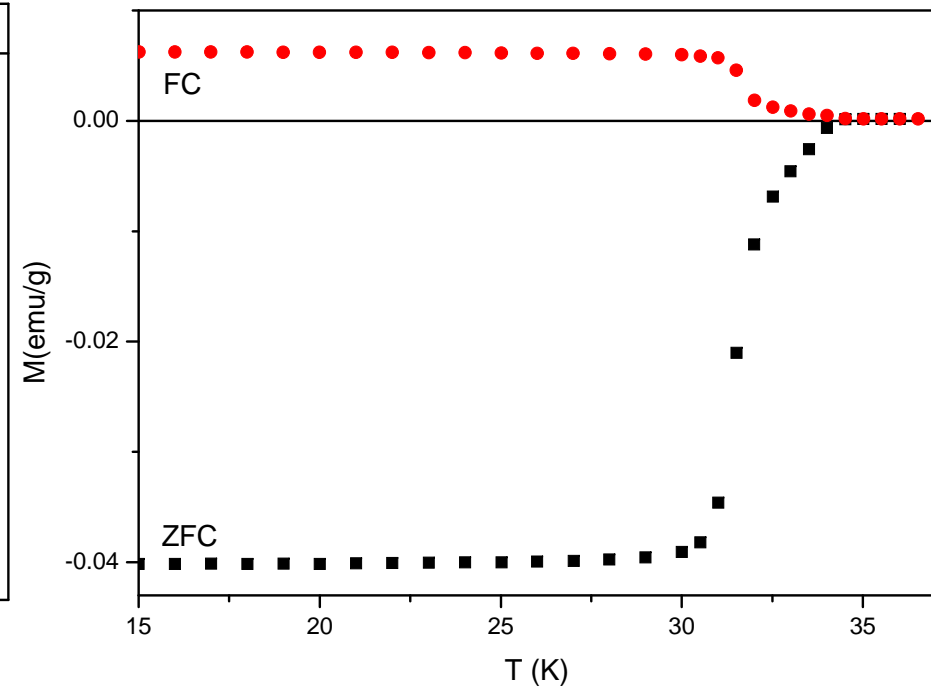
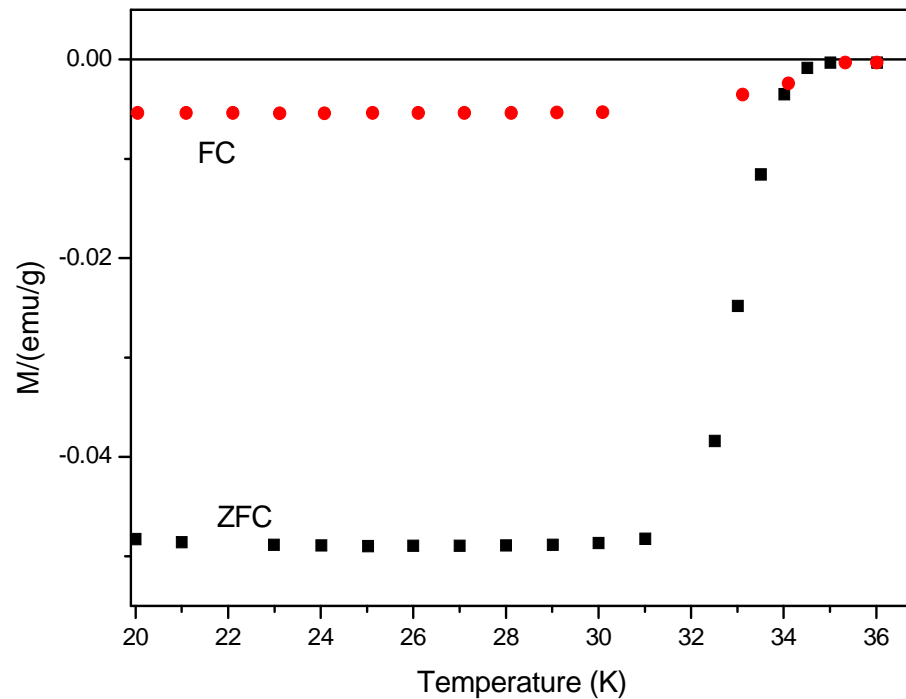
(Saint-James and De Gennes in 1963)

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(ii) PME (Wohleben effect)

At low H only, in some HTSC materials **positive** magnetization signals appear via the FC procedure.



The paramagnetic Meissner effect (PME)

Hand waiving models

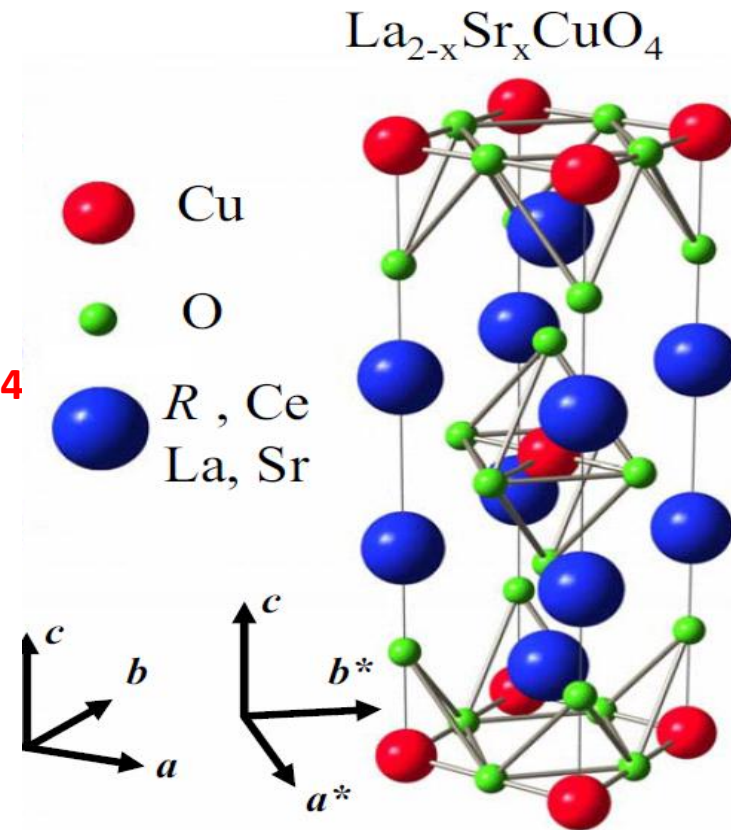
(1) PME originates from flux capture of impurities (such as oxygen vacancies) or surplus oxygen atoms) or by in-homogeneous regions in HTSC

(2) Surface pinning effect are at the root of PME. (Nb)

Relatively large **a** and **c** doped **LSCO** single crystals has been grown (by Amit) in an image furnace.

under doped **La**_{1.93}**Sr**_{0.07}**CuO**₄,

optimally doped **La**_{1.85}**Sr**_{0.15}**CuO**₄

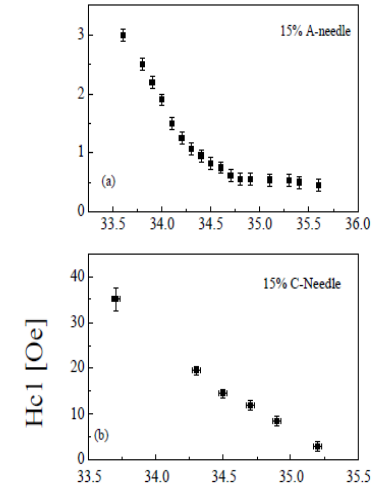
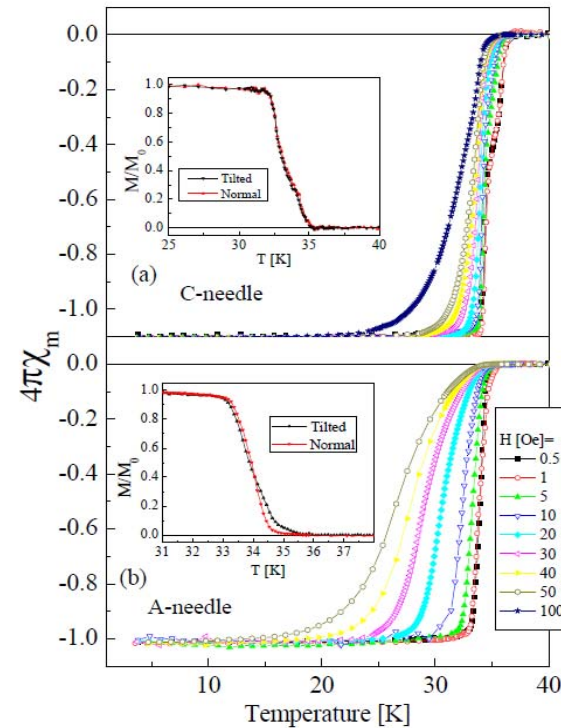
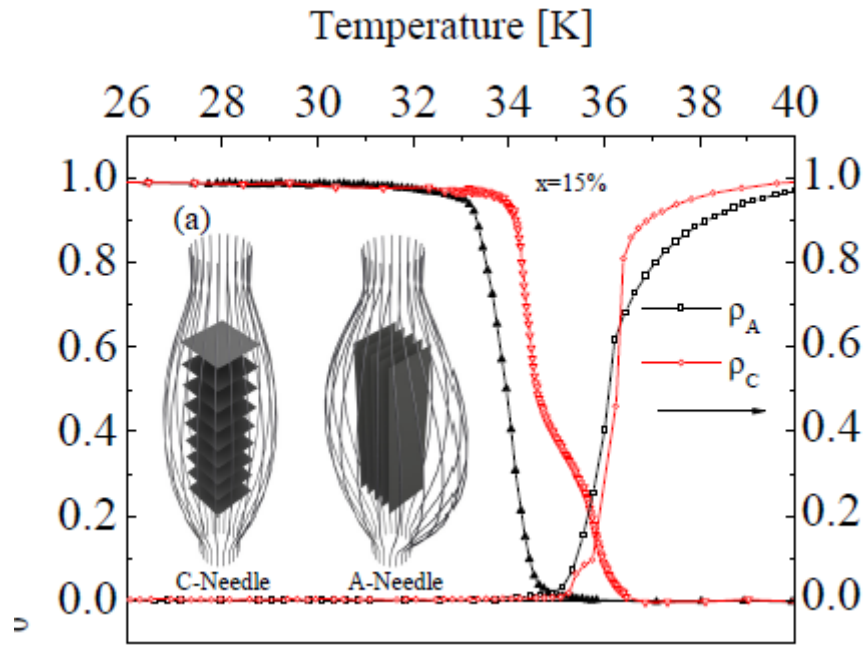


Big crystals

The **od** **c**-crystal (long axis parallel to c) 1.7*2.0*3.2 mm (70 mg)

The **ud** **a**-crystal (long axis parallel to ab) 1.8*2.3*8.5 mm (240 mg)

Anisotropy in $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_4$



- 1) The same zero resistance is observed in the two crystals but $M_C = 36.5$ K $>$ $M_a = 35$ K
- 2) A knee which appears in the **c-crystal** only for $H < 10$ Oe.

Two T_C values, due to **stripes** or to **disorder** along the **c-axis**

The motivation

To construct (for the first time) the phase diagram of, $H_{C2}(T)$ and $H_{C3}(T)$ in LSCO along the ab planes and the c axis

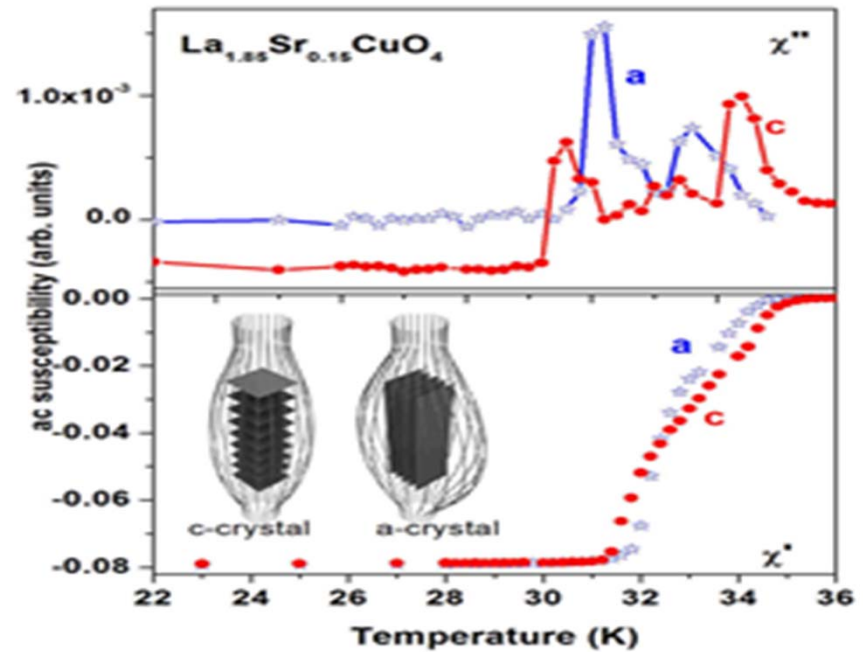
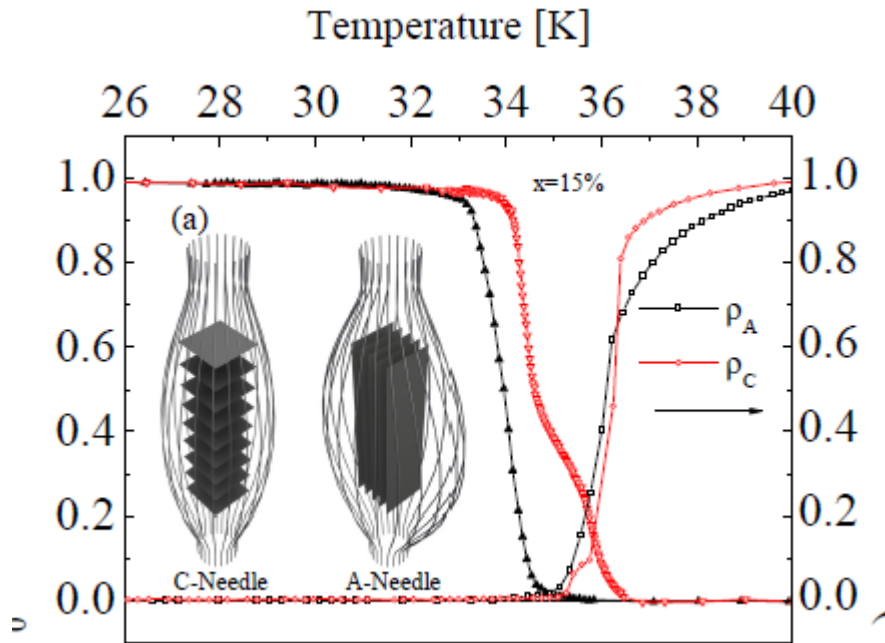
For LSCO (In contrast to YBCO) a limited number of publications have been reported on $H_{C2}(T)$ in the two orientations.

No report on $H_{C3}(T)$.

$$H_{C2}^a > H_{C2}^c \quad H_{C2}^a / H_{C2}^c = 5.4$$

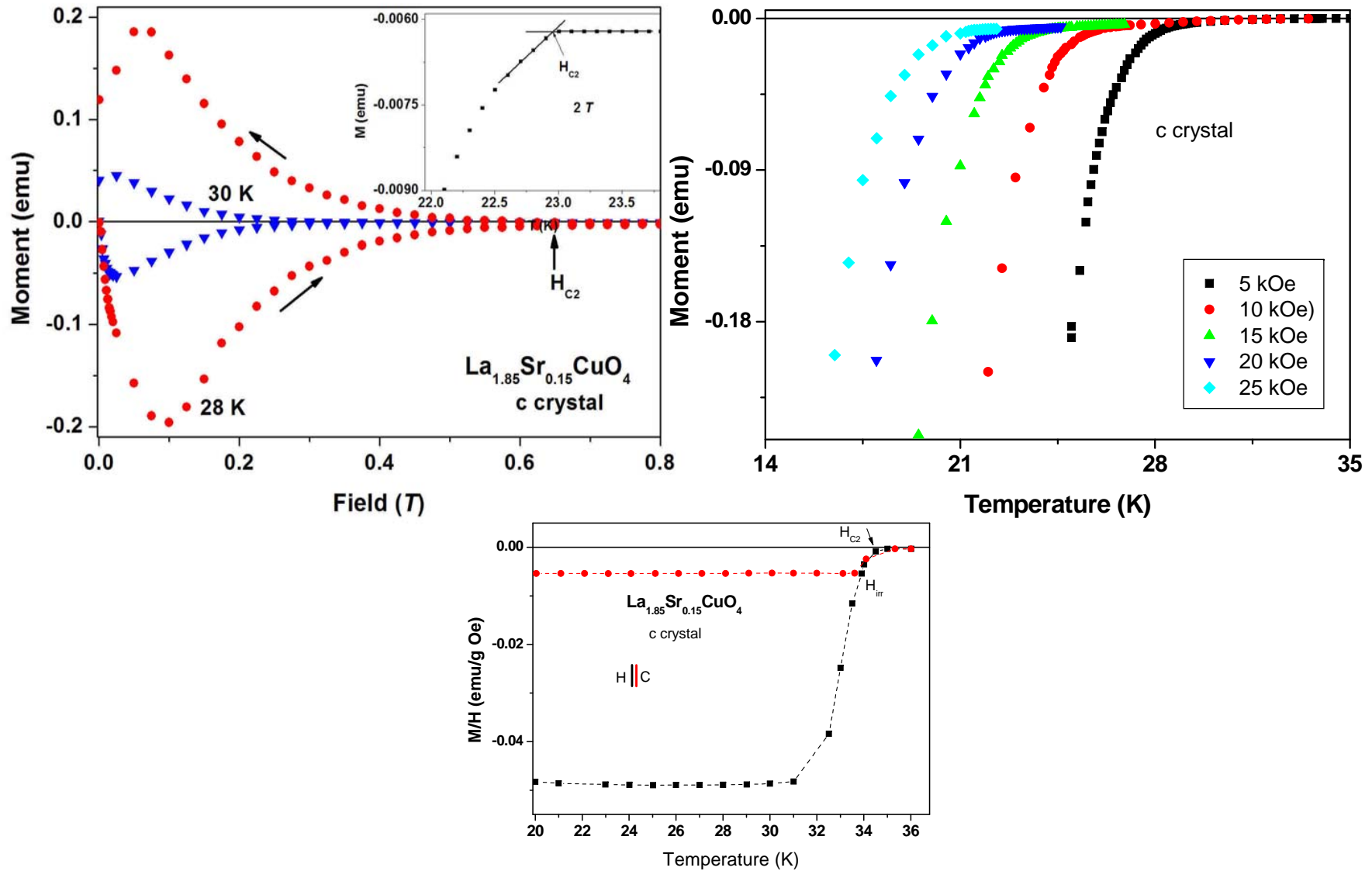
$$H_{C2}^c = \Phi_0 / 2\pi \xi_{ab}^2, \quad H_{C2}^a = \Phi_0 / 2\pi \xi_{ab} \xi_c, \quad \xi_{ab} > \xi_c, \quad \frac{H_{c2,\parallel}}{H_{c2,\perp}} = \frac{\xi_{GL,ab}}{\xi_{GL,c}}$$

- $H_{C2}(T)$ was determined by **dc** magnetization studies (SQUID)
- $H_{C3}(T)$ was determined by **ac** susceptibility studies (in the SQUID)

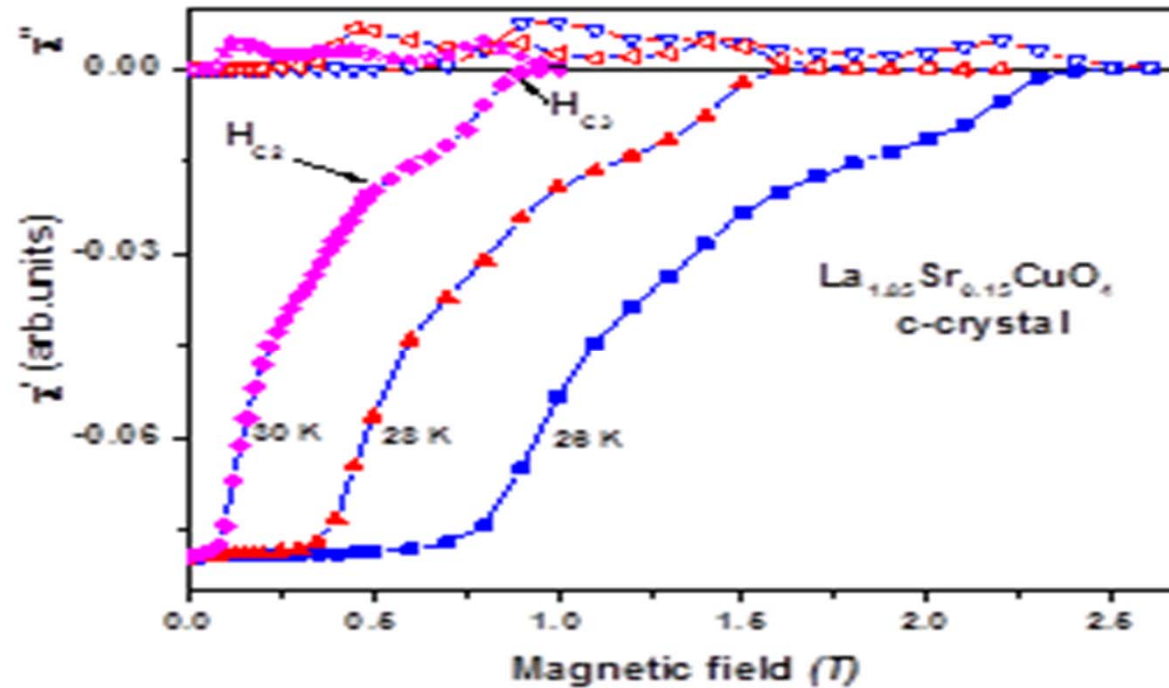


The crystals are not homogeneous in **both** orientations.

dc magnetization studies for H_{C2}

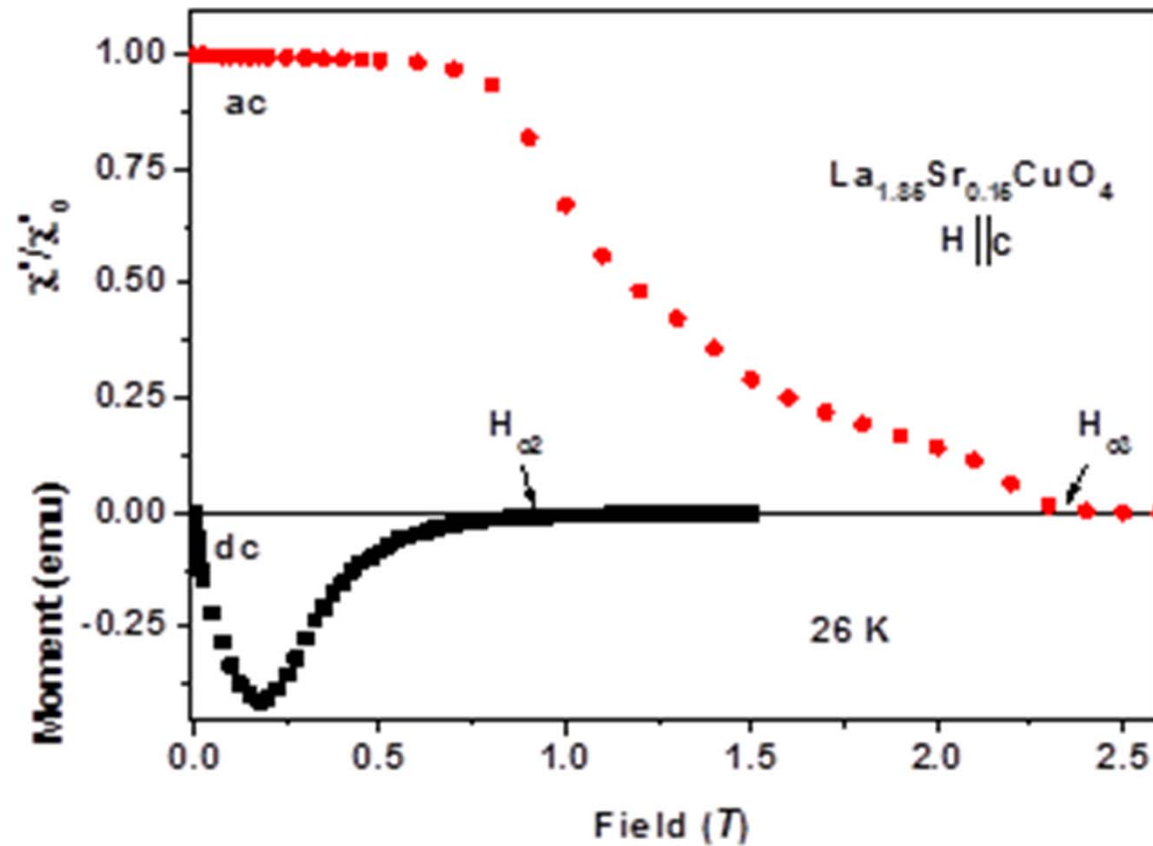


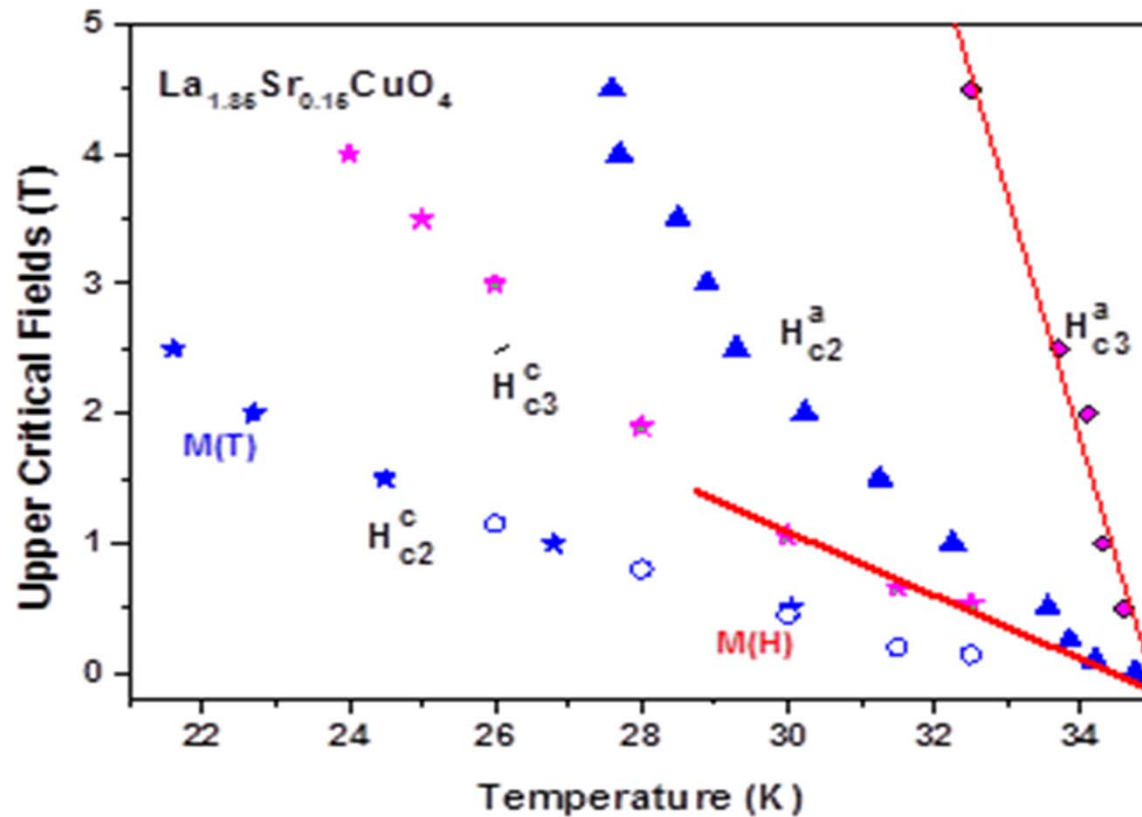
ac magnetization studies for H_{c3}



$h_0=0.05$ Oe at various frequencies up to $\omega/2\pi = 1465$ Hz.

dc and ac magnetization studies





The first phase diagram!!!

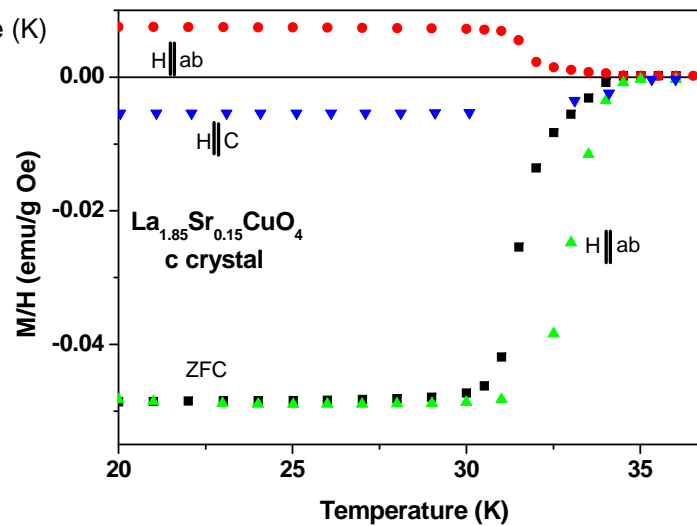
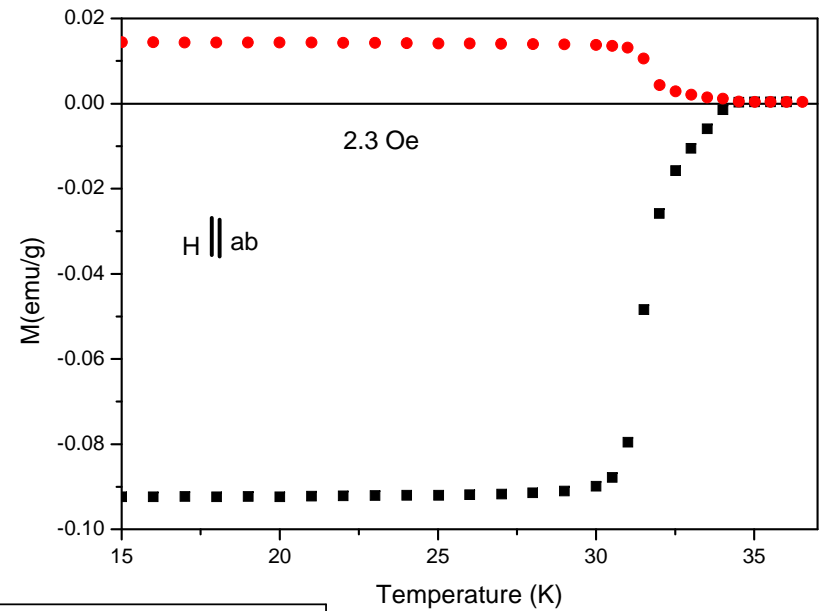
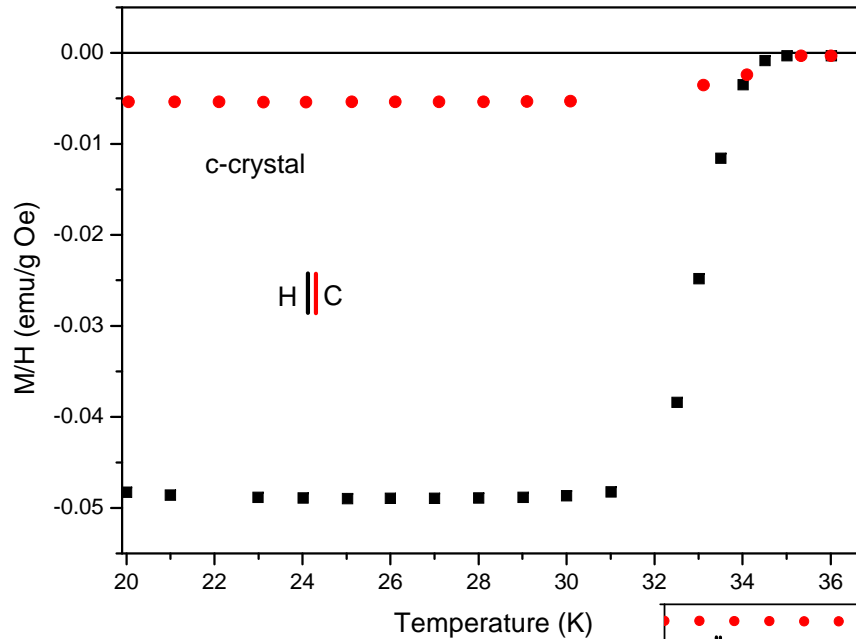
$$1) H_{c2}^a / H_{c2}^c = 2.8$$

$$2) \gamma^c = H_{c3} / H_{c2} \sim 1.8(2)$$

$$3) \gamma^{ab} = H_{c3} / H_{c2} \sim 4.0(2) !!!$$

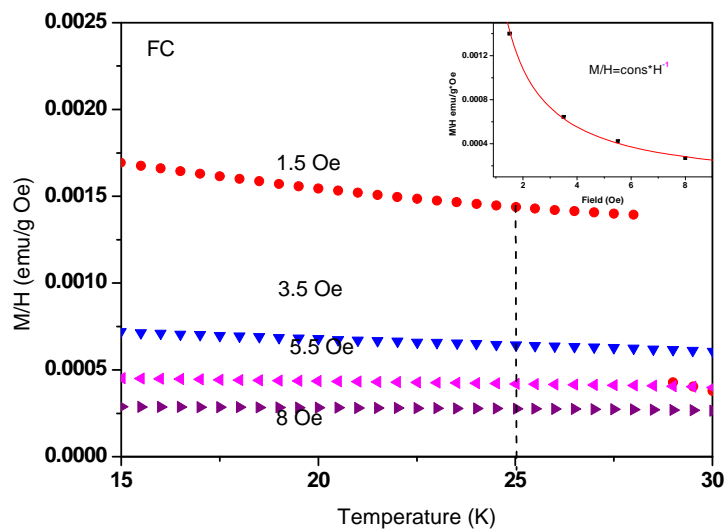
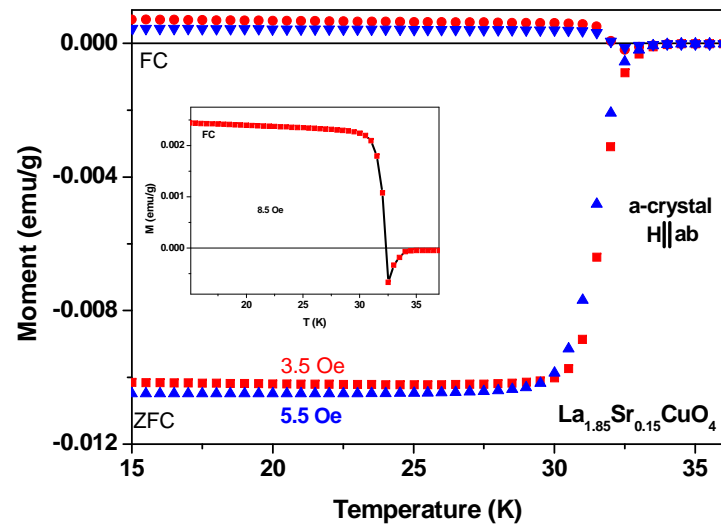
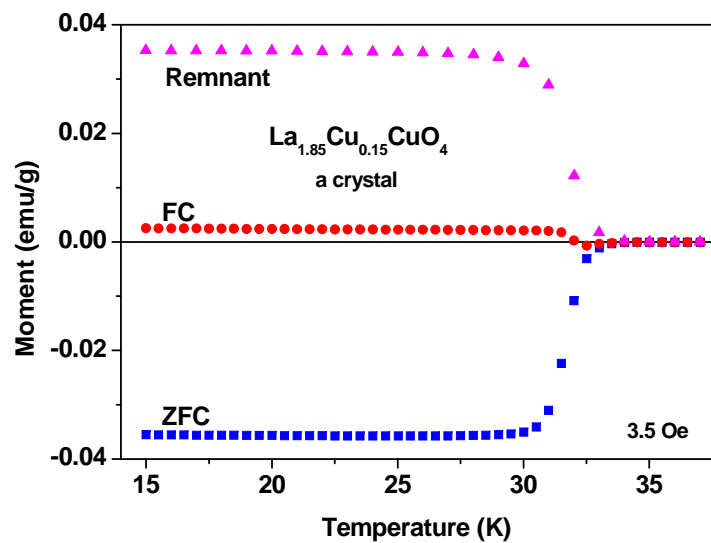
c-crystal $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_4$

PME occurs for H par to ab

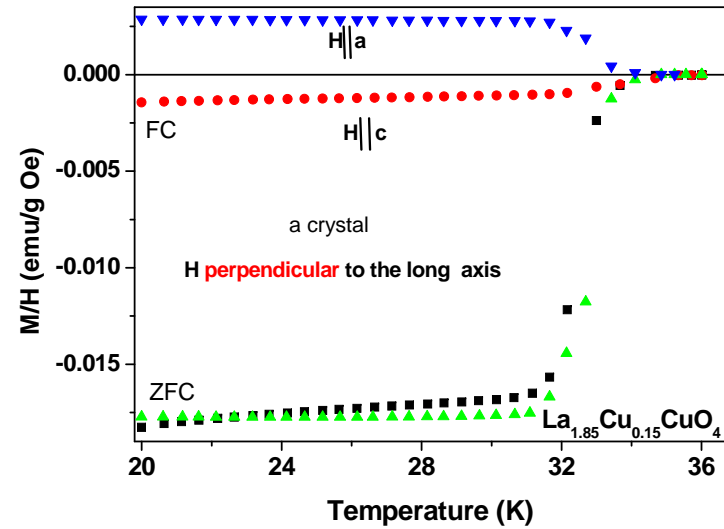
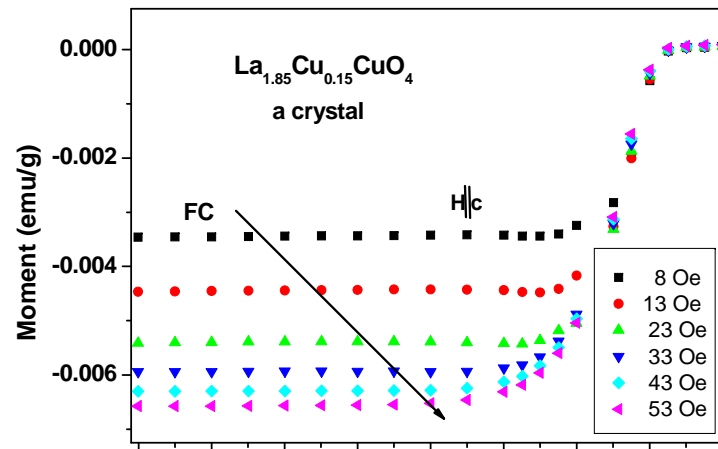


a-crystal $\text{La}_{1.85}\text{Sr}_{0.15}\text{CuO}_4$

H par a



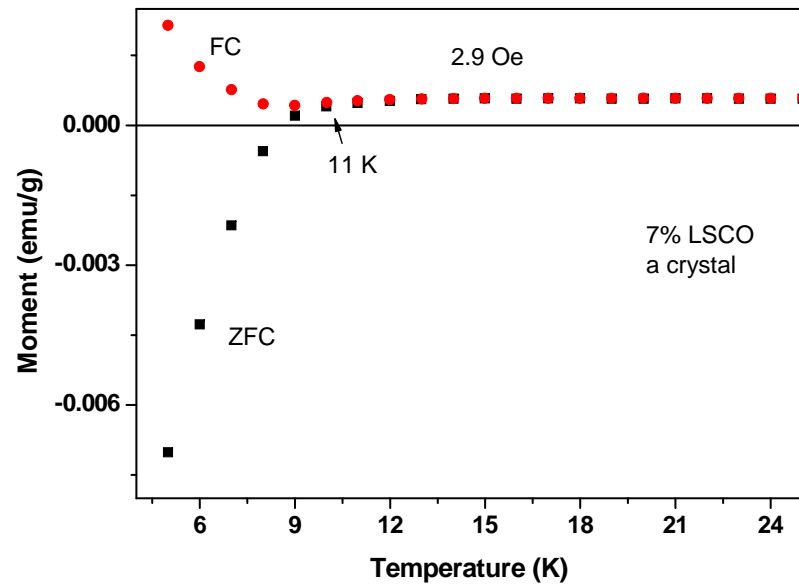
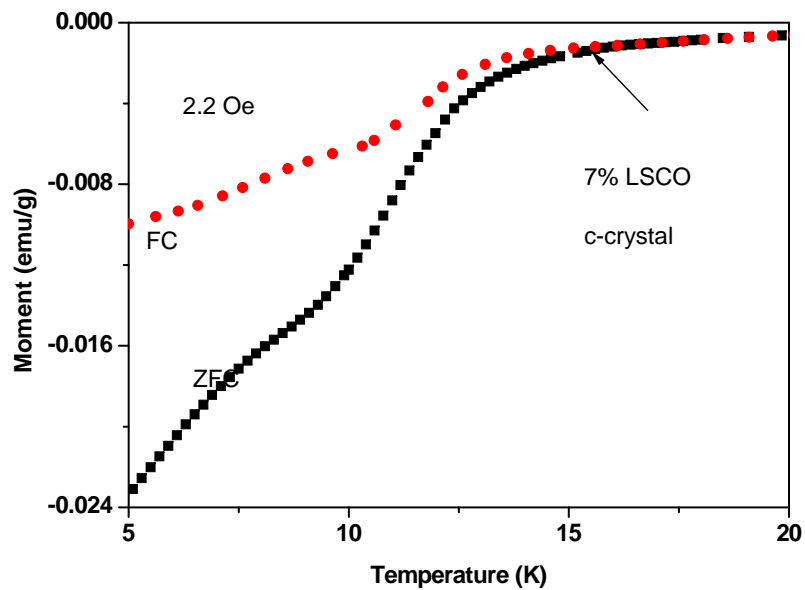
A crystal



PME occurs only for H par to a

Under-doped 7% LSCO

PME occurs for **H** par to **ab**



Summary of the results

(1) The first phase diagram of H_{c2} (T) and H_{c3} (T) for both **ab** and **c** directions

$$\gamma^c = H_{c3}/H_{c2} = 1.8(2) \quad \gamma^a = H_{c3}/H_{c2} = 4.0(2) !!!$$

(2) PME is observed only for H parallel to the **ab** planes

We claim that the two phenomena are an **intrinsic** property of LSCO

Are they connected to each other ?

For both crystals, the same criteria were employed for determination of the upper critical fields.

(big crystals, 3.2 and 8.5 mm long)

The anisotropy observed, is **not a result of** inhomogeneity of the crystals due to the spread in stoichiometry.

Because inhomogeneity, should affect **simultaneously** the **a** and **c** crystals in the two different orientations.

Thanks for your kind attention