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Specific Heat Anomalies in  $\text{La}_{2-x}\text{M}_x\text{CuO}_4$  (M

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# Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

## Materials & Chemical Sciences Division

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**Specific Heat Anomalies in  $\text{La}_{2-x}\text{M}_x\text{CuO}_4$  (M = Ba, Sr;  
x = 0.09, 0.12, 0.15) near 70 and 100K**

D.A. Wright, J.P. Emerson, B.F. Woodfield, R.A. Fisher,  
N.E. Phillips, M.K. Crawford, and E.M. McCarron, III

June 1991



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**SPECIFIC HEAT ANOMALIES IN**  
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**NEAR 70 AND 100K**

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## SPECIFIC-HEAT ANOMALIES IN $\text{La}_{2-x}\text{M}_x\text{CuO}_4$ (M=Ba, Sr; x=0.09, 0.12, 0.15) NEAR 70 AND 100K

D.A. WRIGHT, J.P. EMERSON, B.F. WOODFIELD, R.A. FISHER, N.E. PHILLIPS, M.K. CRAWFORD<sup>+</sup>, and E.M. McCARRON, III<sup>+</sup>

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Specific heat measurements show, for LMCO [M=B(Ba), S(Sr); x=0.09, 0.12, 0.15], hysteresis and anomalous behavior in the 85-125K region and, for LBCO(0.12) and LSCO(0.09), similar magnetic field-dependent anomalies near 70K. Neutron and x-ray studies by others have shown the existence of an orthorhombic-tetragonal transition for LBCO near 70K but gave no indication of structural transitions in the other cases. The occurrence of transitions, and their x-dependence, in these materials is of interest for the possibility of its connection with the x-dependence of superconducting properties including the isotope effect.

On cooling, LBCO with  $0.05 < x < 0.2$  undergoes a series of structural transitions: high-temperature tetragonal (HTT)  $\rightarrow$  low-temperature orthorhombic (LTO)  $\rightarrow$  low-temperature tetragonal (LTT)<sup>1,2</sup>. The LTO and LTT phases coexist in a ratio depending on x and T<sup>1</sup>. These structural changes involve small rotations of the Cu-O octahedra, which causes a buckling of the CuO<sub>2</sub> planes<sup>1</sup>. The small differences between the LTO and LTT structures produce large effects on the superconducting properties. For x=0.12 (mostly LTT phase) there is a large reduction in the Meissner fraction<sup>1,3</sup>. There are also anomalies in the resistivity, Hall coefficient, thermoelectric power and magnetic susceptibility near the LTO $\rightarrow$ LTT region<sup>4</sup>. There is a correlation of the isotope effect with the LTO $\rightarrow$ LTT transition<sup>5,6</sup>, which is consistent with a recent theoretical analysis of the LTT phase<sup>7</sup>. Although LSCO shows an essentially identical x-dependence of the isotope effect<sup>5</sup>, similar structural studies show no evidence of the existence of the LTT phase<sup>5,6</sup>.

Specific-heat (C) measurements in the range 0.3-125K in magnetic fields (H) of 0 and 7T were undertaken to study the structural transitions in LBCO and to search for evidence of similar transitions in LSCO. A preliminary report on the results is presented here.

Zero field and 7T data for LBCO(0.12), for which the maximum extent of the LTO-

LTT transformation is expected, are displayed in Fig. 1. They show the occurrence of an anomaly near 70K, the approximate temperature of the transition, and a second anomaly at higher temperatures. The 70-K anomaly is clearly suggested by the zero-field data; it is suppressed, to below a smooth interpolation between the high- and low-temperature data, in 7T. (The field dependence of the anomaly is qualitatively consistent with the occurrence of an anomaly in the susceptibility<sup>4</sup>.) It is displayed as  $[C(0)-C(7T)]/T$  in the upper part of Fig. 2. LBCO(0.09, 0.15), for which the LTO-LTT transition occurs to a lesser extent, showed no detectable anomaly or field dependence of C in the region of 70K. However, for LSCO(0.09), for which structural studies have failed to detect an LTO-LTT transition<sup>5,6</sup>, there is a 70-K anomaly in some ways similar to that in LBCO(0.12). The anomaly is not conspicuous in the zero-field data, but the field dependence of C in that region, shown in the lower part of Fig. 2, is clearly very similar to that of LBCO(0.12). (The feature near 30K is associated with the superconducting transition.) For both anomalies there is an entropy discrepancy in the vicinity of 100K, but it could be compensated by a small field dependence of C, within the experimental error, at higher temperatures.

All samples showed features somewhat reminiscent of the second, higher temperature, anomaly in LBCO(0.12). For all LSCO samples, C was dependent on the thermal history for  $T > 80K$ . For LBCO(0.12, 0.15) no such hysteresis was observed, but for  $x=0.09$  marked hysteresis was observed. Figure 3 is a plot of  $C/T$  vs. T for  $T > 75K$  showing the anomalies in the 100K region. For LBCO(0.09) two data sets are shown to illustrate the hysteresis. For those cases where there was no hysteresis, there was little or no effect of H on C for  $T > 80K$ . There is a recent report<sup>8</sup> that for LSCO(0.12) the elastic constants show a small anomaly centered near 110K, but there seems to be no other evidence of structural changes.

In conclusion, for LSCO, a feature has been found in C similar to that observed at 70K in LBCO. The nearly identical x-dependencies of the isotope effects in the two systems may well be related to this feature, in spite of the failure to detect a structural transition in LSCO by other means. In addition, anomalous behavior in the 85-125K region for all samples indicates the occurrence of previously unrecognized phenomena.

## ACKNOWLEDGMENTS

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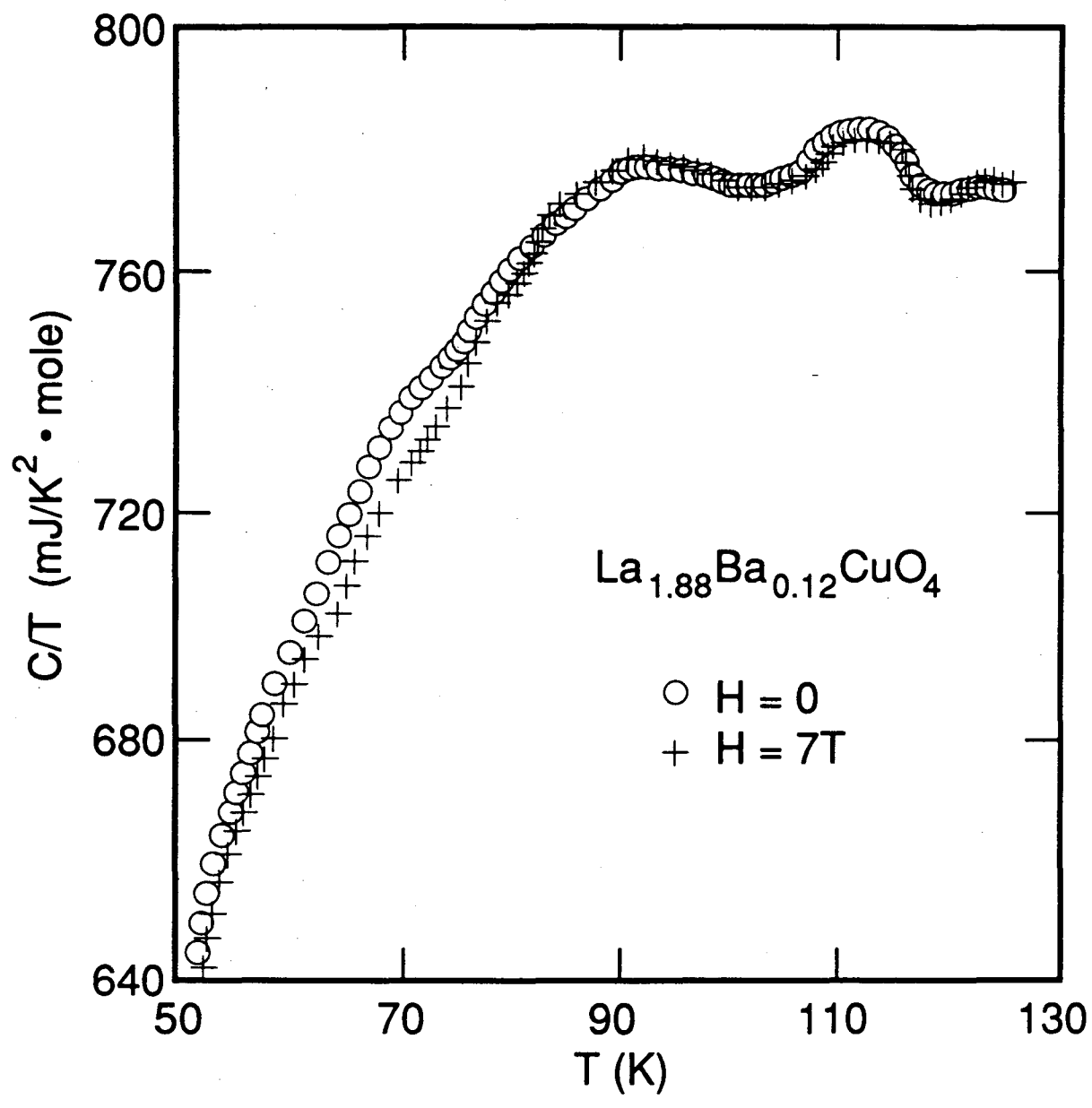
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## FIGURE CAPTIONS

Fig. 1. Anomalies in C near 70 and 100K for LBCO.

Fig. 2. Field dependence of C for LMCO below 100K.

Fig. 3. Anomalous region in C for LMCO,  $85 < T < 125$ K.



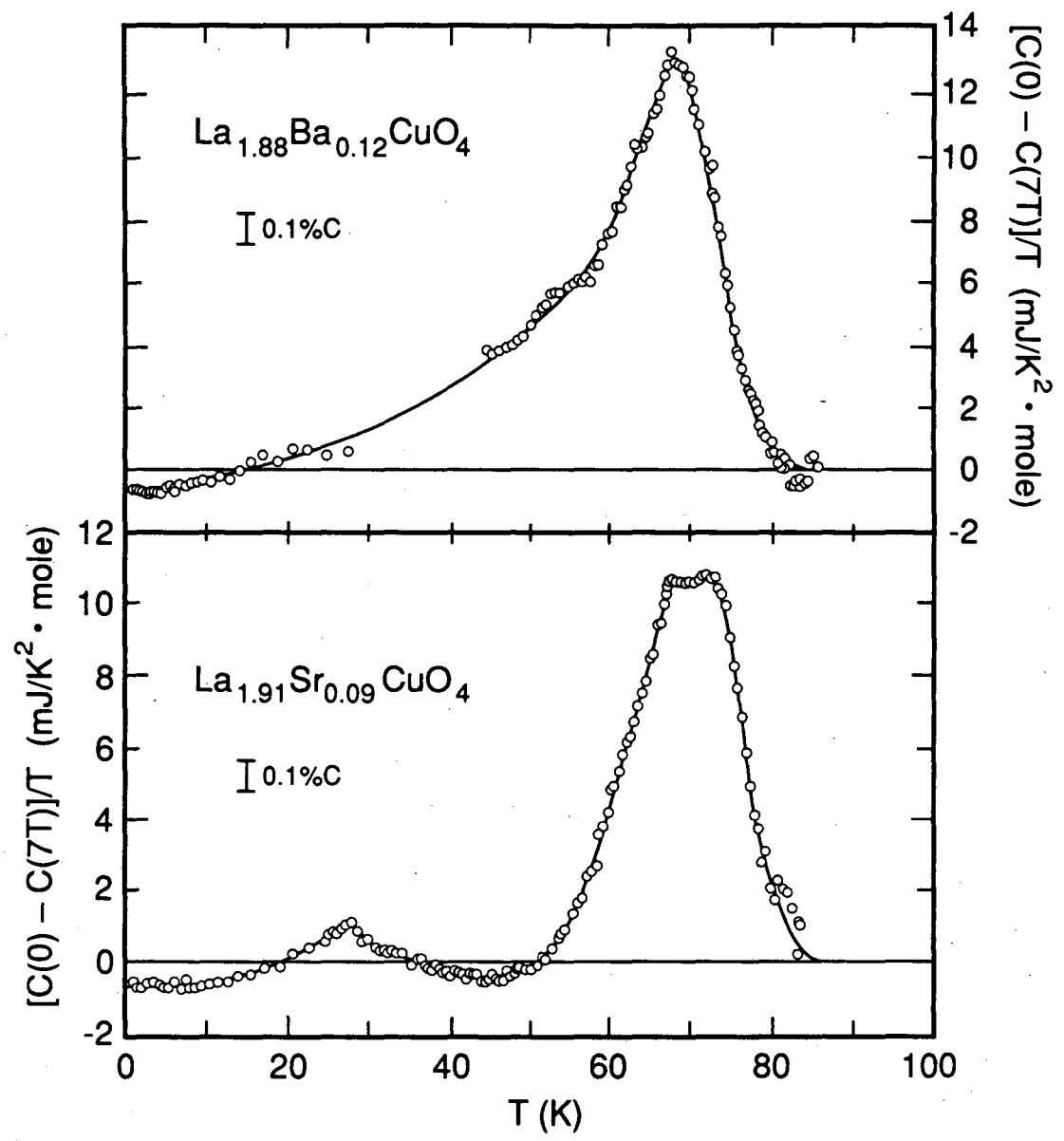
$\text{La}_{1.88}\text{Ba}_{0.12}\text{CuO}_4$

○ H = 0  
+ H = 7T

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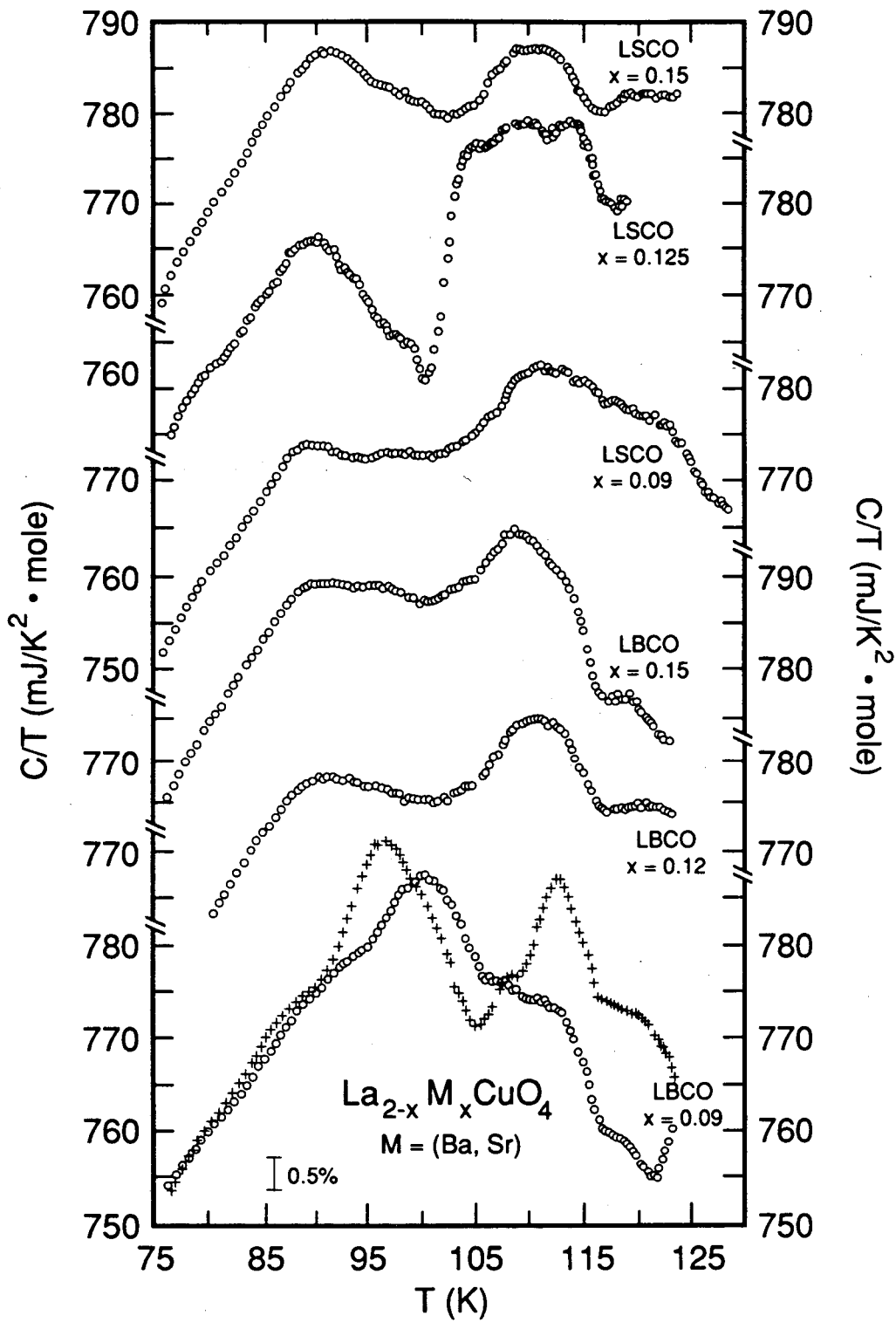
FIGURE 1





XBL 916-1142

FIGURE 2



XBL 916-1146

FIGURE 3

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