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Short Range Spin Correlations in the CMR Material $La_{1.4}Sr_{1.6}Mn_2O_7$

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Short Range Spin Correlations in the CMR Material $La_{1.4}Sr_{1.6}Mn_2O_7$

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The $(La_{1-x}Sr_x)_3Mn_2O_7$ compounds are layered materials that exhibit higher magneto-resistance than the corresponding 3D manganite perovskites. Quasi-elastic neutron scattering on a polycrystalline sample of $La_{1.4}Sr_{1.6}Mn_2O_7$ shows that the spin fluctuation spectrum of the these layered CMR materials is qualitatively similar to those found in the perovskite manganites $(La,Ca)MnO_3$; their concentration, lifetime, and coherence length increase as T decreases to T_C. Unlike the perovskites we find a lower spin-diffusion constant above T_C of ~5 meV $Å^2$.

Keywords: colossal-magneto-resistance, $(La_{1-x}Sr_x)_3Mn_2O_7$, magnetic polarons

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The close interplay among charge, spin, and lattice degrees of freedom in the colossal magneto-resistive (CMR) manganite oxides is widely believed to play an important role in the mechanism of transport in these itinerant ferromagnets. Among the current models of transport in the three-dimensional magneto-resistive perovskite materials is that magnetic polarons—mobile lattice distortions carrying spin—play a fundamental role, at least above the Curie temperature (T_C). [1,2]. Supporting evidence for this model have been provided recently by DeTeresa, *et al.* from in-field small angle neutron scattering experiments on the perovskite $La_{2/3}Ca_{1/3}MnO_3$. [2] In this paper we report inelastic neutron scattering measurements from the layered CMR material $La_{1.4}Sr_{1.6}Mn_2O_7$.

Inelastic neutron scattering data were taken from a 15g, single phase polycrystalline sample of $La_{1.4}Sr_{1.6}Mn_2O_7$ using the time-of-flight chopper spectrometer PHAROS at MLNSC, Los Alamos National Laboratory. Data were measured as a function of temperature, using an incident energy E_i=12.1 meV, except for data measured at 115 K where incident energies of 12.1 and 8.1 meV were used to extend the Q-range of the measurement. Neutron powder diffraction data were measured as a function of temperature from 20-300K, using (SEPD) at IPNS at the Argonne National Laboratory. This polycrystalline sample was characterized using a.c. susceptibility and resistivity; a transition from a PI-FM was observed at 116K.

Fig. 1 shows the spectrum at 115 K and 30 K, with a gaussian fit to each: while there is little statistically significant deviation from the gaussian at 30 K, at 115 K the gaussian is clearly unable to fit the data. The addition of a lorentzian term $L(\varepsilon)= BI\Gamma/\pi(\varepsilon^2+\Gamma^2)$ to fit the quasi-elastic component gives a much better fit to the data (ε is the energy transfer, B the Bose-Einstein factor, I the integrated intensity, and Γ the half-width at half maximum). This gives an intensity and a lifetime ($\tau = h/\Gamma$) for the spin correlations at each temperature (Fig. 2). The quasi elastic scattering diverges as $Q \rightarrow 0$, suggesting that the nature of the scattering is ferromagnetic. Similar observation have been made by Lynn *et al.* [3] for the three dimensional perovskite manganites.

The intensity of the quasi-elastic scattering increases as the sample is cooled from 322 K to T_C, then decreases below T_C, with similar behavior for the lifetime. Fitting the intensity as a function of $|Q|$ gives a correlation length of ~12 Å at 128 K, while fitting the energy width as a function of $|Q|$ gives a spin-diffusion constant of ~5 meV Å^2. This value is substantially lower than the 30 meV Å^2 measured for $La_{0.67}Ca_{0.33}MnO_3$[3] and may reflect the effect of reduced dimensionality on the dynamics of spin fluctuations.

Neutron powder diffraction measurements from the same sample used for the inelastic scattering measurements, show that a relaxation of the lattice occurs at T_C. For the perovskite materials this has been interpreted as the relaxation of localized lattice distortion from lattice polarons. The close correlation of the spin-dynamics (i.e. the increase of the quasi elastic scattering as $T \rightarrow T_C$), with the relaxation of the lattice suggests that these two phenomena are coupled. This observation is qualitatively similar to results reported by De Teresa *et al.* [2] for $La_{2/3}Ca_{1/3}MnO_3$. However, magnetic scattering from layered $La_{1.4}Sr_{1.6}Mn_2O_7$ is complicated by the fact that in two-dimensional magnetic systems critical magnetic fluctuations can be enhanced well above T_C (e.g. K_2CuF_4 [4]). Work is currently underway to decouple the expected 2-D ferromagnetic fluctuations from any additional signal that may emerge from magnetic polarons.

In conclusion, we observe a quasi-elastic magnetic scattering in $La_{1.4}Sr_{1.6}Mn_2O_7$, between $0.7<TC<2.8T_C$. The intensity of the scattering and the lifetime of spin fluctuations increases as T decreases to T_C. This phenomenon correlates strongly with the electronic (insulator-metal) and structural transition at the onset of 3D magnetic ordering.

This work was supported by the U.S. Department of Energy, Basic Energy Sciences-Materials Sciences under contract W-7405-ENG-36 (TMK, DNA, RAR) and W-31-109-ENG-38 (JFM, RO, JDJ).

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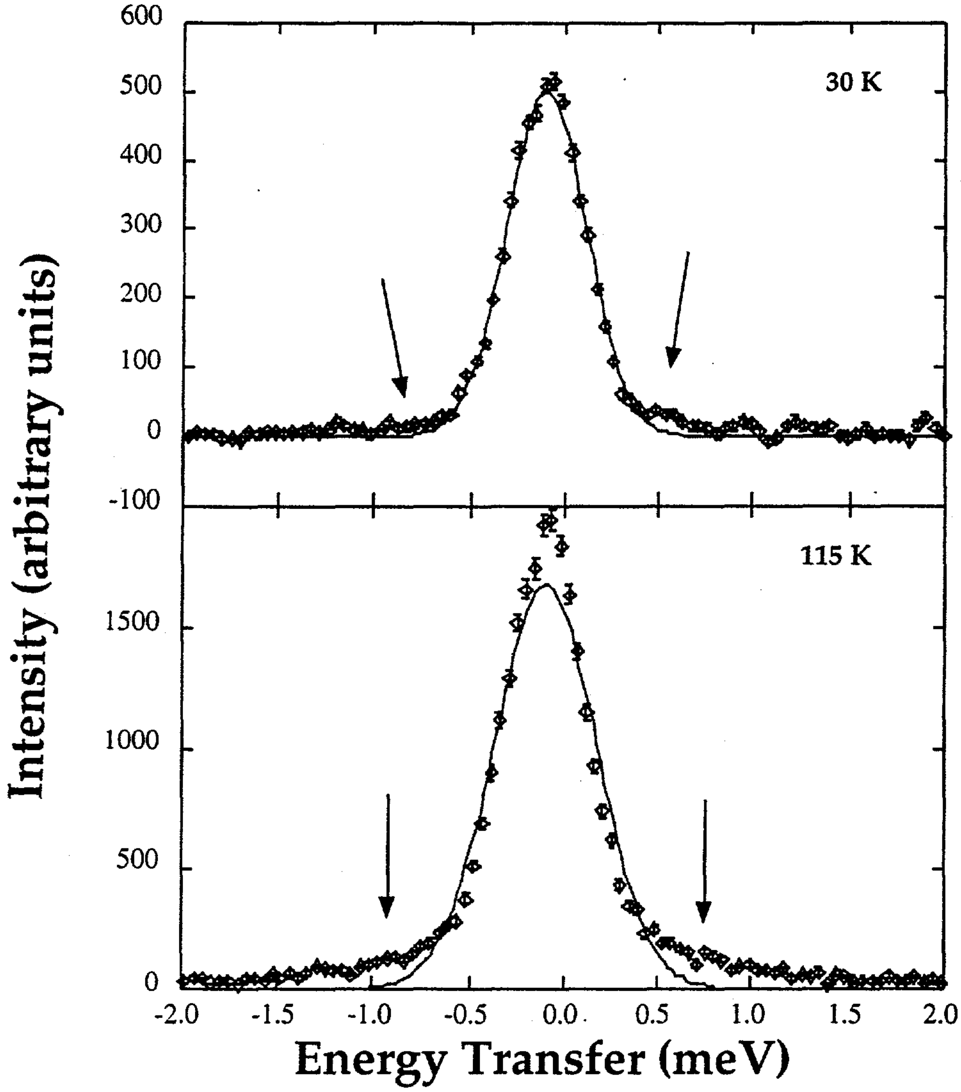
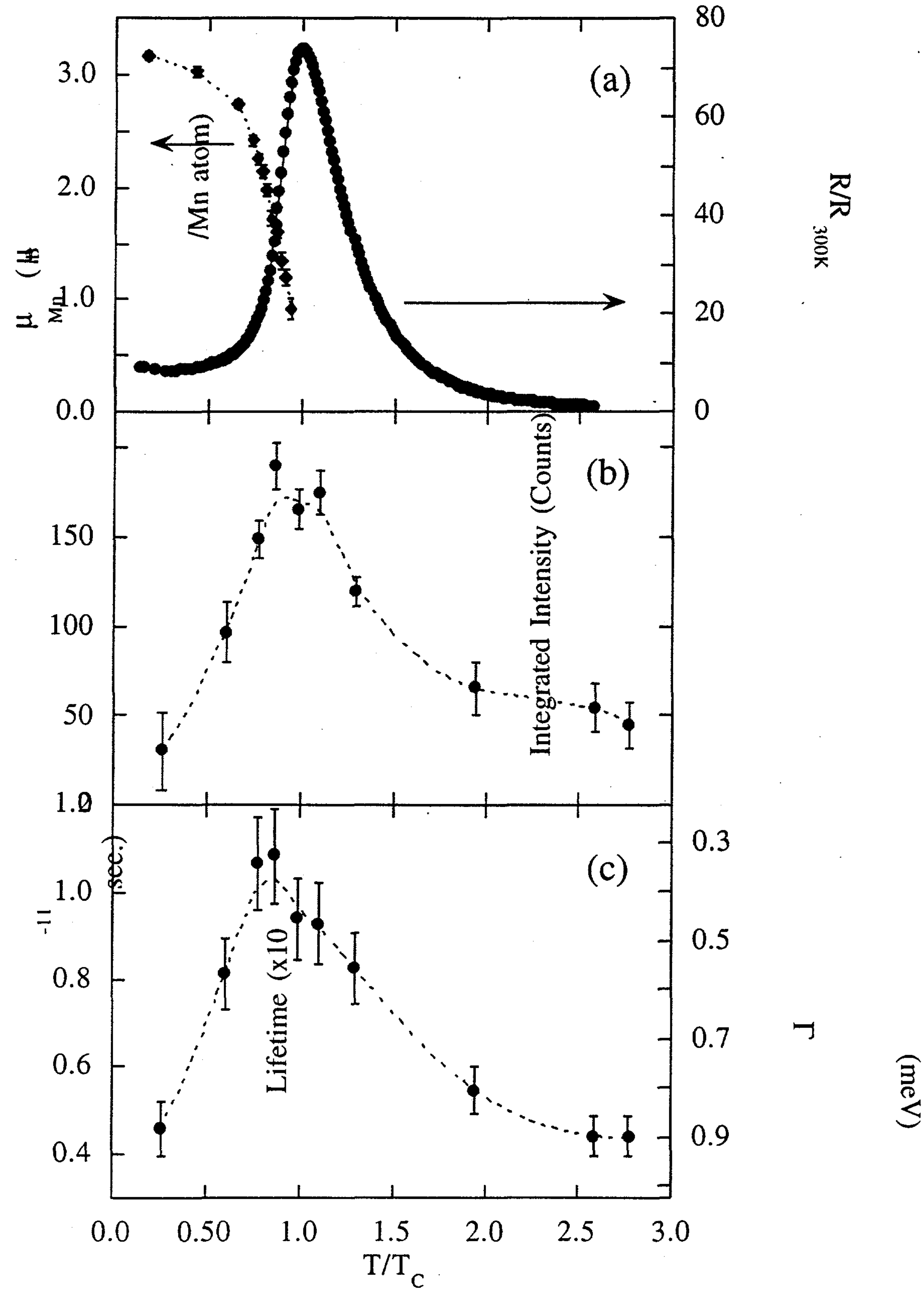
Figure captions:

Fig. 1: Quasi-elastic spectrum from $La_{1.4}Sr_{1.6}Mn_2O_7$ at 30 K (top) and 115 K (bottom). The solid curves are gaussian fits.

Fig. 2: (a) Temperature dependent resistivity and magnetization (determined from Rietveld refinement of neutron powder data) (b) Intensity of the quasi-elastic component as a function of temperature. (c) Lifetime ($=h/\Gamma$) as a function of temperature.



600
500
400
300
200
100
0
-100
30 K
115 K
1500
1000
500
0
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
Intensity (arbitrary units)
Energy Transfer (meV)



(a)
(b)
(c)
/Mn atom)
Integrated Intensity (Counts)
Lifetime (x10
sec.)
-11
R/R
300K
Γ
(meV)
T/T
C