Correlated Polarons in Dissimilar Manganites

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Introduction

The wide variety of ground states exhibited by the perovskite manganites ($R_{1-x}M_xMnO_3$) originates in the interplay of the charge, orbital and lattice and spin degrees of freedom. Recent work has focused on the role of the electron-phonon interaction, believed to be a necessary ingredient for modeling the temperature dependence of magnetic and transport behavior.[1,2] In colossal magnetoresistance (CMR) materials, strong electron-phonon coupling results in the formation of localized charge carriers with associated lattice distortions —or polarons—in the paramagnetic insulating phase.

Methods and Materials

In order to elucidate the role of the electron-phonon coupling, we report x-ray scattering studies of two identically doped manganites, which have different trivalent cations. To first order, such substitution does not affect the charge, orbital or spin degrees of freedom, but only alters the lattice degree of freedom. One result of this is a change in the relative strength of the electron-phonon coupling.

The systems chosen for this study are $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) and $Pr_{0.7}Ca_{0.3}MnO_3$ (PCMO). Each are paramagnetic insulators at high temperatures. Below T_c=252K, LCMO becomes a ferromagnetic metal. Below T_{co}=220K, PCMO becomes an antiferromagnetic insulator.

Results

Remarkably, despite the contrasting ground states of these two materials, the x-ray scattering above their respective transitions was very similar.[3] In each case, broad, diffuse peaks were observed at (1.5,2,0) and symmetry-related positions, with a width corresponding to a correlation length of 1-2 lattice constants (Fig. 1). The two materials only differed on cooling through their respective transitions. In LCMO the intensity abruptly dropped to near zero on cooling into the metallic phase. In contrast, in PCMO the intensity increased rapidly, and the peak sharpened as the ordered, insulating phase was approached.

Discussion

The significance of these results lies in the similarity of the high-temperature scattering, despite the differences in the ground states. The magnitude of the wavevector and the size and stability of the correlation length leads to the suggestion that the correlations arise from composite objects. We label these objects "CE-type bipolarons," based on the proposed structure shown in Fig. 2.

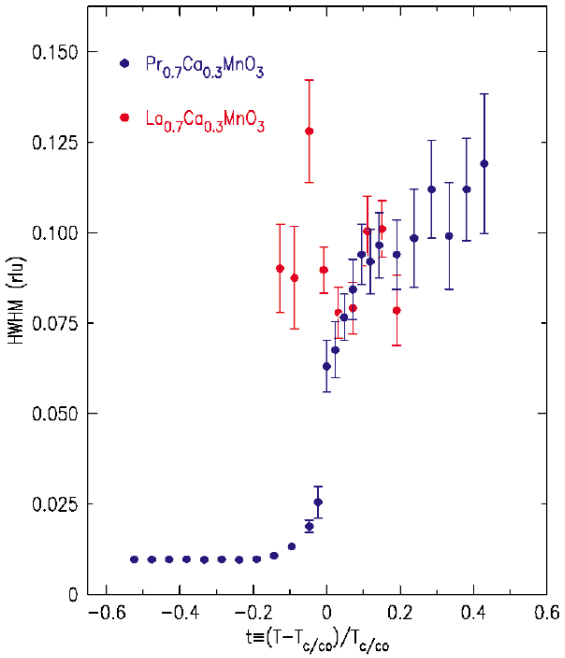

FIG. 1. The fitted half widths of the observed correlations as a function of reduced temperature.

The structure is that of an orbital order domain in the CE-type phase, and consists of neighboring orthorhombic unit cells along the [110] direction, with two Mn^{2+} ions—hence bipolarons—between the orbitally ordered Mn^{3+} ions.

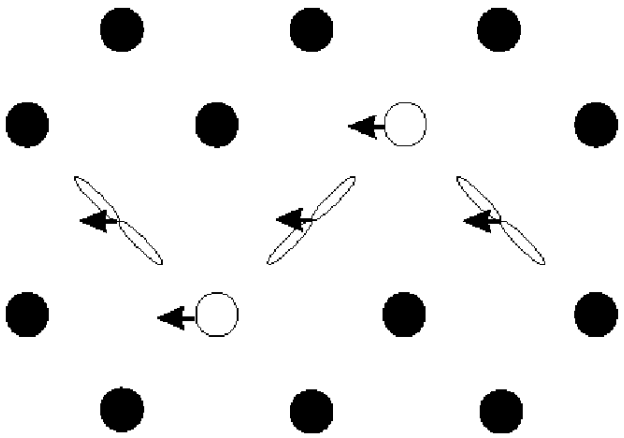

FIG. 2. Schematic diagram of the structure of a CE-type bipolaron.

Acknowledgments

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