

# A Resonant X-ray Scattering Study of Octahedral Tilt Ordering in $\text{LaMnO}_3$ and $\text{Pr}_{1-x}\text{Ca}_x\text{MnO}_3$

M. v. Zimmermann,<sup>1</sup> C. S. Nelson,<sup>1</sup> Y.-J. Kim,<sup>1</sup> J. P. Hill,<sup>1</sup> D. Gibbs,<sup>1</sup> H. Nakao,<sup>2</sup> Y. Wakabayashi,<sup>2</sup> Y. Murakami,<sup>2</sup> Y. Tokura,<sup>3</sup> Y. Tomioka,<sup>3</sup> C.-C. Kao,<sup>4</sup> D. Casa,<sup>5</sup> C. Venkataraman,<sup>5</sup> T. Gog<sup>5</sup>

<sup>1</sup> Dept. of Physics, Brookhaven National Laboratory, Upton, NY, U.S.A.

<sup>2</sup> Photon Factory, Institute of Materials Structure Science, Tsukuba, Japan

<sup>3</sup> Joint Research Center for Atom Technology (JRCAT), Tsukuba, Japan

<sup>4</sup> National Synchrotron Light Source, Brookhaven National Laboratory, Upton, NY, U.S.A.

<sup>5</sup> CMC-CAT, Advanced Photon Source, Argonne National Laboratory, Argonne, IL, U.S.A.

## Introduction

During the last several years, there has been enormous interest in x-ray resonant scattering studies of orbital ordering in transition metal oxides.<sup>1-9</sup> Here, we report an x-ray scattering study of octahedral tilt ordering in the manganite series  $\text{Pr}_{1-x}\text{Ca}_x\text{MnO}_3$  with  $x=0.4$  and  $0.25$  and in  $\text{LaMnO}_3$ .

## Methods and Materials

The sensitivity to tilt ordering is achieved by tuning the incident x-ray energy to the  $L_I$ ,  $L_{II}$ , and  $L_{III}$  absorption edges of Pr and La, respectively. The polarization dependence is predominantly  $\sigma$  to  $\pi$ , and the azimuthal dependence follows a sin-squared behavior. These results lead to a description of the cross section in terms of Templeton scattering in which the tilt ordering breaks the symmetry at the rare earth site.

## Results

Figure 1 shows the energy dependence of the scattering at the  $(0,1,0)$  orbital wavevector of  $\text{Pr}_{0.75}\text{Ca}_{0.25}\text{MnO}_3$ . A large resonant signal is visible at  $\hbar\omega=6.547$  keV near the Mn K edge. Remarkably, there is also a resonant feature at the Pr LII edge with  $\hbar\omega=6.44$  keV. The latter resonance arises from octahedral tilt ordering. The most interesting result of the present work is our observation that octahedral tilt ordering persists above the orbital ordering transition temperatures in all three samples. Indeed, we identify separate structural transitions, associated with the onset of orbital and tilt ordering, respectively,

## Discussion

The main features of the resonant profiles for  $\text{Pr}_{0.75}\text{Ca}_{0.25}\text{MnO}_3$ , are reproduced above the orbital ordering temperature. Importantly, from the perspective of the theory of Benedetti et al.,<sup>10</sup> no changes in the L-edge lineshapes are observed with increasing temperature through the orbital transition. From this we conclude that the main features of the L-edge resonant profiles reported here originate in octahedral tilt ordering and that any contributions to the L-edge resonances arising from the Mn orbital order are too small to be detected. A full discussion of the present results has been accepted by *Physical Review B*.<sup>8</sup>

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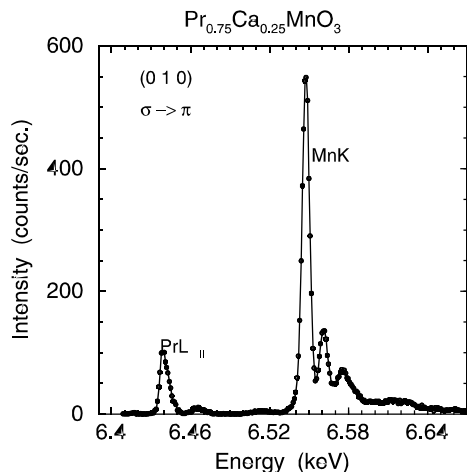


FIG. 1. The energy dependence of the scattering at the  $(0,1,0)$  orbital wavevector of  $\text{Pr}_{0.75}\text{Ca}_{0.25}\text{MnO}_3$ .