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Doping fluctuation-driven magneto-electronic phase separation in $La_{1-x}Sr_xCoO_3$ single crystals

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The doped perovskite cobaltites, in particular $La_{1-x}Sr_xCoO_3$ (LSCO), have emerged as productive systems for the study of the magneto-electronic phase separation phenomenon widely observed in complex oxide materials. It is now well established that this system phase separates into hole-rich ferromagnetic clusters embedded in a hole-poor non-ferromagnetic insulating matrix at low doping. These clusters percolate at a critical doping value near $x = 0.17$ leading to a crossover from short- to long-range ferromagnetic order and a simultaneous insulator-metal transition. In this work we have used multiple complementary experimental probes (e.g. small-angle neutron scattering (SANS), heat capacity, and magnetotransport) to establish that high quality single crystals actually exhibit magnetic phase separation only over a well-defined doping range, $0.04 < x < 0.22$. We further show that these limits can be perfectly reproduced by simple statistical simulations where the existence of local ferromagnetism is driven solely by the inevitable local compositional fluctuations that are present at such small length scales. These length scales are defined by the mean cluster size which is determined directly by SANS. The same simulations also reproduce the doping dependence of both the observed magnetic phase fractions and SANS intensity. A remarkable consequence of this analysis is that it suggests that the magnetic phase diagram measured on macroscopic specimens is applicable even at length scales as small as 1 nm. Most importantly, it is clear from this work that models based on true electronic phase separation are not required to explain the physical properties of these cobaltites. Co-authors: C. He, S. El-Khatib, J. Wu, (UMN), J.W. Lynn (NIST), H. Zheng, J.F. Mitchell (Argonne National Lab). Work supported by DoE and NSF.