Topological defects in hexagonal manganites: from multiferroics to cosmology

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Topological defects, such as domain walls and vortices, are pervasive in complex matter such as superfluids, liquid crystals, the earth’s atmosphere, and the early universe [1]. Topological defects have been fruitful playgrounds for emergent phenomena. Recently, vortex-like topological defects, called magnetic skyrmions, were observed in helical magnets without inversion symmetry [2]. The interplay between the topological spin texture of skyrmions and the spins of conduction electrons may lead to novel spintronic applications [3]. Multiferroics are materials with coexisting magnetic and ferroelectric orders, where inversion symmetry is also broken [4-8]. The cross-coupling between two ferroic orders can result in strong magnetoelectric coupling. Therefore, it is of both fundamental and technological interest to visualize cross-coupled topological defects in multiferroics. Indeed, topological defects with six interlocked structural antiphase and ferroelectric domains merging into a vortex core were revealed in multiferroic hexagonal manganites [9, 10]. Numerous vortices are found to form an intriguing self-organized network, and may be used to test Kibble-Zurek model of early universe [11, 12]. Many emergent phenomena, such as enhanced conduction and unusual piezoelectric response, were observed in charged ferroelectric domain walls protected by these topological defects [13, 14]. In particular, alternating uncompensated magnetic moments were discovered at coupled structural antiphase and ferroelectric domain walls in hexagonal manganites using cryogenic magnetic force microscopy (MFM) [15], which demonstrates the coupling between ferroelectric and magnetic orders. Using a newly-developed Magnetoelectric Force Microscopy (MeFM) [16], which combines MFM with in-situ modulating high electric fields, we directly visualize the magnetoelectric response of the multiferroic domains in hexagonal manganites [17, 18]. Our results reveal a giant enhancement of magnetoelectric response of a lattice mediated magnetoelectric effect near a spin-reorientation critical point.

Reference