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Using neutron scattering to explore new magnetoelectric phenomena in both thin films and skyrmion lattices

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Neutron scattering continues to be an invaluable tool for exploring the microscopic magnetic properties of magnetoelectric (ME) and multiferroic materials. Here I will present studies where neutron scattering techniques less commonly used for studying MEs have provided pivotal insight into new ME coupling phenomena. Firstly, we have used polarized neutron reflectometry (PNR) in a study of multiferroic and strained orthorhombic (o-) $LuMnO_3$ thin films [1]. Unlike bulk o-$LuMnO_3$ which is a commensurate antiferromagnet, the films display drastically different properties and are simultaneously incommensurately antiferromagnetic and ferromagnetic at low temperature. The pivotal PNR experiments allowed us to measure the spatial distribution of the ferromagnetic magnetization in the films, and show that the ferromagnetism is most pronounced close to the film-substrate interface which is highly strained due to the lattice mismatch. We could further show the ferromagnetism and antiferromagnetism in the film to be directly coupled, and so demonstrate the promising functional properties of these films. Secondly, we have used small-angle neutron scattering (SANS) to study the topologically protected magnetic spin vortices, or skyrmions, in the chiral-lattice ME insulator Cu_2OSeO_3. Until 2012, skyrmions had been observed only in (semi)conducting B20 compounds where it is known that they can be manipulated by conduction electrons. From our SANS experiments on Cu2OSeO3 [2], we show that applied electric *fields* can control the skyrmion lattice orientation in insulators, and in an essentially lossless manner that is dependent on both the size and sign of the electric field. These results provide the first evidence for a the electric field control of topologically protected magnetism in bulk magnetoelectrics.

[1] J.S. White *et al.*, Phys. Rev. Lett. **111**, 037201 (2013).
[2] J.S. White *et al.*, J. Phys.: Condens. Matter **24**, 432201 (2012).