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Beller Lecture: Artificial Ferroic Systems

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In artificial ferroic systems [1], novel functionality is engineered through the combination of structured ferroic materials and the control of the interactions between the different components. I will present two classes of these systems, beginning with hybrid mesoscopic structures incorporating two different ferromagnetic layers whose static and dynamic behaviour result from the mutual imprint of the magnetic domain configurations [2]. Here we have demonstrated a new vortex core reversal mechanism [3], which occurs when it is displaced across domain boundaries with a magnetic field. I will then describe our progress on artificial spin ice, consisting of arrays of dipolar-coupled nanomagnets arranged in frustrated geometries. We have employed photoemission electron microscopy to observe the behaviour of emergent magnetic monopoles in an array of nanomagnets placed on the kagome lattice [4]. We have also created artificial spin ice with fluctuating magnetic moments and observed the evolution of magnetic configurations with time. This has provided a means to study relaxation processes with a controlled route to the lowest-energy state [5]. Recently, we have demonstrated with muon spin relaxation that these magnetic metamaterials can support thermodynamic phase transitions [6], and future directions include the incorporation of novel magnetic materials such as ultrathin magnetic films [7], the investigation of 3D structures [8], as well as the implementation of x-ray resonant magnetic scattering to study magnetic correlations in smaller nanomagnets and at faster timescales [9]. [1] L.J. Heyderman and R.L. Stamps, JPCM (2013); [2] G. Heldt et al., APL (2014); [3] P. Wohlhuter et al., Nature Comms (2015); [4] E. Mengotti et al., Nature Phys. (2011); [5] A. Farhan et al., Nature Phys. and PRL (2013); [6] L. Anghinolfi et al., Nature Comms (2015); [7] V. Kapaklis et al., Nature Nanotech. (2014); [8] C. Donnelly et al., PRL (2015); [9] J. Perron et al., PRB (2013)