Merons, bimerons and skyrmions in α-Fe_2O_3: from cosmology to spintronics

The field of quantum matter/quantum materials draws inspiration from a variety of theories, seeking materials in which they can be embodied and verified. In some cases, the materials in question end up being rather useful, though not necessarily in a way that is closely related to the original research motivation. A celebrated example [1] is the analogy, proposed by Wojciech H. Zurek, between cosmological strings [2] and vortex lines in the superfluid, which suggested cryogenic experiments to test cosmological string formation in ^{4}He. The work I will describe in this talk started off as an attempt to seek the analogue of cosmological strings in easy-axis antiferromagnets with low in-plane anisotropy, leading to an approximate U(1) symmetry.
A well-known example of such materials is hematite (α-Fe_2O_3), which orders at a high Néel temperature (T_N ~ 960 K). At room temperature and above, the spins are aligned perpendicular to the high-symmetry trigonal axis and are also slightly canted due to the Dzyaloshinskii-Moriya interaction, giving rise to a 'weak' but measurable net ferromagnetism. Below the Morin transition temperature (T_M ~ 260 K), the spins flip out of plane and lose their canting, leading to perfect antiferromagnetism and the loss of the net magnetic signal. We reasoned that the above-Morin phase should be topologically rich and could in principle support vortices, while the easily accessible low-temperature phase would be topologically 'trivial'. I will discuss our recent work [3,4], in which we demonstrated that, indeed, hematite supports a rich variety of topological textures (merons, antimerons, bimerons), which can be tuned in and out of existence simply by cycling temperature over a narrow range through T_M or by application of biaxial/uniaxial strain [5]. Remarkably, these magnetic textures can be imaged in real space by X-ray spectral microscopy (X-PEEM, transmission X-ray microscopy and holography [6]). I will also discuss recent experiments, performed in collaboration with Cambridge colleagues, in which we imaged by N-V centre microscopy [7] the 'emergent' multipolar charges associated with topological textures. My final question is: can topological textures in hematite be at all useful? I will argue that the answer may be yes, particularly in the blooming field of antiferromagnetic spintronics/skyrmionics.

References

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