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Beller Lectureship: Magnetism at the edge; Anhysteretic, athermal magnetic response at oxide surfaces and interfaces[1]

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Magnetism in oxides is normally associated with transition-metal ions having a partly-filled d(or f) shell. The common hexagonal ferrite magnets $BaFe_{12}O_{19}$ and $SrFe_{12}O_{19}$ that are produced in quantities exceeding a million tons a year annum are a good example. In recent years, techniques honed to cater for the high-T_C superconductor boom have been applied to produce a range of oxide thin films and nanoparticles, which exhibit magnetic properties that are quite different to those of the bulk material. Oxide-oxide interfaces are full of surprises, especially when one of them is polar, inducing electronic reconstruction to avoid a polar catastrophe. The formation, location and magnetism of the resulting two-dimensional electron gas will be discussed. The data give lie to the common assumption of additivity of the magnetism of a thin film and its substrate. More puzzling is the elusive temperature-independent, anhysteretic magnetism of some thin films and nanoparticles, which cannot be accommodated in the current paradigm of magnetism in solids. Classical micromagnetic analysis would suggest that only a tiny fraction of the sample volume is involved ($\sim 10^{-3}$ for thin films, $\sim 10^{-6}$ for nanoparticles), yet there are no signs of collective magnetic order such as increasing coercivity at low temperatures or a Curie point at high temperature. The anhysteretic magnetisation curve is temperature-independent (unlike that of a superparamagnet). In CeO_2 nanoparticles there is a characteristic length scale of order 100 nm required for the appearance of the anomalous magnetic response. We propose an explanation in terms of giant orbital paramagnetism due to coupling with zero-point fluctuations of the vacuum electromagnetic field, which predicts a magnetization curve of the form $M = M_0\mathrm{x}/(1+\mathrm{x}^2)^{1/2}$, where $\mathrm{x} = CB$; the constant C corresponds to the characteristic wavelength and lengthscale, 330 nm in this case.

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