**Frustrated Materials and Magnetoelectric Interactions**

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**Activities: Multiferroics, Strongly Interacting Systems, Neutron Scattering, Electronics**

The quest for an improved control of the electric polarisation with an externally applied magnetic field (which for example can impact the engineering of novel RAM elements), is directed in a family of strongly interacting materials involving frustrated magnetic interactions. Within this topic we demonstrate fundamental modification of low-dimensional, triangular spin lattices, with anisotropic super-exchange interactions, when spin and/or orbital degrees of freedom are tuneable variables.

**Background.** The search for new materials which combine coupled electric and (ferro- or antiferro-) magnetic dipole order is at the forefront of current research with significant fundamental and technological impact [1]. “Multiferroicity” of this type appears to be a rather hard to achieve in a single phase chemical system, as it is proved that the corresponding order parameters are mutually exclusive; this in effect limits the number of good candidate materials [2].

**Aims.** Since the simultaneous presence of the aforementioned order parameters does not necessarily imply strong coupling, we are interested to identify new systems with potential improved “interference” between magnetism and ferroelectricity (FE) and in a sense to attempt drawing clues on what is the possible microscopic mechanism for multiferroic behaviour. Recent experimental results as well as theoretical advances postulate [3, 4] the plethora of competing magnetic interactions, intrinsic to frustrated magnets (Fig. 1a), as a good reason behind the enhanced sensitivity of dielectric properties upon the application of a magnetic field in this class of materials.

The outcome of our fundamental studies on frustrated delafossites (AMO$_2$: A$^+$= nonmagnetic monovalent ion, M$^{3+}$= magnetic 3d transition metal; Fig. 1b), where an anisotropic triangular lattice topology is realized, is to expand our research into exploiting such 2D materials as potential induced magnetoelectrics. In geometrically frustrated magnets [5], each spin cannot satisfy all pairwise interactions (Fig. 1a – middle) and therefore remains disordered to temperatures well below the Curie-Weiss temperature where magnetic order is expected. As a consequence, the ground state degeneracy imposed by lattice topology may lead to unconventional magnetic properties, including spin-liquid states. Also, under certain conditions (c.f. magneto-elastic coupling) frustration can be relieved and a novel magnetic structure develops (Fig. 2).

**Actions.** The general objective entails understanding frustrated lattice topologies to enhance the coupling of magnetic and ferroelectric order parameters. We study (i) low-T, subtle structural distortions, which accompany order-disorder (spin or orbital) transitions, (ii) if electric polarisation can develop along the magnetic order, (iii) measure the excitations to derive microscopic parameters (exchange interactions (J), anistropy (D) etc). The results aim to motivate the testing theories concerning diverse chemical nature magnetoelectrics.

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**Figure 1:** (a) Crystal symmetry imposed degeneracy in simple two-dimensional (2D) lattice (AF= antiferromagnetic, FM= ferromagnetic bonds). (b) Temperature evolution of the dc magnetic susceptibility in frustrated delafossites.

**References**