Multiferroicity emerging from frustrated spin interactions

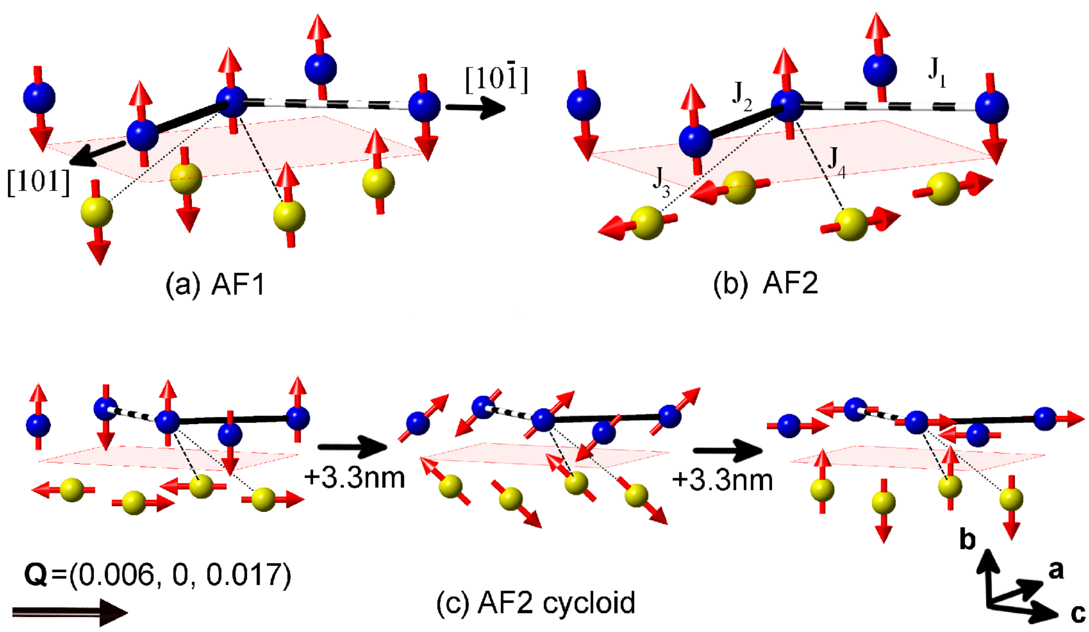
Dr James Lloyd-Hughes* & Prof. Julie B. Staunton (Physics)

Ferroelectricity and ferromagnetism are two examples of cooperative phenomena in condensed matter physics, where microscopic interactions lead to macroscopic properties. Multiferroics are a rare class of materials that exhibit both magnetic and electric dipole order. The potential for strong magnetoelectric effects, such as the control of magnetic states with electric fields, is offering the exciting prospect of novel data storage and processing paradigms.

In some multiferroics the ferroelectric state emerges from complex long-range magnetic structures, where spins adopt cycloidal or conical patterns. In these materials strong coupling between electric and magnetic order can occur, but to date such effects are limited to below room temperature. The challenge before significant device development can proceed is to increase the stability temperature of multiferroic phases, while retaining significant magnetoelectric coupling.

In this project the magnetic structures that can induce ferroelectricity will be investigated, with reference to the model system of cupric oxide (CuO). At low temperatures CuO has a local magnetic spin structure on Cu ions parallel to or anti-parallel to the *b*-axis of the monoclinic crystal [red arrows in Figure (a)]. The energetics of such systems is influenced by spin-spin interactions, and multiple, competing interactions with different strengths and signs often contribute [labelled J_n in Figure (b)]. By constructing a spin energetics model the role of frustrated spin interactions in driving a phase transition to a magnetic state that supports ferroelectricity will be elucidated. Such a cycloidal spin state is pictured in Figure (c), where magnetic spins along the **Q** direction are rotated.

The project will require the student to gain some background in magnetism and crystal structure in solid state physics. Geometrical constraints and modifications will be explored to gain an understanding of how interactions promote the formation of complex spin structures. Comparisons with existing experimental data will be used to constrain modelling work. The natural progression of this project into ab-initio calculations and/or models of spin dynamics is highly desirable, and would provide fertile ground for further PhD work.



* Please contact me via j.lloyd-hughes@warwick.ac.uk if you would like to discuss this project in more detail.