Low temperature property studies of the possible frustrated magnetoelectric compound $PrMgAl_{11}O_{19}$

Supervisor: Gaël Bastien and Ross H. Colman

Magnetism is a fascinating research area, because it is a nice playground to study many body physics and statistical mechanics, with potential uses in electronics and energy applications. Frustrated magnets are magnetic materials where all the magnetic interactions cannot be simultaneously satisfied and thus compete with each other. In these materials a large variety of magnetically ordered states and disorder states are possible, often with very small energy differences between them. It was recently proposed that interacting electric dipolar moments may also lead to similar frustration in compounds with the magnetoplumbite crystal structure [1][2]. Some of the materials in the family contain both frustrated electric and frustrated magnetic moments and we have recently observed that the dielectric properties of $NdMgAl_{11}O_{19}$ can be influenced by an applied magnetic field, implying so called magnetoelectric coupling. Magnetoelectric coupling in this family, along with the electric and magnetic frustration, leads to the possibility to tune between energetically similar magnetic states using applied electric fields, or between electric states using magnetic fields. Such possibilities are fascinating to explore, with very few model materials available to probe both frustration and multiferroic coupling simultaneously.

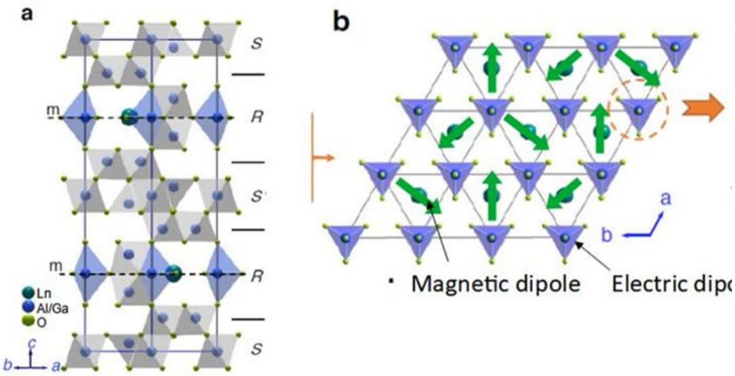

Figure 1 : (adapted from Reference [1]) (a) Crystal structure of the hexaaluminates and hexagallates.

(b) view from the top showing the nested lattices of magnetic dipoles (green arrows) and electric dipoles (double pyramids).

Investigating the ground-state properties of these materials is best performed using single-crystals.

The work will consist of the measurement of temperature-dependent property measurements of $PrMgAl_{11}O_{19}$, and subsequent analysis of the results. Single crystals are already prepared, but nice samples must be selected from the mixture. The samples can then by oriented by laue diffraction to measure properties along specific crystallographic axis directions.

Magnetic properties will be measured down to 1.8 K using a Quantum Design Magnetic Properties Measurement System. Any magnetic transitions of the Pr^{3+} triangular sublattice will be observed and analysed.

Specific heat measurements down to 0.3 K will also be performed in a Physical Properties Measurement System, to search for both magnetic and ferroelectric transitions. These measurements can also be performed in various magnetic fields to investigate the field-dependence of the magnetic properties.

References:

[1] S.-P. Shen, J.-C. Wu, J.-D. Song, X.-F. Sun, Y.-F. Yang, Y.-S. Chai, D.-S. Shang, S.-G. Wang, J. F. Scott, and Y. Sun, *Nature Communications* 2016 , **7** .
[2] M. Ashtar, Y. X. Gao, C. L. Wang, Y. Qiu, W. Tong, Y. M. Zou, X. W. Zhang, M. A. Marwat, S. L. Yuan, and Z. M. Tian, *Journal of Alloys and Compounds* 2019, **802** , 146.
[3] Alemayehu S. Admasu and Durga Sankar Vavilapa, https://arxiv.org/abs/2103.05587.