Understanding Spin Textures in Frustrated Magnets

J. A. M. Paddison¹, H. Zhang², B. Rai³, J. Yan¹, A. F. May¹, M. B. Stone¹, S. Calder¹, M. D. Frontzek¹, D. A. Dahlbom², K. M. Barros⁴, S. Do¹, S. Gao¹, M. J. Cliffe³, C. Batista², A. D. Christianson¹

¹Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA, ²University of Tennessee, Knoxville, TN 37996, USA, ³Savannah River National Laboratory, Aiken, SC 29808, USA, ⁴Los Alamos National Laboratory, Los Alamos, NM 87545, USA, ⁵University of Nottingham, Nottingham NG7 2RD, United Kingdom

paddisonja@ornl.gov

Keywords: Frustrated magnetism, topological magnetism, neutron scattering

Magnetic frustration can suppress conventional magnetic ordering and stabilize unconventional magnetic states. These states can include spin liquids, in which conventional long-range magnetic order is absent. Alternatively, frustration may promote complex long-range magnetic order with novel properties. For example, materials with noncoplanar magnetic structures can show unusual physical properties driven by their nontrivial topology [1].

Both spin liquids and complex magnetic orders present exciting challenges for crystallographic analysis. On the one hand, the absence of magnetic Bragg scattering in spin liquids means that analysis of diffuse magnetic scattering is crucial. On the other hand, Bragg intensities alone may contain insufficient information to solve non-coplanar magnetic states. In particular, such states are often multi-wavevector (multi-\(q\)) structures, which are challenging to solve because their magnetic Bragg diffraction patterns are usually identical to single-\(q\) structures in the presence of domain or powder averaging [2].

In this talk, I will discuss how information obtained from diffuse, inelastic, and Bragg scattering can be combined to determine spin textures in frustrated magnets, and to identify the magnetic interactions that stabilize these states. I will focus on two classes of frustrated magnetic materials. First, I show that the insulating double perovskites Ba₂YRuO₆ and Ba₂LuRuO₆ [3,4] host a noncoplanar triple-\(q\) structure on the face-centred cubic lattice. Our study employs inelastic neutron-scattering experiments to measure the spin-wave excitations in powder samples of these materials. By refining the magnetic structure and magnetic interactions simultaneously against our inelastic neutron-scattering data, we show that a triple-\(q\) structure yields the best agreement with experiment, and this state is stabilized by non-Heisenberg interactions in the Hamiltonian, namely biquadratic interactions [5]. Second, I discuss the intermetallic Gd₃PdSi₃, in which Gd³⁺ ions occupy a triangular lattice. This centrosymmetric material hosts a multi-\(q\) skyrmion spin texture under small applied magnetic fields [6]. I show how the magnetic diffuse scattering measured above its magnetic ordering temperature can identify the magnetic interactions that stabilize the skyrmion phase, establishing a space of magnetic interactions that can promote skyrmion formation [7].

I conclude by discussing the outlook for refinement of magnetic models in interaction space, and introduce a computer program that can be used to refine interaction models against magnetic diffuse scattering data [8].


This work was supported by the U.S. Department of Energy, Office of Science, Basic Energy Sciences, Materials Sciences and Engineering Division. It used resources at the Spallation Neutron Source, a DOE Office of Science User Facility operated by the Oak Ridge National Laboratory.