Magnetic anisotropy in Dy garnets

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Amongst geometrically frustrated architectures candidates is the hyperkagome network, which consists in a twisted spatial arrangement of corner-sharing triangles, and which can be found in rare-earth (R) garnets R₂Si₃O₇. Gd₃Ga₅O₁₂ (GGG) and Yb₅Ga₅O₁₂ (YbGG) are among the most studied members of this family, and it has been proposed that both exhibit an emergent long- or short-range multipolar director state [1, 2], owing to the interplay between anisotropy and near-neighbor exchange. Both also show a modest XY crystal field anisotropy, in contrast with most other rare-earth garnets, which have a strong Ising-like anisotropy. Combined with dipolar interactions, the latter leads to a classical long range (multi-axis) magnetic ordering, thus suggesting a less prominent role of frustration, compared with the isotropic case. Using a comprehensive combination of neutron scattering techniques, including polarized neutron powder diffraction [3] analyzed with the newly developed CrysPy software [4], as well as powder and single-crystal diffraction, and inelastic neutron scattering, we investigated this issue, focusing on the evolution of the magnetic properties between Dy₅AlO₁₂ (DyAG) and Dy₅GaO₁₂ (DyGG). Polarized neutron powder diffraction led to the first direct measurement of the Dy³⁺ anisotropy in these two garnets (Fig. 1). Replacing Al for Ga modifies the Dy³⁺ local anisotropy from Ising-like in DyAG to quasi-planar (XZ) in DyGG [5]. This result was confirmed by the Landé factors derived from the crystal electric field scheme determined by inelastic neutron scattering for both compounds. Neutron diffraction was then used to determine the magnetic ground state of both garnets, which was identified as multi-axis in both [5]. These results show that magnetic frustration in garnets can be controlled through the degree of anisotropy of the rare-earth ion; according to a point charge modeling, anisotropy change is linked with small variations of the oxygen positions surrounding Dy³⁺ ions, calling for further studies on the impact of chemical pressure on the Ising character of the Dy anisotropy. A strong boost in the study of polycrystalline magnetic compounds by polarized neutron diffraction is to be expected in the near future, in parallel with the update of the CrysPy software to treat time-of-flight data from the European Spallation Source instruments for instance.

Figure 1. DyAG (left) and DyGG (right) (a) flipping difference (γ⁺ − γ⁻) diffraction pattern collected at 5 K in 5 T. The measured (calculated with CrysPy) 2D pattern is shown in the top (bottom) panel. (b) Projection on the Bragg angle 2θ. Reflections positions are marked by vertical ticks. The black line shows the difference between the experimental points (blue) and the model (orange line). γ is the azimuthal angle and ν is the elevation angle in the laboratory coordinate system (xyz) [5].