Crystal-field–driven magnetoelectric coupling in rare-earth hexaaluminates

Sonu Kumar,[1] Gael Bastien,[2] Ross H Colman,[2] Mateusz Kempinski,[1] Maxim Savinov,[3] Karol Zaleski,[4] Petr Proschek,[2] Malgorzata Sliwinska Bartkowiak,[1] and Stanislav Kamba[3]

[1]*Adam Mickiewicz University, Faculty of Physics and Astronomy,*
Department of Experimental Physics of Condensed Phase, Poznań, Poland
[2]*Charles University, Faculty of Mathematics and Physics,*
Department of Condensed Matter Physics, Prague, Czech Republic
[3]*Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic*
[4]*Adam Mickiewicz University, NanoBioMedical Centre, Poznań, Poland*

Rare-earth hexaaluminates $\mathrm{LnMgAl_{11}O_{19}}$ host triangular-lattice $4f$ moments in which the magnetic ion and its crystal-electric-field (CEF) scheme stabilize distinct *quantum-disordered* ground states, ranging from non-Kramers $\mathrm{Pr^{3+}}$ to Kramers $\mathrm{Ce^{3+}}$ and $\mathrm{Nd^{3+}}$ systems [1–3]. The magnetoplumbite lattice simultaneously supports intrinsic dielectric dipoles associated with antipolar distortions of oxygen polyhedra, providing a highly polarizable background [4]. Within this framework we demonstrate *CEF-driven magnetoelectricity*: in Kramers doublets (Ce, Nd), magnetoelectric (ME) coupling arises from both direct Zeeman-induced mixing within the ground-state doublet and additional *virtual* admixing to excited CEF levels, producing predominantly biquadratic P^2M^2 behavior. In contrast, non-Kramers quasi-doublets (Pr) enable more complex and strongly temperature-dependent coupling channels governed by the detailed low-energy CEF structure. These results establish $\mathrm{LnMgAl_{11}O_{19}}$ as a tunable platform in which targeted CEF engineering controls nonlinear magnetoelectric responses [5,6].

References:

[1] S. Kumar et al., Phys. Rev. B 111 (2025) 174444.
[2] S. Kumar et al., arXiv 2505.18898 (2025).
[3] G. Bastien, S. Kumar et al., arXiv 2506.16207 (2025).
[4] G. Bastien et al., Adv. Mater. (2024) 202410282.
[5] S. Kumar et al., Phys. Rev. B 112 (2025) 224431.
[6] S. Kumar et al., arXiv 2511.12355 (2025).