Contribution ID: **13** Type: **Oral**

Effect of the magnetic metal site on the dipolar-octupolar pyrochlores Nd2Ru2O7 and Nd2Ir2O7

Tuesday, 3 June 2025 14:00 (15 minutes)

Pyrochlore oxides with the formula R2M2O7 (R representing a rare-earth element and M a metal ele-ment) consist of two interpenetrating pyrochlore lattices, and are a rich playground to stabilize unconven-tional magnetic frustrated phases [1]. In this family, Nd-based compounds exhibit intriguing physics due to the dipolar-octupolar nature of the Nd3+ ground state doublet [2]. In particular, at low temperature, they stabilize a peculiar dipolar-octupolar antiferromagnetic ground state which manifests as a so-called all in- all out state with a reduced ordered magnetic moment along the local ⟨111⟩ directions of the tetrahedra. When the M4+ metal ion carries a magnetic moment, its ordering can strongly impact the magnetic properties of the R3+ ion. For example, a fragmented state was discovered in Dy2Ir2O7 and Ho2Ir2O7 [3-4], stabilized by the molecular field induced by the antiferromagnetic ordering of the Ir4+ magnetic moments and the rare-earth. Recent studies suggest that ruthenate compounds may also stabilize fragmented states [5].

In this context, we are interested in the Nd2Ir2O7 and Nd2Ru2O7 compounds, which are expected to combine these physics. In both systems, the Nd3+ ion exhibits an all in - all out ordering with a reduced ordered moment [6-7], which reminds the dipolar-octupolar ordering of Nd2Zr2O7. However, our detailed study of the temperature dependence of the magnetic properties of both compounds using neutron diffraction (ILL D1B) and high resolution inelastic neutron scattering (ILL IN5), show that it is considerably affected by the presence of the metal ion.

While the metal ion orders into two different magnetic structures in both compounds (all in - all out in Nd2Ir2O7 [7] and easy-plane antiferromagnetic Γ5 in Nd2Ru2O7 [8]) and at two different temperature scales (150 K and 35 K respectively), our measurements combined with spin wave and mean field analysis show that the temperature dependence of the ordered moment and the spin excitations in both systems can only be understood by introducing in the Hamiltonian a coupling between the octupolar component of the Nd3+ ion and the metal. This term generates an octupolar moment and magnetic excitations at much larger temperature than in Nd2Zr2O7 and its existence provides an exciting new playground to study unconventional magnetic states with dipolar-octupolar rare-earth ions.

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Session Classification: Contributed talks