# Giant Magnetic Hysteresis in $Sr_3NiIrO_6$

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## Introduction

$Sr_3NiIrO_6$ forms a trigonal structure in which Ni and Ir alternate in chains along the c-axis, and the chains form a hexagonal structure in the a-b plane [1]. It belongs to a family of compounds with similar structure including $Ca_3CoMnO_6$, $Ca_3Co_2O_6$, $Sr_3CoIrO_6$, [1,2] and others. These materials can have highly frustrated magnetic interactions and in the case of $Ca_3CoMnO_6$ show multiferroic properties. In particular, when the magnetic moments are Ising-like, these materials may be examples of the Axial Next Nearest Neighbor Ising model (ANNNI) [3]. By substituting magnetic 5d $Ir^{4+}$ into the structure, we have the potential to create the most Ising-like moments in this family. Previous measurements on polycrystals of $Sr_3NiIrO_6$ show magnetic hysteresis below ~50 K, and a feature in the magnetic susceptibility below 85 K [1]. X-ray absorption of other family members suggest that Ni, which occupies an octahedral oxygen cage, is divalent and Ir, which occupies a trigonal bipyramid of oxygen, is tetravalent.

## Experimental

We measured extraction magnetometry in a short pulse magnet up to 60 T in polycrystals and in the first-reported single crystals of this material.

## Results

**Figure 1** shows the magnetization for H || ab and H || c for a single crystal grown from a Ni-rich flux with $Sr_3Ni_{1.05}Ir_{0.95}O_6$. We find an extremely large coercive magnetic field of 40 T at T = 4 K, in fact the highest coercive fields of any material to our knowledge. The magnetization is highly anisotropic, and for H || ab, the magnetization is roughly linear and not hysteretic in applied magnetic fields up to 60 T. This is consistent with the magnetic moments being highly anisotropic and constrained to the c-axis, and canting linearly as the magnetic field is applied along ab. In Ni-rich polycrystalline samples, coercive fields of up to 30 T were also observed.

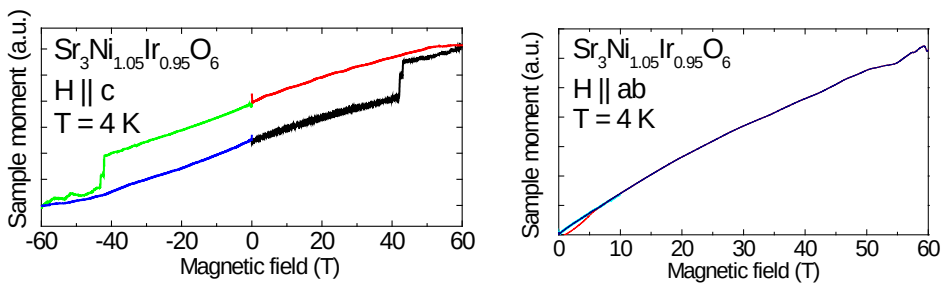


**Figure 1** Magnetization of single crystalline $Sr_3Ni_{2-x}Ir_xO_6$ grown from a Ni-rich batch with x = 0.95. Measurements performed in a short pulse magnet to 60 T using an extraction magnetometer.

## Conclusions

We observe the highest coercive field (40 T) of any magnetic materials to our knowledge, which we attribute to the strongly anisotropic 5d $Ir^{4+}$ moments. Further measurements are in progress.

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## References

[1] D. Mikhailova *et al.*, Phys. Rev. B 86, 134409 (2012); D. Flahout *et al.*, Eur. Phys. J. B 35, 317 (2003)
[2] V. Hardy *et al.*, Phys. Rev. B 70, 064424 (2004); Y. J. Choi *et al.*, Phys. Rev. Lett. 100, 047601 (2008); V. Kiryukhin *et al.*, Phys. Rev. Lett. 102, 187202 (2009).
[3] Y. Kamiya and C. D. Batista. Phys. Rev. Lett. 109, 067204 (2012); W. Selke, Phys. Reports 170, 213 (1988).