Thermal conductivity and magnetic torque study in the honeycomb magnets

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Introduction

Low-dimensional spin systems display a multitude of quantum phenomena, providing an excellent forum for the exploration of unconventional ground states and their exotic excitations. The Kitaev model [1] has attracted a particular attention, both theoretically and experimentally, because it possesses an exactly solvable quantum spin-liquid (QSL) ground state and has possible realizations in a number of candidate materials. Thermal transport measurements combined with magnetic torque have been a powerful tool for elucidating the itinerant nature of QSLs as a result of their high sensitivity to the low-energy excitation spectrum, and in fact studies of low-dimensional insulating quantum magnets have revealed significant contributions to heat conduction from unconventional spin excitations.

Experimental

We have studied in-plane thermal conductivity and magnetic torque using capacitive cantilever for three different single crystalline insulating magnets, $RuCl_3$, $CrCl_3$ and Na_2IrO_3. All three of them exhibit quasi 2-dimensional honeycomb lattice plane. Thermal conductivity ($CrCl_3$) and magnetic torque ($RuCl_3$) measurements as a function of applied field with *in-plane* rotation, were performed at SCM-2 and magnetic torque of Na_2IrO_3 measurement was done at Cell 9 resistive magnet in NHMFL at Tallahassee FL.

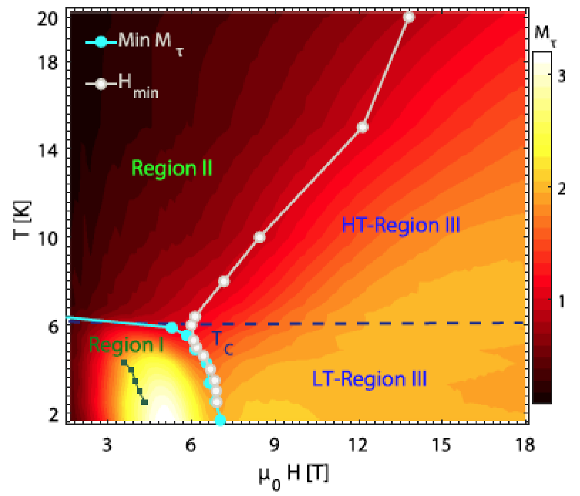

Figure 1 Phase diagram of RuCl3 inferred from the magnitude of magnetic torque (color). White circles indicate the field at which κ (H) becomes the minimum (Adapted from [2])

Results and Discussion

Our result on $RuCl_3$ and Na_2IrO_3 revealed a couple of common experimental ground of the QSL candidate materials and related physics. First, spin-liquid phase is likely to emerge in a system with a feeble long range order as shown in the phase of diagram of $RuCl_3$ (Fig 1). For instance, the observation of multiple Neel temperatures in $RuCl_3$ depending on c-axis stacking properties indicates the fragility of magnetic order. Second, field-induced spin-disordered state may host the QSL phase, which has been relatively overlooked area of the phase diagram. It is encouraging to observe strongly non-linear torque in Na2IrO3 (Fig. 2), which is very similar to what was observed in $RuCl_3$ near the field-induced spin-disorder: It motivates us to investigate the magnetic torque and heat transport in the compounds that belong to the same family [e.g. Na_2RuO_3, and $(Na_{1-x}Li_x)_2IrO_3$]. Moreover, thermal conductivity also provides a unique window into the interactions between phonons and spin degrees of freedom to identify qualitative changes in spin-phonon interaction resulting from the presence (or lack of) strong SOC, via comparison among similar magnetic insulators, where varying composition controls the SOC strength while maintaining a similar crystal structure [$RuCl_3$ vs. $CrCl_3$ and Na_2IrO_3 vs. Na_2RuO_3]. In such case, SOC is only one parameter that can be varied, and the effect on spin-phonon interaction of varying the type or geometry of magnetic interaction will be further explored.

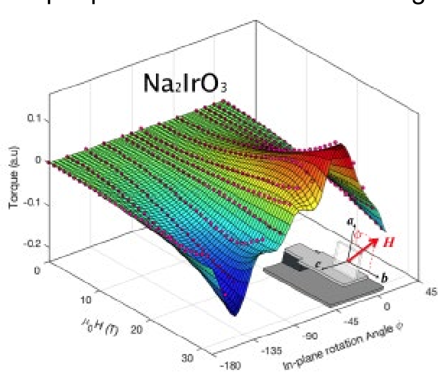

Figure 2 Magnetic torque with in-plane rotation. Surface plot is a fit of the data (red circles) a non-linear magnetic susceptibility tensor.

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References

[1] A. Kitaev, Ann. Phys. 321, 2 (2006).
[2] I. A. Leahy et al., Phys. Rev. Lett. 118 187203 (2017).