Fractional spin excitations in the Kitaev candidate compound $RuBr_3$

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A Kitaev spin liquid has attracted interest because of an exactly solvable nonmagnetic ground state and the fractionalization of spins into itinerant and localized Majorana fermions [1]. Since the theoretical proposal that the bond-dependent Ising interactions can be realized in some Iridium and Ruthenium compounds [2], a lot of efforts have been invested to search for the appropriate candidate. $RuBr_3$ is the new Kitaev candidate material that may host fractional spin excitations. It crystallizes into *R*-3, where Ru^{3+} ions form a regular honeycomb lattice [3]. It exhibits antiferromagnetic order below 34 K. The canting angle from a honeycomb plane was found to be 64 degrees and much larger than that of $RuCl_3$ (34-50 degrees)[4], suggesting that Kitaev interactions are much larger than non-diagonal Γ terms.

We performed order parameter scans of the representative magnetic reflection Q_{mag} = (0, 1/2, 1) to investigate the nature of the magnetic order and measured the temperature variations of the constant *Q*-scan at Q_{mag} (0.67 $Å^{-1}$) by using thermal-neutron triple-axis spectrometer 4G GPTAS installed at the JRR-3 reactor. 10 g of powder samples were prepared. For the order parameter scan, the wavelength was set to 2.36 $Å^{-1}$ using pyrolytic graphite and the horizontal collimations of 40'-40'-40'-open were employed. For the constant-*Q* scan, pyrolytic graphite 002 reflections were used for monochromating and analyzing neutrons. Scattered neutron energies were fixed to E_f = 14.7 meV. The analyzer was set in a both horizontally and vertically focusing condition to increase counting efficiency.

Figure 1 shows the temperature dependence of the 0 1/2 1 reflection. The temperature dependence was fit by a power law function together with a quadratic term to introduce the critical scattering empirically. The fit yields the value of 0.34(3), which is close to the value of the 3D XY or Heisenberg order. The temperature variation of the constant-*Q* scan is shown in Figure 2. Strong intensities remain near Q_{mag} even above the transition temperature. This is quite in contrast with that of $RuCl_3$[5], where the spin excitations above T_N are centered around *Q* ~ 0 or Γ point. This difference should indicate that antiferromagnetic interactions dominate the magnetism of $RuBr_3$ while ferromagnetic Kitaev interactions are dominant in $RuCl_3$. This is also consistent with their Weiss temperatures estimated from the magnetic susceptibility.

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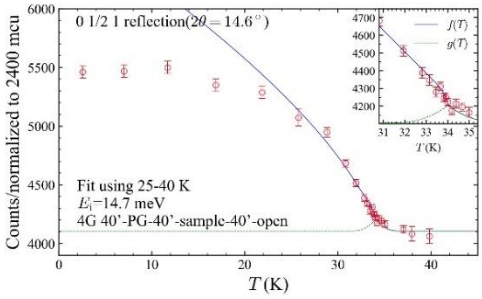

Fig. 1. The temperature dependence of the 0 1/2 1 reflection. Blue and green curves represent the total fitting function and the critical scattering empirically introduced in the fit, respectively.

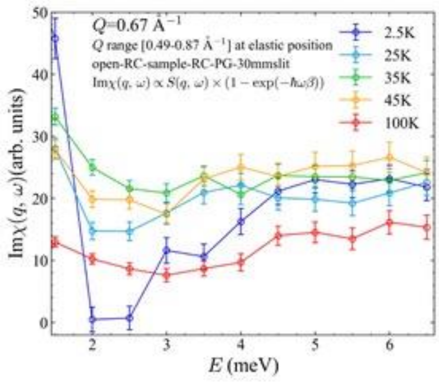

Fig. 2. Im χ estimated from the constant-*Q* scan at 0.67 $Å^{-1}$.