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# Magnetic properties of quantum kagome antiferromagnet $InCu_3(OH)_6Cl_3$

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**Abstract**

We have succeeded in synthesizing new Kapellasite-type $S$ = 1/2 kagome antiferromagnet $InCu_3(OH)_6Cl_3$ (In-Kapellasite). The magnetic properties of In-Kapellasite have been studied by magnetic susceptibility, heat capacity, and high-field magnetization measurements. In-Kapellasite exhibited quite unique magnetic properties due to strong frustration, including the successive developments of short-range and long-range magnetic ordering. Remarkably, we found the 1/3 magnetization plateau in the *MH* curve of In-Kapellasite which is the first clear experimental realization in quantum kagome antiferromagnets, and thus, it will bring important insights for the field-induced quantum many-body state of frustrated magnets.

## 1. Introduction

The quantum kagome antiferromagnet is a good platform to verify various quantum many-body states, including spin liquids, magnon crystals and supersolid in magnetic fields[1)]. However, due to the lack of appropriate model materials, it has not been easy to verify these rich theoretical predictions. We report here on the successful synthesis of a novel model material In-Kapellasite for the quantum kagome antiferromagnets and the discovery of a magnon many-body state observed as the 1/3 plateau in magnetic fields.

## 2. Experiment

Polycrystalline and single crystal samples were grown by a hydrothermal method. Magnetic measurements up to 7 T were performed by a SQUID magnetometer. High-field magnetization measurements on polycrystalline samples were performed by induction method in pulsed high magnetic fields up to 50 T at the Center for Advanced High Magnetic Field Science in Osaka University. Heat capacity was measured by the relaxation method using a Quantum Design PPMS above 2 K and a self-developed calorimeter below 2 K up to 14 T.

## 3. Results and discussion

### 3.1 Structural analysis

In-Kapellasite crystalizes in trigonal system with the space group $P31m$ with lattice constant $a$ = 12.3235 Å, $c$ = 6.0347 Å. This compound has the Kapellasite-type kagome network[2)]. The kagome network is slightly distorted to have two kinds of $Cu^{2+}$ isosceles triangles as shown in Fig. 1. However, there are three-fold axes on In site, which is the significant difference of most other distorted kagome compounds.

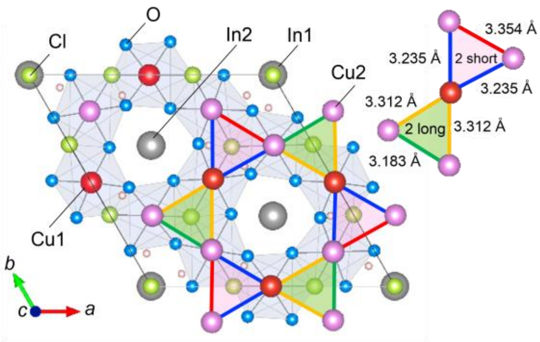


Fig. 1. The crystal structure of $InCu_3(OH)_6Cl_3$, a view from $c$-axis. Upper right bow tie shows two triangles with bond lengths.

### 3.2 Magnetic Properties

The temperature dependence of magnetic susceptibility on polycrystalline samples obeys the Curie-Weiss law above 50 K. We determined Curie constant and Weiss temperature $C$ = 0.53, $\Theta_W$ = -12.8, and estimated the paramagnetic effective moment $\mu_{eff}$ = 2.05, which corresponds to the theoretical value for $S$ = 1/2 system. While the magnetic susceptibility shows no cusp anomaly down to 2 K, it exhibits an upturn around 7 K which is also confirmed in heat capacity as a broad peak (Fig. 2(a)). Heat capacity detected the sharp peak at 1.8 K, indicating a development of a long-range magnetic order. Interestingly, 1/3 magnetization plateau was observed in high-field magnetization as depicted in Fig. 2(b) which is thought to be a clear experimental realization of the quantum many-body state. Fig. 2(c) is the phase diagram plotting the anomalies observed in these measurements. The long-range magnetic order is suppressed by magnetic fields of 8 T and then the 1/3 plateau emerges. Importantly, the 1/3 plateau phase is the short-range ordered state characterized by the heat capacity measurements. Therefore, it is expected that the plateau phase is realized as a state with significant spin fluctuations in accordance with a strong frustration on kagome network of In-Kapellasite.

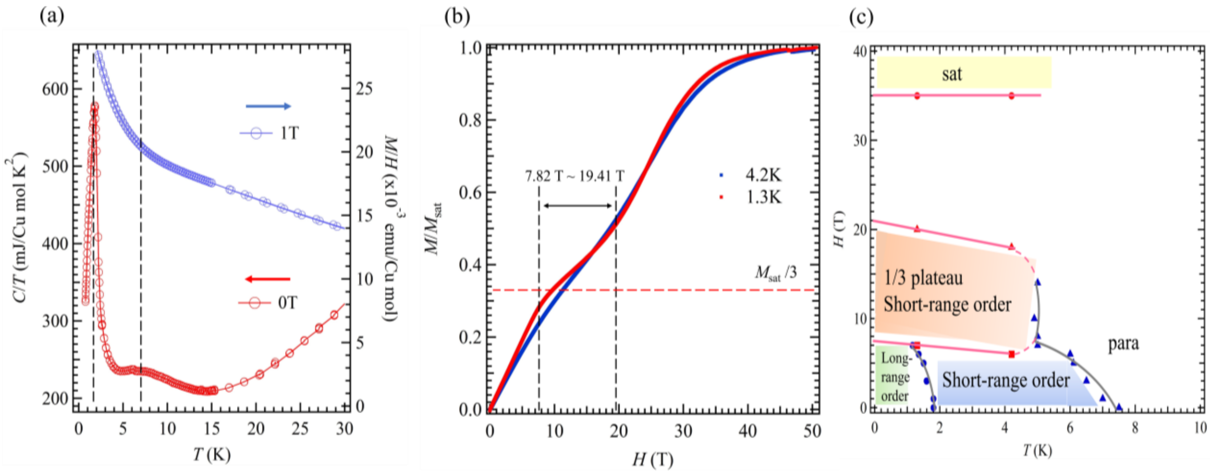


Fig 2. (a) The temperature dependence of magnetic susceptibility (blue) and heat capacity (red). The broken lines show the long-range and short-range order temperatures, respectively. (b) High-field magnetization at 1.3 K (red) and 4.2 K (blue). Red broken line shows 1/3 of saturation magnetization value. (c) Phase diagram of $InCu_3(OH)_6Cl_3$.

### 4. Conclusions

We discovered the clear 1/3 magnetization plateau in newly found quantum kagome antiferromagnet $InCu_3(OH)_6Cl_3$. Interestingly, the phase is characterized with a short-range spin correlation, so it is expected that the large fluctuations originated from kagome network remains even in the plateau state. Understanding of the essential magnetic properties of this compound provides experimental insights of magnon many-body state in magnetic field of quantum kagome antiferromagnet.

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