# Magnetization "steps" in a spin-1/2 kagome lattice of volborthite

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There has been a controversial issue on the ground state of the spin-1/2 kagome lattice antiferromagnet (KAFM). Theoretically predicted is a tiny gap of the order of a few percent of the nearest-neighbor antiferromagnetic interaction $J$ in the magnetic excitation spectrum [1]. Interestingly, the gap is expected to be filled up with many singlet states so that there is no gap in the thermal excitation. This means that a classically degenerate ground state spreads over a singlet continuum due to quantum fluctuations.

On the other hand, experimentalists have struggled for long time to find an ideal material to realize such a spin-1/2 kagome lattice in nature. In actual materials, some unfavorable effects such as a structural distortion, chemical disorder, interplane or higher-order intra-plane interactions always exist more or less and may disrupt or mask the intrinsic properties of the KAFM. Two minerals containing copper 2+ ions with $S$ = 1/2 are now studied extensively as candidates. One is volborthite $Cu_3V_2O_7(OH)_2{\bullet}2H_2O$ [2,3] and the other is herbertsmithite $ZnCu_3(OH)_6Cl_2$ [4]. The former possesses a slightly distorted kagome lattice made of Cu ions, while the latter comprises a structurally perfect kagome lattice. However, recent studies on the latter compound have found that an exchange between Cu and Zn ions takes place and may mask the intrinsic properties of the kagome plane. In fact, a large Curie tail towards $T$ = 0 was observed in the magnetic susceptibility of herbertsmithite, which was ascribed to nearly-free Cu spins at the Zn site. In this sense, herbertsmithite is a structurally perfect but compositionally imperfect kagome compound. In contrast, such a chemical exchange may not occur in volborthite, because Cu and V ions are in very different valence states of 2+ and 5+.

The magnetic susceptibility of volborthite shows a broad maximum at $T \sim 22$ K $\sim J$ / 4 that is indicative of certain short-range order, without any anomaly indicative of long-range order down to 2 K [2]. The ground state of volborthite seems not gapped, but close to a quantum critical regime in two dimension. Recently, we were successful in preparing a polycrystalline sample of much better quality, which diminished almost completely a Curie tail in magnetic susceptibility present in our previous samples, and carried out magnetization measurements down to 60 mK [5]. What has come up in the new sample is still a non-gapped ground state without long-range order but with unusual behavior in magnetization under magnetic fields, suggesting a novel spin liquid or long-range RVB state realized in volborthite.

References

[1] Ch. Waldtmann, *et al.*, Eur. Phys. J. B 2, 501 (1998).
[2] Z. Hiroi, *et al.*, J. Phys. Soc. Jpn. 70, 3377 (2001); A. Fukaya, *et al.*, Phys. Rev. Lett. 91, 207603 (2003).
[3] F. Bert, *et al.*, Phys. Rev. Lett. 95, 087203 (2005).
[4] M. P. Shores, *et al.*, J. Am. Chem. Soc. 127, 13462 (2005).
[5] H. Yoshida, *et al.*, in preparation.