High Magnetic Field Phase Diagram of $Tb_2Ti_2O_7$ along [111]

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Introduction

The possible ground states of the pyrochlore quantum magnet $Tb_2Ti_2O_7$ have been discussed for more than two years. The most important outstanding question is whether the ground state is a quantum spin ice with a "two-in two-out" configuration. One approach to determine the nature of the spin ordering of the ground state is to measure the magnetization or magnetic susceptibility along the [111] direction, where the pyrochlore lattice can be seen as alternating stacks of kagome and triangular layers. If the ground state is a quantum spin ice, a series of magnetic transitions will be observed from the quantum spin ice state, to a quantum kagome ice and then to a "three-in one-out" state as the applied magnetic field is increased

Experimental

We carried out low-field ac magnetic susceptibility measurements of single crystals of $Tb_2Ti_2O_7$ down to 18 mK using the dilution refrigerator of the NHMFL High B/T facility. The magnetization measurements up to 35 T and ac magnetic susceptibility measurements up to 18 T were performed in the Milikelvin Laboratory of the NHMFL DC Facility using a ^{3}He cryostat.

Results and Discussion

The phase diagram inferred from the low-field ac magnetic susceptibility measurements is shown in Fig. 1. Phase I is a quantum spin ice, Phase II a quantum kagome ice, Phase III a thermally disordered spin liquid and Phase IV a three-in one-out structure. Phase V and Phase VI were observed by high-field magnetization and magnetic susceptibility measurements. Phase VI may tend to be a full-polarization in high magnetic fields, while the mechanism responsible for Phase V is not fully understood.

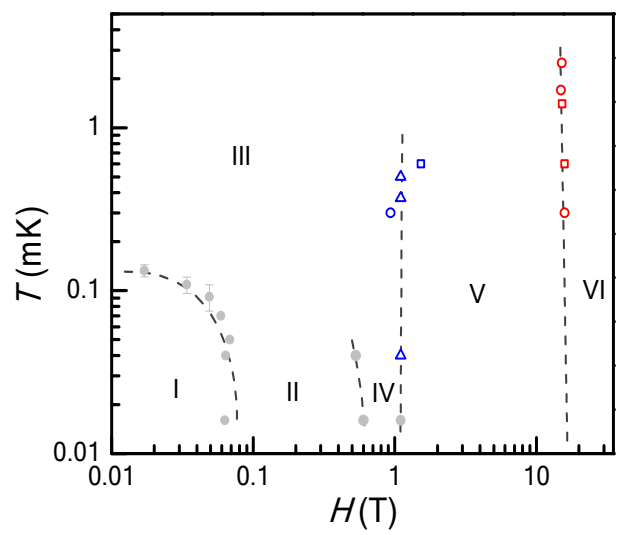

Fig. 1. Phase diagram for $Tb_2Ti_2O_7$

Conclusions

The magnetic field – temperature phase diagram for the [111] direction of $Tb_2Ti_2O_7$ has been completed up to 35 T. Direct evidence for the existence of a quantum spin ice has been found.

Acknowledgements

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References

[1] L. Yin *et al*., Phys. Rev. Lett., **110**, 137201 (2013).