Field Driven Quantum Criticality in the Spinel Magnet $ZnCr_2Se_4$

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Introduction

Quantum phase transition and quantum criticality are associated with qualitative but continuous changes in relevant physical properties of the underlying quantum many-body system at an absolute zero temperature. In the vicinity of quantum criticality, the low-energy and long-distance properties are controlled by the quantum fluctuation and the critical modes of the phase transition such that certain interesting and universal scaling laws could arise. It is well known that quantum criticality often occurs in the system with competing interactions where different interactions favor distinct phases or orders. Recently, we performed detailed low temperature measurements on a spinel compound $ZnCr_2Se_4$ [1], in which the Cr^{3+} ion hosts the localized electrons and gives rise to the spin-3/2 local moments that form a 3D pyrochlore lattice. Interestingly, our experimental results suggest a quantum critical point (QCP) between the spiral spin state and the polarized state and identify the previously unidentified regime as the quantum critical regime.

Experimental

AC susceptibility was measured in SCM2 at the DC field facility in Tallahassee.

Results and Discussion

The real part of ac susceptibility χ' in Fig. 1(a) clearly shows two peaks at H_{c1} and H_{c2}. Meanwhile, a small bump at H_{c1}, a sharp peak at H_{c2}, and a step-like anomaly near 9.5 T are clearly seen for the imaginary part χ'' measured at 7.5 K. This step-like anomaly is in accordance with the plateau observed from the sound velocity measurements around 10 T at 2 K, which has been correlated to the onset of a fully polarized magnetic phase at H_{c3}. Upon further cooling, H_{c3} moves to lower fields and is hardly discernible below 1.5 K from the ac susceptibility measurement, while H_{c2} shifts to higher fields (see the inset in Fig. 1(b)). By combining this ac susceptibility data with the dc magnetization, specific heat, and thermal conductivity results, we constructed a detailed magnetic phase diagram for $ZnCr_2Se_4$. A quantum critical point is deduced between the spiral spin state and the polarized phase. The solid (dashed) boundary refers to an actual phase transition (crossover). The pink region is marked as the quantum critical regime.

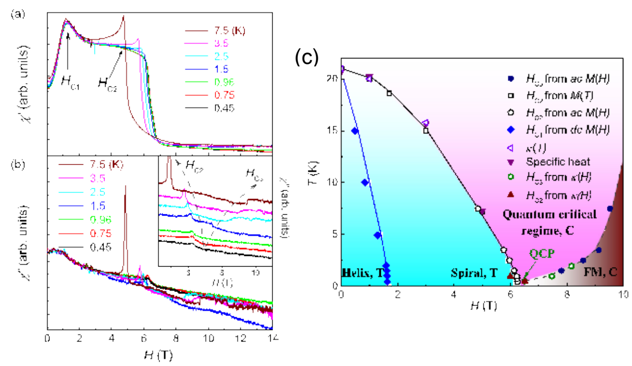

Fig. 1 The magnetic field dependence at several temperatures. (a) the real component; (b) the imaginary component. The inset in (b) shows the enlargement of the high- field data. The arrows indicate the evolution of high-field anomalies with increasing temperatures. (c) Magnetic phase diagram for $ZnCr_2Se_4$. "T" and "*c*" refer to the tetragonal and the cubic structure, respectively. "Helix," "Spiral," and "FM" stand for the helix spin state, spiral spin state, and spin-fully polarized state, respectively.

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References

[1] Gu, C. C., *et al*., Physical Review Letters **120**, 147204 (2018).