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Transverse-Field Quantum Phase Transitions in $CoNb_2O_6$

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The ferromagnetic Ising chain in a transverse magnetic field displays the perhaps best understood theoretical example of a quantum phase transition. It has been suggested that $CoNb_2O_6$ represents a manifestation of one-dimensional ferromagnetic Ising chains. An unresolved question concerns the consequences of the intrachain interactions vis a vis weak interchain coupling for the precise form of the magnetic order and the associated nature of the quantum phase transitions under transverse field. Namely, seminal high-resolution neutron and THz spectroscopy suggest transverse-field quantum criticality of a one-dimensional ferromagnetic Ising chain, where weak antiferromagnetic interchain coupling results in bound states with an emergent E8 symmetry [1,2]. More recently, THz spectroscopy pointed at two different ferromagnetic intrachain interactions with a weak antiferromagnetic interchain coupling, advertised as twisted Kitaev chains [3]. We report a high-resolution transverse-field susceptibility study of the magnetic phase diagram of single-crystal $CoNb_2O_6$. At zero magnetic field the onset of incommensurate antiferromagnetic order below T_{N1} = 3.04 K is followed by a transition to commensurate antiferromagnetic order below T_{N2} = 2.02 K. For a magnetic field accurately applied perpendicular to the easy magnetic ac-plane of the orthorhombic crystal structure, the commensurate and the incommensurate antiferromagnetic order are suppressed at B_{c1} = 4.7 T and B_{c2} = 5.7 T, respectively, where the emergent E8 bound states may be attributed to quantum criticality at B_{c1}. Tilting the magnetic field systematically away from the hard axis using a vector magnet [4] additional spin-flop transitions emerge, suggesting the existence of further quantum phase transitions. Our study provides thermodynamic evidence of the character of the quantum phase transitions in $CoNb_2O_6$ under transverse field and underscores the potential of this materials as a platform to explore the rich physics of ferromagnetic Ising chains with weak interchain interactions [5].

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