A Novel Strongly Spin-Orbit Coupled Quantum Dimer Magnet: $Yb_2Si_2O_7$

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Through the study of theoretical proposals for quantum spin liquids and high-temperature superconductivity several novel phases of matter have been discovered. One such state is the quantum dimer magnet, which exhibits a field-induced Bose-Einstein condensate (BEC) phase that occupies a symmetric dome in the field vs. temperature phase diagram. Many compounds based on 3d magnetic cations have been found that exhibit a quantum dimer state with a BEC phase. We have found a new realization in the distorted honeycomb-lattice material $Yb_2Si_2O_7$. The distorted honeycomb lattice gives rise to shorter Yb-Yb bonds, naturally allowing dimerization of the shorter bonds. Yb^{3+}'s high spin-orbit coupling combined with crystal field effects results in pseudo-spin ½ angular momentum that leads to anisotropic exchange interactions between quantum spins. Single crystals of $Yb_2Si_2O_7$ were grown via the optical floating zone technique at Colorado State University. Our single crystal inelastic neutron scattering, specific heat, and ultrasound velocity measurements show the expected field-induced transition to a BEC-like phase, which occur at significantly lower critical fields than previously studied compounds due to the 4f magnetism. However, the high-field part of the BEC dome is interrupted by an unusual regime that is characterized by a broad feature in the specific heat (compared to the BEC magnetic ordering transition). Evidence of a pseudo-Goldstone mode from the inelastic neutron scattering spectrum persists throughout the BEC dome. This is consistent with the spontaneous breaking of the continuous U(1) symmetry that is expected for a BEC. Our results on $Yb_2Si_2O_7$ raise the question of how anisotropic exchange in strongly spin-orbit coupled materials modifies the field induced phases of quantum dimer magnets.