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Magnetic field destroys long-range magnetic order in the Cu₂GaBO₅ ludwigite

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The quantum spin systems Cu₂MBO₅ (M = Al, Ga) with the ludwigite crystal structure consist of a structurally ordered Cu²⁺ sublattice in the form of three-leg ladders, interpenetrated by a structurally disordered sublattice with a statistically random site occupation by magnetic Cu²⁺ and nonmagnetic Ga³⁺ or Al³⁺ ions. A microscopic analysis based on density-functional-theory calculations for Cu₂GaBO₅ reveals a frustrated quasi-two-dimensional spin model featuring five inequivalent antiferromagnetic exchanges. A broad low-temperature ¹¹B nuclear magnetic resonance points to a considerable spin disorder in the system. In zero magnetic field, antiferromagnetic order sets in below T_N ≈ 4.1 K and ~2.4 K for the Ga and Al compounds, respectively. From neutron diffraction, we find that the magnetic propagation vector in Cu₂GaBO₅ is commensurate and lies on the Brillouin-zone boundary in the (H0L) plane, q_m = (0.45, 0, −0.7), corresponding to a complex noncollinear long-range ordered structure with a large magnetic unit cell. Muon spin relaxation is monotonic, consisting of a fast static component typical for complex noncollinear spin systems and a slow dynamic component originating from the relaxation on low-energy spin fluctuations. Gapless spin dynamics in the form of a diffuse quasielastic peak is also evidenced by inelastic neutron scattering. Most remarkably, application of a magnetic field above 1 T destroys the static long-range order, which is manifested in the gradual broadening of the magnetic Bragg peaks. We argue that such a crossover from a magnetically long-range ordered state to a spin-glass regime may result from orphan spins on the structurally disordered magnetic sublattice, which are polarized in magnetic field and thus act as a tuning knob for field-controlled magnetic disorder.

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