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Quantum versus Classical Spin Fragmentation In Dipolar Kagome Ice Ho3Mg2Sb3O14[1]

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A promising route to realize entangled magnetic states combines geometrical frustration with quantum-tunneling effects. Spin-ice materials are canonical examples of frustration, and Ising spins in a transverse magnetic field are the simplest many-body model of quantum tunneling. Here, we show that the tripod kagome lattice material $Ho_3Mg_2Sb_3O_{14}$ unites an ice-like magnetic degeneracy with quantum-tunneling terms generated by an intrinsic splitting of the Ho^{3+} ground-state doublet, which is further coupled to a nuclear spin bath. Using neutron scattering and thermodynamic experiments, we observe a symmetry-breaking transition at $T^* \approx 0.32$ K to a remarkable quantum state with three peculiarities: a dramatic recovery of magnetic entropy associated with the strongly coupled electronic and nuclear degrees of freedom; a fragmentation of the spin into periodic and ice-like components strongly affected by quantum fluctuations; and persistent inelastic magnetic excitation spectrum down to $T \approx 0.12$ K. These observations deviate from expectations of classical spin fragmentation physics on a kagome lattice, which can be alternatively understood in a framework of dipolar kagome ice under a homogeneous transverse field. Using various theoretical approaches, including random phase approximation, mean-field approximation, and exact diagonalization, our calculations establish the existence of a highly entangled fragmented state in a region where the transverse field remains a perturbation to the dipole-dipole interactions, which we coin as a quantum spin fragmented state. However, hyperfine interactions play a crucial role in suppressing quantum correlations and dramatically alter the single-ion and collective properties of $Ho_3Mg_2Sb_3O_{14}$. Our results thus highlight the crucial role played by hyperfine interactions in frustrated quantum magnets and motivate further theoretical investigations of the interplay between spin fragmentation and coherent quantum tunneling. [Reference: Z.L. Dun, X. Bai, J.A.M. Paddison, et al., arXiv:1806.04081]

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