

Experimental report

02/11/2023

Proposal: 4-05-851

Council: 10/2022

Title: Determine the QSL ground state of a dipole-octupole pyrochlore Ce₂Zr₂O₇

Research area: Physics

This proposal is a new proposal

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Samples: Ce₂Zr₂O₇

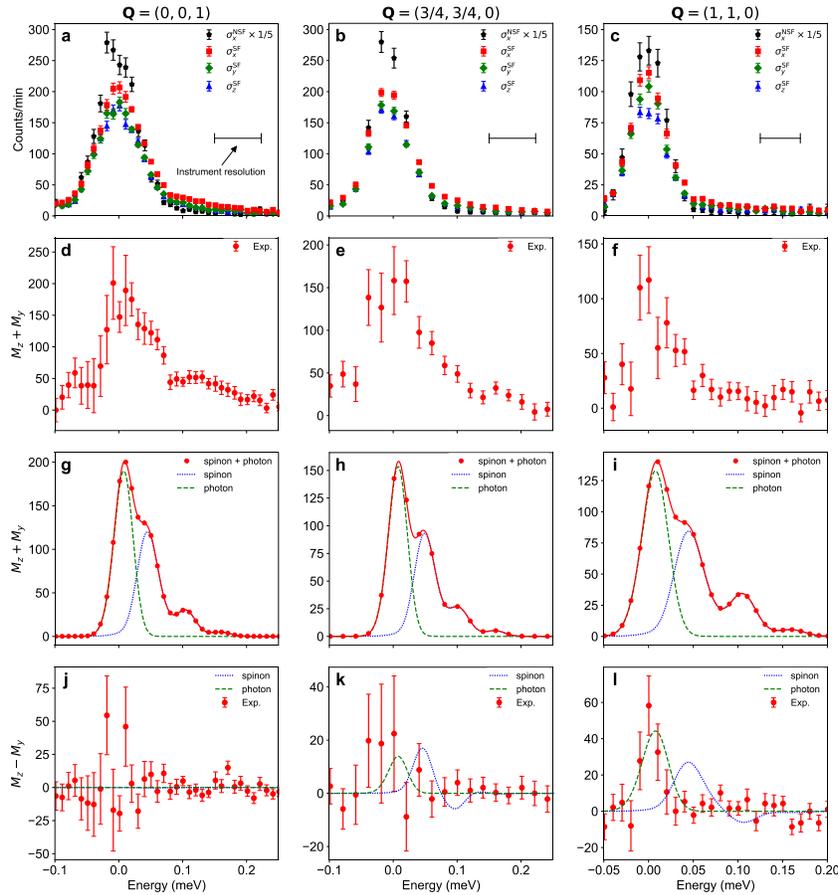
Instrument	Requested days	Allocated days	From	To
ORIENTEXPRESS	1	1		
THALES	4	4	14/04/2023	18/04/2023

Abstract:

In the case of the Ce-based pyrochlores with the dipole-octupole doublet, the ground state can support two distinct symmetry-enriched U(1) quantum spin liquid (QSL): a dipolar QSL and an octupolar QSL, distinguished by the roles of the dipole and octupole components in each phase. Ce₂Zr₂O₇ is a rare example of a quantum spin liquid candidate that may have an octupole doublet ground state similar to Ce₂Sn₂O₇. Recent studies claim that Ce₂Zr₂O₇ sits right on the boundary of dipolar QSL and octupolar QSL. A neutron polarization analysis on the spin excitation continuum will conclusively determine if these excitations are associated with electron fractionalization. For any local moment magnetism, spin waves and spin glass excitations should only have a transverse component, while fractionalization of octupolar interaction should instead have a longitudinal component, thus nailing down the origin of the QSL state.

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The polarized neutron experiment was performed on a piece of single crystal $\text{Ce}_2\text{Zr}_2\text{O}_7$ (~ 2 grams) in the $[h, h, l]$ scattering plane using an incident energy of 3.2 meV and 2.5 meV at dilution refrigerator temperature. By measuring one non-spin-flip channel and three spin-flip channel (SF_x , SF_y , and SF_z), we extracted the pure magnetic signals without performing the subtraction of the so-called high-temperature background, which was used in all previous inelastic neutron scattering experiment on Ce-based pyrochlore QSL candidates.



As shown in the figure, the true magnetic signal is only ~10 % of the non-spin-flip channel, which changes at 10 K could easily overwhelm the magnetic signals. By performing simple math, we can extract the pure magnetic signal $M_y + M_z$. Surprisingly, It has a much larger value at the elastic line at all three points we scanned, which has never been observed before. We identified the signal at the elastic line as the long-sought artificial “photon” in the lattice analog of QED. By collaborating with theorist, we fitted the parameters, and concluded that $\text{Ce}_2\text{Zr}_2\text{O}_7$ has dominant couplings between the x-components of the underlying pseudospins and a small interaction between x- and z-components that makes the emergent photon visible to neutrons. This lends further overwhelming support to the identification of $\text{Ce}_2\text{Zr}_2\text{O}_7$ as a long-sought-after experimental realization of QSL.