Magnetic oscillations due to spinons in a quantum spin liquid hosted by a Kagome lattice

G. Zheng[1], Y. Zhu[1], K. Chen[1], B. Kang[2], D. Zhang[1], K. Jenkins[1], A. Chan[1], Z. Zeng[3,4], A. Xu[3,4], O. Valenzuela[5], J. Blawat[5], J. Singleton[5], S. Li[3,4,6], P. Lee[2] & Lu Li[1]

[1]Department of Physics, University of Michigan, Ann Arbor; [2]Department of Physics, MIT, Cambridge, MA 02139; [3]Beijing National Laboratory for Condensed Matter Physics, Beijing 100190, China; [4]Physical Sciences, University of CAS, Beijing 100190, China; [5]National High Magnetic Field Laboratory, Los Alamos, NM 87545; [6]Songshan Lake Materials Laboratory, Guangdong 523808, China

Funding Grants: USA: NSF DMR-2128556; DOE BES; Gordon & Betty Moore Fdn; China: 2022YFA1403400, 2021YFA1400401, GJTD-2020-01, XDB33000000.

Magnetization measurements strongly suggest that the Kagome lattice Mott insulator $YCu_3(OH)_6Br_2[Br_{1-y}(OH)_y]$ (YCOB) is a quantum spin liquid. In such a system, antiferromagnetic order is suppressed by geometrical frustration and quantum fluctuations. Under these conditions, spin–charge separation of electrons can produce charge-neutral spinons, fermions that possess spin but no charge. Using ultrasensitive torque magnetometry, de Haas-van Alphen oscillations are observed, giving strong evidence for both the spinons and an effective gauge field which allows the coupling of the applied magnetic field to these charge-neutral particles. A theoretical model of spinon band structure that includes Dirac nodes near the 1/9 magnetization plateau produces quantitative predictions consistent with the observed oscillations.

The Figure shows several aspects of the experiments. The observation of a 1/9 plateau in the magnetization of YCOB at around 20 T (a), is a strong indication that the material is a quantum spin liquid; the data were recorded in the 75 T Duplex magnet. At fields above the 1/9 plateau, de Haas-van Alphen oscillations are seen in the second derivative of the magnetic torque with respect to field [(b), dotted lines]; their presence in several samples of YCOB and in data from both the 60 T Midpulse magnet, and the 41.5 T quasistatic magnet (b), show they are an intrinsic property of YCOB. The oscillations show a complicated dependence on the orientation of the YCOB crystals (c) caused by the gauge field; angles shown are between the crystal *c* axis and the field. The temperature dependence of the oscillations (d) is consistent with the spinons being fermions; it agrees with the Lifshitz-Kosevich formula, originally derived for electrons in metals. The inset to (d) shows the bespoke torque magnetometer (designed in a collaboration between the MagLab and industry) employed for measurements in both pulsed and quasistatic fields.

Zheng, G.; Zhu, Y.; Chen, K.; Kang, B.; Zhang, D.; Jenkins, K.; Chan, A.; Zeng, Z.; Xu, A.; Ayala Valenzuela, O.E.; Blawat, J.; Singleton, J.; Li, S.; Lee, P.A.; Li, L., *Unconventional magnetic oscillations in a kagome Mott insulator,* **Proc. National Academy of Sciences (PNAS)**, **122** (5), e2421390122 (2025) **doi.org/10.1073/pnas.2421390122**

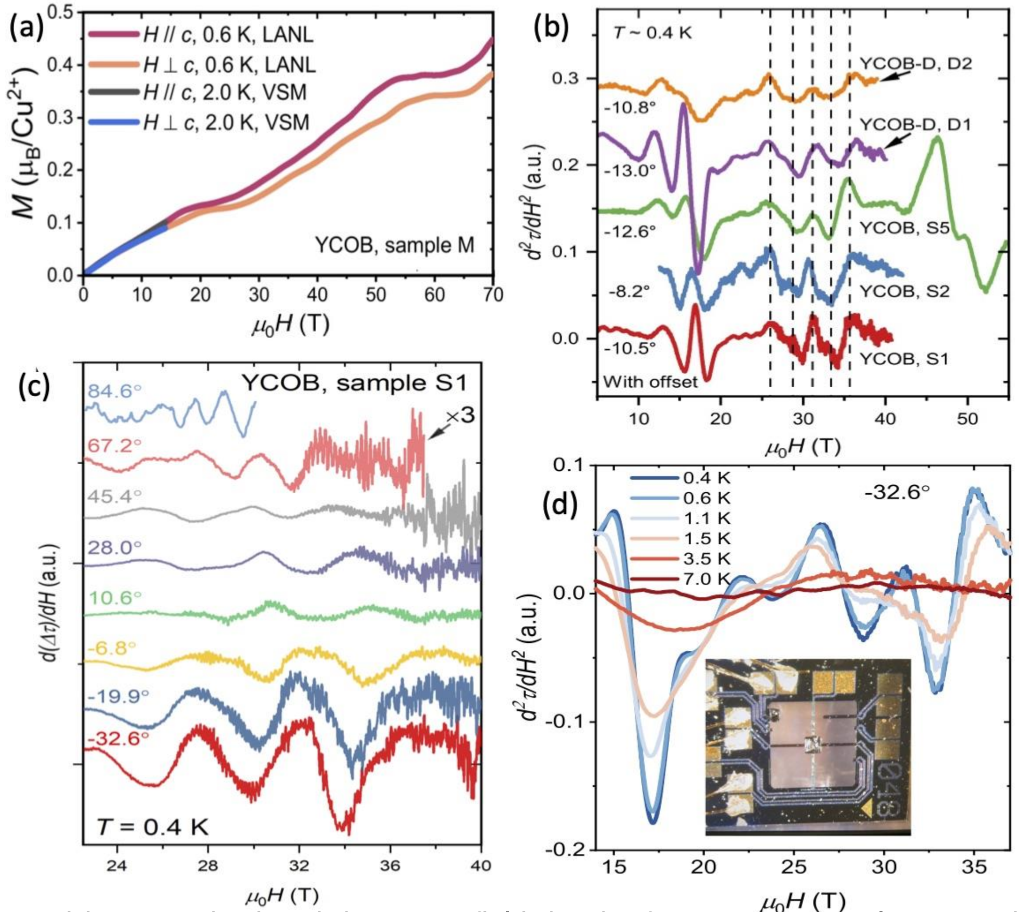

Figure. (a) Magnetization (*M*) versus field ($\mu_0 H$) of a YCOB crystal at two different orientations. (b) $d^2\tau/dH^2$, where τ = torque, for several YCOB samples. (c) Torque oscillations for different angles between *H* and the crystal *c* axis. (d) Oscillations in $d^2\tau/dH^2$ versus field for several different temperatures. Inset: torque magnetometer chip.