

Magnetic quantum oscillations due to a spinon Fermi surface in a wide band-gap Kagome-Mott insulator

John Singleton¹

¹*National High Magnetic Field Laboratory Pulsed-Field Facility,
Los Alamos National Laboratory, Los Alamos NM 87545, USA*

From an early age, we are taught that metals are good conductors of electricity and heat but that insulators are not. At High School we learn that metals contain vast numbers of charged electrons that are free to move and carry heat and current, whereas insulators do not. At University, we find out that electrons are fermions, and perhaps comprehend Fermi-Dirac statistics, leading to the well-known definition that *a metal is a solid with a Fermi surface*. The Fermi surface is the constant-energy surface which at zero temperature separates the occupied electron states from the empty in momentum space; if we know the size and shape of a metal's Fermi surface, we understand how its free electrons behave and hence can account for almost all of its electrical, thermal and magnetic properties. Over the past decade, this comforting picture has been upset by experiments on various materials at high magnetic fields and low temperatures. Though these substances are electrical insulators, they exhibit the de Haas-van Alphen effect - an oscillatory phenomenon in magnetic field that is smoking-gun evidence for a Fermi surface; i.e., it is usually seen only in metals.

After a brief review of the above phenomena, I shall concentrate on measurements of the Kagome-lattice Mott insulator $\text{YCu}_3(\text{OH})_6\text{Br}_2[\text{Br}_{1-y}(\text{OH})_y]$ (YCOB) in magnetic fields of up to 75 T [1]. Our pulsed-field magnetization experiments strongly suggest that 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. Further constraints are placed on the spinon Fermi surface using high-field susceptometry, capacitance and thermal experiments [2] on YCOB single crystals. A theoretical model of spinon band structure that include Dirac nodes near a $1/9$ magnetization plateau produces quantitative predictions consistent with the observed oscillations. Finally I shall review very recent measurements on other spin-liquid candidates [3] that point to the oscillations as possible universal behaviour in such systems.

References:

- [1] Guoxin Zheng *et al.*, PNAS **122** (5) e2421390122 (2025)
- [2] Guoxin Zheng *et al.*, Phys. Rev. X **15**, 021076 (2025)
- [3] Dipranjan Chatterjee *et al.*, Preprint (2026)

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