



Magnetic Torque Anomaly in the Quantum Limit of Weyl Semimetals

Philip J. W. Moll¹, Andrew C. Potter¹, Nityan L. Nair¹, B. J. Ramshaw^{2,3}, K. A. Modic^{2,3}, Scott Riggs^{2,3}, Bin Zeng^{2,3}, Nirmal J. Ghimire², Eric D. Bauer², Robert Kealhofer¹, Filip Ronning², James G. Analytis¹,



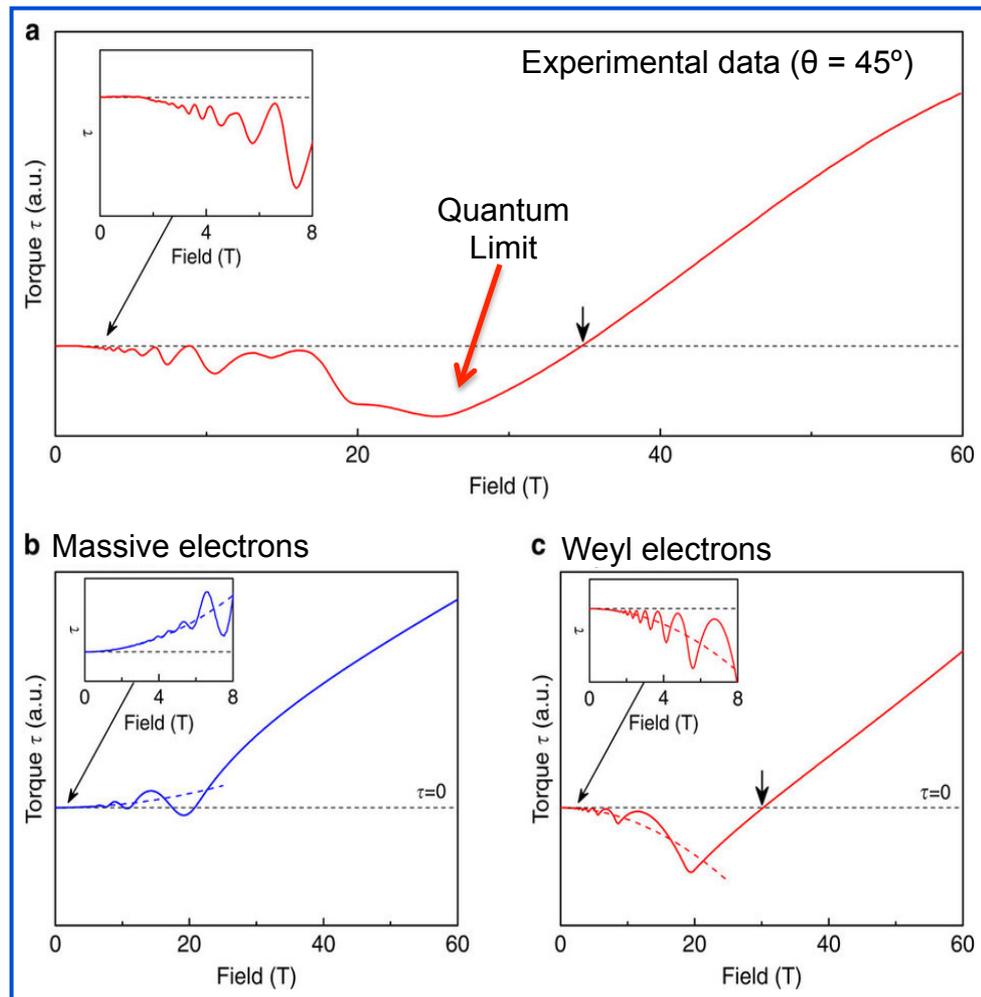
1. University of California at Berkeley, 2. Los Alamos National Laboratory, 3. MagLab

Funding Grants: Office of Naval Research (No. N00014-15-1-2674),

Gordon and Betty Moore Foundation's EPIQS Grant (GBMF4374), G.S. Boebinger (NSF DMR-1157490)

Electrons in Weyl and Dirac systems behave as massless quasi-particles because they exhibit linear energy-momentum dispersion relationships. This work focused on finding a clear experimental signature for what is very often a subtle behavior arising from topology. This research shows that the magnetic torque changes sign in a Weyl semimetal in the quantum limit, defined as the magnetic field value beyond which all electrons are in the lowest-energy Landau level. This sign change signals a reversal of the magnetic anisotropy that can be directly attributed to the topological nature of the Weyl electrons. These results establish that high-field magnetic torque measurements provide a direct experimental method to identify and distinguish Weyl and Dirac fermions both from each other and from conventional electron behavior.

Resistance and torque measurements of single crystal NbAs were performed in both pulsed and DC magnetic fields. Researchers found quantitative agreement among different samples using both capacitive and piezo-resistive cantilevers. Fig. (a) shows the torque of NbAs measured in high fields, highlighting the main experimental observation: at the quantum limit (~25T), the magnetic torque shows a well-defined kink and soon changes sign, exhibiting a sizable, almost linear, behavior up to the highest applied fields of 60 T. The lower figures show the predicted torque behavior for both (b) conventional massive electrons and (c) Weyl electrons.



Facilities: 65 T pulsed magnet, 45 T Hybrid DC magnet.

Citation: Moll, P.J.W.; Potter, A.C.; Nair, N.L.; Ramshaw, B.J.; Modic, K.A.; Riggs, S.; Zeng, B.; Ghimire, N.J.; Bauer, E.D.; Kealhofer, R.; Ronning, F. and Analytis, J.G. "Magnetic torque anomaly in the quantum limit of Weyl semimetals," *Nature Communications* **7**, 12492 (2016), doi:10.1038/ncomms12492