

A Tale of Two Uncoupled Superconducting Gaps

Md Shafayat Hossain^{1*}, Qi Zhang^{2*}, Eun Sang Choi^{3*}, Danilo Ratkovski^{3*}, Bernhard Lüscher^{4*}, Yongkai Li^{5*}, Yu-Xiao Jiang², Maksim Litskevich², Zi-Jia Cheng², Jia-Xin Yin², Tyler A. Cochran², Brian Casas³, Byunghoon Kim², Xian Yang², Jinjin Liu⁵, Yugui Yao⁵, Alimamy Bangura³, Zhiwei Wang⁵, Mark H. Fischer⁴, Titus Neupert⁴, Luis Balicas³, M. Zahid Hasan²

¹University of California, Los Angeles, USA ²Princeton University, Princeton, USA. ³National High Magnetic Field Laboratory, ⁴University of Zurich, ⁵Beijing Institute of Technology

Funding Grants: K. M. Amm (NSF DMR-2128556); M.Z.H. (Gordon and Betty Moore Foundation; GBMF9461 and DOE/BES DE-FG-02-05ER46200); L.B. (DOE-BES through award DE-SC0002613)



Since its discovery in 1911, superconductivity has revealed unexpected quantum phenomena, especially when pairing symmetry is difficult to predict in systems with multiple electronic degrees of freedom and competing orders, as in cuprates and iron-based superconductors. Kagome superconductors AV_3Sb_5 ($A = K, Rb, Cs$), with their unique band features—van Hove singularities near the Fermi level, flat bands, geometric frustration, and charge order that breaks both time-reversal and lattice symmetries—can serve as a fertile platform for unconventional superconductivity. Yet, no definitive evidence for unique superconducting states had been established.

In CsV_3Sb_5 , we discovered a very exotic superconducting quantum phenomenon that has not been reported for other material platforms – namely two decoupled superconducting gaps (states) leading to two distinct superconducting regimes as a function of the temperature that show distinct characteristics without any phase transition between them.

Thermodynamic, electrical, and thermal transport measurements reveal residual quasiparticle weight in the higher-temperature regime (0.8–3.5 K), indicating ungapped Fermi-surface regions or nodal pairing, which vanish as a second gap emerges below 0.8 K. At lower temperatures, in-plane upper critical fields are enhanced, and thermal conductivity shows reoriented anisotropy, consistent with an asymmetric or nodal low-temperature gap. Although two anomalies appear in the heat capacity, angular anisotropy measurements show preserved symmetry, ruling out a phase transition. Instead, our results demonstrate band-selective superconductivity with unusually weak inter-band coupling, unlike MgB_2 or iron pnictides.

This work establishes CsV_3Sb_5 as the first known superconductor with two decoupled superconducting gaps and no transition between them. The finding opens new directions for understanding pairing symmetry in kagome systems and multiband superconductivity more broadly.

Facilities and instrumentation used: SCM1 and SCM2

Citation: Hossain, MD.S.; Zhang, Q.; Choi, E.S.; Ratkovski, D.R.; Lüscher, B.; Li, Y.; Jiang, Y.X.; Litskevich, M.; Cheng, Z.J.; Yin, J.X.; Cochran, T.A.; Casas, B.W.; Kim, B.; Yang, X.; Liu, J.; Yao, Y.; Bangura, A.; Wang, Z.; Fischer, M.H.; Neupert, T.; Balicas, L.; Hasan, M.Z., *Unconventional gapping behaviour in a kagome superconductor*, *Nature Physics* (2025) doi.org/10.1038/s41567-024-02770-z

