“Lazarus” Superconductivity: Extreme Re-Entrant Superconductivity

S. Ran[1,2,3], I-L. Liu[1,2,3], Y.S. Eo[1], D.J. Campbell[1], P. Neves[1], W.T. Fuhrman[1], S.R. Saha[1,2], C. Eckberg[1], H. Kim[1], D. Graf[4], F. Balakirev[5], J. Singleton[5,6], J. Paglione[1,2], and N.P. Butch[1,2]

1 CNAM, Department of Physics, University of Maryland 2 NIST Center for Neutron Research 3 Department of Materials Science and Engineering, University of Maryland 4 NHMFL Florida State University 5 NHFML Los Alamos National Laboratory 6 Department of Physics, The Clarendon Laboratory, University of Oxford

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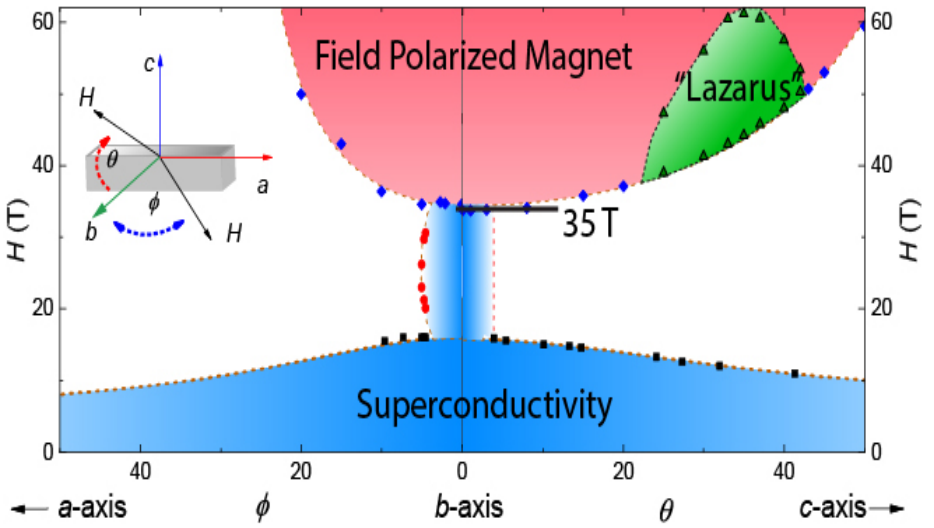
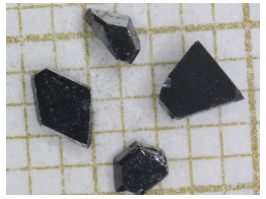
MagLab users recently discovered that UTe_2 is an exotic superconductor below 1.6K, with outstanding properties: 1) strong spin fluctuations that suggest proximity to magnetic order, 2) a large residual specific heat that suggests that half of the electrons are not gapped in the superconducting state, and 3) an anisotropic and very large upper critical field that exceeds available laboratory magnetic fields.

Higher field xperiments required the MagLab’s magnets to determine the largest value of the upper critical magnetic field: an amazing 35T (blue region in the figure), which is an incredibly upper critical field for a superconductor with a 1.6K critical temperature. Indeed, 35T is an order of magnitude greater than the paramagnetic limit of conventional superconductors above which all electron spins would be expected to be aligned. This find strongly indicates that spins of the paired electrons in UTe_2 are parallel in a spin triplet configuration, not antiparallel as in most superconductors.

Unexpectedly, a new superconducting phase was found to be stabilized at even higher fields, but only over a limited range of field direction. This reentrant “Lazarus” superconductivity between 40T and 65T challenges our understanding of how magnetic fields typically destabilize superconductivity. In addition, these spin-triplet superconducting states are strong candidates for unusual nodal p-wave pairing and may harbor sought-after topological Majorana zero-energy modes.



Magnetic field versus angle dependence of the superconducting phases in UTe_2. The “low-field” phase (blue) extends to 35T, but only over a narrow angular window with the magnetic field very nearly aligned along the b-axis. At even higher fields, reentrant “Lazarus” superconductivity was discovered (green), which is stable at such high magnetic fields that it challenges our theoretical understanding of superconductivity.



Single crystals of UTe_2 from the Butch group at University of Maryland. Credit: Sheng Ran

Facilities and instrumentation used: 35 T resistive magnet, 45 T hybrid magnet (DC) and 65 T pulsed magnets

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