MAR17-2016-020246

Abstract for an Invited Paper
for the MAR17 Meeting of
the American Physical Society

## Beyond Triplet: Unconventional Superconductivity in a Spin-3/2 Topological Semimetal

HYUNSOO KIM, Center for Nanophysics and Advanced Materials, Department of Physics, Univeristy of Maryland, College Park, MD 20742, USA

In all known fermionic superfluids, Cooper pairs are composed of spin-1/2 quasi-particles that pair to form either spin-singlet or spin-triplet bound states. The ”spin” of a Bloch electron, however, is fixed by the symmetries of the crystal and the atomic orbitals from which it is derived, and in some cases can behave as if it were a spin-3/2 particle. The superconducting state of such a system allows pairing beyond spin-triplet, with higher spin quasi-particles combining to form quintet or even septet pairs. Here, we report evidence of unconventional superconductivity emerging from a spin-3/2 quasiparticle electronic structure in the half-Heusler semimetal YPtBi, a low-carrier density noncentrosymmetric cubic material with a high symmetry that preserves the $p$-like $j = 3/2$ manifold in the Bi-based $\Gamma_8$ band in the presence of strong spin-orbit coupling. With a striking linear temperature dependence of the London penetration depth, the existence of line nodes in the superconducting order parameter $\Delta$ is directly explained by a mixed-parity Cooper pairing model with high total angular momentum, consistent with a high-spin fermionic superfluid state. We propose a $\mathbf{k} \cdot \mathbf{p}$ model of the $j = 3/2$ fermions to explain how a dominant $J$=3 septet pairing state is the simplest solution that naturally produces nodes in the mixed even-odd parity gap. Together with the underlying topologically non-trivial band structure, the unconventional pairing in this system represents a truly novel form of superfluidity that has strong potential for leading the development of a new generation of topological superconductors.