Contribution ID: **134** Contribution code: **P-MON-6** Type: **Poster**

Unconventional superconductivity in topological ruthenium silicides with Kramers and hourglass fermions

Monday, 29 August 2022 18:40 (20 minutes)

The convergence of two major research strands in modern condensed-matter physics: topological materials and unconventional superconductivity, constitutes a new field of study. Topological materials with Kramers or hourglass fermions represent a special subclass, recently realized in materials lacking inversion symmetry or with a nonsymmorphic space group. At the same time, there is a surge of interest in identifying time-reversal symmetry (TRS) breaking (a key feature of unconventional superconductivity) in this class of materials, as a new routine way to realize topological superconductivity.

By using the muon-spin rotation and relaxation technique, backed by detailed theoretical analyses, we show that TRuSi (*T* = Ti, Nb, Hf, and Ta) noncentrosymmetric materials represent a family of compounds encompassing all the above unique properties [1]. Their bulk normal states behave as three-dimensional Kramers nodal-line semimetals, characterized by a fairly large antisymmetric spin-orbit coupling and by glide-reflection-protected hourglass-like fermions. We also identify surface states near the Fermi level of TRuSi materials More interestingly, NbRuSi and TaRuSi undergo a superconducting transition, which spontaneously breaks TRS below T_c, while surprisingly showing a fully-gapped superconducting ground state. This superconducting ground state is consistent with a unitary (*s* + *ip*) pairing, i.e., with a mixture of spin-singlet and spin-triplet pairings. As such, the TRuSi family provides an ideal platform for investigating the rich interplay between the exotic properties of Kramers nodal-line/hourglass fermions and unconventional superconductivity.

[1] T. Shang, J. Z. Zhao, et al., and T. Shiroka, submitted to *Sci. Adv.* (2022).

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Session Classification: Posters

Track Classification: Strongly correlated electron systems