凝縮系物理学ゼミナール
Condensed Matter Seminar

Date: 13:30-15:00, Wednesday, 13 December 2023

Title: Field-induced superconductivity mediated by odd-parity multipole fluctuation

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Abstract:

The conventional superconductivity is typically fragile in the presence of the external magnetic field. In contrast, the counter-intuitive field-induced superconductivity have been observed in some materials. Understanding the origin of the field-induced superconductivity presents a significant challenge in the condensed matter physics.

In the Chevrel phase and the organic superconductors, field-induced superconductivity is observed, which is attributed to the Jaccarino-Peter effect [1]. Furthermore, in the uranium-based superconductors, the field-induced superconductivity originated from the ferromagnetic quantum critical fluctuations is established.

Recently, in the locally noncentrosymmetric heavy-fermion superconductor CeRh2As2, the field-induced phase transition within the superconducting state has garnered significant interest [2]. The locally noncentrosymmetric crystalline structure of this material encodes the sublattice degrees of freedom into the Cooper pair. The multiple superconducting phase diagram of CeRh2As2 is thought to result from a phase transition from a sublattice-symmetric state to a sublattice-antisymmetric state. Intriguingly, the crystalline structures of certain uranium-based superconductors also exhibit sublattice degrees of freedom. Additionally, the locally noncentrosymmetric cerium-based superconductor CeSb2 [3] and magic-angle twisted trilayer graphene [4] have been observed to exhibit field-induced superconductivity. In materials such as cerium- and uranium-based superconductors, as well as magic-angle twisted trilayer graphene, superconductivity might be driven by electronic correlation effects. Consequently, exploring the interplay between sublattice degrees of freedom, electronic correlation effects, and magnetic fields is a significant mission in the field of superconductivity research.

In this talk, we introduce a novel mechanism for field-induced superconductivity that is intrinsic to sublattice degrees of freedom. This mechanism is characterized by the lifting of degeneracy of multipole fluctuations, which in turn induces an unconventional channel for inter-sublattice Cooper pairing. Our findings demonstrate that a two-sublattice structure selectively promotes odd-parity multipole fluctuation. The application of a magnetic field disrupts time-reversal symmetry, leading to the emergence of unconventional Cooper pairing driven by these degeneracy-lifted multipole fluctuations. Our calculated phase diagrams reveal the presence of a field-induced odd-parity superconducting state across a broad range of spin-orbit coupling strengths.

References :
[1] V. Jaccarino and M. Peter, Phys. Rev. Lett. 9, 290 (1962).
[2] S. Khim et al., Science 373, 1012 (2021).
[3] O. P. Squire, et al., Phys. Rev. Lett. 131, 026001 (2023).
[4] Y. Cao et al., Nature 595, 526 (2021).