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Gapless superconductivity and its real-space topology in quasicrystals

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There are increasing interests in topological phenomena in quasicrystals (QCs), which possess long-range order without periodicity. Superconductivity has been discovered experimentally in QCs [1], and some theoretical works have shown that topological superconductivity can emerge in two-dimensional QCs such as Ammann-Beenker (AB) QCs [2]. However, there is no fundamental difference in the nature of topological superconductivity compared with that in periodic systems, and no new topological phenomenon unique to QCs has been found so far.

Some QCs including AB QCs exhibit a flat band of highly degenerate confined states at zero kinetic energy, due to local geometry of their quasicrystalline lattice. In this work, we show the stable occurrence of gapless superconductivity in AB QCs under magnetic field at or near half filling, where the chemical potential lies in or near the highly degenerate flat band. Gapless superconductivity originates in broken translational symmetry and confined states, and therefore it is unique to QCs. When Rashba spin-orbit coupling is present, this gapless superconducting phase can be topologically nontrivial, with edge states at near-zero energy among numerous bulk states. Even though this phase is gapless, its topological nature can be signified by a nonzero pseudospectrum invariant in real space given by a spectral localizer [3].

[1] K. Kamiya et al., Nat. Commun. 9, 154 (2018); Y. Tokumoto et al., Nat. Commun. 15, 1529 (2024); T. Terashima et al., npj Quantum Mater. 9, 56 (2024).
[2] M. Hori, T. Sugimoto, T. Tohyama, and K. Tanaka, Phys. Rev. B 110, 144512 (2024).
[3] K. Saito, M. Hori, R. Okugawa, K. Tanaka, and T. Tohyama, arXiv:2410.01236.

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Keyword-3

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Author: Mr SAITO, Kazuma (Tokyo University of Science)

Co-authors: Mr HORI, Masahiro (University of Saskatchewan); Dr OKUGAWA, Ryo (Tokyo University of Science); Prof. TANAKA, K. (University of Saskatchewan); Prof. TOHYAMA, Takami (Tokyo University of Science)

Presenter: Prof. TANAKA, K. (University of Saskatchewan)

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