Spin-fluctuation-mediated chiral d-wave superconductivity in α-$\mathcal{T}_3$ lattice

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Chiral superconductivity spontaneously breaks time-reversal symmetry and can host nontrivial topological properties, including edge states and Majorana quasiparticles. However, candidate materials remain limited, motivating the search for microscopic mechanisms that can stabilize chiral superconductivity in a broader class of systems. In hexagonal systems, two-dimensional irreducible representations allow two-component superconducting order parameters and provide a natural setting for chiral pairing. In particular, chiral superconductivity arising from electronic correlations has been extensively discussed in graphene [1], although superconductivity has not been observed in monolayer graphene, partly because of its low density of states and relatively weak electronic correlations.

Here, we focus on an incipient flat band near the Fermi level, which can enhance electronic correlations relevant to unconventional superconductivity. We study the α-$\mathcal{T}_3$ lattice [2], an extension of the dice lattice that hosts both Dirac points and a flat band. To investigate anisotropic superconductivity, we analyze an extended Hubbard model with off-site attractive interactions within the mean-field framework and find two distinct chiral $d + id'$-wave superconducting phases characterized by different Chern numbers [3]. We further investigate whether such pairing can emerge from purely repulsive electronic interactions. Using the fluctuation-exchange (FLEX) approximation [4] for the repulsive Hubbard model, we find a d-wave superconducting instability corresponding to one of the chiral $d + id'$ states obtained in the attractive model [3]. This suggests that the off-site attractive model can be regarded as an effective description of the pairing interaction generated in the repulsive Hubbard model. The pairing interaction is associated with antiferromagnetic spin fluctuations between the rim sites, which may be enhanced by the presence of the incipient flat band.

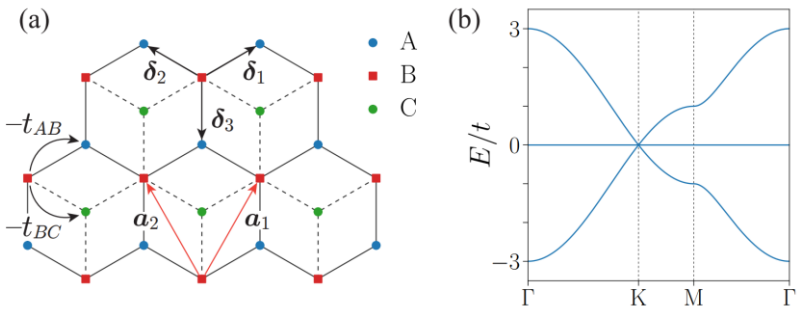


Figure 1: (a) Real-space structure of the α-$\mathcal{T}_3$ lattice. Hopping is allowed only between the hub (B) and rim (A and C) sites. (b) Tight-binding band structure of the α-$\mathcal{T}_3$ lattice.

[1] A. M. Black-Schaffer and C. Honerkamp, J. Phys.: Condes. Matter **26**, 423201 (2014).
[2] A. Raoux *et al.*, Phys. Rev. Lett. **112**, 026402 (2014).
[3] M. Kakoi and K. Kuroki, Phys. Rev. B **113**, 165104 (2026).
[4] N. E. Bickers, D. J. Scalapino, and S. R. White, Phys. Rev. Lett. **62**, 961 (1989).