Superconductivity in a Chern band: effects of time-reversal-symmetry breaking and topology

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Time-reversal-symmetry breaking is generally detrimental for superconductivity. However, recent experiments found superconductivity emerging in materials showing an anomalous Hall effect, indicative of time-reversal-symmetry breaking. We study the stability of superconducting orders and the mechanisms that suppress superconductivity in the prototypical anomalous Hall system, the Haldane model, where complex hopping parameters result in loop currents with a compensated flux pattern and topologically non-trivial bands. We find that neither singlet nor triplet states are generically suppressed, but the real-space structure plays a crucial role in the stability of the orders. Interestingly, the nearest-neighbor chiral states of $d \pm id$ or $p \pm ip$ symmetry couple linearly to the flux, leading to critical temperatures depending on the chirality. We further study the anomalous thermal Hall effect, κ_{xy} /T, which vanishes at zero temperature for trivial superconducting states, but reaches a finite value corresponding to the Chern number in a topological superconducting state. Our results illustrate that broken time-reversal symmetry through a finite flux is neither generically destructive for superconductivity, nor does it imply non-trivial topologically of the emerging superconductor. However, for multiple competing pairing channels the flux order favors a chiral superconducting state.