Screening current allows superconductivity in the quantum Hall edge

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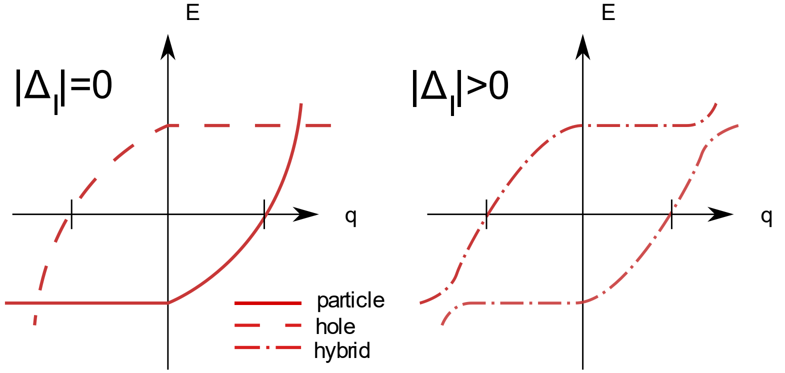
Abstract

In a strong magnetic field, electrons in a 2D material propagate along the edge of the material (quantum Hall effect). A nearby superconductor can induce superconductivity into this edge through a process called Andreev reflection, where electrons reflect off a surface as holes. We construct a many-body model of the process to clarify recent experimental results, and show that the superconductor must host both a screening current at the surface as well as spin-orbit coupling for Andreev reflection to occur.

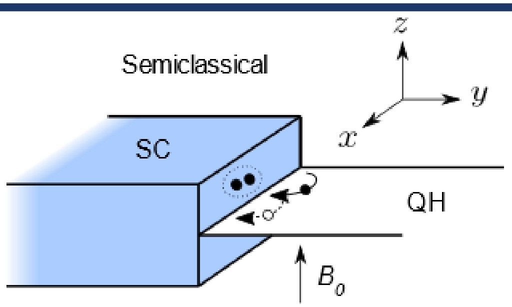
$$H_{SC} + H_t + H_{1D}$$

$$\rightarrow H_{\text{eff}} = \sum_q \left[E_{\text{eff},q}\, \hat{c}^\dagger_{\uparrow,q} \hat{c}_{\uparrow,q} + \Delta_{\text{I},q} \left(\hat{c}^\dagger_{\uparrow,k_s+q} \hat{c}^\dagger_{\uparrow,k_s-q} + H.c. \right) \right]$$

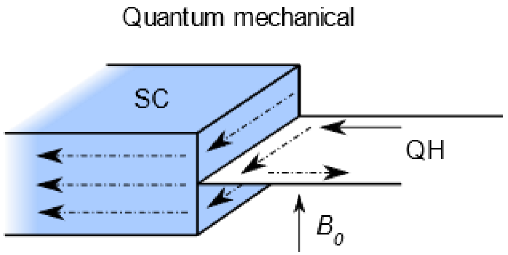
Effective superconductivity
Integrating out the superconductor leads to an explicit model of the particle/hole hybridization in the quantum Hall edge.



Project Description
We construct a many-body Hamiltonian of a chiral, spinless quantum Hall edge state with tunnelling coupling to a superconductor, and integrate out the superconductor fields.



The resulting effective model of the edge state is explicit and analytical, allowing quantitative and qualitative predictions for experiments. In particular, it clears up unresolved questions on momentum and spin conservation.



Key Results

- Microscopical effective model of the superconducting edge state
- Explicit momentum and spin conservation from well-understood mechanisms
- Many-body nature allows natural extension of fractional quantum Hall

Impact

- Clarification of past experiments, and critical predictions for the future
- Extension to fractional quantum Hall important for finding non-abelian anyons, exotic states able to encode and protect quantum information

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