Emergent topology by Landau level mixing in quantum Hall-superconductor nanostructures

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A two-dimensional electron gas (2DEG) in the presence of a strong magnetic field exhibits the quantum Hall (QH) effect, which supports chiral 1D conducting states at the edges. Proximity to a superconductor (SC) leads to the formation of chiral Andreev edge states (CAES) [1-3]: hybridized electron-hole states with promising potential applications in quantum metrology and topologically protected quantum computing. Although the strong magnetic fields required for the QH effect are detrimental to superconductivity, recent experiments have achieved QH-SC hybrid junctions based on InAs 2DEGs [4], graphene [5], and magnetic topological insulators [6]. Although these experiments involve conventional SCs, where Cooper pairs are formed by electrons with opposite spins, experimental evidence for emerging CAES has been found even in the lowest QH edge states, where spins are polarized by ultra-strong Zeeman coupling.

In this study [7], we theoretically investigate the formation of CAES in hybrid junctions consisting of a superconducting stripe on top of a 2DEG. Hybridization of CAES from both sides of the SC finger [see Fig. 1 (a)] yields a complex phase diagram showing different topological phases [see Fig. 1b], which depend on system parameters such as the chemical potential and the width of the SC stripe. Among these phases, we found a realization of the long-sought *p*-wave superconducting state at even filling factors, enabling its detection at lower fields. We demonstrate that distinct gapped phases exhibit specific signatures in nonlocal electron transport and that topological phases are resilient to disorder (see Fig. 2) and edge imperfections.

References

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Figures

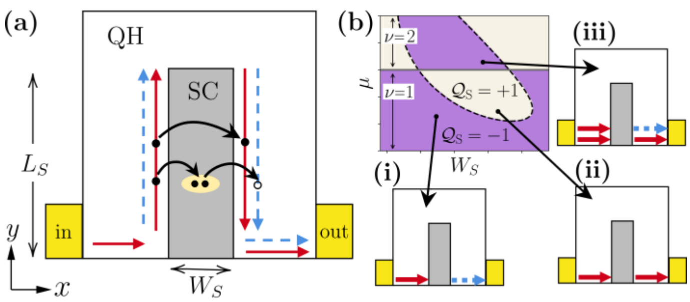

Figure 1: (a) Sketch of the SC finger on top of a 2DEG in the QH regime. Solid red (dashed blue) arrows represent electron (hole) edge states coupled by the SC (gray) that form the CAESs. (b) Schematic phase diagram for an infinite SC stripe for the two lower filling factors ν. Panels (i-iii) indicate the dominant transport processes in each region of the phase diagram for a finite SC finger.

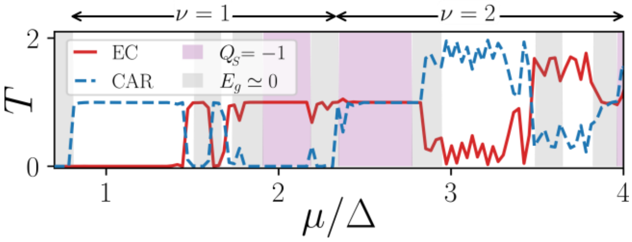

Figure 2: (b) Transmission probabilities for CAR and EC processes in a finite finger geometry including Anderson disorder. The purple (grey) areas correspond to the topologically non-trivial (gapless) regions of a stripe geometry with the same width and periodic boundary conditions.