Highlights

Electronic and thermal transport from the nanoscale to the macroscale – 2019

Z4 parafermions in weakly interacting superconducting constrictions at the helical edge of quantum spin Hall insulators

C. Fleckenstein[1], N. Traverso Ziani[2], B. Trauzettel[1]

[1]Institute for Theoretical Physics and Astrophysics, University of Wuerzburg, Wuerzburg, Germany
[2]CNR-SPIN c/o Università di Genova– Via Dodecaneso 33, Genova, Italy

PHYSICAL REVIEW LETTERS 112 (2019) 066801

The edges of two-dimensional topological insulators are promising candidates for applications in spintronics, superconducting spintronics, and topological quantum computation. The main reason behind their appeal is the combined presence of spin momentum locking and symmetry protection from backscattering. Spin momentum locking amounts to the fact that electrons with opposite spin propagate in opposite directions; the protection from backscattering implies that deviations from perfect conductivity can only take place via inelastic scattering, unless time-reversal symmetry is broken. At present, many two-dimensional topological insulators have been engineered, and the time for conceiving and realizing topological nanostructures has come. This step represents a major experimental and theoretical challenge. Indeed, most proposals rely on the possibility to induce magnetic gaps, or on the presence of strong electron-electron interactions. However, magnetic barriers appear challenging to be implemented and the screening in topological insulators is rather efficient. The available tools are hence weak interactions, induced superconductivity, and long constrictions (LC) between helical edge states. In our work, we show that these ingredients are indeed enough for the realization of parafermions. Such exotic particles are generalizations of Majorana fermions that may appear in interacting topological systems. They are known to be powerful building blocks of topological quantum computers. Existing proposals for the realization of parafermions in topological insulators typically rely on strong electronic correlations which, as mentioned, are hard to achieve. We identify a novel physical system in which parafermions generically develop. It is based on a LC, proximized by an s-wave superconductor. Our analysis suggests that parafermions are emerging bound states in this setup in the weakly interacting regime and in the absence of ferromagnetic barriers. Furthermore, we identify a situation in which Majorana fermions and parafermions can coexist.

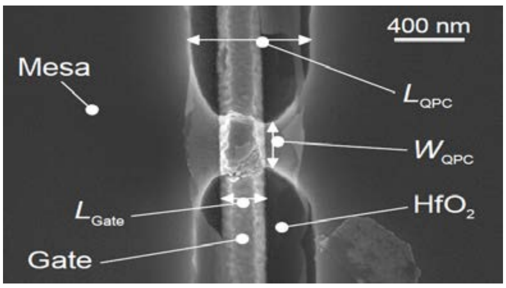

Fig. 1: First realization of a topological quantum point contact based on a Hg(Cd)Te quantum well. L strands for length of the LC, W for its width.
For details, see Nat. Phys. 16, 83 (2020).

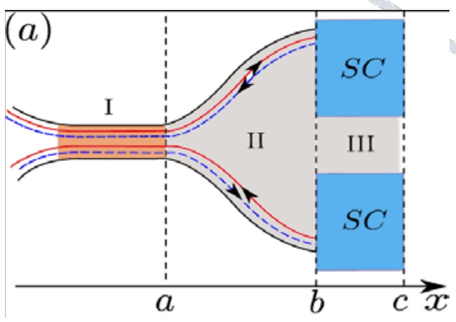

Fig. 2: The setup we propose for the parafermions. Here SC represents s-wave superconductors that proximize the topological insulator. The orange region is the topological quantum point contact, the parafermions are trapped in the region II.