Master 2 thesis project 2025

Braiding between a Bogolubov quasiparticle and a superconducting vortex

This theoretical internship is in the field of conventional superconductivity. The aim is to study the idea of Hansson et al. [Hansson2004] that the proper way to describe conventional superconductivity is in terms of topological order of the X.-G. Wen type (rather than in terms of spontaneous symmetry breaking of a gauge symmetry and the existence of a local order parameter). In this perspective, the excitations of a superconductor (the Cooper pair condensate, the Bogolubov quasiparticle and the superconducting vortex) are re-interpreted as being fractionalized topological quasiparticles known as "anyons" of the toric code [Kitaev2003]: the Cooper pair condensate is the trivial or vacuum anyon, the Bogolubov quasiparticle is the ε-anyon, the superconducting vortex is the m-anyon and the bound-state of a Bogolubov quasiparticle and a superconducting vortex is the e-anyon.
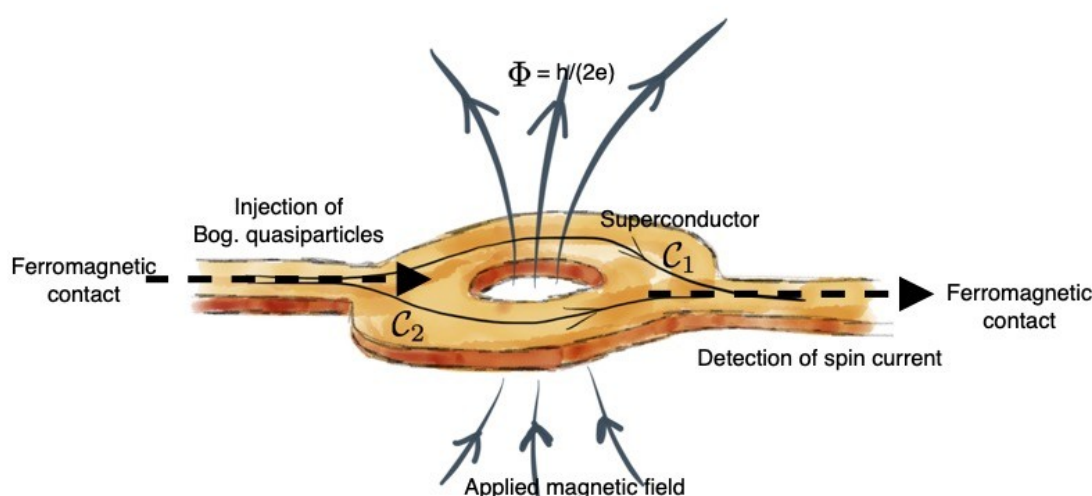

Figure 1: Aharonov-Bohm interferometer for Bogolubov quasiparticles around a superconducting vortex (adapted from D. Carpentier, Séminaire Poincaré 2014).

The concrete project is to study an Aharonov-Bohm (AB) interferometer for Bogolubov quasiparticles encircling a superconducting vortex (see figure). The relevant Bogolubov quasiparticles are those near the band edge (i.e. those at lowest energy) which are charge neutral (equal weight superposition of an electron and a hole) spin ½ fermions: this is the definition of a Majorana fermion. The Bogolubov quasiparticle current will either be described as a spin current or as a heat current. The prediction is that the interferences in the AB loop are destructive for an odd number of vortices and constructive for an even number. This is the same as saying that there is a mutual-statistical phase of π between an ε-anyon and an m-anyon. We will use the standard Bogolubov-de Gennes description of a superconductor to study analytically and numerically this interferometer. We will also need the Landauer-Büttiker formalism of mesoscopic transport.

References:
[Hansson04] T.H. Hansson, V. Oganesyan, S.L. Sondhi, arXiv.cond-mat/0404327 (Ann Phys 2004)
[Kitaev03] A. Kitaev, arXiv:quant-phys/9707021 (Ann Phys 2003)

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