**Interplay of Aharonov-Bohm interference and signatures of Majorana fermions**

*T.C. BartoloA, J.S. SmithA, C. MüllerB*, *T.M. StaceB*, *B. MuralidharanC*, *J. H. ColeA*

AChemical and Quantum Physics, School of Science, RMIT University, Melbourne, Australia

BARC Centre of Excellence for Engineered Quantum Systems (EQUS), School of Mathematics and Physics, University of Queensland, Brisbane, 4072, Australia

CDepartment of Electrical Engineering, IIT Bombay, Powai, Mumbai-400076, India

Majorana fermions (MFs) are a theoretical particle which, unlike conventional fermions, act as their own antiparticle. The non-abelian nature of these particles means than the physical action of braiding one MF around another imparts a non-trivial phase. Recently a condensed matter realisation of these particles was suggested by Kitaev whereby MFs would exist at the ends of superconducting nanowires1. Encoding information in such a system would be topologically protected from noise, as a global perturbation would be required to destroy the stored information. Systems with such a topological protection are therefore highly sought after for computing and information storage purposes2.

Figure 1. Semiconducting ring with two Kitaev chains embedded within (white). Each Kitaev chain hosts one Majorana fermion at each of its ends (blue spheres). A magnetic field (Φ) is applied perpendicularly to this ring and a current (I) is passed through the ring.

The primary signature of the existence of MFs in superconducting nanowires is a zero bias conductance (ZBC) feature in the transport response of the wires. There have thus far been several experiments which produce signatures of Majorana bound states (MBS)3,4. However there are several alternative explanations for such a feature which can cast doubt over the origin of the ZBC observed in experiment. Alternative explanations include effects such as Andreev bound states and weak antilocalisation which can manifest sub-energy gap states that can be mistaken for the ZBC characteristic to MFs. It is therefore important to devise a method of distinguishing systems which definitively contain MBS from other topologically trivial effects3. To this end we are exploring circuit geometries which are capable of hosting Majorana fermions at the superconducting/normal interfaces within the circuit. A computational model for these unique geometries allows us to study the interplay between MBS and the interference effects induced applied by magnetic fields.

We begin by computationally examining a ring comprised of two Kitaev chains with a normal conducting links between them (see Fig. 1), where the MFs form at the normal/superconducting interfaces. MFs from neighbouring Kitaev chains in the ring may interact and hybridize as a function of their separation. Consequently, we compute transport signatures as a function of ring dimensions to study how MFs in this geometry interact. Further, an applied magnetic field induces Aharonov-Bohm interference due to path differences around the ring5. This allows for an analysis of signatures of MFs as a function of the magnitude and direction of an applied magnetic field. This computational model can inform future experiments which probe the topological properties of Majorana fermions.

**References**

1. Kitaev, A. Y. Unpaired Majorana fermions in quantum wires. Physics-Uspekhi 44, 131–136 (2001).
2. Hasan, M. Z. & Kane, C. L. Colloquium : Topological insulators. Rev. Mod. Phys. 82, 3045–3067 (2010).
3. Mourik, V. *et al.* Signatures of Majorana fermions in hybrid superconductor-semiconductor nanowire devices. *Science* **336,** 1003–7 (2012).
4. Rokhinson, L. P., Liu, X. & Furdyna, J. K. The fractional a.c. Josephson effect in a semiconductor–superconductor nanowire as a signature of Majorana particles. Nat. Phys. 8, 795–799 (2012).
5. Aharonov, Y. & Bohm, D. Further Considerations on Electromagnetic Potentials in the Quantum Theory. Phys. Rev. 123, 1511–1524 (1961).