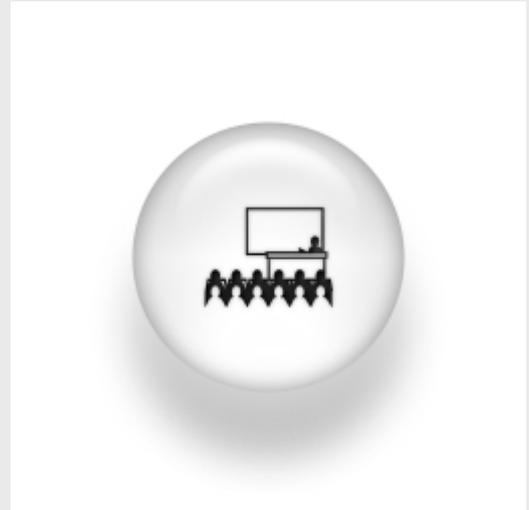


## Josephson current in finite-length nanowire SNS junctions with Majorana fermions

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*Ramón Aguado*

ICMM, CSIC

ABSTRACT:

The combination of strong spin-orbit effect with a Zeeman field may lead to the formation of helical electron liquids in single-channel semiconducting nanowires. When such an helical wire is contacted with an s-wave superconductor it is possible to induce a topological phase in which the system supports Majorana bound states (MBS) [1,2]. The Josephson current through junctions of these one-dimensional topological superconductors exhibits an anomalous  $4\pi$  periodic phase ( $\phi$ ) dependence owing to the presence of MBS. Such a 'fractional' Josephson effect, which originates from a parity-protected level crossing of zero-energy MBS at  $\phi = \pi$ , is ubiquitous in systems supporting MBS [3,4,5] and provides an important experimental signature towards detecting MBS in a solid-state setting. To date, most of the theoretical studies have been restricted to either simplified models, such as Kitaev's [2], or to infinite-length superconducting junctions (except [6]). In this talk, I will discuss the Josephson effect in more realistic SNS junctions of arbitrary transparency and when both the normal and the nanowire regions are of finite length, namely beyond the short-junction and infinite topological superconductor limits. In general, the spectrum of Andreev bound states can become rather intricate and dense as opposed to the infinite-length case. Moreover, the low-energy spectrum around  $\phi = \pi$  shows always anticrossings, originated from hybridization of four MBS, which may preclude the experimental observation of the fractional Josephson effect. At finite bias voltages, Landau-Zener dynamics involving the MBS and quasi-continuum Andreev levels gives rise to a nontrivial ac Josephson current. Interestingly, the ac current phase diagram as a function of the Josephson frequency/normal transmission shows regions of  $4\pi$  periodicity which are tunable through bias/gate voltages [7].

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