Majorana states in presence of electron interactions: spinful fractional Josephson junction with a quantum dot

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Typically a quantum dot in contact with the end Majorana bound state of a topological wire is effectively non-interacting due to large Zeeman splitting, caused by the external magnetic field required for topological state to emerge. However, if the dot is created inside a topological Josephson junction, the magnetic fields creating topological phases in the junction wires can be oriented anti-parallel and cancel inside the dot. It allows electron interactions to operate in the dot. We investigate such a junction for variable Zeeman splitting; from the maximal one (non-interacting dot) to the one when the both dot spin-sublevels are in the superconducting gap. In consistency with the recent experiments, we assume that the dot is made from the same materials as the wires, which allows the formation of the bound fermionic state of the dot out of two adjacent Majoranas. Possible pairing of the end Majoranas inside the wires is also taken into account. The density of states of the dot is probed by an additional tunnel electrode at the top of the junction. We show that electron interactions renormalize height of the Majorana peak and introduce characteristic asymmetry of the gate voltage dependence of the transverse zero-bias conductance through the dot.