

Contents

List of symbols	iii
Contents	iv
Abstract	viii
Resumen	ix
1. Motivation and outline	1
Resumen del Capítulo 1	3
2. Multiterminal Josephson junctions as topological matter	6
2.1. Introduction and motivation	6
2.2. From “Berry-ology” to topology	7
2.2.1. The Chern theorem	11
2.2.2. Two level systems	12
2.2.3. Weyl points as sources or sinks of Berry curvature	13
2.3. The rudiments of topological Bloch theory	14
2.4. Multiterminal superconducting devices as topological matter	16
2.4.1. Transconductance quantization: a topological signature	19
2.4.2. On the effect of the continuum states	21
2.5. State-of-the-art and outlook	26
Resumen del Capítulo 2	28
3. Floquet-Andreev states in three-terminal Josephson junctions: Engineering topology with a periodic drive	29
3.1. Introduction and motivation	29
3.2. Floquet formalism in a nutshell	30
3.3. Green’s function technique: from Wigner to Floquet representation	32
3.4. Case of study: a three-terminal Josephson junction with a quantum dot	35
3.4.1. Equilibrium properties: Andreev bound states	36
3.4.2. Dispersion relation of the ABS and Dirac singularities	39

3.4.3. Large-gap limit and mapping to a honeycomb lattice	41
3.5. Berry curvature tomography: a local protocol	43
3.6. Inducing topology by driving: Floquet-Andreev physics	47
3.6.1. Berry curvature of the Floquet-Andreev states and band inversion	49
3.6.2. Topological phase diagram	52
3.7. Conclusions	54
Resumen del Capítulo 3	55
4. A three-terminal Josephson junction with Majorana bound states	58
4.1. Introduction and motivation	58
4.2. A recipe for Majoranas	60
4.2.1. The Kitaev model	60
4.2.2. Nanowire with Rashba spin-orbit coupling and Zeeman interac-	
tion: a solid-state implementation	62
4.3. A three-terminal junction with a central flux	66
4.3.1. Phase averaged transconductance	69
4.3.2. Andreev bound states	70
4.3.3. Low energy model for the Kitaev regime	72
4.3.4. Topological Hamiltonian as a useful tool: contributions from the	
ABS and the continuum states.	73
4.4. Conclusions	76
4.5. Appendix A: Boundary Green's functions of the uncoupled leads by	
decimation.	77
Resumen del Capítulo 4	78
5. Superconducting correlations at the edge of a quantum Hall insulator	81
5.1. Introduction and motivation	81
5.2. Chiral Andreev edge states	82
5.2.1. A simple low-energy model	86
5.2.2. Transport signatures in a multiterminal setup	88
5.2.3. Conductance: numerical results	89
5.3. SC-QH-SC Josephson junctions	93
5.3.1. Andreev bound states	93
5.3.2. Supercurrent and Fraunhofer patterns	97
5.3.3. Band-bending and flux-periodicity of the critical current	101
Resumen del Capítulo 5	103
6. Nonequilibrium edge transport in quantum Hall based Josephson jun-	
ctions	106
6.1. Introduction	106

6.2. Model and methods	108
6.2.1. Hamiltonian approach	108
6.2.2. Normal transmission of the model	110
6.2.3. Calculation of the time averaged dc current	112
6.3. Current-voltage characteristics	113
6.4. Comparison with non-chiral transport	120
6.5. Summary and conclusions	123
6.6. Appendix A: Perfect matching condition	124
6.7. Appendix B: Green's functions in Floquet representation	125
Resumen del Capítulo 6	128
7. Majorana fermions on the quantum Hall edge	131
7.1. Introduction	131
7.2. Tight-binding model of the Josephson junction	132
7.2.1. Supercurrent and Fraunhofer patterns	134
7.2.2. Andreev bound states	137
7.3. Low-energy spinful model	138
7.3.1. Andreev bound states	141
7.3.2. Josephson supercurrent	144
7.3.3. Kitaev spinless limit	148
7.4. Two edge channel transport results	150
7.5. Conclusions and final remarks	152
7.6. Appendix A: Calculation of $\mathcal{G}(\alpha, \alpha, i\omega_m)$	153
7.7. Appendix B: Kitaev limit within a Green's function approach.	154
Resumen del Capítulo 7	156
8. Imaging chiral Andreev reflection in the presence of Rashba spin-orbit coupling	158
8.1. Introduction	158
8.2. The 2DEG with Rashba spin-orbit interaction	160
8.3. Transverse magnetic focusing simulations	162
8.4. Low transparency regime	167
8.5. Summary and conclusions	170
Resumen del Capítulo 8	171
9. Summary	174
Resumen del Capítulo 9	176
A. The Bogoliubov-de Gennes (BdG) formalism	180

Contents	vii
Bibliography	183
List of publications	196
Agradecimientos	202