The 11th Capri Spring School on Transport in Nanostructures 2015

	Sunday 12.04.2015	**Monday 13.04.2015**	**Tuesday 14.04.2015**	**Wednesday 15.04.2015**	**Thursday 16.04.2015**	**Friday 17.04.2015**	**Saturday 18.04.2015**
Chair		Grabert	Egger	Tagliacozzo	De Martino	Bercioux	
9:00-9:55		Leggett	Heiblum	Leggett	Leggett	Leggett	
10:00-10:55		Ando	Ando	Ando	Ando	Schnyder	
11:00-11:30		Coffee Break					
11:30-12:25		Heiblum	Fu	Fu	Fu	Fu	
13:00-14:30		Lunch break					
Chair		Bercioux	Sodano		Fu	Grabert	
16:00-16:55		Trauzettel	Trauzettel		Schnyder	Schnyder	
17:00-17:30		Coffee Break		Free Afternoon	Coffee Break		
17:30-18:25	Registration Hotel Senaria	Heiblum	Schmidt		Trauzettel	Short Seminars (III)	
18:30-19:15	19:00-19:30	Short Seminars (I)	Calvo		Short Seminars (II)	Closing	
20:00 Dinner	Le Arcate	Il Solitario	Le Arcate		Le Arcate	Le Arcate	

Conference excursion to Amalfi/Ravello (if weather permit)
Starts at 9 pm
Return 6 pm

Ando	Introduction to topological superconductivity and its experimental status
Fu	Physics of Majorana fermion zero modes
Heiblum	Edge states in the quantum Hall effect - their nature & use
Leggett	Topological quantum computation, Majorana fermions, and Cooper-paired fermion systems
Schnyder	Models, symmetries, and classification of topological superconductors
Trautzettel	Superconducting hybrid structures based on quantum spin Hall systems

List of Short Talks

Monday Session	Stephan Plugge	Majorana Entanglement Bridge
	Petra Hoegl	Magnetoanisotropic Andreev reflection in ferromagnet/superconductor junctions
	Sunghun Park	Probing Majorana braiding phase in Corbino—geometry Josephson junction
Tuesday Session End at 19:00	Thomas Schmidt	Non-Abelian parafermions in time-reversal invariant interacting helical systems
	Reyes Calvo	Challenges in 2D-topological insulator materials investigated by novel local probes
Thursday Session	Maia Garcia Vergniory	Electronic and spin structure of topological surface state in Sn-based ternary topological insulators
	Pavel Ioselevich	Josephson junctions between topological and conventional superconductors
	Yuval Baum	Gapless Topological phases
Friday Session	Arbel Haim	Signatures of Majorana Zero Modes in Spin-Resolved Current Correlations
	Olesia Dmytruk	Cavity quantum electrodynamics with mesoscopic topological superconductors
	Paul Baireuther	Andreev-Bragg reflection from an Amperian superconductor

Abstract short talks: Monday Session

From 18:30 to 19:15

Stephan Plugge (HHU Düsseldorf) — **Majorana Entanglement Bridge**

We study the concurrence of entanglement between two quantum dots in contact to Majorana bound states on a floating superconducting island. The distance between the Majorana states, the charging energy of the island, and the average island charge are shown to be decisive parameters for the efficiency of entanglement generation. Our predictions can be quantitatively explained in terms of teleportation and crossed Andreev reflection processes. We find that long-range entanglement with distance-independent concurrence is possible over wide parameter regions, where the proposed setup realizes a "Majorana entanglement bridge". We also study the time-dependent concurrence after a parameter quench, which reveals the timescale for generating entanglement in this system.

Sunghun Park (University of Braunschweig) — **Probing Majorana braiding phase in Corbino-geometry Josephson junction**

For probing the braiding phase of Majorana bound states (MBS), we propose an experimental setup consisting of a Corbino-geometry Josephson junction on the surface of a topological insulator, in which two MBS can be created and rotated. We find that if a metallic tip is weakly coupled to the junction, the braiding phase can be detected in the time-averaged differential conductance of the tip-Majorana coupling.

Petra Hoegl (University of Regensburg) — **Magnetoanisotropic Andreev reflection in ferromagnet/ superconductor junctions**

Andreev reflection spectroscopy of ferromagnet/superconductor (F/S) junctions is an important probe of spin polarization. We theoretically investigate spin-polarized transport in F/S junctions in the presence of Rashba and Dresselhaus interfacial spin-orbit fields and show that Andreev reflection can be controlled by changing the magnetization orientation. This suggests a similar control of the superconducting proximity effect and Majorana states. We predict a giant in- and out-of-plane magnetoanisotropy of the junction conductance. If the ferromagnet is highly spin polarized - in the half-metal limit - the magnetoanisotropic Andreev reflection depends universally on the spin-orbit fields only. Our results show that Andreev reflection spectroscopy can be used for sensitive probing of interfacial spin-orbit fields in F/S junction.

Abstract short talks: Tuesday Session

From 18:30 to 19:00

Thomas Schmidt (University of Luxemburg) — **Non-Abelian parafermions in time-reversal invariant interacting helical systems**

The interplay between bulk spin-orbit coupling and electron-electron interactions produces umklapp scattering in the helical edge states of a two-dimensional topological insulator. If the chemical potential is at the Dirac point, umklapp scattering can open a gap in the edge state spectrum even if the system is time-reversal invariant. We determine the zero-energy bound states at the interfaces between a section of a helical liquid which is gapped out by the superconducting proximity effect and a section gapped out by umklapp scattering. We show that these interfaces pin charges which are multiples of $e/2$, giving rise to a Josephson current with 8π periodicity. Moreover, the bound states, which are protected by time-reversal symmetry, are fourfold degenerate and can be described as Z_4 parafermions. We determine their braiding statistics and show how braiding can be implemented in topological insulator systems.

Reyes Calvo (NanoGune) — **Challenges in 2D-topological insulator materials investigated by novel local probes**

In the Quantum Spin Hall textbook picture, a 2D topologically non-trivial insulator (2DTI) is expected to present conductive edge states protected against backscattering. The application of a magnetic field should lift this protection, and above a critical field the material would enter a trivial insulator regime, where the edge conduction fully disappears. In real 2DTI materials, such as inverted HgTe quantum wells, however, the picture seems to be more complex and scattering happens over long enough distances (around microns). Furthermore, although the resistance of the devices increases in the presence of a magnetic field, but some predictions, such as the removal of the edge conduction have not been yet directly probed. In our work, we use novel local probe techniques to shed some light into the above challenges. On the one hand, Scanning Gate Microscopy results allow us to identify the microscopic origin of scattering in the quantum spin hall edge states. On the other hand, Microwave Impedance Microscopy results reveal that edge conduction persists unexpectedly at high magnetic fields. Finally, we propose the use of lateral hetero junctions to probe the nature of such unexpected states.

Abstract short talks: Thursday Session

From 18:30 to 19:15

Maia Garcia Vergniory (DIPC) — **Electronic and spin structure of topological surface state in Sn-based ternary topological insulators**

We report the bulk and surface electronic properties and spin polarization of a new rich family of Sn-based ternary complex topological insulators studied by means of first principles calculations. These compounds exist in different stoichiometries: $Sn_xA_yB_z$ (A:Sb and Bi) (B: Te and Se). The crystal structure of these compounds are characterized by alternating along hexagonal axis quintuple, septuple and nonuple layer van der Waals bonded building blocks. We reveal that the bulk band gap in these systems is about 200 meV and the spin polarization near the Dirac point is up to 85%, one of the highest predicted hitherto. At the same family, for some of these compounds which crystal structure has ionic-covalent bonded Bi_2Te_3 and crystalline topological insulator SnTe atomic layers within building block the complex SOIinduced bulk band inversion caused by competition of band inversions in Bi_2Te_3 and in SnTe layers occurs and results in inherently nonlinear dispersion of the topological surface state.

Pavel Ioselevich (Max Planck Institute for Solid State Research) — **Josephson junctions between topological and conventional superconductors**

We consider the stationary Josephson current between a topological and a conventional superconductor. The underlying time-reversal symmetry breaking allows for more complicated behaviour than in conventional junctions. In particular, the dependence on the superconducting gaps is asymmetric, and the supercurrent can be strongly suppressed in the tunneling limit, so that $I_c R_n << 1$ in a short junction.

Yuval Baum (Weizmann Institute of Science) — **Gapless Topological phases**

The existence of an excitation gap in the bulk spectrum is one of the most prominent fingerprints of topological phases of matter. We propose a family of two dimensional Hamiltonians that yield an unusual class of topological semi-metals and superconductors with a gapless bulk spectrum that coexists with well-localized chiral/helical edge modes.

Abstract short talks: Friday Session

From 18:30 to 19:15

Arbel Haim (Weizmann Institute of Science) — **Signatures of Majorana Zero Modes in Spin-Resolved Current Correlations**

We consider a normal lead coupled to a Majorana bound state. We show that the spin-resolved current correlations exhibit unique features which distinguish Majorana bound states from other low energy resonances. In particular, the spin-up and spin down currents from a Majorana bound state are anti-correlated at low bias voltages, and become uncorrelated at higher voltages. This behavior is independent of the exact form of coupling to the lead, and of the direction of the spin polarization. In contrast, an ordinary low-energy Andreev bound state gives rise to a positive correlation between the spin-up and spin-down currents, and this spin-resolved current-current correlation approaches a non-zero constant at high bias voltages. We discuss experimental setups in which this effect can be measured.

Olesia Dmytruk (University Paris Sud) — **Cavity quantum electrodynamics with mesoscopic topological superconductors**

We study Majorana fermions in topological superconductors coupled to a microwave cavity. These quasiparticles can emerge as zero-energy modes in p-wave superconductors. By probing the light exiting from the cavity, one can reveal the electronic susceptibility of the p-wave superconductor. The susceptibility allows us to determine the topological phase transition point, the emergence of the Majorana fermions, and the parity of the ground state of the topological superconductor. All these effects are due to the interplay between the Majoranas and the bulk states in the superconductor.

Paul Baireuther (Leiden University) — **Andreev-Bragg reflection from an Amperian superconductor**

Recently, Patrick A. Lee proposed a new mechanism behind the mysterious pseudo-gap phase in high temperature Cuprate superconductors. This unconventional “Amperian” pairing mechanism pairs electrons from the same region of the Fermi surface. Hence, the Cooper pairs have a finite crystal momentum. We propose an experimental signature of Amperian pairing using a ballistic Y-junction between two normal leads and the superconductor. Doing numerical studies using the KWANT package we found that the cross-conductance has the opposite sign for Amperian pairing than it has either in the normal state or for the usual BCS pairing.