The 14th Capri Spring School on Transport in Nanostructures 2018

	Sunday 15.04.2018	Monday 16.04.2018	Tuesday 17.04.2018	Wednesday 18.04.2018	Thursday 19.04.2018	Friday 20.04.2018	Saturday 21.04.2018
Chair		Grabert	Schönenberger	Tagliacozzo	Egger	Tagliacozzo	
9:00-9:55		Franke (1)	Franke (2)	Nazarov (3)	Fabrizio (1)	Fabrizio (2)	
10:00-10:55		Levy Yeyati (1)	Levy Yeyati (2)	Levy Yeyati (3)	Berg (1)	Jarillo-Herrero (3)	
11:00-11:30		Coffee Break					
11:30-12:25		Urbina (1)	Urbina (3)	Jarillo-Herrero (1)	Jarillo-Herrero (2)	Berg (3)	
13:00-16:00		Lunch Break					School excursion to Pompeii/ Sorrento (if weather permits) Start at 9 am, Capri Harbour Return by 6 pm
Chair		Egger	De Martino		De Martino	Grabert	
16:00-16:55		Nazarov (1)	Nazarov (2)		Berg (2)	Short Talks (3)	
17:00-17:30		Coffee Break			Coffee Break		
17:30-18:25	Registration Hotel Senaria 19:00-19:30	Urbina (2)	Marganska (25+5min)	Free Afternoon	Tafuri (1)	Concluding remarks & excursion information	
18:30-19:30		Short Talks (1)	Poster Session		Short Talks (2)		
20:00 Dinner	Le Arcate	Il Solitario	Le Arcate		Le Arcate	Le Arcate	

Erez Berg	Majorana zero modes and their generalizations
Michele Fabrizio	Cooling by laser pulses low energy degrees of freedom of alkali-doped fullerides superconductors
Katharina Franke	Scanning Tunneling Spectroscopy of Shiba and Majorana states
Pablo Jarillo-Herrero	Topology, Correlations and Superconductivity with 2D Materials
Alfredo Levy Yeyati	Hamiltonian approach to transport in conventional and topological superconducting nanojunctions
Yuli Nazarov	Novel topologies in multi-terminal superconducting junctions
Francesco Tafuri	Josephson coupling in unconventional and extreme conditions
Cristian Urbina	Probing and manipulating Andreev states

Contributed Talks

Monday Session (12+3)	Di Xu	Quantized Majorana conductance
	Alexander Schuray	The influence of the non-locality of Majorana bound states on the supercurrent
	Lucila Peralta Gavensky	Topological aspects of Floquet-Andreev states in three-terminal Josephson junctions with a quantum dot
	Dominik Maile	Quantum phase transition with dissipative frustration
Tuesday Session 25+5	Magdalena Marganska	Majorana quasiparticles in semiconducting carbon nanotubes
Thursday Session (12+3)	Julie Baumard	Non-uniform superconducting phases generated by spin-orbit interaction
	Matthew Brooks	Theory of Strain-Induced Confinement in Transition Metal Dichalcogenide Monolayers
	David Indolese	Edge current at the van Hove singularity in a graphene-hBN superlattice
	Stefan Ilic	Enhancement of the upper critical field in disordered transition metal dichalcogenide monolayers
Friday Session (12+3)	Pablo Orus	Vortex transport in superconducting W-C nanostructures
	Jette van den Broeke	Thermodynamic study of topological Kondo insulators
	Jaakko Mastomaki	Superconducting tunnel junctions and nanorefrigeration using InAs nanowires
	Xuzhe Ying	Topological Metals

Abstract short talks: Monday Session

From 18:30 to 19:30

Di Xu (TU Delft) — *Quantized Majorana conductance*

Majorana zero-modes hold great promise for topological quantum computing. A semiconductor nanowire coupled to a superconductor can be tuned into a topological superconductor with two Majorana zero-modes localized at the wire ends. Tunneling into a Majorana state will resolve a zero-bias-peak (ZBP) in the differential conductance. The Majorana ZBP-height is predicted to be quantized at the universal conductance value of $2e^2/h$ at zero temperature. Previous experiments, however, have shown ZBPs much smaller than $2e^2/h$. The primary reason is due to dissipation from the soft gap. Here, we demonstrate that we have solved the soft gap problem, which leads to the observation of a quantized zero-bias peak. The quantized tunnel-conductance plateau against tunnelling strength can uniquely identify a topological Majorana zero-mode as far as tunneling spectroscopy is concerned.

Alexander Schuray (TU Braunschweig) — *The influence of the non-locality of Majorana bound states on the supercurrent*

We consider the Josephson effect between an *s*-wave superconductor and a nanowire with Majorana bound states (MBS) at its ends. The wave functions for the MBS in a finite length wire are calculated as a function of the Rashba spin orbit coupling, proximity induced superconductivity and an applied Zeeman field to show that the spin-canting angles of the two MBS mainly govern the behavior of the critical current. A numerical calculation reveals that residual *s*-wave pairing in the higher energy excitations also contributes to the critical current.

Lucila Peralta Gavensky (Instituto Balseiro) — *Topological aspects of Floquet-Andreev states in three-terminal Josephson junctions with a quantum dot*

A proposal to induce topological properties in a three terminal Josephson junction with a quantum dot by breaking time-reversal symmetry with a microwave field is made. In this case, the Floquet-Andreev levels are the ones that determine the topological structure of the junction. Indeed, non-trivial Berry curvatures develop in the artificial Brillouin zone determined by the superconductors phases when driving the junction with a chiral perturbation. A relation between the Floquet Berry curvature in the non-resonant regime and the transconductance of the driven system is derived..

Dominik Maile (University of Konstanz) — *Quantum phase transition with dissipative frustration*

We study the quantum phase transition of the one dimensional phase model in the presence of dissipative frustration, provided by an interaction of the system with the environment through two non-commuting operators. Such a model can be realised in Josephson junction chains with shunt resistances and resistances between the chain and the ground. Using a self-consistent harmonic approximation, we determine the phase diagram at zero temperature which exhibits a quantum phase transition between a long-range ordered phase, corresponding to the superconducting state, and a disordered phase, corresponding to the insulating state with localised superconducting charge. Interestingly, we find that the critical line separating the two phases has a non monotonic behaviour as a function of the dissipative coupling strength. This result is a consequence of the frustration between (i) one dissipative coupling that quenches the quantum phase fluctuations favouring the ordered phase and (ii) one that quenches the quantum momentum (charge) fluctuations leading to a vanishing phase coherence. Moreover, within the self consistent harmonic approximation, we analyse the dissipation induced crossover between a first and second order phase transition, showing that quantum frustration increases the range in which the phase transition is second order. The non monotonic behaviour is reflected also in the purity of the system that quantifies the degree of correlation between the system and the environment, and in the logarithmic negativity as entanglement measure that encodes the internal quantum correlations in the chain.

Abstract short talks: Tuesday Session

From 17:30 to 18:00

Magdalena Marganska (University of Regensburg) — *Majorana quasiparticles in semiconducting carbon nanotubes*

The Majorana bound states in proximitized semiconducting carbon nanotubes arise by a similar mechanism as those in the semiconducting nanowires, but with several advantages: nanotubes can be synthesized nearly without defects; their small size and hollow structure allows microscopic modelling; their tiny diameter yields only one relevant transverse mode, fourfold degenerate. Our numerical simulations of a proximitized nanotube capture both the topological phase transition and the formation of Majorana states. Using an effective analytical four-band model we analyze the system's symmetries and calculate a topological phase diagram, predicting the parameter ranges which are the most promising for planned experiments.

Abstract short talks: Thursday Session

From 18:30 to 19:30

Julie Baumard (LOMA - University of Bordeaux) — *Non-uniform superconducting phases generated by spin-orbit interaction*

Non-uniform superconducting states raise great interest in the scientific community. One of the most famous is the FFLO state, predicted in the 1960's. It is characterized by a higher critical field than usual. The FFLO state appears at low critical temperature, which makes it difficult to observe experimentally. In this presentation, we will show that adding spin-orbit interaction allows the modulated phase to appear at high critical temperature. We have studied two systems combining superconductivity, spin-orbit interaction and a Zeeman field, in one dimension.

Matthew Brooks (University of Konstanz) — *Theory of Strain-Induced Confinement in Transition Metal Dichalcogenide Monolayers*

Recent experimental studies of out-of-plane straining geometries of transition metal dichalchogenide (TMD) monolayers have demonstrated sufficient band gap renormalisation for device application such as single photon emitters. Here, a simple continuum-mechanical plate-theory approach is used to estimate the topography of TMD monolayers layered atop nanopillar arrays. From such geometries, the induced conduction band potential and band gap renormalisation is given, demonstrating a curvature of the potential that is independent of the height of the deforming nanopillar. Additionally, with a semi-classical WKB approximation, the expected escape rate of electrons in the strain potential may be calculated as a function of the height of the deforming nanopillar. This approach is in accordance with experiment, supporting recent findings suggesting that increasing nanopillar height decreases the linewidth of the single photon emitters observed at the tip of the pillar, and predicting the shift in photon energy with nanopillar height for systems with consistent topography.

David Indolese (University of Basel) — *Edge current at the van Hove singularity in a graphene-hBN superlattice*

If a graphene layer is placed on top of hexagonal boron nitride such that their crystallographic axes are aligned, a Moiré superlattice forms. The resulting periodic potential modifies deeply the graphene band-structure, manifesting by the appearance of new Dirac points accompanied by van Hove singularities at low energy. We investigated the Josephson effect in such a superlattice, which contains information about its specific band structure. By measuring the interference pattern of the critical current as a function of the magnetic field, we show that edge current appear at the van Hove singularity, attributed to electron localization in the bulk.

Stefan Ilic (INAC/CEA Grenoble) — *Enhancement of the upper critical field in disordered transition metal dichalcogenide monolayers*

We calculate the effect of impurities on the superconducting phase diagram of transition metal dichalcogenide monolayers in the presence of an in-plane magnetic field. Due to strong intrinsic spin-orbit coupling, the upper critical field greatly surpasses the Pauli limit at low temperatures. We find that it is insensitive to intravalley scattering and, ultimately, limited by intervalley scattering.

Abstract short talks: Friday Session

From 16:00 to 16:55

Pablo Orus (Instituto de Ciencia de Materiales de Aragón) — *Vortex transport in superconducting W-C nanostructures*

Dissipation effects caused by vortex motion within a type II superconductor exhibit the potential to be exploited for quantized information transfer if the movement is carried in a controlled way. In this contribution, we report the observation of nonlocal voltage in superconducting W-C nanowires grown by focused ion beam induced deposition. Corresponding nonlocal resistances up to 8 Ω in value are detected, generated by vortices travelling along a 10 μm-long channel. Supported by the agreement with numerical simulations based on the Ginzburg-Landau theory, these results further strengthen the potential applicability of vortices as quantized information carriers in superconducting nanodevices.

Jette van den Broeke (University of Utrecht) — *Thermodynamic study of topological Kondo insulators*

One of the main candidates for a three-dimensional fully bulk-gapped topological insulator is the topological Kondo insulator SmB_6. Experiments reveal an upturn in its heat capacity at low temperatures, which has not yet been understood theoretically. It was conjectured that metallic edge states could be responsible for this puzzling behavior. Here, we verify this possibility both theoretically and experimentally. First, we provide a thermodynamic study of SmB_6. We start with a general thermodynamic description of topological Kondo insulators using a mean-field slave-boson approximation and Hill thermodynamics. In this approach, we study the phase transitions using the critical exponents of the model, and show that it is consistent with the Josephson hyper-scaling relation. Then, we turn to SmB_6 and separate the bulk from the boundary contributions to the heat capacity. We find that although the edges lead to an increase in the heat capacity upon lowering the temperature, the effect is unmeasurably small. Then, we investigate SmB_6 experimentally, and show that the heat capacity does not change as the total surface increases, which confirms that the surface states cannot be responsible for the upturn.

Jaakko Mastomaki (University of Jyvaskyla) — *Superconducting tunnel junctions and nanorefrigeration using InAs nanowires*

I demonstrate clean tunnel characteristics in $Al/Al_2O_3/AlMn$ - InAs nanowire - $AlMn/Al_2O_3/Al$ tunnel junctions with a current suppression by 4 orders of magnitude for a junction bias below the Al superconducting gap. The junctions can be used as sensitive thermometers and provide also electronic cooling of the semiconducting nanowire with a peak refrigeration of about 10 mK at bath temperatures 250 - 350 mK.

Xuzhe Ying (University of Minnesota-Twin Cities) — *Topological Metals*

I will discuss how to obtain a gapless phase from a topological gapped phase by breaking both time reversal and inversion symmetry. The specific model would be 2D p+ip chiral superconductor. 2D chiral superconductor belongs to symmetry class D with particle-hole symmetry and could support chiral Majorana. A supercurrent could break inversion symmetry and make system gapless. I'm going to discuss that particle-hole symmetry guarantees that there is a metallic phase which is distinct from trivial metal.

Poster session

Tuesday From 18:00 to 19:30

1. Benedikt Kratochwil (ETH Zürich) — *Coupling superconducting high impedance resonators to quantum dot qubits*
2. Diana Watfa (University Paris Sud) — *Super current and Josephson emission of a carbon nanotube based Josephson junction in the Kondo regime.*
3. Sandeep Upadhyay (University of Würzburg) — *Study of Induced superconductivity in strained HgTe Weyl semimetal*
4. Joeri de Bruijckere (TU Delft) — *Superconducting Transport through Individual Molecules*
5. Oladunjoye Awoga (Uppsala University) — *Probing unconventional superconductivity in proximized graphene by impurity scattering*
6. Jacob Fuchs (University of Regensburg) — *Hybrid structures of topological insulators and superconductors - a possible realization of Cooper pair splitting?*
7. Felix Keidel (University of Würzburg) — *Tunable hybridization of Majorana bound states at the quantum spin Hall edge*
8. Daniele Torsello (TU Torino) — *The ASIDI project: a microbeam facility for localized functionalization of materials and proof of concept quantum devices development*
9. Krzysztof Ptaszynski (Polish Academy of Sciences) — *Quantum coherence reducing power fluctuations of the steady-state nanoelectronic heat engine*
10. Johan Ekström (University of Luxembourg) — *Transport properties of Coulomb blockaded T-junctions hosting Majorana bound states*
11. Mariia Sidorova (Institute of Optical Sensor Systems - Berlin) — *Electron Energy Relaxation in Thin Superconducting NbN Films*
12. Michal Papaj (Massachusetts Institute of Technology) — *Multichannel charge Kondo effect in superconducting and Majorana islands*
13. Maria Victoria Ale Crivillero (Transport properties of FeSe-based heterostructures) — *Transport properties of FeSe-based heterostructures*
14. Gergö Fülöp (University of Basel) — *Probing topological superconductivity with noise measurements*
15. Abhay Kumar Nayak (Weizmann Institute) — *Spectroscopic visualization of epitaxially grown Aluminum on InAs Nanowire*
16. 17. Piotr Rożek (TU Delft) — Majorana-based architecture for simulating fermions