



# The 19<sup>th</sup> Capri Spring School on Transport in Nanostructures 2025

	Sunday 06.04.2025	Monday 07.04.2025	Tuesday 08.04.2025	Wednesday 09.04.2025	Thursday 10.04.2025	Friday 11.04.2025	Saturday 12.04.2025
Chair		Schönenberger	De Martino	Tagliacozzo	Schönenberger	Egger	School excursion to Pompeii/ Sorrento (if weather permits) Start at 8 am, Anacapri Return by 8 pm at Capri Harbor
9:00-9:55		Filipp (1) <i>Online</i>	Fu (1)	Fu (2)	Pothier (2)	Strunk (2)	
10:00-10:55		Akhmerov (1)	Glazman (1)	Pothier (1)	Demler (1)	Pothier (3)	
11:00-11:30	Coffee Break & Poster Session						
11:30-12:25		Guarcello	Mayer	Glazman (2)	Fu (3)	Glazman (3)	
13:00-16:00	Lunch Break						
Chair		Egger	Bercioux	Free Afternoon  <i>Posters need to be changed on this day</i>	Bercioux	De Martino	
16:00-16:55		Filipp (2) <i>Online</i>	Akhmerov (2)		Strunk (1)	Demler (3)	
17:00-17:30		Coffee Break & Poster Session			Coffee Break & Poster Session		
17:30-18:25	Registration Hotel Senaria	Participant talk (1)	Filipp (3) <i>Online</i>		Demler (2)	Participant talk (3)	
18:30-19:30		Poster Session (1)	Participant talk (2)	Poster Session (2)	Concluding remarks		
20:00 Dinner	Le Arcate	Le Arcate	Le Arcate	Free dinner	Le Arcate	Le Arcate	



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<b>Anton Akhmerov</b>	Lecture 1: Building effective models of superconducting devices Lecture 2: Andreev states and Fermi surface topology
<b>Eugene Demler</b>	Photons for many body physics: a platform and probe
<b>Stefan Filipp</b>	Superconducting Qubits for Quantum Computing — <i>Online</i>
<b>Liang Fu</b>	New forms of superconductivity
<b>Leonid Glazman</b>	Quasiparticles superconducting qubits
<b>Claudio Guarcello</b>	Josephson Junctions and Their Dynamics: from RCSJ to SQUIDs and Quantum Devices
<b>Julia Meyer</b>	Multiterminal Josephson junctions
<b>Hugues Pothier</b>	Andreev states in superconducting weak links
<b>Christoph Strunk</b>	Anomalous Josephson effects in ballistic Josephson junctions - how to rectify supercurrents using electron spin



# Poster sessions

<b>Monday</b>  <b>Poster Session (1)</b> (18:30 - 19:30)	Silvan Aepli — <i>The Josephson effect in long, clean SNS junctions</i>	Maryam Darvishi — <i>Josephson Effect at Arbitrary Disorder Strength in Systems with Generic Spin-Dependent Fields</i>
	Tobias Kuhn — <i>The Kitmon: A Kitaev-Transmon qubit</i>	José Luis del Olmo Naranjo — <i>Protected-Andreev-spin qubit</i>
	Mihály Bodócs — <i>Superconducting Dot Coupled Parallel Quantum Dots</i>	Daniele Di Miceli — <i>Proximity-Induced Superconductivity into Thin Film</i>
	Vincenzo Bruno — <i>Dynamical control in a one-dimensional system</i>	Evgenia Georgiadou — <i>Proximity effect in normal/superconductor heterostructures</i>
	Daan Buseyne — <i>Material Characterisation of Superconducting NbTiN</i>	Cajetan Heinz — <i>Fractional Josephson Effect in QSHIs</i>
	Verena Caspari — <i>Noise measurements of Josephson junctions with STM</i>	
<b>Thursday</b>  <b>Poster Session (2)</b> (18:30 - 19:30)	Abbas Hirkani — <i>Higher Josephson harmonics in sc circuits</i>	Sebastian ten Haaf — <i>Edge and bulk states in a three-site Kitaev chain</i>
	Serafim Babkin — <i>Superconducting Proximity Effect in 2D Hole Gasest</i>	Juan Daniel Torres Luna — <i>How to compare Majorana platforms?</i>
	Klaiv Mertiri — <i>Complex Tunneling Processes</i>	Ivan Tsitsilin — <i>Superconducting qubits at elevated frequencies</i>
	Antonella Restino — <i>Scanning SQUID imaging of superconducting circuits</i>	Aiken van Waveren — <i>A Matter of Recrystallisation: Superconducting Si:B</i>
	Luigi Ruggiero — <i>RF Hybrid Devices n Planar Ge Proximitized epi-Al</i>	Vera Montoto — <i>Moiré Mott insulating phases in twisted 1T-TaS<sub>2</sub></i>
	Oliver Solow — <i>Exceptional points in multiterminal SNS junction</i>	Dhananjay Joshi — <i>Towards Kitaev chains in InAs/Al 2DEGs</i>



# Short talks sessions

<b>Monday Session</b> (12+3)	Aman Anand	2D Dirac fermions in a mass superlattice
	Filippo Gaggioli	Vortex-antivortex lattice in rhombohedral graphene
	Sandesh Kalantre	Microwave cQED probes of frustrated magnets
	Jakob Lenschen	Measuring mm-wave resonances at mK-temperatures
<b>Tuesday Session</b> (12+3)	Yuriko Baba	Hidden topological states in QH-SC heterostructures
	Johanna Berger	Anomalous Josephson effect in a kinked junction
	John Chiles	Multiplet Supercurrents in a Josephson Circuit
	Samuele Fracassi	Diode effect in a perturbed topological JJ
<b>Friday Session</b> (12+3)	Kristoffer Leraand	Phonon-mediated spin-polarized SC in alternating magnets
	Leonardo Pierattelli	Delta-T noise in nanoscale hybrid devices
	Adrian Reich	BKT transitions in topological SMS junctions
	Aravindh Swaminathan Shankar	Superconducting wormhole in the Yukawa SYK mode
	Vladimir Zakharov	Luttinger liquid on a lattice
Dario Bercioux	Information regarding the excursion to Pompeii & Sorrento	



# Short talks abstracts: Monday Session

From 17:30 to 18:30

**Aman Anand** (City St George's, University of London) — *2D Dirac fermions in a mass superlattice*

We investigate the energy dispersion of two-dimensional Dirac fermions subject to a periodic mass modulation (mass superlattice) in the presence of a magnetic field. Using a magnetic Bloch state construction, we analyze the resulting band structure and compare it with that of a finite array of alternating mass barriers. Within this framework, we explore transport properties, including Hall conductivity and Weiss-like oscillations, shedding light on the interplay between magnetic quantization and periodic mass modulation.

**Filippo Gaggioli** (Massachusetts Institute of Technology) — *Vortex-antivortex lattice in rhombohedral graphene*

The discovery of superconductivity in tetralayer rhombohedral graphene has thrown a challenge to the conventional wisdom of condensed matter physics. In the normal state, isospin and valley polarization naturally break time-reversal symmetry, while trigonal warping enforces  $C_{3z}$ . Below the critical temperature, the superconducting phase displays signatures of chiral behavior and is stabilized by out-of-plane fields as large as  $\sim 0.5$  T. In this work, we employ the Ginzburg-Landau formalism to find a novel spontaneous vortex-antivortex lattice phase for fields smaller than  $\sim \phi_0/\ell^2$  ( $\ell^2$  being the unit cell area) and explain the experimental observations at low electron densities in a semi-quantitative manner. Finally, we make contact with the microscopics of this graphene system by deriving our Ginzburg-Landau theory from a model electronic Hamiltonian.

**Sandesh Kalantre** (Stanford University) — *Microwave cQED probes of frustrated magnets*

Over the past two decades, tremendous advancements in superconducting circuits have been enabled by careful engineering of devices to shield quantum degrees of freedom from decoherence by the environment. Circuits combining Josephson junctions and coplanar resonators lead to qubits with long coherence times and are by design desensitized to perturbations from the environment. In this work, we flip around this sensitivity to the environment and ask - what if we used sensitive superconducting circuits to probe novel condensed matter phenomena? We use an electron spin resonance setup involving superconducting resonators to probe frustrated magnetic systems. In particular, we work with a spin-liquid candidate  $\text{TbInO}_3$  and show that magnetic frustration continues to persist down to almost three orders of magnitude below the Curie-Weiss scale. Such techniques can be adapted to studies of other frustrated magnetic systems and superconductors.

**Jakob Lenschen** (Karlsruher Institut of Technology) — *Measuring mm-wave resonances at mK-temperatures*

We propose and test a cryogenic setup comprising dielectric waveguides for mm-wave frequencies in the range of 75 – 110 GHz and temperatures down to 10 mK. The targeted applications are quantum technologies at millimeter-wave frequencies, which require measurements at low photon numbers and noise. We show that the high density polyethylene waveguides combine a frequency independent low photon loss with a very low heat conductance. The dielectric waveguides are thermally anchored and attenuated at several stages of the cryostat. They are individually protected by additional metallic shields to suppress mutual cross-talk and external interference. With this setup, multiple superconducting resonances of a Fabry-Pérot cavity were measured at 10 mK. We find quality factors up to 15 million in the single photon limit for resonances above 100 GHz. These results show no evident influence of atomic two-level systems in the cavity.



# Short talks abstracts: Thursday Session

From 17:30 to 18:30

**Yuriko Baba** (IFIMAC, Universidad Autónoma de Madrid) — *Hidden topological states in QH-SC heterostructures*

In a quantum Hall (QH) state, the proximity to a superconductor (SC) leads to the formation of hybridized electron-hole states called chiral Andreev edge states (CAES). Although the strong magnetic fields required for the QH are detrimental to superconductivity, recent experiments have achieved QH-SC hybrid junctions on InAs 2DEGs, graphene, and magnetic topological insulators. In this work, we theoretically study the formation of CAES in QH-SC hybrid junctions on a 2DEG. Using numerical simulations in Kwant, we study the formation of spin-polarized triplet Cooper pairs induced by Rashba spin-orbit coupling and Zeeman splitting. We also consider the effect of the geometry of nanodevices in a narrow-finger configuration. In these geometries, the coupling of CAES can induce a topological band inversion and trivial localized states, both of which show particular signatures in non-local electron transport.

**Johanna Berger** (University of Regensburg) — *Anomalous Josephson effect in a kinked junction*

In Josephson junctions based upon hybrid Al/InAs heterostructures, the interplay between Rashba spin-orbit interaction and Zeeman fields gives rise to an anomalous phase-shift  $\phi_0$  in the current-phase relation. Here, we introduce an approach to measure the  $\phi_0$ -shift via a kinked junction geometry. An intentional step-like variation of  $\phi_0$  along the junction is introduced by a kink in the weak link, which changes its angle with respect to an in-plane magnetic field. This results in a unique quantum interference pattern, from which the corresponding  $\phi_0$ -shift is extracted with the help of a minimal theoretical model in dependence of in-plane fields and electrostatic gating.

**John Chiles** (Duke University) — *Multiplet Supercurrents in a Josephson Circuit*

Josephson networks are a promising platform for harboring synthetic topological phases of matter and Floquet states. These networks have hosted Cooper multiplets—coherent transport of four or more electrons through splitting of Cooper pairs and subsequent Andreev reflections. In this talk, we demonstrate multi-junction dynamical supercurrents emerging from an engineered Josephson network. The dynamical supercurrents include features similar to Cooper quartets as well as an unexpected supercurrent mediated between adjacent contacts through a superconducting island. The supercurrents exhibit expected Shapiro step quantization under microwave drive and can be explained through dynamical stabilization in the RCSJ model of the device.

**Samuele Fracassi** (Università degli studi di Genova) — *Diode effect in a perturbed topological JJ*

The breaking of time-reversal and inversion symmetry can lead to unique effects in Josephson junctions, such as the anomalous Josephson effect or supercurrent rectification. We consider a Josephson junction based on a quantum spin Hall system as the normal channel, subject to a magnetic field aligned with spin momentum locking. In proximity to one of the metallic edges, a local tip is introduced. We show that magnetic tips offer a tunable mechanism for both  $\phi_0$  response and supercurrent rectification.



# Short talks abstracts: Friday Session

From 18:30 to 19:30

**Kristoffer Leraand** (Norwegian University of Science and Technology) — *Phonon-mediated spin-polarized SC in altermagnets*

We consider the possibility of phonon-mediated unconventional superconductivity in a recently discovered new class of antiferromagnets, dubbed altermagnets. Within a weak-coupling approach, and using a minimal Lieb lattice model for altermagnets, we find a dominant superconducting instability odd in momentum and even in spin with spin-polarized Cooper pairs. We discuss the origin of this unusual result in terms of the spin-structure of the altermagnetic Fermi surface, in combination with the momentum-space structure of the effective phonon-mediated electron-electron interactions on the Fermi surface

**Leonardo Pierattelli** (Scuola Normale Superiore di Pisa) — *Delta-T noise in nanoscale hybrid devices*

In this work we use the Landauer-Büttiker scattering approach to analyze the properties of charge current noise when temperature biases are present between the normal contacts of an electronic system. We find out that such thermally-induced noise contains information that would be inaccessible via electrically-induced noise measurements. In particular, noise induced by temperature differences depends on a quantity that is strictly related to the heat conductance of the system, both in the linear and in the large-bias limit. Our findings could be used in the future for advanced thermometry applications in hybrid systems, and for the precise characterization of their scattering properties.

**Adrian Reich** (Karlsruhe Institute of Technology) — *BKT transitions in topological SMS junctions*

We study quantum phase transitions in a long and narrow topological Josephson junction. The low-energy excitations comprise Majorana fermions propagating along the junction, coupled to magnons in an embedded ferromagnetic layer. Based on mean-field and renormalization group arguments, we predict the existence of Berezinskii-Kosterlitz-Thouless transitions in this system, both in the case of a magnetic easy-plane and easy-axis anisotropy. In the easy-axis regime, this is based on an emerging effective easy-plane, spanned by the easy-axis and the component of the magnetization which couples to the Majoranas. We conclude by presenting a conjecture for the full phase diagram of the model.

**Aravindh Swaminathan Shankar** (Abdus Salam ICTP, Trieste) — *Superconducting wormhole in the Yukawa SYK mode*

We show that two Yukawa-SYK models with a weak tunneling contact can have an exotic superconducting hybrid thermofield-double-like state holographically dual to a traversable wormhole connecting two black holes with charged scalar hair. The hybrid thermo-field-double/wormhole state is distinguishable by anomalous scaling of revival oscillations in the fermionic Green's function. Accessible signatures of the transition to this phase in the temperature dependence of the critical Josephson current is also discussed.



# Short talks abstracts: Friday Session

From 18:30 to 19:30

**Vladimir Zakharov** (Leiden University) – *Luttinger liquid on a lattice*

Applying powerful numerical many-body techniques to massless Dirac fermions requires discretizing the model on a lattice. However, this task encounters the well-known fermion-doubling problem: any local, symmetry-preserving discretization of the momentum operator introduces a spurious second Dirac point, leading to hybridization of the cones and opening a gap at zero energy. Here, we present two complementary approaches – quantum Monte Carlo simulations and tensor network calculations – that work around this issue by employing the same tangent fermion discretization. This discretization uniquely preserves the topological protection of the unpaired Dirac cone by exploiting the fact that the nonlocal Hamiltonian of tangent fermions allows for a local generalized eigenproblem.

**Dario Bercioux** (Donostia International Physics Center) – *Information regarding the excursion to Pompei & Sorrento*

Important information for the excursion on Saturday to Pompeii and Sorrento.