# TT 76: Superconductivity: Tunnelling and Josephson Junctions II

Time: Thursday 15:00–17:45 Location: H 3010

TT 76.1 Thu 15:00 H 3010

**Chiral adiabatic transmission protected by Fermi surface topology** — Isidora Araya Day[1,2], •Kostas Vilkelis[1,2], Antonio Lucas Rigotti Manesco[2], Ahmet Mert Bozkurt[1,2], Valla Fatemi[3], and Anton Akhmerov[2] — [1]QuTech, Delft University of Technology, Delft 2600 GA, The Netherlands — [2]Kavli Institute of Nanoscience, Delft University of Technology, P.O. Box 4056, 2600 GA Delft, The Netherlands — [3]School of Applied and Engineering Physics, Cornell University, Ithaca, NY 14853 USA

We demonstrate that Andreev modes that propagate along a transparent Josephson junction have a perfect transmission at the point where three junctions meet. The chirality and the number of quantized transmission channels is determined by the topology of the Fermi surface and the vorticity of the superconducting phase differences at the trijunction. We explain this chiral adiabatic transmission (CAT) as a consequence of the adiabatic evolution of the scattering modes both in momentum and real space. We identify an effective energy barrier that guarantees quantized transmission. We expect that CAT is observable in nonlocal conductance and thermal transport measurements. Furthermore, because it does not rely on particle-hole symmetry, CAT is also possible to observe directly in metamaterials.

TT 76.2 Thu 15:15 H 3010

**Magnetization dynamics and Peierls instability in topologicalJosephson structures** — •Adrian Reich[1], Erez Berg[2], Jörg Schmalian[1,3], and Alexander Shnirman[1,3] — [1]Institute for Theoretical Condensed Matter Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Department of Condensed Matter Physics, Weizmann Insitute of Science, Rehovot 76100, Israel — [3]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany

We study a long topological Josephson junction with a ferromagnetic strip between two superconductors. The low-energy theory exhibits a nonlocal in time and space interaction between chiral Majorana fermions, mediated by the magnonic excitations in the ferromagnet. We show that sufficiently strong and long-ranged interactions may induce a $Z_2$-symmetry breaking, leading to a tilting of the magnetization and the opening of a fermionic gap, analogous to the Peierls instability in the commensurate Fröhlich model. Within a Gaussian fluctuation analysis, we estimate critical values for the temporal and spatial nonlocality of the interaction, beyond which the symmetry breaking is stable at zero temperature. We compare these results with a renormalization group analysis of closely related models and conclude that nonlocality, i.e., the stiffness of the magnetization in space and time, stabilizes the symmetry breaking. In the stabilized regime, we expect the current-phase relation to exhibit an experimentally accessible discontinuous jump. At nonzero temperatures, the long-range order is destroyed by solitons, which in our case carry each a Majorana zero mode.

TT 76.3 Thu 15:30 H 3010

**Quartet Tomography in Multiterminal Josephson Junctions** — •David Christian Ohnmacht[1], Marco Coraiola[2], Juan Jose García-Esteban[1,3], Deividas Sabonis[2], Fabrizio Nichele[2], Wolfgang Belzig[1], and Juan Carlos Cuevas[1,3] — [1]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany — [2]IBM Research Europe—Zurich, Säumerstrasse 4, 8803 Rüschlikon, Switzerland — [3]Departamento de Física Teórica de la Materia Condensada and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain

We investigate the detection of quartets in hybrid multiterminal Josephson junctions [1]. Using simple models of quantum dots coupled to superconducting leads, we find that quartets are ubiquitous and show how to rigorously extract their contribution to the current-phase relation (CPR). We also demonstrate that quartets are closely related to the hybridization of Andreev bound states (ABSs) in these systems and propose a method to identify quartets directly in ABS spectra. We illustrate our method by analyzing the spectroscopic measurements of the ABS spectrum in a threeterminal Josephson junction realized in an InAs/Al heterostructure [2]. Our analysis strongly suggests the existence of quartets in the studied hybrid system.

[1] D. C. Ohnmacht et. al., arXiv:2311.18544 (2023)
[2] M. Coraiola et. al., Nat. Commun. 14 (2023) 6784

TT 76.4 Thu 15:45 H 3010

**Equal contribution of even and odd frequency pairing for normal metal metal/superconductor junctions** — •Shun Tamura[1], Viktoriia Kornich[1], and Björn Trauzettel[1,2] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Würzburg, Germany

Odd-frequency pairings are odd under the exchange of the relative time or frequency of the superconducting pairing. Odd-frequency pairing emerges specifically at the surface or interface of superconductors. We calculate the conductance of normal metal/superconductor junctions based on the linear response theorem. We observe that the contributions to the conductance from odd and even frequency pairings are equal, even though the superconductor follows a conventional s-wave spin-singlet pairing.

TT 76.5 Thu 16:00 H 3010

**Analysis of Inelastic Tunneling Spectrum of Lead Phthalocyanine Adsorbed on Superconducting Pb(100)** — •Athanasios Koliogiorgos and Richard Korytár — Department of Condensed Matter Physics, Charles University in Prague, Czech Republic

A wealth of information can be gained from the vibrational spectrum of adsorbed molecules on metal surfaces. Such spectrum can be accessed by inelastic electron tunneling in scanning-tunneling microscopy. A recent experimental study has reported resonances in a lead phthalocyanine (PbPc) molecule on a superconducting Pb(100) which were attributed to vibrational excitations. These excitations appear as peaks in the first derivative of the current-voltage relation within the superconducting gap, in a scanning-tunneling setup. Here we introduce an innovative computational approach to analyze the inelastic tunneling spectra of PbPc adsorbed on Pb(100) surfaces. Our method focuses on the vibrational spectrum observed in the first derivative of the current-voltage relation. This spectrum provides insights into the adsorbate's vibrational transitions and the interplay of electronic and vibrational states in molecular systems. Our approach diverges from conventional methods by calculating vibrational transitions from isolated molecular electronic orbitals, thus avoiding issues related to the continuous density of states in metals. This refinement facilitates an accurate interpretation of the experimental spectra. Our results highlight the importance of considering two-vibron processes. We also explore the impact of charge transfer and molecular magnetism on the vibrational spectrum by comparing neutral and charged states of PbPc.

**15 min. break**

TT 76.6 Thu 16:30 H 3010

**Resistivity tensor of vortex-lattice states in Josephson junction arrays** — •Alexander Penner[1], Karsten Flensberg[2], Leonid Glazman[3], and Felix von Oppen[1] — [1]Freie Universität Berlin — [2]University of Copenhagen — [3]Yale University

Two-dimensional Josephson junction arrays frustrated by a perpendicular magnetic field are predicted to form a cascade of distinct vortex lattice states. Here, we show that the resistivity tensor provides both structural and dynamical information on the vortex-lattice states and intervening phase transitions, which allows for experimental identification of these symmetry-breaking ground states. We illustrate our general approach by a microscopic theory of the resistivity tensor for a range of magnetic fields exhibiting a rich set of vortex lattices as well as transitions to liquid-crystalline vortex states.

TT 76.7 Thu 16:45 H 3010

**Fermionic versus bosonic description of dissipation in Josephson junctions** — •Oleksiy Kashuba, Theodoulos A. Costi, and Roman-P. Riwar — Peter Grünberg Institute, Theoretical Nanoelectronics, Forschungszentrum Jülich, D-52425 Jülich

The Caldeira-Leggett model is the commonly accepted go-to approach to describe dissipation in superconducting circuits [1]. However, this model predicts a superconductor-insulator transition whose experimental verification is still heavily debated. Starting with the microscopic picture of a Josephson junction coupled to a normal metal, we notice that it matters whether the limit of large superconducting gap is taken before or after the wideband limit (where bosonization ap-

plies). For the former, the interaction cannot be mapped exactly to the Caldeira-Leggett model [2]. Instead, we find a generalized Kondo model, which, for large charging energies, reduces to the standard anisotropic Kondo model. While this model features a phase transition of its own, the parameters that control the transition are different. In particular, the phase transition can only occur if the partial capacitance between the superconducting island and normal metal is allowed to be negative. In the same fashion, Langevin equation for quantum phase derived directly from the microscopic model has additional contributions to the ohmic term compared to the Caldeira-Leggett model. Our work thus indicates that different microscopic realizations of the bath may give rise to different phase diagrams.

[1] F. Guinea, V. Hakim, A. Muramatsu, Phys. Rev. Lett. 54 (1985) 263
[2] G. Schön, A. Zaikin, Phys. Reports 198 (1990) 237

TT 76.8 Thu 17:00 H 3010

**Half-integer Shapiro steps in highly transmissive InSb nanoflag Josephson junctions** — Andrea Iorio[1], Alessandro Crippa[1], Bianca Turini[1], Sedighe Salimian[1], Matteo Carrega[2], Luca Chirolli[1], Valentina Zannier[1], Lucia Sorba[1], Elia Strambini[1], Francesco Giazotto[1], and •Stefan Heun[1] — [1]NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Piazza San Silvestro 12, 56127 Pisa, Italy — [2]CNR-SPIN, Via Dodecaneso 33, 16146 Genoa, Italy

We investigate a ballistic InSb nanoflag-based Josephson junction with Nb superconducting contacts. The high transparency of the superconductor-semiconductor interfaces enables the exploration of quantum transport with parallel short and long conducting channels. Under microwave irradiation, we observe half-integer Shapiro steps that are robust to temperature, suggesting their possible nonequilibrium origin. Our results demonstrate the potential of ballistic InSb nanoflags Josephson junctions as a valuable platform for understanding the physics of hybrid devices and investigating their nonequilibrium dynamics.

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TT 76.9 Thu 17:15 H 3010

**Fractional transconductance via nonadiabatic topological Cooper pair pumping** — Hannes Weisbrich[1], •Raffael L. Klees[2], Oded Zilberberg[1], and Wolfgang Belzig[1] — [1]Universität Konstanz — [2]Universität Augsburg

Many robust physical phenomena, such as the integer quantum Hall effect, rely on topological invariants arising from geometrical and topological properties of the underlying quantum states. Furthermore, the interplay of many-body correlations and topology leads to the more exotic fractional quantum Hall effect, in which anyons, particles with fractional statistics, lead to a fractional quantized conductance. While the topology of the integer effect can be realized as a quantized transconductance in superconducting multiterminal systems [1-2], a proposal for its fractional counterpart is still missing. In this talk, we present such a proposal based on an engineered chain of Josephson junctions that fills this research gap and demonstrates how to generate a fractional quantized transconductance [3]. We show that this transconductance occurs at robust plateaus as a result of nonadiabatic Landau-Zener transitions. Our proposal paves the way for future quantum simulations of correlated exotic many-body out-of-equilibrium states in Josephson junction systems.

[1] R.-P. Riwar *et al.*, Nat. Commun. **7** (2016) 11167
[2] R. L. Klees *et al.*, Phys. Rev. Lett. **124** (2020) 197002
[3] H. Weisbrich *et al.*, Phys. Rev. Research **5** (2023) 043045

TT 76.10 Thu 17:30 H 3010

**Evidence for multiple Andreev reflection (MAR) in a hybrid superconducting single-electron transistor** — •Jens Siewert[1,2], Laura Sobral Rey[3], David C. Ohnmacht[3], Clemens B. Winkelmann[4], Wolfgang Belzig[3], and Elke Scheer[3] — [1]University of the Basque Country, 48080 Bilbao, Spain — [2]Ikerbasque, 48009 Bilbao, Spain — [3]University of Konstanz, 78457 Konstanz, Germany — [4]Université Grenoble Alpes & CNRS, 38000 Grenoble, France

MAR and Coulomb blockade (CB) are competing phenomena in superconducting single-electron transistors: While MAR tends to significantly change the number of island excess charges, CB excludes such processes at small bias voltages. Despite substantial experimental effort over the years, up to now no unambiguous evidence for MAR processes in superconducting CB devices has been reported. To study this problem we have experimentally investigated a novel device, a single-electron transistor with one superconductor-superconductor (S-S) junction and a superconductor-normal (S-N) junction [1]. The realization of the S-S junction is chosen as a mechanically controllable break junction, such that different conductance regimes and coupling strengths can be studied in the same device. We find clear evidence for the presence of MAR processes in the current-voltage characteristics of our SSN single-electron transistor, both in the subgab region as well as for bias voltages where single-quasiparticle tunneling is possible and MAR is suppressed in single junctions.

[1] L. Sobral Rey et al., Phys. Rev. Lett. 132, 057001 (2024)