TT 48: Topological Superconductors

Time: Thursday 9:30–11:15 Location: HSZ 304

TT 48.1 Thu 9:30 HSZ 304

Superconductivity mediated by topological phonons — •Alessio Zaccone — Department of Physics, University of Milan, 20133 Milano, Italy

Topological phononic insulators are the counterpart of three-dimensional quantum spin Hall insulators in phononic systems and, as such, their phononic topological surfaces are characterized by Dirac cone-shaped gapless edge states arising as a consequence of a bulk-boundary correspondence. We proposed [1] a theoretical framework for the possible superconductivity in these materials, where the attractive interaction between electrons is mediated by topological phonons in nontrivial boundary modes. Within the BCS limit, we developed a self-consistent two-band gap equation, whose solutions show that the superconducting T_c has a nonmonotonic behavior with respect to the phononic frequency in the Kramers-like point. This remarkable behavior is produced by a resonance that occurs when electrons and phonons on the topological surfaces have the same energy: this effectively increases the electron-phonon interaction and hence the Cooper pair binding energy, thus establishing an optimal condition for the superconducting phase. With this mechanism, the T_c can be increased by well over a factor 2, and the maximum enhancement occurs in the degenerate phononic flat-band limit.

[1] D. Di Miceli, C. Setty, A. Zaccone, Phys. Rev. B 106, 054502 (2022)

TT 48.2 Thu 9:45 HSZ 304

Topological superconductivity on the honeycomb lattice: Effect of normal state topology and disorder — •Stephan Rachel — School of Physics, University of Melbourne, Australia

The search for topological superconductors is one of the most pressing and challenging questions in condensed-matter and material research. Despite some early suggestions that doping a topological insulator might be a successful recipe to find topological superconductors, to date there is no general understanding of the relationship of the topology of the superconductor and the topology of its underlying normal state system. Here we present an analysis of doped insulators - topological and trivial. Our approach allows us to study and compare superconducting instabilities of different normal state systems and present rigorous results about the influence of the normal state system's topology. If time permits we will also discuss the influence of disorder on topological superconductivity on the honeycomb lattice.

TT 48.3 Thu 10:00 HSZ 304

Ground state topology of a multiterminal superconducting double quantum dot — •Lev Teshler, Hannes Weisbrich, and Wolfgang Belzig — Universität Konstanz, Konstanz, Germany

Multiterminal Josephson junctions can provide topological Andreev bound states in the space of the superconducting phases [1]. The topology of the Andreev bound states manifests itself in a quantized transconductance when applying voltages to two terminals. Such systems are candidates to realise higher-dimensional topology and non-Abelian Berry phases using their synthetic dimensions [2]. For practical purposes a linear arrangement of quantum dots coupled to superconductors might be beneficial and was shown to exhibit nontrivial topology [3]. In this work, we study a double quantum dot in which each dot is coupled to two superconductors. This system that depends on three superconducting phase differences already displays non-trivial topology in terms of the first Chern number and is an example that allows to study the fundamental properties of this class of systems. We will study the ground state and the respective topological phase diagram for different sets of parameters of the double quantum dot. Furthermore, we will also discuss the influence of Coulomb interaction and Zeeman splitting on the topological properties of the ground state.

[1] R.-P. Riwar et al., Nat. Commun. 7, 1 (2016)
[2] H. Weisbrich et al., PRX Quantum 2, 010310 (2021)
[3] R. Klees et al., Phys Rev B 103, 014516 (2021)

TT 48.4 Thu 10:15 HSZ 304

Fractional transconductance via non-adiabatic topological Cooper pair pumping — •Hannes Weisbrich[1], Raffael L. Klees[2], Oded Zilberberg[1], and Wolfgang Belzig[1] — [1]Universität Konstanz — [2]Universität Würzburg

Many robust physical phenomena in quantum physics are based on topological invariants, which are intriguing geometrical properties of quantum states. A prime example is the 2D quantum Hall effect with its quantized quantum Hall conductance in units of $\frac{e^2}{h}$ protected by the respective 2D topology. A comparable effect in superconducting systems is the appearance of a quantized transconductance in units of $\frac{4e^2}{h}$ for topological Andreev bound states in multiterminal Josephson junctions.

In this work, we theoretically demonstrate how fractional quantized plateaus in the transconductance can be observed as a result of topological Cooper pair pumping in a chain of Josephson junctions. The fractional plateaus in the transconductance are stabilized by non-adiabatic Landau-Zener transitions which even allow for a robustness to disorder in the chain.

TT 48.5 Thu 10:30 HSZ 304

Magnetic-domain mediated topological superconductivity in a Josephson Junction — •Ignacio Sardinero[1], Rubén Seoane Souto[2,3], and Pablo Burset[1] — [1]Department of Theoretical Condensed Matter Physics, Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera, Universidad Autónoma de Madrid, 28049 Madrid, Spain — [2]Division of Solid State Physics and NanoLund, Lund University, S-221 00 Lund, Sweden — [3]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, DK-2100 Copenhagen, Denmark

Topological superconductors are appealing building blocks for robust and reliable quantum information processing. Most platforms for engineering topological superconductivity rely on a combination of materials with intrinsic spin-orbit coupling and external magnetic fields, which are usually challenging to manipulate. We propose and describe a setup without spin-orbit or magnetic fields where a conventional Josephson junction is linked by a narrow ferromagnetic insulator with multi-domain structure along the interface. Our calculations show that sequences of magnetic domains preserving the net magnetization's rotation direction are sufficient for generating topological superconductivity in a wide range of parameters and degrees of disorder. We find that the topological phase transition strongly depends on the magnitude and period of the net magnetization. Interestingly, a phase bias across the junction can control and tune the formation and localization of a pair of Majorana zero-energy modes along the junction interface, with an observable effect on the current-phase relation.

TT 48.6 Thu 10:45 HSZ 304

Symmetry enriched entanglement properties of chiral Skyrme insulators — •Joe Winter[1,2,3], Bernd Braunecker[3], and Ashley Cook[1,2] — [1]Max Planck Institute for Chemical Physics of Solids, Nothnitzer Straße 40, 01187 Dresden, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Nothnitzer Straße 38, 01187 Dresden, Germany — [3]SUPA, School of Physics and Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9SS, UK

The expectation value of an observable $\mathcal{O}$ may be computed with a density matrix ρ as $\mathrm{Tr}\,(\rho\mathcal{O})$. In this work, we introduce the symmetry-enriched partial trace operation for density matrices, $\tilde{\rho}_{\mathcal{T}} = \tilde{\mathrm{Tr}}_{\bar{\mathcal{T}}}\,(\rho)$, a partial trace performed over $\bar{\mathcal{T}}$ degrees of freedom on a density matrix as part of partial computation of an expectation value for an observable $\mathcal{O}$. That is, for representation of observable $\mathcal{O}$ after tracing out $\bar{\mathcal{T}}$ being $\mathcal{O}_{\mathcal{T}}$, $\tilde{\rho}_{\mathcal{T}}$ satisfies $\mathrm{Tr}\,(\rho\mathcal{O}) = \langle\mathcal{O}\rangle = \langle\mathcal{O}_{\mathcal{T}}\rangle = \mathrm{Tr}\,(\tilde{\rho}_{\mathcal{T}}\mathcal{O}_{\mathcal{T}})$, with symmetry-enrichment deriving from differences in symmetry between $\mathcal{O}$ and $\mathcal{O}_{\mathcal{T}}$. We use this to characterize bulk-boundary correspondence of topological skyrmion phases, by computing the symmetry-enriched reduced density matrix in the 2D bulk of a topological skyrmion phase, and for slab geometries with open boundary conditions in one direction. We show winding of this reduced density matrix matches winding of the spin expectation value vector in the bulk, and the entanglement spectrum of the reduced density matrix for the slab geometry reveals $\mathcal{Q}$ topologically-protected, chiral edge modes for skyrmion number $\mathcal{Q}$ characterizing the bulk topological skyrmion phase.

TT 48.7 Thu 11:00 HSZ 304

Non-Hermitian dimerized interacting Kitaev chain — •Sharareh Sayyad[1] and Jose Lado[2] — [1]MPI for the sicence of light, Erlangen, Germany — [2]Aalto University, Espoo, Finland

Non-Hermitian models have risen as a new paradigm to manipulate and interpret various emergent quantum phenomena. While numerous studies have been focused on exploring (effective) non-Hermitian non-interacting models. The role of interactions in modifying the non-interacting non-Hermitian physics still needs to be well-explored. In this talk, I will present how incorporating many-body interactions can enrich non-interacting physics. To be more precise, combining our exact analytical results and tensor- network numerical calculations, I will discuss the phase diagram of the non-Hermitian dimerized interacting Kitaev chain. Here, the non-Hermiticty is due to the complex-valued nearest-neighbor density-density interaction strength. I will show that the ground state degeneracy of this system may be fourfold, twofold, or nondegenerate, depending on the parameter regimes. I will further discuss how these degeneracies are lifted in the presence of non-Hermiticity. Elaborating on this behavior clarifies the role of non-Hermiticity in washing out multiple phases in the phase diagram of the Hermitian interacting model.