TT 6: Topological Superconductors

Time: Monday 9:30–11:00 Location: CHE/0091

TT 6.1 Mon 9:30 CHE/0091

Experimental Signatures of Gate-Tuneable One-Dimensional Edge Channels in Bi_2Se_3 Josephson Junctions — •Feike van Veen[1], Femke Witmans[1], Jara Vliem[2], Daniel Vanmaekelbergh[2], Chuan Li[1], and Alexander Brinkamn[1] — [1]MESA+ Institute for Nanotechnology, University of Twente, Hallenweg 15, 7522 NH Enschede, The Netherlands — [2]Debye Institute for Nanomaterials Science, Utrecht University, Princetonplein 1, 3584 CC Utrecht, The Netherlands

The quantum spin Hall (QSH) effect exhibits helical edge channels that can be utilized in the development of quantum computing [1]. Such QSH states are expected to be present in the hybridization gap that opens at the Dirac point in ultrathin 3D topological insulators (TIs) when opposite topological surface states hybridize [2]. In a previous study, an enhanced density of states has been probed at the edges of ultrathin colloidal Bi_2Se_3 nanoplatelets (NPLs) with scanning tunnelling spectroscopy [3]. Here, we study superconducting transport properties of these Bi_2Se_3 NPLs and reveal strong signatures of a 1D edge state contribution. Moreover, we found experimental evidence of a thickness dependence as is described by theoretical frameworks [2]. We can deplete the NPLs, hereby destroying the supercurrent, allowing for an "on" or "off" mode of the JJs. These observations contribute to the understanding and development of (non)-topological JJs made of ultrathin 3D TIs and shed new light on previous studies on superconductivity induced in QSH states.

[1] 10.1103/RevModPhys.82.3045
[2] 10.1103/PhysRevB.97.075419
[3] 10.1021/acs.nanolett.3c04460

TT 6.2 Mon 9:45 CHE/0091

Higher-order topological states in antiferromagnet/superconductor interface — •Ignacio Sardinero[1,4], Yuriko Baba[2], Rubén Seoane-Souto[3], and Pablo Burset[1,4] — [1]Department of Theoretical Condensed Matter Physics, Universidad Autónoma de Madrid, 28049 Madrid, Spain — [2]Instituto de Estructura de la Materia (IEM-CSIC), Serrano, 121, 28006 Madrid, Spain — [3]Instituto de Ciencia de Materiales de Madrid (ICMM-CSIC), Sor Juana Inés de la Cruz, 3, 28049 Madrid, Spain — [4]Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain

Topological superconductors (TSs) are promising candidates for reliable quantum information processing. While field-free platforms often rely on ferromagnets, their stray magnetization hinders scalability. Antiferromagnets (AFMs) offer a novel approach by providing local time-reversal symmetry breaking without macroscopic magnetization. Motivated by recent experiments [1], we investigate TS in van der Waals AFM/superconductor hybrid structures. We show that trivial Andreev bound states can localize at uncompensated magnetic edges, which could explain the recent experiment [1]. Then, we propose a pathway to nontrivial topological phases driven by the interplay of AFM with Rashba or Ising spin-orbit couplings. We demonstrate that specific crystalline symmetries, particularly mirror symmetry combined spin-flip operations, stabilize second-order topological superconducting phases, characterized by a finite quadrupole moment.

[1] C. González-Sánchez et al., arXiv:2505.18578

TT 6.3 Mon 10:00 CHE/0091

Topological superconductivity induced by atomic-scale skyrmion lattices — •Felix Nickel and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel

Topological superconductivity, which can host Majorana zero modes with potential applications in topological quantum computing, relies on unconventional superconductors not known to exist in nature. However, magnet*superconductor hybrid systems (MSHs), built from ultra-thin magnetic layers on conventional superconductors, can induce such unconventional pairing [1]. While much research has focused on ferromagnetic systems with substantial spin*orbit coupling (SOC), non-collinear magnetic structures have been only sparsely investigated. Among them, atomic-scale skyrmion lattices are particularly interesting, as they lead to topological orbital moments and a topological Hall effect. They also offer a promising platform for MSHs, since their non-coplanar spin arrangement, characterized by the scalar spin chirality, induces spin mixing naturally, even in the absence of SOC.

We present a systematic study based on a tight-binding model of various collinear, non-collinear, and non-coplanar spin textures and analyze their effect on the superconducting substrate. We relate the scalar spin chirality to the topological phase of the superconductor, characterized by its Chern number. For magnetic textures with finite scalar spin chirality, we find topological superconductivity, indicating a direct link between both properties [2].

[1] R. Lo Conte *et al.*, Riv. Nuovo Cim. **47**, 453 (2024)
[2] F. Nickel *et al.*, npj Spintronics **3**, 13 (2025)

TT 6.4 Mon 10:15 CHE/0091

Topologically enabled superconductivity in 2D quantum materials — •Francesca Paoletti[1], Daniele Guerci[2], Giorgio Sangiovanni[1], Urban F. P. Seifert[3], and Elio J. König[4] — [1]JMU Würzburg — [2]Massachusetts Institute of Technology — [3]Universität zu Köln — [4]University of Wisconsin-Madison

We investigate the role of Green's function zeros in strongly interacting topological Mott insulators, focusing on their meaning and physical interpretation. Recent advancements, particularly through slave rotor calculations of the Kane-Mele-Hubbard model, have established a connection between zeros and spinons and with U(1) gapped spin liquids. We find a macroscopic spin-charge separation resulting from the non-trivial interplay with the conventional boundary modes of the topological insulator. We further employ our method to an attractive Hubbard-Haldane honeycomb model. In this context, the extensive slave-rotor mean-field calculations are used as a microscopic foundation to determine the phase diagram of the model as well as important phenomenological properties, such as the coherence length and penetration depth (Pearl length) within a topologically enabled mechanism of superconductivity.

TT 6.5 Mon 10:30 CHE/0091

Euler band topology in superfluids and superconductors — •Shingo Kobayashi[1], Manabu Sato[2], and Akira Furusaki[1] — [1]RIKEN Center for Emergent Matter Science, Wako, Saitama, Japan — [2]Department of Applied Physics, University of Tokyo, Bunkyo, Tokyo, Japan

Real band topology often appears in systems with space-time inversion symmetry and is characterized by invariants such as the Euler and second Stiefel-Whitney classes. Here, we examine the generic band topology of Bogoliubov de-Gennes (BdG) Hamiltonians with $C_{2z}T$ symmetry, where C_{2z} and T are twofold rotation about the z axis and time-reversal symmetries, respectively. We discuss the Euler band topology of superfluids and superconductors in the DIII and CI Altland-Zirnbauer symmetry classes. We demonstrate our theory with two examples: the superfluid ^{3}He B phase in magnetic field and the nodal lines of multi-orbital s-wave superconductors in class CI. These results provide a theoretical framework for exploring Euler band topology in superfluids and superconductors and offer a unified understanding of the robustness of topological phases under TRSB perturbations, including Majorana Ising physics and higher-order topology.

TT 6.6 Mon 10:45 CHE/0091

Topology of non-normalizable physical vector fields — •Philipp Gessler, Alessandro Pignedoli, Alexander Neuhaus, Pascal Dreher, Frank Meyer zu Heringdorf, Maria Azhar, and Karin Everschor-Sitte — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47048 Duisburg, Germany

Topological classification of physical vector fields typically relies on normalizing the field and using homotopy groups to classify them. When field amplitudes vanish, normalization becomes impossible, preventing a direct topological classification. We resolve this by mapping the d-dimensional vector field into a (d+1)-dimensional space, enabling a general classification scheme for non-normalizable fields. Applying this method to the transverse electric mode of a classical electromagnetic waveguide, we reveal their topological nature. This approach extends topological analysis to a broad range of physical systems, including magnetism, water waves, and ferroelectrics.