SYTS 1: Topological Superconductor-Magnet Heterostructures

Time: Thursday 15:00–17:45 Location: HSZ 01

Invited Talk SYTS 1.1 Thu 15:00 HSZ 01

Blending of superconductivity and magnetism via topological solitons — •Christos Panagopoulos — Nanyang Technological University, Singapore

Topological solitons and quantum mechanics have been intertwined for the past 60 years. Even before the term soliton had been coined, Abrikosov theory predicted the formation of vortices in the phase field of superconductors, an exemplar exposition of macroscopic quantum coherence. Recent work shows that solitons are in fact a timely and promising platform for quantum operations. I will demonstrate the viability of using spin topology to influence a superconductor at selective length scales through a completely new material architecture namely, a stack of magnets and a superconductor that shows stable vortices above elongated chiral spin textures, as well as isolated skyrmions. This is an ideal geometry for fluxonics and chiral superconductivity, as well as quantum processes such as non-perturbative, non-contact Majorana braiding.

Invited Talk SYTS 1.2 Thu 15:30 HSZ 01

Topological landscaping in magnet-superconductor heterostructures — •Sebastián A. Díaz — University of Duisburg-Essen, Duisburg, Germany

Magnet-superconductor heterostructures, due to the rich interplay between their adjacent order parameters, are fertile grounds for novel topological phenomena. Our theoretical studies demonstrate that topological defects in the magnetic order parameter lend themselves as versatile tools to landscape the superconducting order and its topological excitations. A chain of antiferromagnetic skyrmions induces topological superconductivity and supports Majorana bound states - the building blocks of topological quantum computing [1]. Ferromagnetic skyrmions coupled to superconducting vortices form a bound pair that can be used to braid Majorana bound states [2]. These findings strongly suggest that magnet-superconductor heterostructures are ideal arenas to further explore how magnetism and superconductivity influence each other to engineer and manipulate their order parameters and topological excitations.

[1] S. A. Díaz et al., Phys. Rev. B 104, 214501 (2021)
[2] J. Nothhelfer et al., Phys. Rev. B 105, 224509 (2022)

Invited Talk SYTS 1.3 Thu 16:00 HSZ 01

Experimental study of minigaps and end states in bottom-up designed multi-orbital Shiba chains — •Jens Wiebe — Universität Hamburg, Department of Physics, 20355 Hamburg, Germany

Chains of transition-metal atoms on *s*-wave superconductors evoke multiorbital Shiba bands inside the gap of the substrate. If a spin-orbit coupled band overlaps with the Fermi energy, a topologically nontrivial minigap may open up which can potentially host Majorana bound states at the chain's ends. We study atom-by-atom fabricated chains with respect to such phenomena [1]. Most recent strategies in order to increase the width of topological minigaps [2,3] and experimental methods to decide on the Majorana nature of close-to-zero-energy end states [4] will be presented.

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[1] L. Schneider et al., Nature Physics 17, 943 (2021)
[2] P. Beck et al., arXiv:2205.10062 [cond-mat.supr-con] (2022)
[3] P. Beck et al., arXiv:2205.10073 [cond-mat.supr-con] (2022)
[4] L. Schneider et al., arXiv:2211.00561v1 [cond-mat.supr-con]

15 min. break

Invited Talk SYTS 1.4 Thu 16:45 HSZ 01

Quantum spins and hybridization in artificially-constructed chains of magnetic adatoms on superconducting 2H-$NbSe_2$ — •Katharina J. Franke — Freie Universität Berlin, Berlin, Germany

Magnetic adatom chains on superconducting substrates are promising platforms for topological superconductivity and Majorana zero modes. Signatures of these have been found in densely packed chains with direct exchange interaction among the adatoms. Theoretical predictions suggest chains, where the atoms are sufficiently far spaced that direct hybridization of their d orbitals is negligible, but close enough for substrate-mediated interactions, as an alternative platform.

We build such chains from individual Fe atoms on a 2H-$NbSe_2$ substrate using the tip of a scanning tunneling microscope. In each step we track the evolution of the Yu-Shiba-Rusinov (YSR) states. We find signatures of quantum-spin behavior and YSR band formation consistent with ferromagnetic coupling [1,2].

[1] E. Liebhaber, L. M. Rütten, G. Reecht, J. F. Steiner, S. Rohlf, K. Rossnagel, F. von Oppen, K. J. Franke, Nat. Commun. 13, 2160 (2022)
[2] J. F. Steiner, C. Mora, K. J. Franke, F. von Oppen, Phys. Rev. Lett. 128, 036801 (2022)

Invited Talk SYTS 1.5 Thu 17:15 HSZ 01

Braiding of Majorana zero modes — •Stephan Rachel — School of Physics, University of Melbourne, Australia

There has been tremendous experimental progress in recent years in establishing magnet-superconductor hybrid (MSH) systems as a promising platform for Majorana physics.

In the first part of this talk, I will discuss MSH structures with Re or Nb as a superconducting substrate, and Fe or Mn as magnetic adatoms. In particular, I will illustrate the theoretical challenges to simulate and understand the topological superconductivity and their concomitant Majorana modes in such materials

In the second part of this talk, I will explain our first steps to investigate the braiding of Majorana zero modes. In particular, I will focus on braiding errors which can be introduced from sources such as quasiparticle poisoning and Majorana hybridization, and how these error rates behave in a full quasiparticle background.