TT 16: PhD Focus Session: Symposium on Strange Bedfellows - Magnetism Meets Superconductivity" (joint session MA/AKjDPG) (joint session MA/TT)

At first sight, it seems that the phenomena of magnetism and superconductivity do not go along, as indicated by the Meissner effect, when a magnetic field is completely expelled from the interior of a conventional superconductor. However, the synergy of these two manifestations of nature in condensed matter does occur and can be rather interesting! Theoretical works have predicted the existence of exotic states at the interface between a superconductor and a magnet, such as the sought-after Majorana fermions and spin-triplet superconductivity. The first have been predicted to route an efficient way to implement quantum computers (currently a European scientific flagship), while the latter allows the creation of spin-polarized supercurrents, opening up fundamentally new possibilities for spintronics. Therefore, our symposium aims at putting together experts to provide a fundamental and practical understanding of the subject to discuss most recent developments from the theoretical and experimental sides, and to show perspectives for applications.

Organizers: Annika Stellhorn, Flaviano José dos Santos, Markus Hoffmann (Forschungszentrum Jülich and Peter Grünberg Institut)

Time: Thursday 10:00–12:45 Location: H5

Invited Talk TT 16.1 Thu 10:00 H5

Magnetism and superconductivity: new physics one atom at a time — •Alexander Balatsky — NORDITA — UCONN

In this tutorial I will review the effects of magnetism and electronic defect in conventional and unconventional superconductors. The extreme case of quantum engineering where one builds magnetic and electronic features one atom at a time has proved to be a versatile approach. Impurities and defects are pair breakers in superconductors. I will discuss how defects can also enable new features in superconductors like intragap resonances, topological Majorana modes and seed new superconducting phases. Looking forward I will discuss how we might induce novel physics in superconductors with precise quantum impurity band engineering

TT 16.2 Thu 10:30 H5

Magnetic exchange interactions at proximity of a superconductor — •Uriel Aceves[1,2], Sascha Brinker[1], Filipe Guimaraes[3], and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany — [3]Jülich Supercomputing Centre, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany

The coupling of magnetic impurities to superconductors prompts the arise of exciting physics such as sub-gap states like Yu-Shiba-Rusinov states and Majorana zero modes, which constitute key mechanisms on the road towards a topological quantum computer. The interplay of spin-orbit coupling and (non-collinear) magnetism enriches the complexity and topological nature of the in-gap states hosted in proximity-induced superconductors. However, little is known about the impact of superconductivity on the different contributions to the magnetic exchange interactions, like the bilinear isotropic exchange and the Dzyaloshinskii-Moriya interaction — and in turn the impact on the magnetic textures. In this work, we propose a method for the extraction of the tensor of exchange interactions in the superconducting regime as described by the Bogoliubov-de Gennes equations. Finally, with our multi-orbital tight-binding code TITAN, we investigate a Mn (110) monolayer deposited on the Nb (110) surface and analyze the magnetic interactions of the superconducting and metallic phases.
–Work funded by Horizon 2020–ERC (CoG 681405–DYNASORE).

Invited Talk TT 16.3 Thu 10:45 H5

Magnetic adatom chains on superconducting $NbSe_2$ — Eva Liebhaber[1], Lisa M. Rütten[1], Gael Reecht[1], Jacob F. Steiner[2], Sebastian Rohlf[3], Kai Rossnagel[3], Felix von Oppen[2], and •Katharina J. Franke[1] — [1]Fachbereich Physik, Freie Universität Berlin, Germany — [2]Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Freie Universität Berlin, Germany — [3]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany

Magnetic adatom chains on superconducting substrates constitute a fascinating platform to study the interplay of quantum magnetism and superconductivity. Here, we investigate magnetic adatom chains in the dilute limit. This means that the atoms are sufficiently far spaced that direct hybridization of their d orbitals is negligible, but close enough for sizeable substrate-mediated interactions. We build these chains from individual Fe atoms on a 2H-$NbSe_2$ substrate. Using scanning tunneling microscopy and spectroscopy we first characterize the exchange coupling between the magnetic adatoms and the superconductor by detecting their Yu-Shiba-Rusinov states within the superconducting energy gap. We then use the tip of the STM to assemble dimers, trimers and chains of these Fe atoms. In each step, we track the evolution of the Yu-Shiba-Rusinov states and identify magnetic interactions, hybridization and band formation.

TT 16.4 Thu 11:15 H5

Tuning the interaction between spins coupled to a superconductor on the atomic level — •Felix Küster[1], Ana M. Montero[2], Filipe S. M. Guimarães[2], Sascha Brinker[2], Samir Lounis[2], Stuart S. P. Parkin[1], and Paolo Sessi[1] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, Jülich, Germany

Magnetic impurities coupled to superconducting condensates induce sharp in-gap resonances, the so-called Yu-Shiba- Rusinov (YSR) states. By reducing the distance between impurities, YSR quasiparticles can interact, hybridize, and eventually form bands. Here, we scrutinize the behavior of 3d atoms coupled to niobium by scanning tunneling microscopy and spectroscopy. We demonstrate how the coupling between spins and a superconducting condensate hosting an anisotropic Fermi surface can be tuned by varying the direction and distance between the impurities. We verify the existence of long range coupling as well as the crossing through a quantum phase transition, providing a promising platform for the emergence of topological superconductivity.

Invited Talk TT 16.5 Thu 11:30 H5

Yu-Shiba-Rusinov states and ordering of magnetic Impurities near the boundary — •Jelena Klinovaja — University of Basel, Basel, Switzerland

In my talk, I will discuss properties of one and two magnetic impurities near the boundary of a one-dimensional nanowire in proximity to a conventional s-wave superconductor. We showed that the energies of the subgap states, supported by the magnetic impurities, are strongly affected by the boundary for distances less than the superconducting coherence length. When the impurity is moved towards the boundary, multiple quantum phase transitions periodically occur in which the parity of the superconducting condensate oscillates between even and odd. The magnetic ground-state configuration of two magnetic impurities depends not only on the distance between them, but also explicitly on their distance away from the boundary of the nanowire. As a consequence, the magnetic ground state can switch from ferromagnetic to antiferromagnetic while keeping the interimpurity distance unaltered by simultaneously moving both impurities away from the boundary.

[1] O. Deb, S. Hoffman, D. Loss, and J. Klinovaja, Phys. Rev. B 103, 165403 (2021). [2] H. Ding, Y. Hu, M. T. Randeria, S. Hoffman, O. Deb, J. Klinovaja, D. Loss, and A. Yazdani, Proc. Natl. Acad. Sci. USA 118, 14 (2021). [3] S. Hoffman, J. Klinovaja, T. Meng, and D. Loss, .Phys. Rev. B 92, 125422 (2015). [4] T. Meng, J. Klinovaja, S.

Hoffman, P. Simon, and D. Loss, Phys. Rev. B 92, 064503 (2015).

TT 16.6 Thu 12:00 H5

Temperature-Dependent Spin Transport and Current- Induced Torques in Superconductor-Ferromagnet Heterostructures — •Manuel Müller[1,2], Lukas Liensberger[1,2], Luis Flacke[1,2], Hans Huebl[1,2,3], Akashdeep Kamra[4], Wolfgang Belzig[5], Rudolf Gross[1,2,3], Mathias Weiler[1,2,6], and Matthias Althammer[1,2] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik- Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [4]Norwegian University of Science and Technology, Trondheim, Norway — [5]Physik-Department, Universität Konstanz, Konstanz, Germany — [6]Fachbereich Physik, TU Kaiserslautern, Kaiserslautern, Germany

Proximity effects at superconductor(SC)/ferromagnet(FM) interfaces provide novel functionality in superconducting spintronics. We investigate the injection of spin currents in NbN/permalloy (Py) heterostructures with and without a Pt spin sink layer. Spin currents are excited by broadband ferromagnetic resonance in the Py-layer coupled inductively to a coplanar waveguide and quantitative information on the spin current physics is obtained by measuring the complex microwave transmission as a function of temperature. Our findings, reveal the symmetry and strength of spin-to-charge current conversion in SC/FM heterostructures and provide guidance for future superconducting spintronics devices. Our results are published in Phys. Rev. Lett. **126**, 087201 (2021). We acknowledge financial support by the DFG.

Invited Talk TT 16.7 Thu 12:15 H5

Resonance from antiferromagnetic spin fluctuations for spin-triplet superconductivity in UTe2 — •Pengcheng Dai — Rice University

Superconductivity has its universal origin in the formation of bound (Cooper) pairs of electrons that can move through the lattice without resistance below the superconducting transition temperature Tc. While electron Cooper pairs in most superconductors form anti-parallel spin-singlets with total spin S = 0, they can also form parallel spin-triplet Cooper pairs with S = 1 and an odd parity wavefunction. Spin-triplet pairing is important because it can host topological states and Majorana fermions relevant for fault tolerant quantum computation. However, spin-triplet pairing is rare and has not been unambiguously identified in any solid state systems. Since spin-triplet pairing is usually mediated by ferromagnetic (FM) spin fluctuations, uranium based heavy-fermion UTe2, which has a Tc * 1.6 K, has been identified as a strong candidate for chiral spin-triplet topological superconductor near a FM instability. Here we use inelastic neutron scattering (INS) to show that superconductivity in UTe2 is coupled with a sharp magnetic excitation at the Brillouin zone (BZ) boundary near AF order, analogous to the resonance seen in other exotic superconductors. We find that the resonance in UTe2 occurs below Tc at an energy Er = 7.9kBTc. Since the resonance has only been found in spin-singlet superconductors near an AF instability, its discovery in UTe2 suggests that AF spin fluctuations can also induce spin-triplet pairing for superconductivity.