International Workshop on Superconductivity and Magnetism in Two Dimensional Films and Heterostructures, 30 August - 1 September 2023

SuperQUMAP

Funded by the European Union

Workshop organised within the programme of COST Action Superqumap, CA21144, supported by COST (European Cooperation in Science and Technology).

AIMS AND SCOPE

The discovery of superconductivity and correlated insulating states in twisted bilayer graphene has opened a flurry of activities in related van der Waals materials. Suddenly, the creation of structures consisting of single layers of different materials acquired a twist with the potential to obtain highly tunable and completely novel behavior. This activity suggests the idea of “designer” heterostructures, or “designer quantum materials”. By characterizing and controlling the interaction among different layers, or the interaction between monolayers and a substrate, one can envisage creating materials with certain properties. Interesting examples include strongly increased critical temperatures in FeSe or Ising superconductivity in transition metal monolayers. On the other hand, the combination of hybrid magnetic films with superconductors provides a thrust towards tunable Josephson junctions (φ and π junctions) and the realization of new magnetic devices, thanks to spin polarized sub-bands. Advances in thin film technologies are providing highly controllable situations where the superconducting order parameter is entangled with magnetic degrees of freedom. These and related activities are the arena for an interdisciplinary debate that is opening the possibility to build new superconducting devices and study new behavior in quantum materials. The workshop intends to gather scientists working in these and related fields.

Topics include (and are not limited to):

- Two-dimensional materials: superconductivity and magnetism.
- Thin film heterostructures.
- Superconductivity and magnetism in iron based materials and pnictides.
- Low carrier concentration quantum materials, heterostructures and devices.
- Junctions and Josephson physics.
- SQUID technology and applications.
- Novel developments in thin film deposition.
- Spin orbit and Rashba physics.
- Density functional calculations of interfaces and quantum materials.
- Photoemission and normal state property measurements.

- Advanced techniques: nanoscale imaging, high pressures and strain.

THE COST ACTION SUPERQUMAP

The COST Action SUPERQUMAP is organized by researchers from all European countries and includes collaborators all over the world. Superqumap started in October 2021 and will continue until October 2026. Superqumap will significantly shape research in superconductivity by a series of instruments provided by the well proven COST Action system. These includes two meetings a year, short term scientific missions and support to attend meetings organized by other entities in the same field. The management committee includes researchers from 29 countries, which share the common goal of advancing in the objectives of the Action. The approach is completely open to any researcher that can contribute to the objectives of the Action in any country.

The Action superqumap aims to harness the results obtained recently in superconductivity and build a collaborative effort to provide radically new approaches to superconducting based quantum devices. Research has three main objectives:

· To synthesize, characterize, model and understand superconducting materials and devices using a collaborative approach including techniques and capabilities available all over Europe.

· To improve our understanding of superconductors at interfaces and in combination with other systems such as magnets and insulators.

· To achieve a disruptive advance in superconducting devices for quantum technologies.

The work is organized in three work packages, which aid to shape the meetings and networking activities in which researchers mutually benefit from complementary knowledge to advance in the objectives of the Action.

· Work package 1: Quantum materials

o Obtain topological and triplet superconductivity by tuning correlations and the properties at interfaces.

o Understand the relationship between electronic correlations, magnetism and unconventional superconducting properties.

· Work package 2: New functionalities for sensors and devices

o Control the degree of disorder in low dimensional and low carrier density superconductors.

o Achieve a better understanding of electronic behaviour between the extreme limits of infinity and zero resistance.

o Understand transport in hybrid magnetic-superconducting devices and explore the behaviour of junctions made of hybrid heterostructures.

· Work package 3: Building Quantum Systems.

o Create and characterize novel two-level systems in superconducting junctions and devices suitable for quantum computation.

o Design and test methods for their coherent manipulation in quantum devices.

Everyone interested in contributing to the objectives of the Action is cordially invited to join us. Participation is very easy. First by joining a working group, which will allow us to keep you updated. Then, by attending one of our workshops, schools or conferences, by organizing a short term visit or by disseminating the results obtained in the field of the Action. Other, equally important, initiatives include dissemination activities, such as the promotion of books, both scientific and for the general public and the dissemination of our results.

Programme

Tues. 29th Aug.		Weds. 30th Aug.		Thurs. 31st Aug.	Fri. 1st Sept.
	8:50	*Welcome*			
		1) Unconventional Superconductors		**5) 2D Magnetism & Spin Dynamics**	**8) Superconductivity in Heterostructures**
	9:00	Hermann Suderow		Milorad Milošević	Peter Liljeroth
	9:25	Alix McCollam		José Baldovi	Annica Black-Schaffer
	9:50	Chris Bell		Saroj Dash	José Lado
	10:15	Irina Grigorieva		Kousik Bagani	Jose Martinez Castro
	10:40	Charles Tam		Michal Vališka	Alina Ionescu
	11:05	Coffee		Coffee	Coffee
		2) Spin Control		**6) Novel Techniques & Structures**	**9) High Field Superconductivity**
	11:25	Angela Wittmann		Daniele Fausti	Shu Suzuki
	11:50	Joaquin Fernández-Rossier		Viktor Kabanov	Tomas Samuely
	12:15	Juan José Palacios		Raivo Stern	Anna Böhmer
	12:40	Abdou Hassanien		Jeremy Good	***Concluding Remarks***
	13:05	Lunch		Lunch (13:05 -14:05)	Lunch
Arrival		**3) Vortex pinning & Dynamics**	**14:15-17:30**	Excursion	**Departure (14:20)**
	14:20	Vadim Geshkenbein			
	14:45	Christoph Strunk			
	15:10	Wolfgang Lang			
	15:35	Adrian Crisan	17:30	Coffee	
	16:00	Coffee		**7) Young Researcher Session**	
			17:40	Lucas Baldo	
		4) Superconducting Devices	17.52	Diego López-Alcala	
	16:20	Francesco Tafuri	18.04	Hisakazu Matsuki	
	16:45	Gavin Burnell	18:16	Lukas Nulens	
	17:10	Szabolcs Csonka	18:28	Ignacio Sardinero Sánchez	
	17:35	Ling Hao	18:40	Katja Wurster	
19:00-22:00 Dinner	18:00-20:00	Dinner	19:00-21:00	Conference Dinner	
	20:00-22:00	Poster Session			

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International Workshop on Superconductivity and Magnetism in Two Dimensional Films and Heterostructures - Programme Summary

University of Bath, 30th Aug. – 1st Sept. 2023

Tuesday 29th August

Arrival Day

19:00-22:00 Dinner in The Lime Tree Restaurant

Wednesday 30th August

8:50-09:00 *Welcome* (East Building EB1.1)

Session 1 Unconventional Superconductors (East Building EB1.1)

Chair: Simon Bending

9:00-9:25 S1.1 Herman Suderow: *Visualizing electronic correlations in quantum materials at very low temperatures*

9:25-9:50 S1.2 Alix McCollam: *Fermi surfaces and electronic structure of uranium-based superconductors*

9:50-10:15 S1.3 Christopher Bell: *Controlling The Crystal Structure Of Elemental Uranium Thin Films*

10:15-10:40 S1.4 Irina Grigorieva: *Magnetic-field induced phase transition in centrosymmetric superconductor PdBi2*

10:40-11:05 S1.5 Charles Tam: *Recent progress in x-ray scattering on infinite-layer Nd1-xSrxNiO2*

11:05-11:25 Coffee Break

Session 2 Spin Control (East Building EB1.1)

Chair: Milorad Milosevic

11:25-11:50 S2.1 Angela Wittmann: *Controlling spin at hybrid molecule magnetic interfaces*

11:50-12:15 S2.2 Joaquin Fernández-Rossier: *Strong magnetic proximity effect in Van der Waals heterostructures driven by direct hybridization*

12:15-12:40 S2.3 Juan José Palacios: *Non-equilibrium spin accumulation and magneto-conductance in chiral systems from density-functional & group theory*

12:40-13:05 S2.4 Abdou Hassanien: *Delocalized Spin States at Zigzag Termini of Graphene Nanoribbon*

13:05-14:20 Lunch in East Building L0 Lobby

Session 3 Vortex Pinning & Dynamics (East Building EB1.1)

Chair: Gavin Burnell

14:20-14:45 S3.1 Vadim Geshkenbein: *Superconducting Diodes, Surface Barriers and Critical States of Atomically Thin Superconductors*

14:45-15:10 S3.2 Christoph Strunk: *Supercurrent diodes based on spin-orbit interaction in ballistic Josephson Junctions*

15:10-15:35 S3.3 Wolfgang Lang: *Reentrant Zero Resistance and Ordered Bose Glass of Vortices In Defect-engineered YBCO Thin Films*

15:35-16:00 S3.4 Adrian Crisan: *AC and DC Magnetic Response of CaKFe4As4 and EuRbFe4As4 Single Crystals*

16:00-16:20 Coffee

Session 4 Superconducting Devices (East Building EB1.1)

Chair: Jason Robinson

16:20-16:45 S4.1 Francesco Tafuri: *Ferromagnetic Josephson Junctions: Properties for Potential Applications In Quantum Circuits*

16:45-17:10 S4.2 Gavin Burnell: *Josephson Junctions with Perpendicularly Magnetic Anisotropy Barriers*

17:10-17:35 S4.3 Szabolcs Csonka: *Investigation of graphene-based multi-terminal Josephson junctions*

17:35-18:00 S4.4 Ling Hao: *NanoSQUIDs, SLUG and Graphene for Quantum Applications*

18:00-20:00 Dinner in The Lime Tree Restaurant

20:00-22:00 Poster Session (East Building L1 Foyer)

Posters (In addition see talks in S7 Young Researcher Session which will also be presented as posters)

P1 Syed Akbar: *Thin Film Uranium Germanides*

P2 Johnathan Bressler: *Tunneling into graphene proximitized by NbSe2 at strong in plane magnetic field*

P3 Pablo García Talavera: *Superconducting gap of PtPb4*

P4 Celia González Sánchez: *Fabrication of Hybrid van der Waals Josephson Junctions based on NbSe2*

P5 Xiaodong Hu: *Spin Transport through superconductor / Weyl semimetal heterodevices*

P6 Qiaodong Sun: *Electric control of spin supercurrents in hybrid Rashba structures*

P7 Ignazio Vacante: *Effect of a single impurity in a finite length Graphene Josephson Junction*

P8 Vincenzo Varrica: *Circuit Quantum Electrodynamics with two-dimensional materials-based devices*

P9 Sijie Wang: *Near-absolute spin-valve effect at f-orbital magnet/superconductor interfaces with controlled orbital-to-spin moments*

P10 Jiahui Xu: *Towards quantum transport in metal and ferromagnetic semiconductor thin films structures with absorbed chiral molecules*

P11 Junyi Zhao: *Nonreciprocal Edge Transport in Superconducting Devices with Magnetic Control*

Thursday 31st August

Session 5 2D Magnetism & Spin Dynamics (East Building EB1.1)

Chair: Angela Wiittmann

9:00-9:25 S5.1 Milorad Milošević: *From magnonics to neuromorphic computing in magnetic 2D materials*

9:25-9:50 S5.2 José J Baldoví: *Engineering Spin Excitations In 2D Magnetic Materials*

9:50-10:15 S5.3 Saroj Dash: *Emergent Spin Phenomena in 2D Quantum Materials and Magnetic Heterostructures*

10:15-10:40 S5.4 Kousik Bagani: *Layer dependent magnetization in 2D vdW Cr2Ge2Te6*

10:40-11:05 S5.5 Michal Vališka: *Dramatic Elastic Response Near the Critical End Point of the Itinerant Metamagnets*

11:05-11:25 Coffee

Session 6 Novel Techniques & Structures (East Building EB1.1)

Chair: Wolfgang Lang

11:25-11:50 S9.1 Daniele Fausti: *Quantum spectroscopies for quantum materials*

11:50-12:15 S9.2 Viktor Kabanov: *Dynamics of resistive state in thin superconducting channels*

12:15-12:40 S9.3 Raivo Stern: *NMR In Studies of 2D Quantum Magnets: Examples of SrCu2(BO3)2 & BaCuSi2O6*

12:40-13:05 S9.4 Jeremy Good: M*illikelvin and High Field Platforms for 2D Research*

13:05-14:05 Lunch in East Building L0 Lobby

14:15-17:30 ***Conference Excursion: Guided walking tour of Bath.*** **Coach departs from East Building.**

17:30-17:40 Coffee

Session 7 Young Researcher Session (also presenting posters) (East Building EB1.1)

Chair: Joe Wilcox

17:40-17:52 S7.1 Lucas Baldo Mesa Casa: *Defect-induced band restructuring and length scales in twisted bilayer graphene*

17:52-18:04 S7.2 Diego López-Alcalá: *Exploring Spin-phonon Coupling In Magnetic 2D Metal-Organic Frameworks*

18:04-18:16 S7.3 Hisakazu Matsuki: *Absolute superconducting spin switch with spin-orbit coupling*

18:16-18:28 S7.4 Lukas Nulens: *Catastrophic magnetic flux avalanches in NbTiN superconducting resonators*

18:28-18:40 S7.5 Ignacio Sardinero Sánchez: *Topological Superconductivity In a Magnetic-texture Mediated Josephson Junction*

18:40-18:52 S7.6 Katia Wurster: *YBCO Heterostructures for SQUID-on-Si-Lever*

19:00-21:00 Conference Dinner in The Edge Restaurant

Friday 1st September

Session 8 Superconductivity in Heterostructures (East Building EB1.1)

Chair: Sara Dale

9:00-9:25 S8.1 Peter Liljeroth: *Artificial topological superconductors and heavy fermion systems in heterostructures of 2D materials*

9:25-9:50 S8.2 Annica Black-Schaffer: *Flat Bands and Superconductivity In Graphene Systems*

9:50-10:15 S8.3 José Lado: *Moiré-enabled topological superconductors and impurity spectroscopy in twisted van der Waals heterostructures*

10:15-10:40 S8.4 Jose Martinez Castro: *One-dimensional topological superconductivity in a van der Waals heterostructure*

10:40-11:05 S8.5 Alina Marinela Ionescu: *Tuning the Properties of YBa2Cu3O7-x /Ferromagnet Heterostructures*

11:05-11:25 Coffee

Session 9 High Field Superconductivity (East Building EB1.1)

Chair: Alina Marinela Ionescu

11:25-11:50 S6.1 Shu Suzuki: *Fulde-Ferrel-Larkin-Ovchinnikov state in a superconducting thin film attached to a ferromagnetic cluster*

11:50-12:15 S6.2 Tomas Samuely: *Ising Superconductivity In Misfit Layer Compounds*

12:15-12:40 S6.3 Anna Böhmer: *Tuning Complex Magnetism of 122-type Iron-based Superconductors and Related Compounds via Interlayer Distance*

12:40-13:05 S6.4 ***Concluding Remarks***

13:05-14:20 Lunch in East Building L0 Lobby

14:20-Onwards Departure

SESSION 1 UNCONVENTIONAL SUPERCONDUCTORS

1 - Image available at: http://webs.fmc.uam.es/hermann.suderow/

Herman Suderow

Universidad Autonoma de Madrid, Spain

Visualizing electronic correlations in quantum materials at very low temperatures

1Departamento de Física Teórica de la Materia Condensada, Instituto Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049 Madrid, Spain

**Presenting author:* Hermann.suderow@uam.es

In this talk I will review recently acquired experimental possibilities of cryogenic Scanning Tunneling Microscopy, which include a very high resolution in energy and the capability to cleave in-situ at low temperatures ultra high-quality single crystals. I will discuss the discovery of two-dimensional heavy fermions (2DHF) made of 5f electrons with an effective mass 17 times the free electron mass. These 2DHF present quantized states at terraces. The energy separation between quantized levels is of a fraction of a meV and the level width is set by the interaction with correlated bulk states [1]. Interestingly, we find a new connection between bulk and surface features, which shows that the surface can be used as a powerful probe to address pressing questions about electronic correlations, such as the hidden order problem of URu2Si2. Finally, I will also describe recent work in the layered type-II Weyl semimetal WTe2.

[1] Quantum-well states at the surface of a heavy-fermion superconductor, Edwin Herrera, Isabel Guillamón, Víctor Barrena, William J. Herrera, Jose Augusto Galvis, Alfredo Levy Yeyati, Ján Rusz, Peter M. Oppeneer, Georg Knebel, Jean Pascal Brison, Jacques Flouquet, Dai Aoki & Hermann Suderow, Nature 616, pp 465–469 (2023).

2 - Image available at: https://www.ucc.ie/en/physics/people/academicstaff/

Alix McCollam

University College Cork, Ireland

Fermi surfaces and electronic structure of uranium-based superconductors

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**Presenting author:* amccollam@ucc.ie

Lifshitz transitions of the Fermi surface are increasingly being recognised as significant in a wide variety of strongly correlated and topological materials, and understanding the origin and influence of Lifshitz transitions has led to deeper understanding of key aspects of magnetic, transport or quantum critical behaviour [1-11].

In the ferromagnetic superconductor UCoGe, a magnetic field applied along the *c*-axis induces a series of anomalies in both transport and thermopower that may be caused by Lifshitz transitions [12]. A need to understand the close relationship between magnetism, superconductivity and the heavy electron Fermi surface in this material makes it important to explore if and why a series of magnetic-field-induced Lifshitz transitions occur.

I will present the results of magnetic susceptibility measurements of UCoGe, performed at temperatures down to 45 mK and magnetic fields (B//c) up to 30 T. We observe a series of clearly-defined features in the susceptibility, and multiple sets of strongly field-dependent de Haas-van Alphen oscillations, from which we extract detailed field-dependence of the quasiparticle properties. We complement our experimental results with DFT bandstructure calculations, and include a simple model of the influence of magnetic field on the calculated Fermi surface. By comparing experimental and calculated results, we determine the likely shape of the Fermi surface and identify candidate Lifshitz transitions that could correspond to two of the features in susceptibility [13]. I will compare our results on UCoGe to other recent Fermi surface measurements of UPt3 [7] and UTe2 [14], and discuss the evolution of the Fermi surface in connection to the development of magnetisation and superconductivity in these materials.

[1] S. Paschen et al. Nature 432, 881 (2004).

[2] P.M.C. Rourke et al. Phys Rev. Lett. 101, 237205 (2008).

[3] R. Daou et al. Phys. Rev. Lett. 96, 026401 (2006).

[4] H. Shishido et al., J. Phys. Soc. Jpn. 74, 1103 (2005).

[5] L. Jiao et al. PNAS 112, 673 (2018).

[6] S. Mishra et al. Phys. Rev. Lett. 126, 016403 (2021).

[7] A. McCollam et al. J. Phys. Condens. Matter 33, 075804 (2021).

[8] A. I. Coldea et al. npj. Quant. Mater. 4, 2 (2019).

[9] A. Jayaraman et al. Nano Lett. 21, 1221 (2021).

[10] W. Wu et al. Nat. Mater. 22, 84 (2022)

[11] A. Joshua et al. Nat. Commun. 3, 1129 (2012).

[12] G. Bastien et al., Phys. Rev. Lett. 117, 206401 (2016).

[13] R. Leenen et al. arXiv: 2304.07024 (2023).

[14] D. Aoki et al., J. Phys. Soc. Jpn. 92, 065002 (2023).

3 - Image available at: https://www.bristol.ac.uk/people/person/Chris-Bell-4d8c8f81-6429-435f-b6e5-021e7b7a19da/

Christopher Bell

University of Bristol, United Kingdom

Controlling The Crystal Structure Of Elemental Uranium Thin Films

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**Presenting author:*

From a fundamental condensed matter physics point of view, the properties of uranium are of considerable interest. The physics of uranium's 5*f* electrons is combined with large spin-orbit coupling, charge-density wave order, superconductivity and proximity-induced magnetism, to name but a few of the fascinating electronic properties found in this elemental metal. In Bristol we have the capability to grow thin films incorporating U at ambient and elevated temperatures, giving rise to samples that can be (poly)crystalline, compounds, alloys, and heterostructures. In this talk I will give an overview of some recent work using this growth chamber [1,2] and then focus on the stabilization metastable *hcp* U on Ir and Cu buffers [3]. This hcp crystal symmetry, which does not exist in the bulk of U, is of particular interest due to the enhanced spin-Hall angle theoretically predicted [4].

[1] D. Chaney *et al*., Tuneable Correlated Disorder in Alloys, Phys. Rev. Mater. **5**, 035004 (2021).

[2] E. R. Gilroy *et al*., Magnetic anisotropy in Fe/U and Ni/U bilayers, Phys. Rev. B **103**, 104426 (2021).

[3] R. Nicholls *et al*., Structure and Phase Transitions of Metastable Hexagonal Uranium Thin Films, Phys. Rev. Mater. **6**, 103407 (2022).

[4] M.-H. Wu *et al*., Spin-dependent transport in uranium, Phys. Rev. B **101**, 224411 (2020).

4 - Image available at: https://www.manchester.ac.uk/discover/news/professor-irina-grigorieva-awarded-the-2019-david-tabor-medal-and-prize/

Irina Grigorieva

University of Manchester, United Kingdom

Magnetic-field induced phase transition in centrosymmetric superconductor PdBi2

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**Presenting author:* Irina.V.Grigorieva@manchester.ac.uk

Centrosymmetric superconductor b-PdBi2 has attracted much attention recently due to its topologically nontrivial band structure and predicted multiband superconductivity. However, most studies so far – typically conducted in zero magnetic field – only detect a single s-wave gap. I will review our recent studies where we used tunnelling spectroscopy to demonstrate a magnetic-field driven transition from s-wave superconductivity in low magnetic field to unconventional pairing and a nodal gap in parallel magnetic fields above ~0.2T. Our theory shows that the transition is associated with local breaking of the inversion symmetry and the associated reconstruction of the electronic bands in magnetic field.

Charles Tam

University of Bristol

Recent progress in x-ray scattering on infinite-layer $Nd_{1-x}Sr_xNiO_2$

Charles Tam[1,2*], Jaewon Choi[2], Xiang Ding[3], Liang Qiao[3], and Ke-Jin Zhou,[2]

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Since their experimental realisation in 2019 [1] infinite-layer nickelates have emerged as a new route to study unconventional superconductivity. From the 2D planes of NiO_2 formed of spin ½ Ni^{1+} $3d^9$ ions, the Ni $3d_{x^2-y^2}$ band at the Fermi level, and strong superexchange evidenced by collective spin excitations in the undoped parent compound [2], it is tempting to draw analogies to the cuprate family of high T_c superconductors. However, progress has been limited by challenging material growth. For example, superconductivity has only yet been achieved in 10 nm thin films. While this has limited many experimental probes, resonant inelastic x-ray scattering has proved to be a powerful tool to probe the electronic structure and collective excitations. Here we present resonant inelastic x-ray scattering measurements on infinite layer nickelates, and demonstrate the presence of a lattice symmetry-breaking modulation characteristic of a charge density wave (CDW) in the undoped parent compound [3], potentially further highlighting similarities with the cuprates. Next, we show effect of growth conditions on the normal state CDW signals and the collective spin excitations. Finally, we show the superconducting state is very sensitive to growth conditions, and corresponds to a narrow region of intercalated hydrogen concentration [4]. These results highlight the sensitivity of the normal and superconducting state to growth conditions.

[1] D. Li *et al.* Nature **514** 624-627 (2019).

[2] H. Lu *et al.* Science **373** 213-216 (2021).

[3] C. C. Tam *et al.*, Nature Materials **21** 1116-1120 (2022).

[4] X. Ding, C. C. Tam *et al.*, Nature **615**, 50-55 (2023).

SESSION 2 SPIN CONTROL

5 - Image available at: https://wittmann-lab.uni-mainz.de/team-2/

Angela Wittmann

Johannes Gutenberg University Mainz, Germany

Controlling spin at hybrid molecule magnetic interfaces

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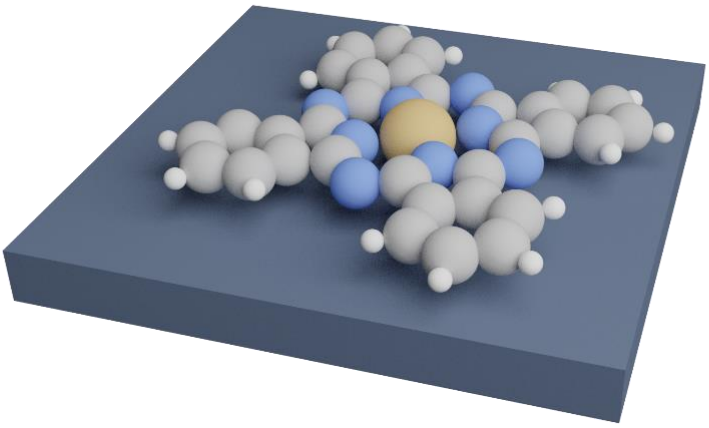
Molecules offer a unique way of controlling and varying the structure at the interface making it possible to precisely tune the underlying interactions and hybridization at the interface by molecular design. There is a growing interest in utilizing the distinctive material properties of organic semiconductors for spintronic applications. In our work, we explore the injection of a pure spin current from a ferromagnetic thin film into a small molecule. We show that both the spin injection efficiency at the interface and the spin diffusion length can be tuned sensitively by the interfacial molecular structure and side chain substitution of the molecule [1].

Recently, chiral molecules have gained significant interest in the context of the highly efficient chiral-induced spin selectivity effect. This highly intriguing phenomenon allows for manipulation of the spin state of charge carriers without the need for magnetic materials or heavy elements with strong atomic spin-orbit coupling. The two recently studied phenomena based on chiral-induced spin selectivity are the chirality-dependent transmission of spins through chiral molecules and the enantiomer-specific adsorption and chirality-dependent induced magnetization upon adsorption of chiral molecules on metal thin films [2]. Here, we show signatures of spin filtering in the spin-to-charge conversion in hybrid non-magnetic chiral molecule/metal thin film structures.

The targeted tunability of the properties at hybrid molecule magnetic interfaces enables the development of novel materials systems and devices tailor-made for specific applications.

[1] A. Wittmann *et al.*, Phys. Rev. Lett. **124**, 027204 (2020).

[2] M. Ozeri *et al.*, J. Phys. Chem. Lett **14**, 48 (2023).



6 - Image available at: https://www.thegraphenecouncil.org/blogpost/1501180/370608/University-of-Alicante-researchers-are-part-of-an-international-team-who-have-created-the-world-s-strongest-nanomagnet

Joaquin Fernández-Rossier

International Iberian Nanotechnology Laboratory (INL), Portugal

Strong magnetic proximity effect in Van der Waals heterostructures driven by direct hybridization

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**Presenting author:* Joaquin.fernandez-rossier@email.com

We propose[1] a new class of magnetic proximity effects based on the spin dependent hybridization between the electronic states at the Fermi energy in a non-magnetic conductor and the narrow spin split bands of a ferromagnetic insulator. Unlike conventional exchange proximity, we show this hybridization proximity effect has a very strong influence on the non-magnetic layer and can be further modulated by application of an electric field. We use DFT calculations to illustrate this effect in graphene placed next to a monolayer of CrI3, a ferromagnetic insulator. We find strong hybridization of the graphene bands with the narrow conduction band of CrI3 in one spin channel

only. We show that our results are robust with respect to lattice mismatch and twist angle variations. Furthermore, we show that an out-of-plane electric field can be used to modulate the hybridization strength, paving the way for applications.

[1] Strong magnetic proximity effect in Van der Waals heterostructures driven by direct hybridization

C Cardoso, AT Costa, AH MacDonald, J Fernández-Rossier, arXiv preprint arXiv:2305.16813

7 - Image available at: https://sites.google.com/site/palaciosjuanjose

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Non-equilibrium spin accumulation and magneto-conductance in chiral systems from density-functional & group theory

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It is theoretically well established that a spin-dependent electron transmission generally appears in chiral systems, even without magnetic components, as long as a strong spin-orbit coupling is present in some of its elements [1]. However, how this translates into the out-of-equilibrium chirality-induced spin selectivity, which is experimentally measured in a variety of systems, is still debated. Aided by non-equilibrium DFT-based quantum transport calculations, here we show that, when spatial symmetries that forbid a finite spin polarization in equilibrium are broken, a net spin accumulation appears at finite bias in an arbitrary two-terminal nanoscopic device (nanojunction). Furthermore, when a suitably magnetized detector is introduced in the system, the net spin accumulation, in turn, translates into a finite magneto-conductance. The symmetry prerequisites are mostly analogous to those for the spin polarization [1], with the vectorial nature given by the direction of magnetization. Implications for two-dimensional and bulk crystals will also be discussed.

[1] W. Dednam, M.A. García-Blázquez, L.A. Zotti, E.B. Lombardi, C. Sabater, S. Pakdel, J.J. Palacios, ACS Nano 17 (2023) 6452-6465.

Delocalized Spin States at Zigzag Termini of Graphene Nanoribbon

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The zigzag termini of armchair graphene nanoribbon offer unique advantages such as selective site functionalization, quantum magnetism and to tune the bonding of ribbon to external electrical leads. In the pristine form, these edges are expected to be spin active, however, due to passivation with hydrogen atoms, the magnetic states are quenched. Here we describe a methodology to revive edge states magnetism and explore the many-body interaction of delocalized π electrons. These findings highlight a possibility of inducing magnetic ordering in passivated GNR by de-hydrogenation of atoms at the peripheries of zigzag termini.

SESSION 3 VORTEX PINNING & DYNAMICS

8 - Image available at: https://itp.phys.ethz.ch/people/professors/geshkenbein.html

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Vadim Geshkenbein

ETH

Superconducting Diodes, Surface Barriers and Critical States of Atomically Thin Superconductors

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A superconducting diode carries dissipationless supercurrents in one direction, but resistive normal currents at finite voltages in the opposite direction, a phenomenon that occurs when the critical current is different in magnitude depending on the polarity, . They offer perfect voltage rectification if an alternating current of magnitude between these values is applied.

Despite the similar names coined, diodes and SC diodes have key symmetry differences due to their vastly different microscopic physics. Superconductors carry currents without voltage gradients, hence a time reversal operation reverts the current flow even when all spatial mirror symmetries that map are broken. Time-reversal can be readily broken by any (residual) magnetic field or magnetic order in the material.

Magnetic and transport properties of atomically thin superconductors are of great interest, especially since the advent of van der Waals technology. In a perpendicular magnetic field H, the magnetic response of these superconductors is characterized by the Pearl length $\lambda_\perp = \lambda^2/d$. For atomically thin films, this penetration depth can easily exceed the sample width, allowing the magnetic field to fully penetrate inside the system. The critical state of these novel superconductors differs significantly from the well-know Bean state describing their bulk counterparts. The critical current $I_c(H)$ is determined by a surface barrier at low fields, where it decreases linearly with the magnetic field. At high fields, pinning from material inhomogeneities plays an important role and $I_c(H)$ decays to a constant value given by the bulk depinning current I_p. In symmetric samples, the critical current displays a sharp triangular peak at H = 0. In novel engineered devices whose edges are purposefully crafted to create asymmetric surface barriers, on the contrary, this peak shifts to a finite field value H_{max}, giving rise to nonreciprocal transport and powerful superconducting diode effects[1,2].

Beyond criticality, the current distribution inside the superconductor rearranges to keep the electric field homogeneous, creating a finite voltage across the sample. Decreasing the applied current, the superconductor remains in the dissipative state until $I \approx I_p$, explaining the hysteretic behavior of recent experimental IV scans[1].

[1] Y. Hou, et al., Ubiquitous superconducting diode effect in superconductor thin films. https://arxiv.org/abs/2205.09276 (2022).

[2] O. V. Dobrovolskiy, et al. Ultra-fast vortex motion in a direct-write Nb-C superconductor, *Nat Commun* **11**, 3291 (2020).

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9 - Image available at: https://www.uni-regensburg.de/physik/fakultaet/studium/forschungsstudiengang/kontakt/index.html

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Supercurrent diodes based on spin-orbit interaction in ballistic Josephson junctions

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The recent discovery of intrinsic supercurrent diode effect [1], and its prompt observation in a rich variety of systems, has shown that nonreciprocal supercurrents naturally emerge when both space- and time-inversion symmetries are broken. In Josephson junctions, the presence of the diode effect depends on the content of higher harmonics in the current phase relation and the magnitude of the anomalous phase shift defined by I will report on both dc and ac-manifestations of the Josephson diode effect in the non-linear inductance in planar Josephson junctions, based on a ballistic Al/InAs-heterostructure that is exposed to an in-plane magnetic field Bip [2]. At low Bip a non-reciprocal term is found in the induc-tance that is linear in Bip. At higher Bip a sign reversal of the magnetochiral term is observed that can be traced back to a 0-p-like transition in the current-phase relation [3]. We demonstrate that diode effect and - phase shift occur together and can be controlled by electrostatic gating.

[1] F. Ando et al., Nature 584, 373 (2020).

[2] C. Baumgartner et al., Nature Nanotech. **17**, 39 (2022).

[3] C. Baumgartner et al., arXiv:2212.13460.

10 - Image available at: https://homepage.univie.ac.at/wolfgang.lang/

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Reentrant Zero Resistance And Ordered Bose Glass Of Vortices In Defect-engineered Ybco Thin Films

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Many advanced superconducting thin film applications demand the creation of topological nanostructures, such as artificial pins for Abrikosov vortices. Ultradense patterns of such pinning sites can be fabricated by scanning the focused beam of a helium-ion microscope over the surface of epitaxially-grown thin $YBa_2Cu_3O_{7-\delta}$ (YBCO) films [1]. This process generates columns of point defects to suppress superconductivity locally. The method overcomes the severe constraints of traditional lithographic techniques while preserving the crystallographic framework of the material.

The present ~10 nm resolution of this technique is demonstrated by ultradense pinning landscapes with magnetic commensurability fields up to 6 T that can be observed over a wide temperature range from the onset of the superconducting transition down to 2 K. Moreover, a reentrant zero-resistance state and a method for estimating the pinning force of an individual vortex will be discussed.

Because YBCO thin films have disordered strong intrinsic pinning, adding an ultradense periodic array of designed pinning centers gives rise to a novel topological phase, recently uncovered as the ordered Bose glass of vortices [2]. It can emerge from a vortex Mott insulator when thermal energy and disorder weaken the vortex correlations. The voltage-current isotherms reveal critical behavior and scale in the vicinity of the second-order glass transition. The latter exhibits a distinct peak in melting temperature at the magnetic commensurability field, as well as a sharp rise in the lifetime of glassy fluctuations. Angle-dependent magnetoresistance measurements in constant Lorentz force geometry [3] unveil a substantial increase of anisotropy compared to a pristine reference film when the density of vortices matches those of the columnar defects. Then, only the magnetic-field component parallel to the columnar defects dominates the pinning, revealing its one-dimensional nature. These findings affirm the concept of an ordered Bose glass phase.

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[1] B. Aichner, B. Müller, M. Karrer, V.R. Misko, F. Limberger, K.L. Mletschnig, M. Dosmailov, J.D. Pedarnig, F. Nori, R. Kleiner, D. Koelle, W. Lang, ACS Appl. Nano Mater., **2** (2019) 5108.

[2] L. Backmeister, B. Aichner, M. Karrer, K. Wurster, R. Kleiner, E. Goldobin, D. Koelle, W. Lang, Nanomaterials **12** (2022) 3491.

[3] B. Aichner, L. Backmeister, M. Karrer, K. Wurster, R. Kleiner, E. Goldobin, D. Koelle, W. Lang, Condens. Matter. **8** (2023) 32.

AC and DC Magnetic Response of $CaKFe_4As_4$ and $EuRbFe_4As_4$ Single Crystals

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The newly discovered *AeA*Fe_4As_4 (where *Ae* is an alkali-earth metal and *A* is an alkali metal) superconductors, also named 1144 family, raised great interest due to some extraordinary properties, like very high critical currents and upper critical fields coupled with quite high critical temperature, multi-component superconductivity, low anisotropy. One of the most studied example is $CaKFe_4As_4$, in which, apart from the above-mentioned properties, it was estimated a very high pinning potential [1] at the liquid hydrogen temperature (envisaged for applications in the future hydrogen economy) and a very steep melting line [2]. A remarkable member of the 1144 family is $CaKFe_4As_4$, which, after a superconducting transition at about 36 K, has a magnetic transition at 15 K, hense a clear coexistence of superconductivity and magnetism. We have used *Quantum Design* PPMS and SQUID MPMS systems to measure the temperature dependence of DC and multi-harmonic AC susceptibility in various DC magnetic fields, magnetization relaxation, and magnetic hysteresis loops. We will present the results of the above measurements, determine some important properties from such measurements and, finally, will make a comparison between the two compositions.

[1] A.M. Ionescur, I. Ivan, D.N. Crisan, A. Galluzzi, M. Polichetti, S. Ishida, A. Iyo, H. Eisaki and A. Crisan, Sci. Rep., 12 (1), (2022) 19132.

[2] I. Ivan, A.M. Ionescu, D.N. Crisan and A. Crisan, Int. J. Mol. Sci., 24 (9), (2023) 7896.

SESSION 4 SUPERCONDUCTING DEVICES

11 - Image available at: https://www.researchgate.net/profile/F-Tafuri

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Ferromagnetic Josephson Junctions: Properties for Potential Applications In Quantum Circuits

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We will report on special properties of hybrid Josephson Junctions (JJs), on how to engineer the macroscopic phase in quantum circuits, which make possible alternative layouts for the superconducting modules inside a more general architecture also through a comparative study of fluctuations and of electro-dynamical properties [1-6]. A special focus will be on junctions employing ferromagnetic barriers. Different types of ferromagnetic barriers give access to specific regimes. A phase diagram for spin nanoscale ordering at Superconductor/Ferromagnet (S/F) interfaces in magnetic JJs can be expressed in terms of the magnetic moment induced in the S-layer [3]. Our findings contribute to drive the design and the tailoring of S/F interfaces also in view of potential applications in quantum computing [1,7].

[1] H. G. Ahmad, V. Brosco, A. Miano, L. Di Palma, M. Arzeo, D. Montemurro, P. Lucignano, G. P. Pepe, F. Tafuri, R. Fazio, and D. Massarotti, Hybrid ferromagnetic transmon qubit: Circuit design, feasibility, and detection protocols for magnetic fluctuations, Phys. Rev. B 105 (2022) 214522

[2] R. Satariano, L. Parlato, A. Vettoliere, R. Caruso, H. G. Ahmad, A. Miano, L. Di Palma, D. Salvoni, D. Montemurro, C. Granata, G. Lamura, F. Tafuri, G. P. Pepe, D. Massarotti, and G. Ausanio, Inverse magnetic hysteresis of the Josephson supercurrent: study of the magnetic properties of thin Nb/Py interfaces, Phys. Rev. B 103 (2021) 224521

[3] R. Satariano, A. F. Volkov, H. G. Ahmad, L. Di Palma, R. Ferraiuolo, A. Vettoliere, C. Granata, D. Montemurro, L. Parlato, G. P. Pepe, F. Tafuri, G. Ausanio, and D. Massarotti, Nanoscale spin ordering and full spin screening in tunnel ferromagnetic Josephson Junctions, under review (2023)

[4] D. Massarotti, H.G. Ahmad, R. Satariano, R. Ferraiuolo, L. Di Palma, P. Mastrovito, G. Serpico, A. Levochkina, R. Caruso, A. Miano, M. Arzeo, G. Ausanio, C. Granata, P. Lucignano, D. Montemurro, L. Parlato, A. Vettoliere, R. Fazio, O. Mukhanov, G. P. Pepe and F. Tafuri, A feasible path for the use of ferromagnetic Josephson junctions in quantum circuits, Low Temp. Phys. 49 (2023) 871

[5] H. G. Ahmad, M. Minutillo, R. Capecelatro, A. Pal, R. Caruso, G.Passarelli, M. G. Blamire, F. Tafuri, P. Lucignano and D. Massarotti, Coexistence and tuning of spin-singlet and triplet transport in spin-filter Josephson junctions,Communications Physics 5 (2022) 2

[6] A. Vettoliere, R. Satariano, R. Ferraiuolo, L. Di Palma, H. G. Ahmad, G. Ausanio, G. P. Pepe, F. Tafuri, D. Montemurro, C. Granata, L. Parlato, and D. Massarotti, Aluminum-ferromagnetic Josephson tunnel junctions for high quality magnetic switching devices, Appl. Phys. Lett. 120 (2022) 262601

[7] H.G. Ahmad, C. Jordan, R. van den Boogaart, D.Waardenburg, C. Zachariadis, P. Mastrovito, A. Lyubenov Georgiev, D. Montemurro, G.P. Pepe, M. Arthers, A. Bruno, F. Tafuri, O. Mukhanov, M. Arzeo and D. Massarotti, Investigating the Individual Performances of Coupled Superconducting Transmon Qubits, Condensed Matter 8 (2023) 29

12 - Image available at: https://condensed-matter.leeds.ac.uk/people/gb/

Gavin Burnell

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Josephson Junctions with Perpendicularly Magnetic Anisotropy Barruers

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Josephson junctions containing ferromagnetic weak links have been of interest over the last twenty years due to the additional physics present when pair correlations from the superconductor (S)interact with the exchange field of the ferromagnet (F) and the possibility of creating equal spin, odd-frequency triplet states when the barrier is suitably engineered. In addition to the novel physics, an important potential application lies in the development of cryogenic membranes. In this talk I will present our recent work [1–3] on developing junctions with barriers with perpendicular magnetic anisotropy based on Pt/Co multilayers and ordered alloys and discuss their potential for use in cryogenic computing.

[1] N. Satchell et al., *Spin-Valve Josephson Junctions with Perpendicular Magnetic Anisotropy for Cryogenic Memory*, Appl. Phys. Lett. **116**, 022601 (2020).

[2] N. Satchell, T. Mitchell, P. M. Shepley, E. Darwin, B. J. Hickey, and G. Burnell, *Pt and CoB Trilayer Josephson $\pi $ Junctions with Perpendicular Magnetic Anisotropy*, Sci. Rep. **11**, 11173 (2021).

[3] N. Satchell, S. Gupta, M. Maheshwari, P. M. Shepley, M. Rogers, O. Cespedes, and G. Burnell, *Thin Film Epitaxial [111] Co$_{50}$Pt$_{50}$: Structure, Magnetisation, and Spin Polarisation*, Sci. Rep. **13**, 12468 (2023).

13 - Image available at: https://qi.nemzetilabor.hu/people/szabolcs-csonka

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Investigation of graphene-based multi-terminal Josephson junctions

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The Andreev spectrum of an N-terminal Josephson junction is expected to host Weyl singularities in the (N-1)-dimensional space of the individual superconducting phases, thus mimicing the band structure of topological materials [1]. Graphene is an ideal platform to realize such multiterminal junctions, where high quality Josepshon junctions can be formed in a planar geometry.

First we will show the realization of high quality graphene based Josephson junctions and characterize their behavior using CPR measurements. Afterwards, we investigate a 3-terminal Josephson junction containing hBN-encapsulated graphene as the weak link connecting the terminals. We characterize the junction by DC transport measurements and apply RCSJ simulations to understand the multi-terminal behaviour. By applying current bias to 2 different leads, we obtain a differential resistance map with several complex features and observe the

coexistence of normal and superconducting current paths in the graphene region [2,3,4].

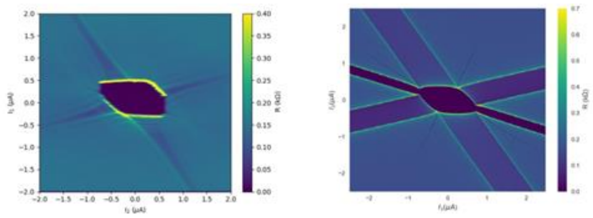
Furthermore, we perform switching current distribution measurements to probe the switching mechanism in this multiterminal system.

[1] R-P. Riwar et al. Nat. Comm. 7, 11167 (2016)

[2] G. V. Graziano et al., Phys. Rev. B 101, 054510 (2020)

[3] A. W. Draelos et al., Nano Lett. (2019)

[4] N. Pankratova et al., Phys. Rev. X 10 (2020)



14 - Figure 1: Differential resistance of a 3-terminal Josephson junction (measurement – left and simulation on the right).

15 - Image available at: https://www.npl.co.uk/people/ling-hao

Ling Hao

National Physical Laboratory

NanoSQUIDs, SLUG and Graphene for Quantum Applications

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Superconducting electronics has moved towards the nanometre scale over recent decades. The drive comes from the need for greater complexity, e.g. arrays of large number of similar (preferably identical) devices. Minimising the size of all components is the obvious route to achieving scalability and reproducibility. Second, maximising the signal amplitude at the input to a superconducting sensor often requires increasing the 'field of view' as far as possible. In many situations this means bringing the sensor as close as possible to the signal source. A third driver is the need to take superconducting sensors to higher operating frequencies, going beyond the usual 5GHz range, employed in superconducting qubits, towards millimetre wave frequencies. This is particularly significant for astronomical observations, allowing the detection of single millimetre wave photons but also allowing a search for axion dark matter to be carried to higher masses. A fourth driver has been the demonstration of Josephson junctions based on graphene barriers. This introduces a further variable which can be used to tune superconducting electronics performance, namely the control of critical current of a weak link by means of an applied electric field. In this talk we will describe how nanobridge junction fabrication by a combination of electron beam lithography and focussed ion beam has led to nanoscale very low noise devices operating at around 4K, and how these devices can impact on various quantum applications such as energy resolved single optical photon measurement, single spin detection, axion dark matter searches and neutrino mass measurement.

SESSION 5 2D MAGNETISM & SPIN DYNAMICS

16 - Image available at: https://www.uantwerpen.be/en/research-groups/cmt/more-information/

Milorad Milošević

NANOlab Center of Excellence, University of Antwerp

From magnonics to neuromorphic computing in magnetic 2D materials

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Monolayer chromium-trihalides, the archetypal two-dimensional (2D) magnetic materials, are readily suggested as a promising platform for high-frequency magnonics. In this talk, I will detail the spin-wave properties of those monolayer ferromagnets, using spin-dynamics simulations parametrized from the first principles. I will show that spin-wave dispersion can be tuned in a broad range of frequencies by strain, paving the way towards flexo-magnonic applications. Further, I will reveal that the ever-present halide vacancies in these monolayers induce surprisingly strong Dzyaloshinskii–Moriya interaction, able to scatter spin-waves, which promotes design of spin-wave guides by defect engineering. Finally, I will discuss the spectra of spin-waves propagating across a moiré-periodic modulation of magnetic parameters in a van der Waals heterobilayer, and show that the nanoscale moiré periodicities in such samples are ideal for realization of a magnonic crystal in the terahertz frequency range. Recalling the additional tunability of magnetism in 2D materials by electronic gating, our results situate these systems among the front-runners for prospective high-frequency magnonic and neuromorphic applications.

17 - Image available at: https://spainculturescience.co.uk/2d-smarties-jose-j-baldovi/

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Engineering Spin Excitations In 2D Magnetic Materials

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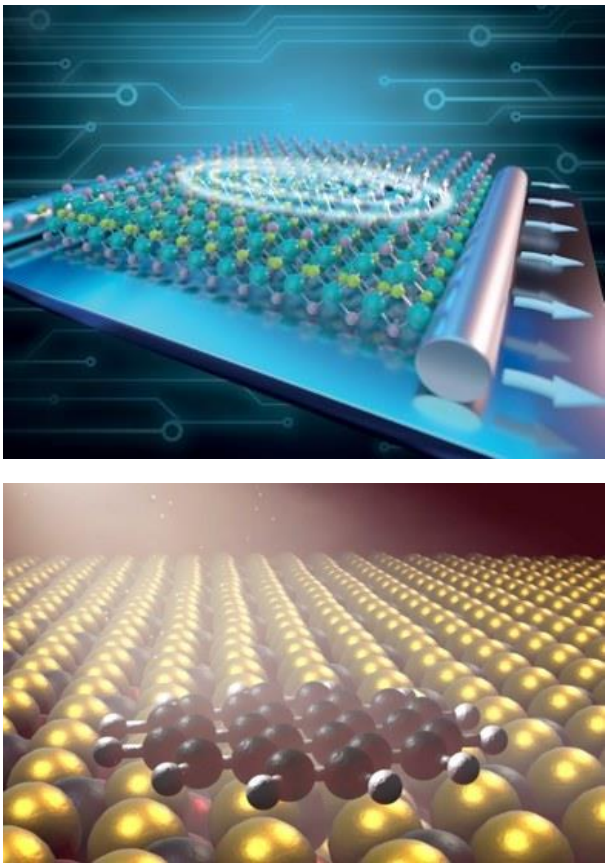
The recent isolation of two-dimensional (2D) magnets offers tantalizing opportunities for spintronics and magnonics at the limit of miniaturization.[1] Among the key advantages of atomically-thin materials are their flexibility, which provides an exciting avenue to control their properties by strain engineering, and the more efficient tuning of their properties with respect to their bulk counterparts. In this presentation we will provide an overview of our recent results on this fascinating topic. First, we will focus on the magnetic properties, magnon dispersion and spin dynamics of the air-stable 2D magnetic semiconductor CrSBr (TC = 146 K)[2] and will investigate their evolution under mechanical strain and Coulomb screening using first-principles.[3] Our results provide a deep microscopic analysis of the competing interactions that stabilize the long-range ferromagnetic order and the orientation of the spin in the monolayer.[4]

Then, we will apply our approach to some of the derivatives of the family of transition-metal phosphorus trichalcogenides and we will show the possibility of tuning spin wave transport by atomic-layer substitution, building a so-called Janus single-layer.[5] Finally, we will introduce novel hybrid molecular/2D heterostructures using sublimable organic molecules to show, as a proof-of-concept, the potential of a chemical approach for magnon spintronics applications.



18 - Fig. 1: Artistic representation of (left) strain-engineering of spin waves in single-layer CrSBr and (right) a coronene molecule on the surface of a 2D magnetic material.

[1] B. Huang, G. Clark, E. Navarro-Moratalla, D. R. Klein, R. Cheng, K. L. Seyler, E. Zhong, E. Schmidgall, M. A. McGuire, D. H. Cobden, W. Yao, D. Xiao, P. Jarillo-Herrero, X. Xu, Nature, 546 (2017) 270–273.

[2] K. Lee, A. H. Dismukes, E. J. Telford, R. A. Wiscons, J. Wang, X. Xu, C. Nuckolls, C. R. Dean, X. Roy, X. Zhu, Nano Lett., 21 (2021), 3511–3517.

[3] D. L. Esteras, A. Rybakov, A. M. Ruiz, J. J. Baldoví, Nano Lett. 22 (2022), 8771–8778.

[4] C. Boix-Constant, S. Mañas-Valero, A. M. Ruiz, A. Rybakov, K. A. Konieczny, S. Pillet, J. J. Baldoví, E. Coronado, Adv. Mater., 34 (2022), 2204940.

[5] A. M. Ruiz, D. L. Esteras, A. Rybakov, J. J. Baldoví, Dalton Trans., 51 (2022), 16818–16823.

19 - Photographer: Oscar Mattsson; Image available at: https://news.cision.com/chalmers/i/saroj-prasad-dash,c15959370

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Chalmers Univeristy of Technology, Sweden

Emergent Spin Phenomena in 2D Quantum Materials and Magnetic Heterostructures

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Two-dimensional (2D) materials and their van der Waals heterostructures represent a new platform for realizing novel charge and spin-based phenomena and device applications. While materials such as graphene are suitable for spin-polarized electron transport, magnets and materials with high spin-orbit coupling are useful for spin-polarized electron sources and their control, and semiconductors are useful for nanoscale electronics. Here, we utilized large-scale CVD graphene for spin interconnect, spin multiplexer, and multifunctional spin logic operations at room temperature [1-4]. To generate spin polarization and control, we engineered 2D material heterostructures by combining the 2D semiconductor MoS_2 and topological materials (WTe_2 and BiSbTeSe) to realize charge-spin conversion and strong proximity-induced spin-orbit coupling [5-8] and with Cr3GeTe2 for proximity magnetism [9]. We recently demonstrated that van der Waals magnet Fe5GeTe2 in heterostructures with graphene acts as efficient spin sources and detectors at room temperature [10] and spin-orbit torque using 2D magnets. These findings open a new platform for electrically creating and gate-controlling spin polarization and nanoscale transistors, providing new opportunities for all-2D heterostructure devices.

[1] Long distance spin communication in chemical vapour deposited graphene,

M.V. Kamalakar, C. Groenveld, A. Dankert, S.P. Dash,

Nature Communications 6, 6766 (2015).

[2] Robust spin interconnect with isotropic spin dynamics in chemical vapor deposited graphene layers and boundaries,

D. Khokhriakov, B. Karpiak, A.M. Hoque, B. Zhao, S. Parui, S.P. Dash,

ACS Nano 14 (11), 15864-15873 (2020).

[3] Two-dimensional spintronic circuit architectures on large scale graphene,

D Khokhriakov, B Karpiak, AM Hoque, SP Dash, Carbon 161, 892-899 (2020).

[4] Multifunctional Spin Logic Operations in Graphene Spin Circuits,

D. Khokhriakov, S. Sayed, A.M. Hoque, B. Karpiak, B. Zhao, S. Datta, S.P. Dash,

Physical Review Applied 18 (6), 064063 (2022).

[5] Electrical gate control of spin current in van der Waals heterostructures at room temperature,

A. Dankert, S.P. Dash,

Nature Communications 8, 16093 (2017).

[6] Tailoring emergent spin phenomena in Dirac material heterostructures,

D Khokhriakov, AW Cummings, K Song, M Vila, B Karpiak, A Dankert, S. Roche, S.P. Dash,

Science Advances 4:eaat9349 (2018).

[7] Gate-tunable spin-galvanic effect in graphene-topological insulator van der Waals heterostructures at room temperature, D. Khokhriakov, A.M. Hoque, B. Karpiak, S.P. Dash,

Nature Communication 11, 3657 (2020).

[8] Unconventional Charge–Spin Conversion in Weyl-Semimetal WTe2, B. Zhao, B. Karpiak, D. Khokhriakov, A. Johansson, A.M. Hoque, X. Xu, S.P. Dash,

Advanced Materials 32, 2000818 (2020).

[9] Magnetic proximity in a van der Waals heterostructure of magnetic insulator and graphene, B Karpiak, AW Cummings, K Zollner, M Vila, D Khokhriakov, AM Hoque, J. Fabian, S. Roche, S.P. Dash,

2D Materials 7 (1), 015026 (2019).

[10] Room Temperature Spin-Valve with van der Waals Ferromagnet Fe_5GeTe_2/Graphene Heterostructure,

B. Zhao, R. Ngaloy, S. Ghosh, S. Ershadrad, R. Gupta, K. Ali, A. Md. Hoque, B. Karpiak, D. Khokhriakov, C. Polley, B. Thiagarajan, A. Kalaboukhov, P. Svedlindh, B. Sanyal, S.P. Dash,

Advanced Materials, 2209113 (2023).

20 - Image available at: https://poggiolab.unibas.ch/people/kousik-bagani/

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Layer dependent magnetization in 2D vdW Cr2Ge2Te6

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Magnetism in reduced dimensions is a fascinating area of research with important implications for the development of magnetic materials and device applications ranging from magnetic storage devices to spintronics. In contrast to bulk materials, 2D materials exhibit intriguing magnetic properties due to the reduced dimensionality. After the realization of long-range ferromagnetic ordering in bilayer Cr2Ge2Te6 and monolayer CrI3, enormous research effort has been devoted to the family of 2D vdW magnetic materials [1,2]. Magnetic properties of these materials are strongly dependent on the number of layers and magnetic coupling between individual layers in vdW heterostructure can lead to the emergence of exotic magnetic phases like skyrmions or other non-collinear magnetic configurations [3].

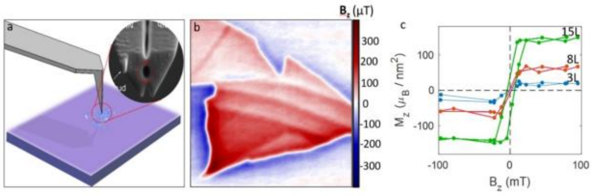
Here, we employ nanometer-scale magnetic imaging to shed light on the magnetic behavior, magnetic anisotropy, spin texture, and magnetic domain structure of a layered magnetic material. We investigate few-layer Cr2Ge2Te6 using our recently developed scanning SQUID-on-lever probe

(Figure 1a). With simultaneous topographic and magnetic imaging, we determine the number of layers and study the layer-dependent magnetization down to bilayer limit (Figure 1b). Nanoscale spatial resolution allows us to investigate domain formation and magnetic length-scales as a function of layer number. By studying local magnetic hysteresis (Figure 1c), we find a layer-dependent magnetic anisotropy in Cr2Ge2Te6.

[1] C. Gong et al. Nature **546** (2017), 265–269.

[2] B. Huang et al. Nature **546** (2017), 270–273.

[3] Y. Xu al. Nature Nanotechnology **17** (2022), 143–147.



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Michal Vališka

Charles University, Prague

Dramatic Elastic Response Near the Critical End Point of the Itinerant Metamagnets

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P. Opletal3, H. Sakai3, Y. Haga3, A. Miyata4, S. Zherlitsyn4, V. Sechovský1 and J.Prokleška1

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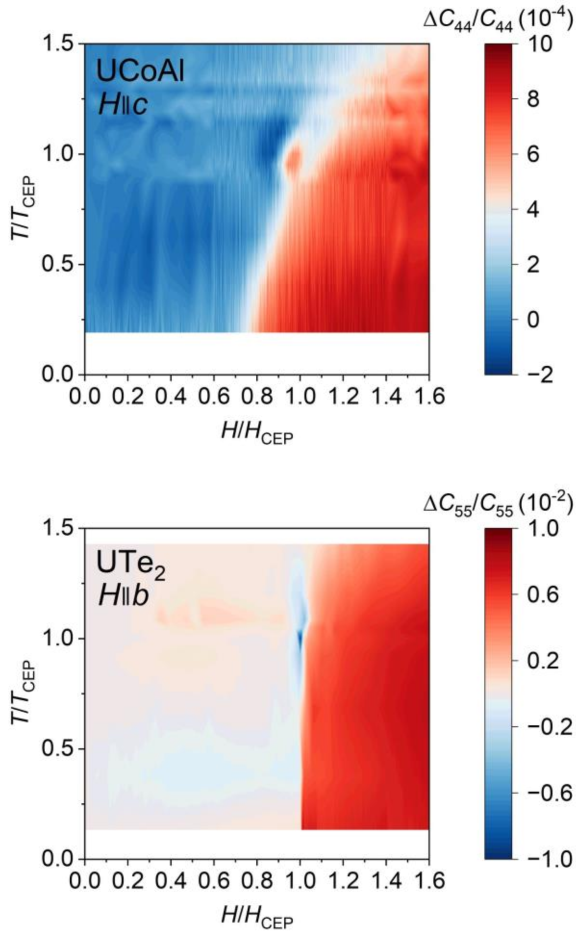
In the *H*-*T* phase diagram of itinerant metamagnets, the first-order transition line terminates at the critical end point, which is analogous to the critical point of the gas-liquid condensation line in the *p*-*T* phase diagram. An ultrasonic study of two itinerant electron metamagnets, UTe_2 and UCoAl, in magnetic fields was conducted to understand how critical magnetic fluctuations affect their crystal lattices. Sharp anomalies of the elastic constants at the critical field of the metamagnetic transition become maximized in a narrow temperature interval around 10.5 K. This temperature corresponds to the critical end point. We attribute these anomalies to lattice instabilities induced by critical magnetic fluctuations via the strong magnetoelastic interaction. The observed anisotropy of the anomaly is discussed in connection with the anisotropy of magnetic fluctuations.



22 - Colored contour plots of relative elastic constants C_{55} of UTe_2 (left panel) and C_{44} of UCoAl (right panel) in the T/T_{CEP} *-* H/H_{CEP} *phase space.*

SESSION 6 NOVEL TECHNIQUES & STRUCTURES

23 - Image available at: https://www.physik.nat.fau.de/person/daniele-fausti/

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Quantum spectroscopies for quantum materials

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The rich phase diagrams of many transition metal oxides (TMOs) is the result of the intricate interplay between electrons, phonons, and magnons. This makes TMOs very susceptible to external parameters such as pressure, doping, magnetic field, and temperature which in turn can be used to finely tune their properties. The same susceptibility makes TMOs the ideal playground to design experiments where the interaction between tailored electromagnetic fields and matter can trigger the formation of new, sometimes exotic, physical properties. This aspect has been explored in time domain studies [1] and has led to the demonstration that ultrashort mid-IR light pulses can "force" the formation of quantum coherent states in matter, disclosing a new regime of physics where thermodynamic limits may be bridged and quantum effects can, in principle, appear at ambient temperatures. In this presentation, I will review our recent results in archetypal strongly correlated cuprate superconductors and demonstrate the feasibility of a light-based control of quantum phases in real materials [2,3,4]. I will then introduce our new approaches to time domain spectroscopy going beyond mean photon number observables [5-10] and show that the statistical features of light can provide information on superconducting fluctuations beyond standard linear and non-linear optical spectroscopies[11]. Finally, I will elaborate on our current directions on leveraging both the electromagnetic field fluctuations and the strong driving of materials to control the onset of quantum coherent states in complex materials.

References:

[1] Advances in physics 65, 58-238, 2016

[2] Science 331, 189-191 (2011)

[3] Phys. Rev. Lett. 122, 067002 (2019)

[4] Nature Physics 17, 368–373 (2021)

[5] Phys. Rev. Lett. 119, 187403 (2017)

[6] New J. Phys. 16 043004 (2014)

[7] Nat. Comm. 6, 10249 (2015)

[8] PNAS March 19, 116 (12) 5383-5386 (2019)

[9] J. of Physics B 53, 145502 (2019)

[10] Optics Letters 45, 3498 (2020)

[11] Light: Science & Applications 11, # 44 (2022)

24 - Image available at: http://www-f7.ijs.si/portfolio-item/viktor-kabanov/

Viktor Kabanov

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Dynamics of resistive state in thin superconducting channels

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When a current in the thin superconducting channel exceeds its critical value, the current-voltage characteristic shows a series of steps and demonstrates hysteresis. We theoretically study how the dynamics of the resistive state in narrow superconducting channels shunted by an external resistor depends on the channel's length L, the applied current J, and parameter u characterizing the penetration depth of the electric field in the nonequilibrium superconductors[1,2]. We found out that the steps in the current-voltage characteristic can be associated with the bifurcations of either the steady state or oscillatory solution. We revealed typical bifurcations which induced the singularities in current-voltage characteristics. Our results in the range of higher currents show that these bifurcations can substantially complicate the dynamics of the order parameter and eventually lead to the appearance of such phenomena as multistability and chaos. We also demonstrate that the hysteresis loop between two different periodic solutions may be controlled by external noise or by the current pulse [3].

[1] V. V. Baranov A.G. Balanov, V.V. Kabanov Phys. Rev. B84, 094527 (2011),

[2] V. V. Baranov A.G. Balanov, V.V. Kabanov Phys. Rev. B87, 174516 (2013),

[3] J. Buh, V. Kabanov, V. Baranov, A. Mrzel, A. Kovič and D. Mihailovic, Nat. Commun. 6:10250 doi: 10.1038/ncomms10250 (2015).

25 - Image available at: https://www.researchgate.net/profile/Raivo-Stern

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NMR In Studies of 2D Quantum Magnets: Examples of SrCu2(BO3)2 & BaCuSi2O6

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The spin-dimer antiferromagnet SrCu2(BO3)2 was investigated in great detail over the past two decades, as it represents the most prominent realization of the Shastry-Sutherland lattice model. In this material, electronic spins of Cu2+ ions within the Cu2(BO3)2 layers forma lattice of mutually orthogonal spin-singlet dimers with significant interdimer interaction, giving rise to pronounced magnetic frustration. We performed NMR measurements1 in pulsed magnetic fields up to 72 T using 11B nuclei.2 We observed a transition from a high-temperature, paramagnetic state to a low-T, commensurate superstructure of field-induced spin-dimer triplets in the 1/3 magnetization plateau. Moreover, the technical approach to measure broadband NMR in pulsed magnetic fields, that was developed in the course of this work, opens the door not only to the exploration of the higher-field ground states of SrCu2(BO3)2, but also to studies of many other quantum magnets with complex interactions that stabilize new phases of matter in very strong magnetic fields.

Han Purple (BaCuSi2O6) is not only a remarkable ancient pigment, but has also served physicists as a valuable model material for studying Bose-Einstein condensation (BEC) of magnons in high magnetic fields. We have characterized the BEC phase by copper and silicon NMR at 50 mK and around 23-27 T. In parallel, we have succeeded to establish low-T structural model of BaCuSi2O6 via scattering techniques. Using these precise low-T structural data and extensive density-functional calculations, we elucidate magnetic couplings in this compound. The resulting magnetic model comprises two types of nonequivalent spin dimers, in excellent agreement with the 63,65Cu NMR data. We further argue that leading interdimer couplings connect the upper site of one dimer to the bottom site of the contiguous dimer, and not the upper-to-upper and bottom-to-bottom sites, as assumed previously. This finding is verified by inelastic neutron scattering data and implies the lack of magnetic frustration in $BaCuSi_2O_6$, thus challenging existing theories of the magnon BEC in this compound.[3] Novel $Sr_{0.1}Ba_{0.9}CuSi_2O_6$ with suppressed structural phase transition and apparently just single set of dimers at low-T is promising new exciting extension of this study.[4,5]

[1] D. Arćon, I. Heinmaa, and **R. Stern** *Low-temperature NMR: Techniques and Applications*, New Developments in NMR, **15**, Modern Methods in Solid state NMR: A Practitioner's Guide, edited by Paul Hodgkinson, 233-261 (2018).

[2] J. Kohlrautz, *et al.*, J. Magn. Reson. 271, 52 (2016).

[3] V.V.Mazurenko, M.V.Valentyuk, **R.Stern**, A.A.Tsirlin, PRL 112, 107202 (2014).

[4] P. Puphal, *et al.*, PRB 93, 174121 (2016).

[5] S. Allenspach, *et al.,* Physical Review Research, **3** (2), 023177 (2021).

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Millikelvin and High Field Platforms for 2D Research

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The study of Graphene 2D materials and surface phenomena using low temperatures down to a few mK and high magnetic fields up to 25 Tesla. Traditionally this required the use of liquid helium, an increasingly expensive resource. Cryogenic has led the way in building instruments that are cryogen free for QHR measurements in Graphene and other 2D materials. In addition we supply vector magnets and 30 mK systems for STM research in collaboration with Unisoku, Japan . This presentation discusses some of the issues involved.

SESSION 7 YOUNG RESEARCHER SESSION & POSTERS

26 - Image available at: https://www.katalog.uu.se/profile/?id=n20-334

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Defect-induced band restructuring and length scales in twisted bilayer graphene

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Twisted bilayer graphene (TBG) hosts a set of moiré bands that become flat at the magic angle. In this work [1] we illustrate, using a fully atomistic tight binding model, how these bands enhance the effects of atomic scale defects, such as non-magnetic impurities and vacancies, leading them to affect a region dictated by the moiré length scale. We find that most defect locations lead to the removal of a moiré band from the low-energy spectrum to the conduction band, which causes states to be removed from the AA region even if the atomic defect is located away from it. We also report an intriguing band replacement process where this band removal continues into a band replacement as a valence band replaces the expelled moiré band. In this case, the depletion of the AA regions is not present and the dominant feature is instead the presence of a graphene-like defect state. As a consequence, we identify two universal length scales for defects, consisting of charge modulations on the atomic scale and on the moiré scale. We show that our conclusions hold beyond the magic angle and for fully isolated defects. Moreover, we show that triple point fermions, which are the crossings of the Dirac point by a flat band, appearing for single, periodic, defects [2], are generally not preserved when adding extended or multiple defects. In summary, our results demonstrate that the normal state of TBG and its moiré flat bands are extremely sensitive to both the location and strength of non-magnetic impurities and vacancies, what should have significant implications for any emergent ordered state.

[1] L. Baldo, T. Löthman, P. Holmvall, A. M. Black-Schaffer, unpublished, arXiv:2304.03018 (2023)

[2] A. Ramires, J. Lado, PRB 99, 245118 (2019)

27 - Image available at: https://www.researchgate.net/profile/Diego-Lopez-Alcala-2

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Exploring Spin-phonon Coupling In Magnetic 2D Metal-Organic Frameworks

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Metal-Organic Frameworks (MOFs) are coordination materials formed by the interconnection between metal ions and organic linkers. This configuration provides this kind of compounds with astonishing features such as the presence of very large surfaces, nanoscale pores and easily tunable structural, electronic and magnetic properties.[1–3] Among all of this MOFs materials, the MCl2(pyz)2 (M = transition metal; pyz = pyrazine) family have displayed high room-temperature electronic conductivity and long-range magnetic order.[4–6] This coordination solid is formed by electrically neutral magnetic layers, thus opening up the possibility of mechanical exfoliation to a few layers.

Here we present a first principles study based on density functional theory (DFT) of the Cr and V derivatives of MCl2(pyz)2 2D layered MOFs. First, we determine the feasibility of exfoliation and the effects on the electronic structure when reducing the dimensionality down to the monolayer limit. Then, we substitute the Cl ligands by heavier halides (Br and I), exploring a promising way to tune the electronic, structural and magnetic properties of these compounds by means of chemical design. As spin-phonon coupling plays an important role in the retaining of magnetic ordering we compute the thermal evolution of magnetic exchange and single-ion anisotropy parameters to elucidate the effect of the lattice vibrations on the magnetic behavior of this family of coordination solids.

[1] H. Furukawa, K. E. Cordova, et al. Science, 341 (2013), 1230444.

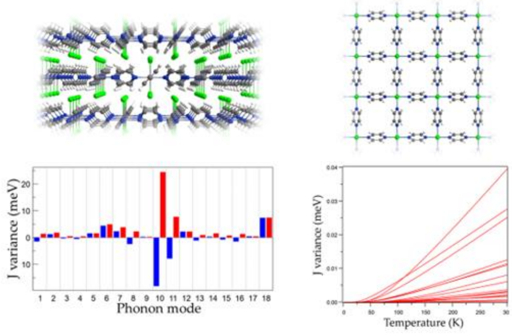
[2] Z. Huang, C. Xiong, et al. Chemical Engineering Journal, 449 (2022), 137722.

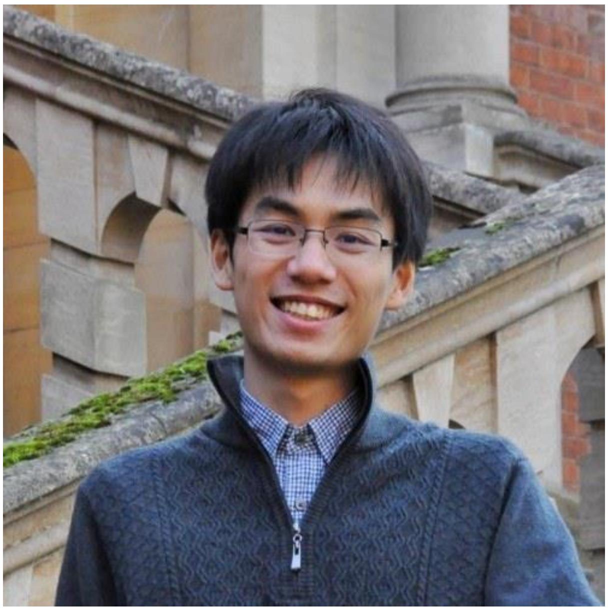
[3] J. Lu, H. Xu. Sci Adv, 8 (2022).

[4] P. Perlepe, P.; I. Oyarzabal, et al. Nat Commun., 13 (2022), 5766.

[5] K. S. Pedersen, P. Perlepe, et al. Nat Chem., 10 (2018), 1056–1061.

[6] P. Perlepe, I. Oyarzabal, et al. Science, 370 (2020), 587–592.





28 - Image available at: https://www.robinson.msm.cam.ac.uk/staff/hisa-matsuki

Hisakazu Matsuki

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Absolute superconducting spin switch with spin-orbit coupling

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At a thin-film superconductor (S) interface with a ferromagnetic insulator (FI), the magnetic proximity effect (MPE) can spin split the superconducting density of states and suppress the critical temperature (Tc) of S. For S metals with weak spin-orbit coupling (SOC), the spin splitting can translate to several Tesla [1], [2] and the Tc suppression can reach tens of mK [3]. For a FI/S/FI spin switch, the Tc suppression is reduced for antiparallel (AP) FI magnetisations due to a net cancellation effect of the MPE in S. Conversely, for parallel (P) magnetizations, the exchange fields add, enhancing the suppression of Tc with the spin switch efficiency ΔTc = Tc(AP) – Tc(P) > 0 [4].

In the presence of SOC, the spin-splitting in S should smear out, reducing ΔTc. However, in optimized EuS/Nb/EuS (FI/S/FI) structures, we observe ΔTc values of more than 1 K and achieve an absolute spin-valve effect ΔTc/Tc ~ 1 by inserting a few nanometers of Au at a single interface. i.e. EuS/Nb/Au/EuS. Scanning tunneling spectroscopy on Nb/Au and EuS/Nb/Au structures show evidence for superconductivity being modified by the presence of MPE. Those results indicate physics that goes beyond the standard quasiclassical picture of S/FI proximity effects in which superconducting spin valve effect is boosted by the large values of Tc in near nm thick Nb in conjunction with strong SOC.

[1] X. Hao, J. S. Moodera, and R. Meservey, Phys. Rev. Lett. **67**, 10 (1991)

[2] E. Strambini, et al., Phys. Rev. Mat. **1**, 054402 (2017).

[3] B. Li, et al., Phys. Rev. Lett. **110**, 097001 (2013)

[4] P. G. de Gennes, Phys. Lett. **23**, 1 (1966)

29 - Image available at: https://fys.kuleuven.be/qsp/people/LukasNulens

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Catastrophic magnetic flux avalanches in NbTiN superconducting resonators

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Superconducting coplanar waveguide (CPW) resonators have become an essential component of quantum circuits due to their ability to readout different qubit systems. These CPW resonators combine a conventional fabrication method with superior quality factors needed to perform circuit quantum electrodynamics [1]. In order to obtain this high performance, the CPW resonators must be screened from external damping sources among which magnetic flux quanta play a particularly detrimental role. Although efficient magnetic screening can be achieved, this is not always a viable option since some qubit implementation schemes require inevitable exposure to a magnetic field [2].

Topological Superconductivity In a Magnetic-texture Mediated Josephson Junction

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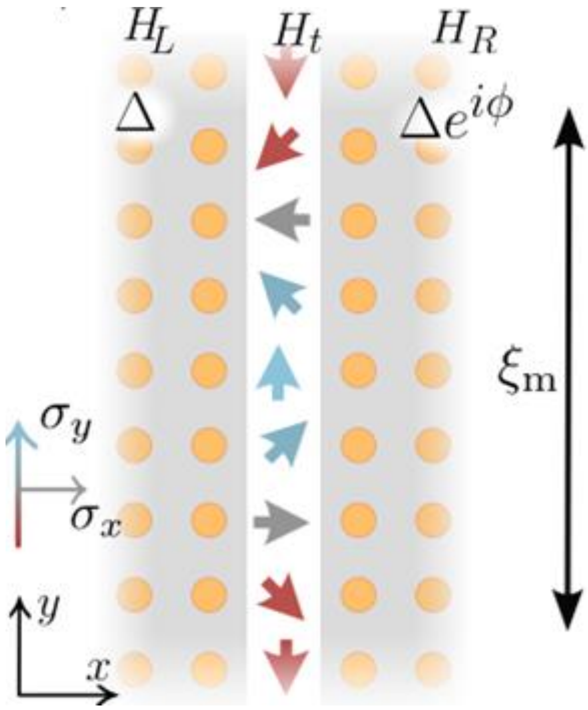
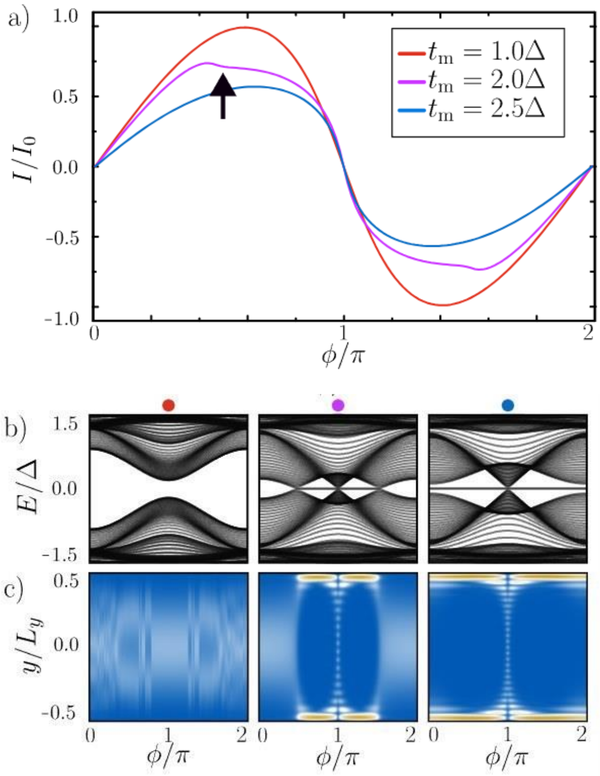
Topological superconductors are appealing building blocks for robust and reliable quantum information processing[1]. Most platforms for engineering topological superconductivity rely on a combination of materials with intrinsic spin-orbit coupling and external magnetic fields, which are usually challenging to manipulate [2]. In this study, we propose a novel setup that eliminates the need for spin-orbit coupling or magnetic fields. Instead, we propose a conventional Josephson junction connecting two-dimensional superconductors via a narrow, magnetically textured barrier [3]. Our findings demonstrate that various arrangements of magnetic domains and textures (see Fig. 1) are sufficient to induce topological superconductivity across a wide range of parameters and degrees of disorder. We also observe that the transition into the topological phase is highly influenced by the magnitude and period of the net magnetization, and can be triggered by a phase bias ϕ applied across the junction (Fig. 2). As a result, the superconducting phase governs 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 of the junction. Different edge states can appear when considering other dimensionalities.

1. S. Das Sarma, M. Freedman, C. Nayak, NPJ Quantum Information **1**, 15001 (2015).
2. Y. Oreg, G. Refael, F. von Oppen, Phys. Rev. Lett. **105**, 077001 (2010).
3. I. Sardinero, R. Seoane Souto, P. Burset, *in preparation*.



30 - Fig.1 One of the magnetic textures considered.



31 - Fig. 2. Localizing edge modes by phase biasing the junction. (a) Current-phase relation for the parameters used on the right. Increasing the magnetization strength facilitates the topological phase transition. (b) Energy bands showing the gap reopening and MZMs at finite ϕ. (c) Local density of states (a.u.) at E = 0 vs junction width, showing the localization of a pair of topological edge states.

32 - Image available at: https://www.researchgate.net/profile/Katja-Wurster

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YBCO Heterostructures for SQUID-on-Si-Lever

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Scanning SQUID microscopy (SSM) is a powerful technique for imaging magnetic fields or dissipation processes. The development of the SQUID-on-tip (SOT) [1] led to a breakthrough in spatial resolution and flux sensitivity for SSM. However, so far SOTs are based on metallic superconductors, e.g., Pb or Al, which limits their operation range to temperatures below about 10 K and magnetic fields below about 1 T.

The use of the high-Tc cuprate superconductor $YBa_2Cu_3O_7$ (YBCO) could enable SSM in the Tesla range and at temperatures up to about 80 K. However, YBCO has a complex crystal structure and a small coherence length, which leads to a high sensitivity to defects on the atomic scale. High quality

YBCO films can only be obtained by epitaxial growth on lattice-matched substrates. Therefore, the SOT approach is not a viable option for the realization of YBCO-based SSM.

An alternative approach to realize YBCO nanoSQUIDs for SSM with high spatial resolution is based on the fabrication of nanoSQUIDs on custom made AFM cantilevers that are fabricated from Si wafers [2]. Here, the challenge is the integration of YBCO thin films on Si wafers. In this work, we present our approach to address that challenge. We use $Sr_3Al_2O_6$ (SAO) and $Sr_2CaAl_2O_6$ (SCAO), which is lattice-matched to perovskite materials, such as $SrTiO_3$ (STO). SAO can be dissolved in water, i.e. it can be used as a sacrificial layer for the realisation of free-standing single-crystalline perovskite thin films [3], including YBCO [4].

We present the development of an epitaxial SAO thin film growth process, based on pulsed laser deposition (PLD) and discuss the properties of the grown SAO films. Furthermore, we describe our process for the heteroepitaxial growth of encapsulated YBCO heterostructures on STO (001) single crystal substrates and discuss the optimization of growth conditions and properties of the layers. And finally, we present our preliminary attempts to transfer YBCO films onto Si surfaces.

[1] D. Vasyukov et al., Nature Nanotechnology 8 (2013) 639.

[2] www.fibsuperprobes.com

[3] D. Lu et al., Nature Materials 15 (2016) 1255.

[4] Z. Chen et al., Phys. Rev. Materials 3 (2019) 060801(R).

SESSION 8 SUPERCONDUCTIVITY IN HETEROSTRUCTURES

33 - Image available at: https://people.aalto.fi/peter.liljeroth

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Artificial topological superconductors and heavy fermion systems in heterostructures of 2D materials

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Van der Waals (vdW) heterostructures have emerged as a playground for realizing and engineering exotic quantum states not readily found in naturally occurring materials. Due to the weak bonding between the layers, it is possible to combine materials with very different physical properties in heterostructures. I will highlight these concepts through our results on realizing topological superconductivity and heavy-fermion physics in vdW heterostructures [1-3]. Topological superconductivity requires combining superconductivity with Rashba-type spin-orbit interactions and magnetism. This can be realized by combining monolayer ferromagnet $CrBr_3$ with superconducting $NbSe_2$ [1,2]. On the other hand, the building blocks of heavy fermion systems - Kondo coupling between a lattice of localized magnetic moments and mobile conduction electrons - can be mimicked in 1T/1H-TaS_2 heterostructures [3]. Depending on the relative strengths of the coupling between the localized moments and the Kondo coupling, the system can be either in a magnetic ground state or in the heavy fermion regime. Exploring the phase diagram of these two phases offers a promising route towards unconventional superconductivity [4]. In general, these examples highlight the versatility of vdW heterostructures in realizing quantum states that are difficult to find and control in naturally occurring materials.

[1] S. Kezilebieke, M.N. Huda, V. Vaňo, M. Aapro, S.C. Ganguli, O.J. Silveira, S. Głodzik, A.S. Foster, T. Ojanen, P. Liljeroth, Nature 588 (2020) 424.

[2] S. Kezilebieke, V. Vaňo, M.N. Huda, M. Aapro, S.C. Ganguli, P. Liljeroth, J.L. Lado, Nano Lett. 22 (2022) 328.

[3] V. Vaňo, M. Amini, S.C. Ganguli, G. Chen, J.L. Lado, S. Kezilebieke, P. Liljeroth, Nature 599, (2021) 582.

[4] S. Wirth, F. Steglich, Nat. Rev. Mater. 1 (2016) 16051.

34 - Image available at: https://www.katalog.uu.se/profile/?id=N10-585

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Flat Bands and Superconductivity in Graphene Systems

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Materials with flat energy bands close to the Fermi level often exhibit extraordinarily high critical ordering temperatures for symmetry breaking orders. The currently most studied example is magic-angle twisted bilayer graphene, where both superconductivity and other correlated orders appear due to low-energy flat bands induced by the resulting moiré pattern, but also simpler carbon structures such as ABC-stacked multilayer graphene exhibits topological surface flat bands.

In this talk I will first show how full-scale atomistic modelling of magic-angle twisted bilayer graphene generates an unexpected superconducting state [1]. Specifically, solving self-consistently for superconductivity assuming local electronic interactions, mimicking closely those of the high-temperature cuprate superconductors, we find *d*-wave nematic ordering on both the atomic and moiré lattice length scales. Despite the *d*-wave nature, the superconducting state surprisingly has a full energy gap. These results show that the superconducting state in twisted bilayer graphene can be distinctly different from that of both monolayer graphene and the cuprate superconductors, which instead hosts a fully gapped chiral *d*-wave and a nodal *d*-wave state, respectively, for the same interaction. Second, I will report how the surface flat bands in ABC-stacked multilayer graphene can host both significantly enhanced superconductivity and magnetism, even at charge neutrality and with no additional twists. By using a fully generic mean-field treatment of all spin-isotropic, two-site charge density and spin interactions up to next nearest neighbor sites and matching with complementary density functional theory calculations, we establish the full phase diagram that contains both spin-triplet *f*-wave superconductivity and a ferrimagnetic state [2]. The favoring of the fully gapped spin-triplet *f*-wave state is in sharp contrast to graphene and bulk ABC-graphite, where instead chiral *d*- or *p*-wave states, together with *s*-wave states, display stronger ordering tendencies, albeit not achievable at charge neutrality. We trace this distinctive behavior to the strong sublattice polarization of the surface flat bands in ABC-stacked multilayer graphene. Together these results illustrate the importance of carefully incorporating the properties of the normal state when studying superconductivity.

[1] T. Löthman, J. Schmidt, F. Parzhigar, and A. M. Black-Schaffer, Commun. Phys., 5 (2022) 92.

[2] O. A. Awoga, T. Löthman, and A. M. Black-Schaffer, arXiv: 2306.12220 (2023)

35 - Image available at: https://www.aalto.fi/en/people/jose-lado

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Moiré-enabled topological superconductors and impurity spectroscopy in twisted van der Waals heterostructures

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Van der Waals materials have allowed realizing a variety of emergent quantum states, including magnetic, correlated, and superconducting states. Interestingly, the tunability of these materials provides an outstanding playground to engineer elusive states of matter typical of complex correlated quantum materials. Here we show that twisted van der Waals materials provide a natural materials platform for realizing topological moire superconductors [1,2], and explore the interplay between moire length scales and local impurities in unconventional states [3,4]. First, we demonstrate the twist between the two materials gives rise to a moire Yu-Shiba-Rusinov electronic structure [1]. The moire pattern further allows to realize topological states in regions of the phase space that would otherwise be topologically trivial, leading to a topological superconducting state whose topological edge states inherit the moire length. We will furthermore show [2] that a similar mechanism allows to create topological superconductivity in twisted graphene bilayers, by exploiting a combination of moire patterns and proximity effects to 2D materials. Finally, we will address the impact of local impurities in these moire enabled topological superconductors [3], demonstrating that they allow inferring the microscopic modulations of parameters driven by the moire pattern using machine learning methods [4].

[1] Shawulienu Kezilebieke, Viliam Vaňo, Md N. Huda, Markus Aapro, Somesh C. Ganguli, Peter Liljeroth, and Jose L. Lado, Nano Lett. 2022, 22, 1, 328–333 (2022)

[2] Maryam Khosravian, Elena Bascones and Jose L. Lado, to appear (2023)

[3] Maryam Khosravian and Jose L. Lado, Phys. Rev. Materials 6, 094010 (2022)

[4] Rouven Koch, Maryam Khosravian and Jose L. Lado, to appear (2023)

36 - Image available at: https://www.fz-juelich.de/en/pgi/pgi-3/research/young-investigators

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One-dimensional topological superconductivity in a van der Waals heterostructure

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One-dimensional (1D) topological superconductivity1is a state of matter that is not found in nature. However, it can be realised, for example, by inducing superconductivity into the quantum spin Hall edge state of a two-dimensional topological insulator. Because topological superconductors are proposed to host Majorana zero modes, they have been suggested asa platform for topological quantum computing. Yet, conclusive proof of 1D topological superconductivity has remained elusive. Here, we employ low-temperature scanning tunnelling microscopy to show1D topological superconductivity in a van der Waals heterostructure by directly probing its superconducting properties, instead of relying on the observation of Majorana zero modes at its boundary. We realise this by placing the two-dimensional topological insulator monolayer WTe2 on the superconductor NbSe2. We find that the superconducting topological edge state is robust against magnetic fields, a hallmark of its triplet pairing. Its topological protection is underpinned by a lateral self-proximity effect, which is resilient against disorder in the monolayer edge. By creating this exotic state in a van der Waals heterostructure, we provide an adaptable platform for the future realization of Majorana bound states. Finally, our results more generally demonstrate the power of Abrikosov vortices as effective experimental probes for superconductivity in nanostructures.

37 - Image available at: https://is.mpg.de/person/ionescu

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Tuning the Properties of YBa2Cu3O7-x /Ferromagnet Heterostructures

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YBa2Cu3O7-x (YBCO)/ferromagnet heterostructures have great potential for a wide range of applications, such as superconducting electronics. Choosing the right ferromagnet for a specific application is of upmost importance. For example, for magnetic imaging of superconductors, a soft magnetic layer with small influence on the superconductor is required. The properties of heterostructures are highly dependent on the type of ferromagnet, the quality of the films, which can be tuned by the deposition conditions and deposition order of the layers. We studied heterostructures of YBCO films and Py and $CaRuO_3$ layers, Gd/Fe multilayers and Ni nanoparticles [1]. The $CaRuO_3$ layers were either in direct contact or separated by a 5 nm $SrTiO_3$ layer [2]. Also, the deposition order and thickness of the films were varied. Detailed measurements of the magnetic moment as a function of temperature, magnetic field and time have been performed for different heterostructures using SQUID magnetometry to investigate the impact of a ferromagnetic layer on the properties of YBCO. It is found that the modification of the superconducting transport in these heterostructures strongly depends on the magnetic and structural properties of the soft-magnetic material. This effect is especially pronounced for an inhomogeneous coating consisting of ferromagnetic nanoparticles. Also, the ferromagnetic properties of CRO are influenced by the deposition order and barrier layer.

[1] A. M. Ionescu. J. Simmendinger, M. Bihler, C. Miksch, P. Fischer, S. Soltan, G. Schütz and J. Albrecht, Supercond. Sci. Technol., 33 (2020) 015002.

[2] A. M. Ionescu, I. Ivan, C. Locovei, M. Onea, A. Crisan, S. Soltan, G. Schutz, J. Albrecht, Materials, 15 (2022) 2345.

SESSION 9 HIGH FIELD SUPERCONDUCTIVITY

38 - Image available at: https://sisuzuki1911.github.io/

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Fulde-Ferrel-Larkin-Ovchinnikov state in a superconducting thin film attached to a ferromagnetic cluster

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We study theoretically the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) states appearing locally in a superconducting thin film with a small circular magnetic cluster [1,2]. We calculate the pair potential, pairing correlations, free-energy density, and quasiparticle density of states for various cluster sizes and exchange potentials by solving the Eilenberger equation in two dimensions. Increasing the exchange potential and cluster size leads to a higher number of nodes in the pair potential. Although the free-energy density beneath the ferromagnet locally exceeding the normal-state value, the FFLO states are stabilized by the superconducting condensate away from the magnetic cluster. Analyzing the pairing-correlation functions, we show that the spatial variation of the spin-singlet *s*-wave pair potential generates *p*-wave Cooper pairs. These odd-frequency Cooper pairs play a dominant role in governing the inhomogeneous subgap spectra observed in the local density of states. Furthermore, we discuss a potential approach for detecting the local FFLO states by measuring the quasiparticle density of states.

[1] S.-I. Suzuki, T. Sato, and Y. Asano, Phys. Rev. B **106** (2022) 104518.

[2] S.-I. Suzuki, T. Sato, A. A. Golubov, and Y. Asano, arXiv:2305.06015.

Ising Superconductivity In Misfit Layer Compounds

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Low-dimensional materials can exhibit remarkable properties different from their bulk counterparts. $NbSe_2$ monolayer is an Ising superconductor with the in-plane upper critical field violating the Pauli limit, while no such behavior occurs in bulk $NbSe_2$ [1]. However, in contrast to bulk, low-dimensional materials are often unstable and impractical for applications. Utilizing various experimental techniques, we found that $(LaSe)_{1.14}(NbSe_2)$ and $(LaSe)_{1.14}(NbSe_2)_2$ bulk misfit layer superconductors exhibit a two-dimensional band structure equivalent to a highly doped $NbSe_2$ monolayer [2]. Moreover, their in-plane upper critical fields exceed the Pauli limit by a factor of up to 10 [3]. From first-principles calculations backed by experimental results we obtained their detailed band structure parameters, such as the values of the reduced interlayer coupling and strong spin-orbit splitting. This quantitative analysis enabled us to explain the microscopic origin of the Ising spin-orbit coupling in bulk superconductors [4].

[1] X. Xi, Z. Wang, W. Zhao, J. H. Park, K. T. Law, H. Berger, L. Forró, J. Shan, and K. F. Mak, Ising pairing in superconducting $NbSe_2$ atomic layers, Nat. Phys. 12 (2016) 139.

[2] R. T. Leriche, A. Palacio-Morales, M. Campetella, C. Tresca, S. Sasaki, C. Brun, F. Debontridder, P. David, I. Arfaoui, O. Šofranko, T. Samuely, G. Kremer, C. Monney, T. Jaouen, L. Cario, M. Calandra,

and T. Cren, Misfit Layer Compounds: A Platform for Heavily Doped 2D Transition Metal Dichalcogenides, Adv. Funct. Mater. (2020) 2007706.

[3] P. Samuely, P. Szabó, J. Kačmarčík, A. Meerschaut, L. Cario, A. G. M. Jansen, T. Cren, M. Kuzmiak, O. Šofranko, and T. Samuely, Extreme in-plane upper critical magnetic fields of heavily doped quasi-two-dimensional transition metal dichalcogenides, Phys. Rev. B 104, (2021) 224507.

[4] arXiv:2304.03074

39 - Image available at: https://www.physik.ruhr-uni-bochum.de/en/Professuren/prof-dr-anna-boehmer/

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Tuning Complex Magnetism of 122-type Iron-based Superconductors and Related Compounds via Interlayer Distance

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As the iron-based superconductors have reached “teen-age” 15 years after their discovery, the large variety of their chemical structures, types of magnetic ordering and the methods available to tune their properties are all the more appreciated. With their square iron layers, the materials feature a variety of related yet distinct magnetic structures. As magnetic order is strongly coupled to the crystal lattice, hydrostatic and anisotropic physical pressures are effective tuning parameters. Related compounds, in which iron is replaced by cobalt, feature similarly rich and tunable magnetic orders, yet lack high-temperature superconductivity.

A highly relevant structural parameter of these tetragonal systems is their c/a ratio related to the interlayer distance. A significant reduction of the c/a ratio is referred to as “tetragonal collapse” and dramatically changes the electronic and magnetic properties. Here, I will discuss how the c/a ratio can be used as a tuning parameter for magnetism and superconductivity the 122-type iron-based systems such as $BaFe_2As_2$ and $CaFe_2As_2$. I will further show how small changes of the c/a-ratio imposed via a piezo-stack can be used to probe the $(Ca,Sr)Co_2As_2$ system close to an instability.

ADDITIONAL POSTERS

40 - Image available at: https://www.linkedin.com/in/syed-akbar-b9727b154/

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Thin Film Uranium Germanides

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Materials that exhibit heavy fermion behaviour also display a wide range of interesting physics from magnetism, unconventional superconductivity and quantum criticality [1, 2]. A large proportion of these materials are uranium-based compounds, such as UGe_2, UBe_{13}, and UPt_3, and have been almost exclusively studied as bulk crystals, with the exception of a series of studies of UX_2Al_3 (X = Ni, Pd) by Jourdan *et al*. around two decades ago [3, 4]. The study of these materials in thin film form opens the possibility of tuning their properties via dimensionality control, proximity to other materials, as well as compressive and tensile strains using different substrates. In this study our ultimate target is UGe_2, which exhibits spin-triplet unconventional superconductivity nearby to itinerant ferromagnetism. We present our preliminary exploration of the U-Ge phase diagram, and attempts to stabilize UGe_2 as a single crystal thin film using d.c. magnetron sputtering. We use three different single crystal substrates (MgO, CaF_2, $SrTiO_3$), a range of substrate temperatures, and several different U:Ge ratios.

[1] Saxena *et al*., Nature **406**, 587 (2000)

[2] Joynt & Taillefer, Rev. Mod. Phys. **74**, 235 (2002)

[3] Jourdan *et al*., Nature **398**, 47 (1999)

[4] Jourdan *et al*., Phys. Rev. Lett. **93**, 097001 (2004)

Tunneling into graphene proximitized by NbSe2 at strong in plane magnetic field

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Some thin transition metal dichalcogenides sustain superconductivity at large in-plane magnetic fields, due to atomic thickness which suppresses orbital decay, and Ising spin-orbit protection, which locks their spins in an out-of-plane orientation. We use thin exfoliated NbSe2 as superconducting electrodes laterally coupled to graphene, making planar, all Van der Waals, two-dimensional Josephson junction devices (2DJJ) which can maintain superconducting behavior above an exceptionally high 8.5 T parallel field [1]. Our device architecture is flexible and robust; Contacts vary in their transparency and can be made highly transparent. The graphene channel can be made diffusive or ballistic or as SQUID devices [2]. In this poster we present the results of an asymmetric device, where one side is strongly proximitized, while the other is weakly coupled. The device allows us to trace the induce gap vs. in-plane magnetic field.

[1] T. Dvir, A. Zalic, E. H. Fyhn, M. Amundsen, T. Taniguchi, K. Watanabe, J. Linder, and H. Steinberg. Physical Review B 103, 115401 (2021).

[2] A. Zalic, T. Taniguchi, K. Watanabe, S. Gazit, H. Steinberg, Nano Lett 2023 Jul 12; 23(13):6102-6108. doi: 10.1021/acs.nanolett.3c01552. Epub 2023 Jun 22.

Superconducting gap of $PtPb_4$

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$PtPb_4$ has attracted attention recently due to its similar structure with the Dirac nodal arc semimetal $PtSn_4$. It has shown a large Rashba splitting and possible topological properties [1-4]. It is also possible that orthorhombic domains stabilize in the surface. This work presents the first measurements and characterization as a function of temperature of the superconducting gap of $PtPb_4$. Reaching temperatures as low as 100 mK, they have provided the critical temperature T_c of this material, where superconductivity vanishes. This value corresponds to roughly 5 K, quite above the previously reported T_c of 2.8 [2,5].

More STM measurements are needed to acquire images of the vortex lattice in $PtPb_4$, as well as topographies with atomic resolution.

[1] K. Lee et al., Phys. Rev. B 103 (2021) 085125.

[2] C. Q. Xu et al., Phys. Rev B 104 (2021) 125127.

[3] L. Wang et al., New J. Phys. 23 (2021) 093030.

[4] H. Wu et al., npj Quantum Mater. 7 (2022), 31.

[5] M. F. Gendron and R E. Jones, J. Phys. Chem. Solids, 23 (1962) 405-406.

41 - Image provided by Celia González Sánchez

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Fabrication of Hybrid van der Waals Josephson Junctions based on NbSe2

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The emergence of van der Waals heterostructures has paved the way for a "designer" approach, in which novel devices and new physics can be obtained by combining the properties of distinct two-dimensional materials. Among the many possibilities in this context, heterostructures based on superconducting few-layer NbSe2 attract great interest for studying Josephson effects and the superconducting proximity effect in 2D systems [1]. Interestingly, recent work has reported on signatures of a topological superconducting phase in heterostructures based on NbSe2 and 2D ferromagnets [2]. Moreover, first demonstrations of magnetic vdW Josephson junctions have been recently reported using a similar material combination [3, 4, 5, 6]. Motivated by the above developments, we present here our first results on nanodevices based on NbSe2, including low temperature DC and high frequency measurements of the Josephson effect in junctions employing 2D tunnel barriers with magnetic texture.

[1] N. Yabuki et al., Nat. Commun., 7 (2016) 10616

[2] S. Kezilebieke et al, Nature, 588 (2020) 424-428

[3] H. Idzuchi et al., Nat. Commun., 12 (2021) 5332

[4] K. Kang et al., arXiv:2101.01327

[5] L. Ai et al., Nat. Commun., 12 (2021) 25

[6] K. Kang et al., Nano Lett., 22 (2022) 5510-5515

42 - Image available at: https://www.robinson.msm.cam.ac.uk/directory

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Spin Transport through superconductor / Weyl semimetal heterodevices

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Transport of spin information over large distances is key for many applications in spintronics. Achieving spin transmission within superconducting devices should lead to reductions in Joule heating and massive improvements in device efficiency and performance. The Weyl semimetal Mn3Ge [1, 2, 3, 4] with an antiferromagnetic or ferrimagnetic phase has recently emerged as a promising material for spin transmission studies in the superconducting [1] and normal [3, 4] states. In this poster, we report the fabrication of magnetron-sputtered thin-films of Mn3Ge and superconducting heterostructures with sub-nanometer-thickness-control in order to investigate the interplay between superconductivity and spin transport in Mn3Ge. The results build a framework for spin-transport control in the superconducting state.

[1] Jeon, Kun-Rok, Binoy Krishna Hazra, Kyungjune Cho, Anirban Chakraborty, Jae-Chun Jeon, Hyeon Han, Holger L. Meyerheim, Takis Kontos, and Stuart SP Parkin. "Long-range supercurrents through a chiral non-collinear antiferromagnet in lateral Josephson junctions." Nature Materials 20, no. 10 (2021): 1358-1363.

[2] Kobayashi, A., T. Higo, S. Nakatsuji, and YoshiChika Otani. "Structural and magnetic properties of Mn3Ge films with Pt and Ru seed layers." AIP Advances 10, no. 1 (2020): 015225.

[3] Hong, Deshun, Naween Anand, Changjiang Liu, Haihua Liu, Ilke Arslan, John E. Pearson, Anand Bhattacharya, and J. S. Jiang. "Large anomalous Nernst and inverse spin-Hall effects in epitaxial thin films of kagome semimetal Mn 3 Ge." Physical Review Materials 4, no. 9 (2020): 094201.

[4] Olayiwola, Idris Opeyemi, Carlos R. Santillán-Rodríguez, José A. Matutes-Aquino, Isis M. Cota-Martínez, Rocío M. Gutiérrez-Pérez, José T. Holguín-Momaca, and Sion F. Olive-Méndez. "Room temperature positive exchange bias in CoFeB/D019-Mn3Ge noncollinear antiferromagnetic thin films." Journal of Alloys and Compounds 955 (2023): 170279.

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Electric control of spin supercurrents in hybrid Rashba structures

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The digital economy ever-increasingly requires denser, faster and more energy efficient data processing, but heat-dissipating ohmic losses limit further performance improvements. Superconducting electronics offers the potential to enhance magnetic memory and logic performance because readout can be achieved with record low heat dissipation1. Furthermore, intrinsic or interfacial spin-orbit coupling (SOC) can enable a thin-film superconductor to exceed the paramagnetic limit2-4. For Rashba-type SOC, theory indicates that the superconducting thermodynamic properties of a finite-size thin film are strongly sample-size dependent due to the creation of edge states4: for example, for a geometrically anisotropic thin film superconductor, the critical field can be tunable through the direction of an externally applied in-plane magnetic field4. These findings open perspectives for the development of superconducting spin-orbitronic devices as well as superconducting structures in which the superconducting state can be controlled with an electric field5,6. In this poster, we discuss our experimental results towards the development of a hybrid superconducting device in which Rashba-SOC and charge accumulation within a thin-film heavy metal (HM) can be tuned via an electric field and so control the superconducting transition of a proximity-coupled thin film superconductor. The electric field is applied to the HM via a ferroelectric lead magnesium niobate-lead titanate (PMN-PT) substrate.

[1] D. Holmes, et al., IEEE Trans. Appl. Superc. 23, 1051 (2013).

[2] J.-F. Mercure, et al., Phys. Rev. Lett. 108, 187003 (2012).

[3] E. Sohn, et al., Nat. Phys. 17, 504-508 (2018).

[4] L. A. B. Olde Olthof, et al., Phys. Rev. B 103, L020504 (2021).

[5] P. Noel, et al., Nature 580, 483-486 (2020).

[6] N. Banerjee, et al., Phys. Rev. B 97, 184521 (2018).

Effect of a single impurity in a finite length Graphene Josephson Junction

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In the field of quantum information, novel quantum technologies based on 2D materials are very promising. In this work we consider a graphene Josephson junction [1] in the intermediate length regime and discuss its quantum sensing capabilities [2] to impurities of different nature. We derive the Andreev bound states spectrum using the Bogoliubov-De Gennes (BdG) equations, analytically in the short GJJ limit [3] and numerically for finite junction lengths. In the case of a single short-range magnetic impurity in the graphene stripe, we analyze the modifications to the Andreev spectrum and the variation of the local density of states (LDOS). We find that the LDOS along a direction parallel to the planar junction oscillates with wavenumbers linked to the stationary states expected from the Andreev bound states spectrum.

[1] M. Titov and C. W. J. Beenakker, Phys. Rev B 74, 041401 (2006).

[2] F. Pellegrino, G. Falci, and E. Paladino, Proceedings 12, 33 (2019).

[3] F. Pellegrino, G. Falci, and E. Paladino, *Commun Phys* 5, 265 (2022)

Circuit Quantum Electrodynamics with two-dimensional materials-based devices

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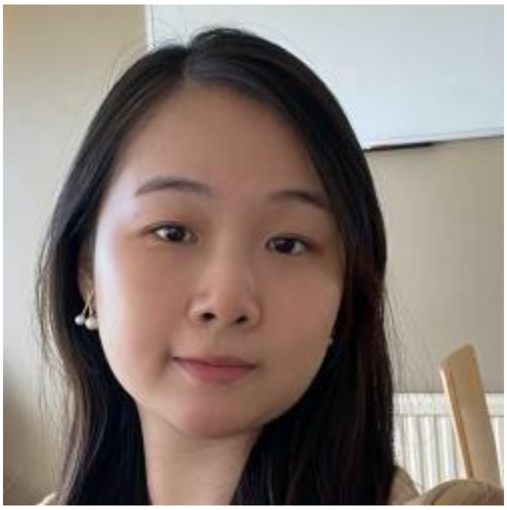
Nowadays, the framework of hybrid quantum systems is characterized by many platforms which have been developed for quantum technology applications. Devices composed of graphene combined with superconductors, such as the so-called graphene Josephson junction, embedded in circuit quantum electrodynamics nanocircuits, have shown exciting potential applications in quantum technologies [1] due to the possibility of tuning resonant frequencies and couplings in situ, by exploiting the gate voltage tunability and the peculiar low energy characteristics of 2D materials. Furthermore, the superconductor-semiconductor hybrid systems have shown compatibility with high magnetic fields [2] and have opened the possibility of realizing noise-protected qubits [3], then they could represent promising platforms for quantum information processing. In the above framework, we studied theoretically the inductive interaction between a superconducting loop containing a graphene Josephson junction and a microwave resonator [4]. In the first part of this work, we used a mean-field approximation to model the system. Then, we solved the self-consistent mean-field problem numerically using standard Python libraries (NumPy, SciPy). Finally, we applied a polaritonic approach based on those previous numerical results to derive the hybridized light-matter excitations of the global system.

[1] J. I.-J. Wang, D. Rodan-Legrain, L. Bretheau, D. L. Campbell, B. Kannan, D. Kim, M. Kjaergaard, P. Krantz, G. O. Samach, F. Yan, et al., Nature nanotechnology, 14 (2019) 120.

[2] J. Kroll, W. Uilhoorn, K. van der Enden, D. de Jong, K. Watanabe, T. Taniguchi, S. Goswami, M. Cassidy, and L. P. Kouwenhoven, Nature communications, 9 (2018) 4615.

[3] A. Gyenis, A. Di Paolo, J. Koch, A. Blais, A. A. Houck, and D. I. Schuster, PRX Quantum, 2 (2021) 030101.

[4] S. Park, C. Metzger, L. Tosi, M. F. Goffman, C. Urbina, H. Pothier, and A. L. Yeyati, Phys. Rev. Lett., 125 (2020) 077701.



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Near-absolute spin-valve effect at f-orbital magnet/superconductor interfaces with controlled orbital-to-spin moments

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The proximity effect between a thin-film superconductor (S) and a ferromagnet (F) can lead to a spin-splitting of the quasiparticle density of states and a suppression of the superconducting critical temperature (*T*C) (1). At a S/F interface, the average magnitude of the spin-splitting in S can be tuned via the micromagnetic state of F with shifts in *T*C between magnetized (*T*c,m) and de-magnetized (*T*c,dm) ferromagnet states being dependent [1-3] on the ratio of the superconducting coherence length (ξ) to the domain wall width (*d*w) ¾ i.e., (*T*c,m- *T*c,dm)/*T*c,dm = Δ*T*C/*T*c,dm µ *ξ*/*d*w can theoretically be infinite for an appropriate combination of S and F thin films in which S is thinner than *ξ*. Experimentally, however, such an absolute spin-valve effect is hard to achieve with Δ*T*C/*T*c,dm ratios tending to be a small fraction of *T*c,dm, indicating physics beyond the standard picture of the S/F proximity effect. Here we report S/F bilayers and F/S/F spin-valves in which F is an f-orbital ferromagnet (HoGd) with a controlled composition to tune the ratio of the orbital to spin components of the magnetization. The results demonstrate that Δ*T*C/*T*c,dm can approach infinity for a large ratio of the orbital moment to spin moment, which enables a near-absolute spin-valve effect. Our results demonstrate that the band structure of the ferromagnet in conjunction with the *ξ*/*d*w can be tuned to enable high performance superconducting memory for energy efficiency electronics. A first principle theory is required in order to understand the relationship between Δ*T*C / *T*c,dm and the ratio of the orbital to spin moment of the F metal.

1. A. Buzdin, Rev. Mod. Phys. 77, 935-976 (2005).
2. M. Houzet and A. I. Buzdin, Phys. Rev. B 74, 214507 (2006).
3. S. Komori, A. Di Bernardo, A. I. Buzdin, M. G. Blamire, and J. W. A. Robinson, Phys. Rev. Lett. 121, 077003 (2018).
4. G. Yang, C Ciccarelli, J. W. A. Robinson, APL Materials 9, 050703 (2021).
5. M. Amundsen, J. Linder, J. W. A. Robinson, I Žutić, N. Banerjee, arXiv: 2210.03549 (2023).

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Towards quantum transport in metal and ferromagnetic semiconductor thin films structures with absorbed chiral molecules

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Chiral molecules (CMs), such as alpha-helix polyalanine, exhibit chiral-induced spin-selectivity (CISS) characteristics, which means that a flow of electron charge across a layer of CMs can result in a spin filtering effect and phase coherent transport (1, 2). Recently, for example, we have demonstrated low temperature phase-coherent transport through thin-film wires of Au and Cu with absorbed CMs (2). For Au, we also observed evidence for induced ferromagnetism associated with the thiol-Au bonding and for Au and Cu, we detected an enhancement of spin-orbit coupling. Here, we systematically study charge transport and magnetic anisotropy in thin films and wires of Au and Au/EuS where EuS is a ferromagnetic semiconductor. The thickness of Au is varied in the 1-10 nm range in order to optimize magnetic hysteresis in Au and magnetic anisotropy modification in Au/EuS structures. The results provide a platform for detailed studies of quantum beheaviour including magnetic control of phase coherence transport and potentially a quantum anomalous Hall effect.

1. R. Naaman, Y. Paltiel, D.H. Waldeck, Nature Reviews Chemistry, **3**, 250 (2019).
2. M. Ozeri *et al.*, The Journal of Physical Chemistry Letters, **14**, 4941-4948 (2023).
3. Z. Shang *et al.*, Small, **18**, 2203015 (2022).

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Nonreciprocal Edge Transport in Superconducting Devices with Magnetic Control

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The proximity effect at a superconductor interface with a ferromagnet layer (S/F) can lead to unconventional electron pairing [1-3] and nonreciprocal edge transport (i.e., a superconducting diode effect (SDE)) [4,5]. The underlying mechanism of the SDE can have mixed origins related to spin-orbit coupling (SOC) or vortex flow with a geometrically asymmetric pinning potential in S and at S/F interfaces in mesoscopic wires [6-8]. Here we report an experimental investigation of the SDE and edge transport in superconducting (Nb, V and RhS) wires interfacial magnetism and/or Rashba SOC versus layer thickness, wire width, temperature and microstructure. The F layer in conjunction with interfacial SOC should affect the pinning potential along the edge regions of an S/F wire and modulate vortex dynamics, driving a nonreciprocal supercurrent [9,10]. Our experiments form a framework for understanding and optimizing the SDE in superconducting wires with the aim of achieving full magnetic control of charge and potentially spin for superconducting quantum devices.

[1] J. Linder and J. W. A. Robinson, Nature Physics **11**, 307 (2015).

[2] S. Komori *et al.*, Science Advances **7**, eabe0128 (2021).

[3] L. A. B. Olde Olthof, L. G. Johnsen, J. W. A. Robinson, and J. Linder, Physical Review Letters **127**, 267001 (2021).

[4] S. Ilić and F. S. Bergeret, Physical Review Letters **128**, 177001 (2022).

[5] K.-R. Jeon, J.-K. Kim, J. Yoon, J.-C. Jeon, H. Han, A. Cottet, T. Kontos, and S. S. P. Parkin, Nature Materials **21**, 1211 (2022).

[6] Y. Hou *et al.*, 2022), p. arXiv:2205.09276.

[7] N. Satchell, P. Shepley, M. Rosamond, and G. Burnell, Journal of Applied Physics **133** (2023).

[8] A. Gutfreund *et al.*, Nature Communications **14**, 1630 (2023).

[9] M. K. Hope, M. Amundsen, D. Suri, J. S. Moodera, and A. Kamra, Physical Review B **104**, 184512 (2021).

[10] L. A. B. Olde Olthof, X. Montiel, J. W. A. Robinson, and A. I. Buzdin, Physical Review B **100**, 220505 (2019).

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