

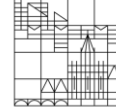


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# Q-M&S 2026

International Conference on  
Correlated Quantum Materials and Solid State Quantum Systems

[www.q-ms.org](http://www.q-ms.org)

July 1-3, 2026

Technische Universität Wien  
[TUtheSky](#) (Room BA11B09, 11th floor)  
Getreidemarkt 9, 1060 Vienna, Austria

[www.tuwien.at](http://www.tuwien.at)

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## SFB Q-M&S



Hopes are high that quantum computers will revolutionize conventional computation and data processing. Although they can already perform certain computations faster than conventional computers, more robust solid state quantum systems are needed to solve the problem of quantum error correction and fully exploit the potential of quantum computing. A currently disjunct field are correlated quantum materials. These are designer materials with properties due to quantum effects of strongly interacting electrons. They represent a highly active but particularly complex area of fundamental solid state physics.

The SFB Correlated Quantum Materials & Solid State Quantum Systems (Q-M&S) is a collaborative research project funded by the Austrian Science Fund and the German Research Foundation, with 10 PIs hosted at 4 institutions in Austria and Germany, aiming to connect both areas. Concepts and methods developed in the context of quantum information and computation will contribute to a better understanding of correlated quantum materials. For example, “entanglement meters” will be devised to unravel the mystery of the strange metal state. In turn, research will be conducted into how correlated quantum materials can be used for quantum applications. Correlated quantum materials with topological properties for instance could lead to very robust and well-controllable quantum devices in novel hybrid systems.

For more information, please visit our project website [www.q-ms.org](http://www.q-ms.org).

## Q-M&S 2026 – Conference program

Technische Universität Wien, TUtheSky (Room BA11B09, 11th floor), Getreidemarkt 9, 1060 Vienna, Austria

	Wednesday, July 1, 2026	Thursday, July 2, 2026	Friday, July 3, 2026
08:30-08:50	Registration		
08:50-09:00	Opening		
09:00-09:45	Elena Hassinger (Karlsruhe Institute of Technology)	Haim Beidenkopf (Weizmann Institute of Science)	Matteo Mitrano (Harvard University)
09:45-10:30	Sophie Guéron (CNRS, Université Paris-Saclay)	Inti Sodemann (University of Leipzig)	Sid Parameswaran (University of Oxford)
10:30-11:00	Coffee	Coffee	Coffee
11:00-11:30	Neven Barišić (TU Wien and University of Zagreb)	Karsten Held (TU Wien)	Zhanybek Alpichshev (ISTA)
11:30-12:00	Georgios Katsaros (ISTA)	Silke Paschen (TU Wien)	Fakher Assaad (Universität Würzburg)
12:00-12:30	Aline Ramires (TU Wien)	Luca Banszerus (University of Vienna)	Denitsa Baykusheva (ISTA)
12:30-14:00	Lunch	Lunch	Lunch
14:00-14:45	Lukas Janssen (Dresden University of Technology)	Shuang Jia (Peking University)	Matthias Eschrig (University of Greifswald)
14:45-15:15	Marta Gibert (TU Wien)	Vladyslav Kozii (Carnegie Mellon University)	Veronika Sunko (ISTA)
15:15-15:30	Coffee	Coffee	Coffee
15:30-15:45			
15:45-16:00			Lucia Vigliotti (ISTA)
16:00-16:15	Marcel Strohmeier (University of Konstanz)	Posters	Shiva Safari (ISTA)
16:15-16:45	Lab tour Institute of Solid State Physics or free discussion time		Closing remarks
16:45-17:00			
17:00-18:00		Ignacio Cirac (MPI of Quantum Optics) - streamed live from ISTA -	Free discussion time
18:30-20:30	Conference dinner		

## Wednesday, July 1, 2026

08:30-08:50	Registration
08:50-09:00	Opening by Silke Bühler-Paschen
Chair	Karsten Held
09:00-09:45 (30+10)	<u>Elena Hassinger</u> , Karlsruhe Institute of Technology <i>Mysteries of the two-phase superconductor CeRh<sub>2</sub>As<sub>2</sub></i>
09:45-10:30 (30+10)	<u>Sophie Guéron</u> , CNRS, Université Paris-Saclay <i>Probing topology with mesoscopic physics</i>
10:30-11:00	Coffee and posters
Chair	Maksym Serbyn
11:00-11:30 (25+5)	<u>Neven Barišić</u> , Technische Universität Wien and University of Zagreb <i>Superconductivity: The case of the cuprates</i>
11:30-12:00 (25+5)	<u>Georgios Katsaros</u> , Institute of Science and Technology Austria <i>Granular aluminum induced superconductivity in germanium for hole spin-based hybrid devices</i>
12:00-12:30 (25+5)	<u>Aline Ramires</u> , Technische Universität Wien <i>Structural reconstruction as the origin of the cuprate pseudogap</i>
12:30-14:00	Lunch
Chair	Kimberly Modic
14:00-14:45 (30+10)	<u>Lukas Janssen</u> , Dresden University of Technology <i>Dirac quantum criticality in moiré materials</i>
14:45-15:15 (25+5)	<u>Marta Gibert</u> , Technische Universität Wien <i>SrCrO<sub>3</sub> thin films</i>
15:15-15:45	Coffee and posters
15:45-16:15 (25+5)	<u>Marcel Strohmeier</u> , University of Konstanz <i>Spectroscopic evidence for nodal pairing symmetry in the non-centrosymmetric superconductor Nb<sub>18</sub>Re<sub>82</sub></i>
16:15-18:00	Lab tour at the Institute of Solid State Physics, Technische Universität Wien Freihaus, Wiedner Hauptstraße 8-10, 1040 Vienna or free discussion time
18:30-20:30	Conference dinner with invited speakers and PIs of the SFB Q-M&S Restaurant Beograd <a href="https://www.restaurant-beograd.com/">https://www.restaurant-beograd.com/</a> Schikanedergasse 7 1040 Vienna

## Thursday, July 2, 2026

Chair	Elke Scheer
09:00-09:45 (30+10)	<u>Haim Beidenkopf</u> , Weizmann Institute of Science <i>Pomeranchuk instability and strange metal in kagome systems</i>
09:45-10:30 (30+10)	<u>Inti Sodemann</u> , University of Leipzig <i>The monopole plasma resonance: a smoking gun of 3D U(1) spin liquids</i>
10:30-11:00	Coffee and posters
Chair	Fakher Assaad
11:00-11:30 (25+5)	<u>Karsten Held</u> , Technische Universität Wien <i>Dawn of entanglement with the pseudogap opening</i>
11:30-12:00 (25+5)	<u>Silke Paschen</u> , Technische Universität Wien <i>Strange metals as a platform to probe entanglement</i>
12:00-12:30 (25+5)	<u>Luca Banszerus</u> , University of Vienna <i>Artificial flat bands in frustrated Josephson junction arrays based on superconductor/semiconductor hybrids</i>
12:30-14:00	Lunch
Chair	Kimberly Modic
14:00-14:45 (30+10)	<u>Shuang Jia</u> , Peking University <i>Giant anomalous Hall and Nernst effects in Ce-based heavy fermions</i>
14:45-15:30 (30+10)	<u>Vladyslav Kozii</u> , Carnegie Mellon University <i>Nonuniform Hall conductivity, quantum geometry, and electron hydrodynamics</i>
15:30-16:00	Coffee and posters
16:00-17:00	Poster session
17:00-18:00	<u>Ignacio Cirac</u> , Max Planck Institute of Quantum Optics <i>Simulating the quantum world with quantum computers</i> (streamed live from ISTA)

Friday, July 3, 2026

Chair	Kimberly Modic
09:00-09:45 (30+10)	<u>Matteo Mitrano</u> , Harvard University <i>Optically driven quantum liquids in one dimension</i>
09:45-10:30 (30+10)	<u>Sid Parameswaran</u> , University of Oxford <i>Twisted M-point materials: A new platform for strong correlations</i>
10:30-11:00	Coffee and posters
Chair	Maksym Serbyn
11:00-11:30 (25+5)	<u>Zhanybek Alpichshev</u> , Institute of Science and Technology Austria <i>Dynamic and kinematic resonances in nonlinear THz Kerr spectroscopy</i>
11:30-12:00 (25+5)	<u>Fakher Assaad</u> , Universität Würzburg <i>Mott transition of photons: quantum Monte Carlo study of Gross-Neveu criticality in a cavity</i>
12:00-12:30 (25+5)	<u>Denitsa Baykusheva</u> , Institute of Science and Technology Austria <i>Squeezed light from strongly-driven <math>\eta</math>-pairing states in the Hubbard model</i>
12:30-14:00	Lunch
Chair	Neven Barišić
14:00-14:45 (30+10)	<u>Matthias Eschrig</u> , University of Greifswald <i>Geometric phases in noncoplanar superconducting spintronics</i>
14:45-15:15 (25+5)	<u>Veronika Sunko</u> , Institute of Science and Technology Austria <i>Magneto-optical detection of time-reversal symmetry breaking in antiferromagnets</i>
15:15-15:45	Coffee and posters
Chair	Karsten Held
15:45-16:15 (25+5)	<u>Lucia Vigiotti</u> , Institute of Science and Technology Austria <i>Intrinsic relaxation and driven multimode dynamics in Josephson junction chains</i>
16:15-16:45 (25+5)	<u>Shiva Safari</u> , Institute of Science and Technology Austria <i>Scale-invariance and topological order in quantum spin systems</i>
16:45-17:00	Closing remarks by Silke Bühler-Paschen
17:00-18:00	Free discussion time

## Invited abstracts

1. Luca Banszerus, University of Vienna  
*Artificial flat bands in frustrated Josephson junction arrays based on superconductor/semiconductor hybrids*
2. Denitsa Baykusheva, Institute of Science and Technology Austria  
*Squeezed light from strongly-driven  $\eta$ -pairing states in the Hubbard model*
3. Haim Beidenkopf, Weizmann Institute of Science  
*Pomeranchuk instability and strange metal in kagome systems*
4. Matthias Eschrig, University of Greifswald  
*Geometric phases in noncoplanar superconducting spintronics*
5. Marta Gibert, Technische Universität Wien  
*SrCrO<sub>3</sub> thin films*
6. Sophie Guéron, CNRS, University of Paris-Saclay  
*Probing topology with mesoscopic physics*
7. Elena Hassinger, Karlsruhe Institute of Technology  
*Mysteries of the two-phase superconductor CeRh<sub>2</sub>As<sub>2</sub>*
8. Lukas Janssen, Dresden University of Technology  
*Dirac quantum criticality in moiré materials*
9. Shuang Jia, Peking University  
*Giant anomalous Hall and Nernst effects in Ce-based heavy fermions*
10. Vladyslav Kozii, Carnegie Mellon University  
*Nonuniform Hall conductivity, quantum geometry, and electron hydrodynamics*
11. Matteo Mitrano, Harvard University  
*Optically driven quantum liquids in one dimension*
12. Sid Parameswaran, University of Oxford  
*Twisted M-point materials: A new platform for strong correlations*
13. Aline Ramires, Technische Universität Wien  
*Structural reconstruction as the origin of the cuprate pseudogap*
14. Inti Sodemann, University of Leipzig  
*The monopole plasma resonance: a smoking gun of 3D U(1) spin liquids*
15. Veronika Sunko, Institute of Science and Technology Austria  
*Magneto-optical detection of time-reversal symmetry breaking in antiferromagnets*

Luca Banszerus

## Artificial flat bands in frustrated Josephson junction arrays based on superconductor/semiconductor hybrids

Luca Banszerus<sup>1</sup>, Christine Andersson<sup>2</sup>, Will Marshall<sup>2,3</sup>, T. Lindemann<sup>4,5</sup>, M. J. Manfra<sup>4,5,6,7</sup>, C. M. Marcus<sup>2,3,8</sup>, and S. Vaitiekėnas<sup>2</sup>

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<sup>2</sup> Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

<sup>3</sup> Department of Physics, University of Washington, Seattle, Washington 98195, USA

<sup>4</sup> Department of Physics and Astronomy, Purdue University, West Lafayette, Indiana 47907, USA

<sup>5</sup> Birck Nanotechnology Center, Purdue University, West Lafayette, Indiana 47907, USA

<sup>6</sup> School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana 47907, USA

<sup>7</sup> School of Materials Engineering, Purdue University, West Lafayette, Indiana 47907, USA

<sup>8</sup> Materials Science and Engineering, University of Washington, Seattle, Washington 98195, USA

Epitaxial semiconductor-superconductor hybrid materials provide a novel highly-tunable platform to study emergent quantum phenomena, taking advantage of gate-controlled density, ballistic transport, and non-sinusoidal current-phase relations. Recently, hybrid Josephson junction arrays have been used to probe the gate-controlled superconductor-insulator transition (SIT), where Josephson couplings can be tuned to be greater than or less than the charging energy of the islands. A perpendicular magnetic field introduces frustration, leading to complex ground states that depend on the geometry of the array. The talk will focus on two-dimensional Josephson junction arrays in the dice lattice geometry, that are predicted to host flat bands when frustrated. I will discuss our efforts to map out the phase diagram as a function of frustration: Frustrations commensurate with the lattice geometry lead to the formation of vortex lattices, which are absent at incommensurate values of frustration. When the array is frustrated by half a flux quantum per plaquette, quantum interference localizes individual Cooper pairs, corresponding to the formation of a flat-band system.

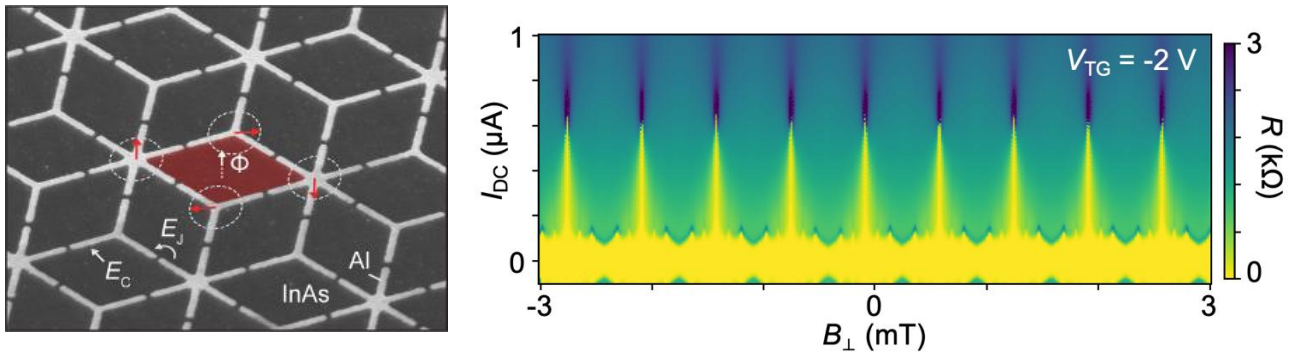


Figure 1. Left: Scanning electron microscopy image of a Josephson junction array in the dice lattice geometry. The charging energies of the superconducting Al islands compete with the Josephson couplings. Right: Device resistance as a function of DC current and perpendicular magnetic field. The switching current exhibits maxima at magnetic fields corresponding to commensurate values of frustration, resulting in the formation of vortex lattices.

Denitsa Baykusheva

## Squeezed light from strongly-driven $\eta$ -pairing states in the Hubbard model

Jonah Richards<sup>1</sup>, Aly Valiev<sup>1</sup>, Palina Shaban<sup>1</sup>, and Denitsa Baykusheva<sup>1</sup>

<sup>1</sup> *Institute of Science and Technology Austria, 3400 Klosterneuburg, Austria*

High-harmonic generation in correlated electronic systems has recently emerged as a sensitive probe of many-body interactions [1,2]. Still, the question on how long-range electronic coherence leaves its imprint on the emitted light and its photon statistics [3,4] remains largely unaddressed.  $\eta$ -pairing states [5] in the half-filled Hubbard model represent exact eigenstates exhibiting off-diagonal long-range order. Here we investigate how  $\eta$ -pairing correlations reshape the strong-field emission. We find pronounced differences compared to the Mott-insulating ground state in both the intensity and the photon statistics of the emitted field, accompanied by a pronounced squeezing of the harmonic emission in the  $\eta$ -state. This indicates that the statistical features of HHG carry diagnostic information about electronic order beyond what power spectra alone reveal. Finally, I will report on experimental progress towards experimental detection of the imprints of electronic correlations in the photon statistics of the emitted harmonics.

- [1] Silva et al., Nat. Photonics 12, 266–270 (2018).
- [2] Murakami et al., Phys. Rev. Lett. 121, 057405 (2018).
- [3] Lange et al., Phys. Rev. A 109, 033110 (2024).
- [4] Lange et al., Phys. Rev. Lett. 135, 043603 (2025).
- [5] [Yang et al., Phys. Rev. Lett. 63, 2144–2147 (1989).

Haim Beidenkopf

## Pomeranchuk instability and strange metal in kagome systems

P. K. Nag<sup>1</sup>, N. Morali<sup>1</sup>, R. Batyabal<sup>1</sup>, J. Souza<sup>1</sup>, M. Haim<sup>1</sup>, A. Gupta<sup>1</sup>, N. Avraham<sup>1</sup>, H. Tan<sup>1</sup>, J. Koo<sup>1</sup>, B. Yan<sup>1</sup>, R. Queiroz<sup>2</sup>, J. Ingham<sup>2</sup>, A. Consiglio<sup>3</sup>, R. Thomale<sup>3</sup>, E. Liu<sup>4</sup>, C. Felser<sup>4</sup>, S. Fang<sup>5</sup>, M. Han<sup>5</sup>, C. John<sup>5</sup>, J. Zheng<sup>5</sup>, J. G. Checkelsky<sup>5</sup>, M. Mahankali<sup>6</sup>, F. Xie<sup>6</sup>, Y. Fang<sup>6</sup>, L. Chen, Q. Si<sup>6</sup>, and H. Beidenkopf<sup>1</sup>

<sup>1</sup> Weizmann Institute of Science, Rehovot 7610001, Israel

<sup>2</sup> Columbia University, New York 10027, USA

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<sup>4</sup> Max Planck Institute for Chemical Physics of Solids, Dresden D-01187, Germany

<sup>5</sup> Massachusetts Institute of Technology, Cambridge 02139, MA, USA

<sup>6</sup> Rice University, Houston 77005, TX, USA

The kagome lattice structure of corner-sharing triangles hosts a variety of electronic motifs that challenge Fermi liquid theory and give rise to exotic responses. The kagome band structure hosts a pair of saddle points that correspond to van Hove singularities with a diverging density of states. Destructive interference further yields a flat band of localized moments. We studied the responses of these flat bands on the atomic scale using scanning tunneling spectroscopy. On the kagome  $\text{Co}_3\text{Sn}$  termination of  $\text{Co}_3\text{Sn}_2\text{S}_2$  we identified a new mechanism under which a breathing distortion turns the kagome van Hove singularity into a higher-order one pinned at the Fermi energy. The strong interactions result in a spontaneous formation of a nematic state under a Pomeranchuk instability [1]. In the kagome metal  $\text{Ni}_3\text{In}$ , the kagome flat band is pinned to the Fermi energy, resulting in the breakdown of Fermi liquid theory, signified by a strange metal non-linear temperature dependence of resistivity. We identify spectroscopically the localized degrees of freedom and their strong interactions with Dirac light bands pertaining to heavy-Fermion systems. We directly visualize quasi-particle collapse in the strange metal state and their revival within the Fermi-liquid part of the phase diagram<sup>2</sup>. Our studies thus reveal the exciting opportunities put forward by kagome metals for the investigation of exotic electronic states ranging from massless Dirac particles<sup>3</sup>, through moderately heavy states exhibiting spontaneous symmetry breaking, to super-heavy ones at which the interaction energy surpasses the bandwidth, extending the universality of the heavy Fermion paradigm to kagome flat bands.

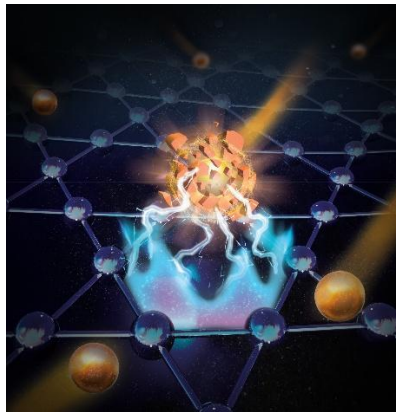


Figure 1. Illustration of quasi-particle collapse in a Kagome flat band.

- [1] P. K. Nag et al., Pomeranchuk Instability Induced by an Emergent Higher-Order van Hove Singularity on the Distorted Kagome Surface of  $\text{Co}_3\text{Sn}_2\text{S}_2$ . arXiv2410.01994.
- [2] J.C. Souza et al., Origin of strange metallicity in a d-orbital kagome metal, *Nat. Phys.* 22, 541 (2026).
- [3] N. Morali et al., Fermi-arc diversity on surface terminations of the magnetic Weyl semimetal  $\text{Co}_3\text{Sn}_2\text{S}_2$ , *Science* 365, 1286 (2019).

Matthias Eschrig

## Geometric phases in noncoplanar superconducting spintronics

Matthias Eschrig<sup>1</sup><sup>1</sup> University of Greifswald, Institute of Physics, D-17489 Greifswald, Germany

Superconducting spintronics is based on spin-polarized Cooper pairs, which appear near the interfaces between superconducting and magnetic materials [1,2]. In the case of a Josephson device containing a strongly spin-polarized itinerant ferromagnet, only Cooper pairs with equal spin relative to the direction of the exchange field contribute to transport over appreciable distances, whereas mixed-spin Cooper pairs are confined to the interface regions and mainly contribute to the basic mechanisms of singlet-triplet mixing and triplet rotation [1]. Typically, the conversion process from spin-singlet to equal-spin pairs requires *non-collinear* magnetic inhomogeneities in the vicinity of the interfaces. If the spin texture in the Josephson junction is also *non-coplanar*, a distinctive Josephson diode effect appears [3-5]. This effect is driven by spin-geometric phases that enter the current-phase relation in a novel way [1,2]. In the case of a spatially slowly varying magnetization profile, they enter via an effective U(1) gauge field that couples with opposite sign to the two spin projections [5]. Noncoplanar superconducting spintronics opens up the field to an entire new set of phenomena related to the interplay between spin-geometric phases and Josephson phases. I present an overview over these novel functionalities.

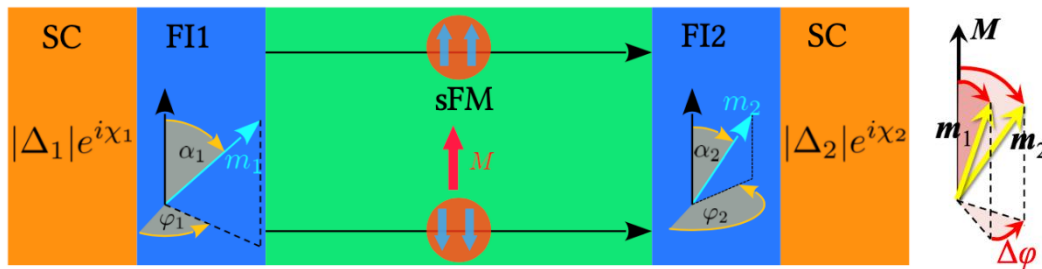


Figure 1. Josephson junction governed by spin-geometric angle  $\Delta\varphi = \varphi_2 - \varphi_1$ , which is of similar fundamental importance for the Josephson current-phase relation as the superconducting phase difference  $\Delta\chi = \chi_2 - \chi_1$ .

This work is supported by the German Research Foundation (DFG) under project number 530670387.

- [1] M. Eschrig, Spin-polarized supercurrents for spintronics: A review of current progress. Rep. Prog. Phys. 78, 104501 (2015).
- [2] M. Eschrig, Phase-Sensitive Interface and Proximity Effects in Superconducting Spintronics, in: Spintronics Handbook, Second Edition: Spin Transport and Magnetism, CRC Press, 2019.
- [3] R. Grein, M. Eschrig, G. Metalidis, and G. Schön, Spin-dependent Cooper Pair Phase and Pure Spin Supercurrents in Strongly Polarized Ferromagnets, Phys. Rev. Lett. 102, 227005 (2009).
- [4] N. L. Schulz, D. Nikolic, and M. Eschrig, Theory of quantum-geometric charge and spin Josephson diode effects in strongly spin-polarized hybrid structures with noncoplanar spin textures, Phys. Rev. B 112, 104515 (2025).
- [5] D. Nikolic, N. L. Schulz, A. I. Buzdin, and M. Eschrig, Spin-resolved Josephson diode effect through strongly spin-polarized conical magnets, Phys. Rev. B 112, 224507 (2025).

Marta Gibert

## SrCrO<sub>3</sub> thin films

Marta Gibert<sup>1</sup>

<sup>1</sup> *Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria*

Perovskite transition-metal oxides are widely studied for their remarkable electronic and magnetic properties. Among them, chromium-based perovskites ACrO<sub>3</sub> (A = alkaline earth metal) remain comparatively unexplored due to the difficulty of stabilizing the Cr<sup>4+</sup> oxidation state, which typically requires extreme synthesis conditions. SrCrO<sub>3</sub> exemplifies this challenge. Although diverse physical properties have been reported, its ground state appears to be both metallic and antiferromagnetic—a rare and intriguing coexistence.

We report the successful synthesis of high-quality epitaxial SrCrO<sub>3</sub> thin films grown by off-axis RF magnetron sputtering. Stabilization of the Cr<sup>4+</sup> valence state required precise control of an extremely low oxygen partial pressure, as confirmed by x-ray absorption spectroscopy. Transport measurements show a strain-induced metal-insulator transition. Metallic behaviour occurs under low strain, reflecting the SrCrO<sub>3</sub> ground state. Increasing tensile strain, however, drives the system toward insulating behavior. DFT+U calculations attribute this transition to a strain-driven Jahn–Teller distortion that lifts orbital degeneracy and opens a bandgap. Muon spin relaxation measurements reveal a magnetic transition at 150K, independent of strain. This transition is associated with a disordered antiferromagnetic state. The structural, transport, and magnetic properties of SrCrO<sub>3</sub>/LaCrO<sub>3</sub> superlattices will also be discussed.

Sophie Guéron

## Probing topology with mesoscopic physics

Sophie Guéron<sup>1</sup>

<sup>1</sup> *Mesoscopic Physics group, Laboratoire de Physique des Solides, Université Paris Saclay, France*

Second Order Topological Insulators (SOTIs) are a new family of materials, predicted to be insulating in the bulk and surfaces, and perfectly conducting along dimensional crystal hinges. Similarly to Quantum Spin Hall edges states in 2D Topological Insulators, the hinge states are expected to carry current with no dissipation and no backscattering, due to their unique spin-momentum-locked configuration, also called helicity. I will present mesoscopic physics experiments that have uncovered the special properties of SOTIs. In particular, I will explain why induced superconductivity was instrumental to the discovery that Bismuth was a Second Order Topological Insulator [1-5]. I will also present recent extension to new SOTI materials [6,7] and to non-superconducting contacts, as well as to the investigation of the current-induced spin polarization due to spin-momentum locking in the hinge states [8]. Finally, I will present a new detection scheme of orbital currents in 2D materials [9], that has the potential to reveal persistent currents circulating at the hinges of a mesoscopic SOTI crystal.

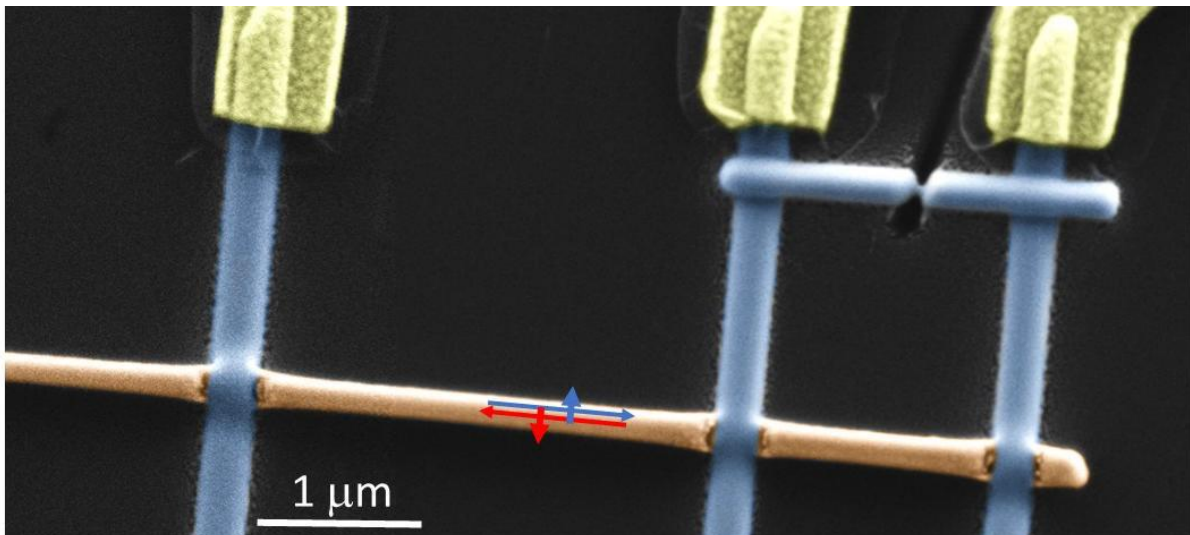


Figure 1. Bismuth nanowire (coloured in brown) inserted in a dc-SQUID made with Focused-Ion-Beam-induced deposition of superconducting tungsten (coloured in blue).

- [1] Schindler et al, Nat. Phys. 14, 918 (2018).
- [2] Murani et al., Nat. Comm. 8,15941 (2017).
- [3] Carlo Beenakker, [https://www.condmatclub.org/uploads/2018/03/JCCM\\_March\\_2018\\_01.pdf](https://www.condmatclub.org/uploads/2018/03/JCCM_March_2018_01.pdf).
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- [5] A. Bernard et al., Nature Physics 19, 358(2023).
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This work is a collaborative work conducted in the Mesoscopic Physics group in Orsay.

Elena Hassinger

## Mysteries of the two-phase superconductor CeRh<sub>2</sub>As<sub>2</sub>

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Superconductors with non-trivial pairing symmetries expand our understanding of correlated quantum matter and show promise for applications in quantum computing. Odd-parity superconductivity is interesting in this regard due to its robustness to magnetic field and possible topological surface states. The phenomenon only occurs in a few materials, the most recognised cases of which are strongly correlated uranium-based systems with weak ferromagnetism. Another candidate is CeRh<sub>2</sub>As<sub>2</sub>, which exhibits a magnetic-field-induced transition between two superconducting phases, currently understood as states of even- and odd-parity pairing. Here, the odd-parity pairing is thought to be stabilised not by ferromagnetism, but by the staggered Rashba spin-orbit interaction caused by the absence of inversion symmetry at the Ce sites. Since the tetragonal crystal structure is centrosymmetric, states of distinct parity are allowed [1,2]. But the superconductivity is not the only mystery of CeRh<sub>2</sub>As<sub>2</sub>. Similarly to other unconventional superconductors, the material hosts a coexisting weak ordered state that can be suppressed by pressure [3-5]. Although the order parameter is not fully identified, internal magnetic fields are evidenced by NMR/NQR [6] and  $\mu$ SR [7] measurements. Intriguingly, the transition temperature decreases with an out-of-plane field, but increases strongly with an in-plane field, which is hard to reconcile with a simple magnetic order but can be explained by considering quadrupolar degrees of freedom [3,8,9]. This unconventional magnetic state and its role for superconductivity are currently in the focus of research on this compound. In my talk, I will highlight experimental results from macroscopic and microscopic measurements under different tuning parameters such as pressure and magnetic field, each nurturing our current understanding of the fascinating properties of CeRh<sub>2</sub>As<sub>2</sub>.

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Lukas Janssen

## Dirac quantum criticality in moiré materials

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<sup>1</sup> *Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, TU Dresden, 01062 Dresden, Germany*

In this talk, I will discuss theoretical results on quantum phase transitions in moiré materials tuned by twist angle. In twisted bilayer graphene, we find a continuous transition from a Dirac semimetal to a Kramers intervalley-coherent insulator, belonging to the Gross-Neveu-XY universality class. In twisted double-bilayer transition metal dichalcogenides, we identify a continuous transition from a Dirac semimetal to an antiferromagnetic insulator with spin-density modulation on the moiré scale. This transition, tunable by twist angle or uniaxial pressure, falls into the Gross-Neveu-Heisenberg universality class. Our results provide theoretical context for, and help elucidate, recent experimental observations of this transition in twisted double bilayer WSe<sub>2</sub>.

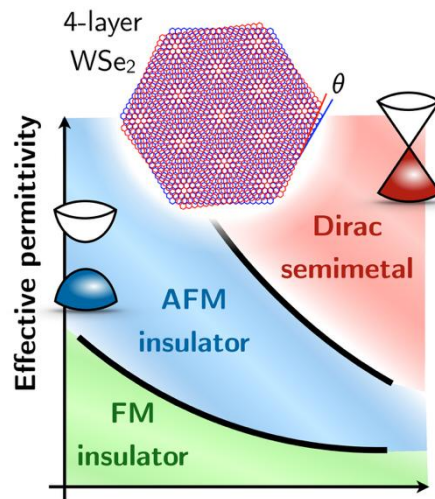


Figure 1. Schematic phase diagram of twisted double bilayer WSe<sub>2</sub>.

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Shuang Jia

## Giant anomalous Hall and Nernst effects in Ce-based heavy fermions

Shuang Jia<sup>1</sup><sup>1</sup> ICQM, School of Physics, Peking University, 100871, Beijing, China

The anomalous Hall effect (AHE) and anomalous Nernst effect (ANE) are two phenomena that describe the perpendicular voltage drop that occurs when a magnetic material is magnetized in the presence of an applied current and a temperature gradient. These effects offer potential applications in future electronic devices and thermoelectric energy conversion. This presentation will discuss our research on the giant AHE and ANE observed in multiple Ce-based, ferromagnetic intermetallic compounds. We observed a massive anomalous Hall conductivity and anomalous Nernst coefficient, which can reach values as high as  $1000 \text{ } \Omega^{-1} \text{ cm}^{-1}$  and  $10 \text{ } \mu\text{V K}^{-1}$ , respectively. Unlike conventional heavy-fermion compounds, where the AHE is caused by coherent skew scattering, the giant anomalous effects observed in our study stem from a strong Berry curvature field resulting from the strong hybridization between the  $f$  and conduction electrons in a ferromagnetic order. Our findings pave the way for exploring correlation-driven topological responses in an itinerant ferromagnetic Kondo lattice environment.

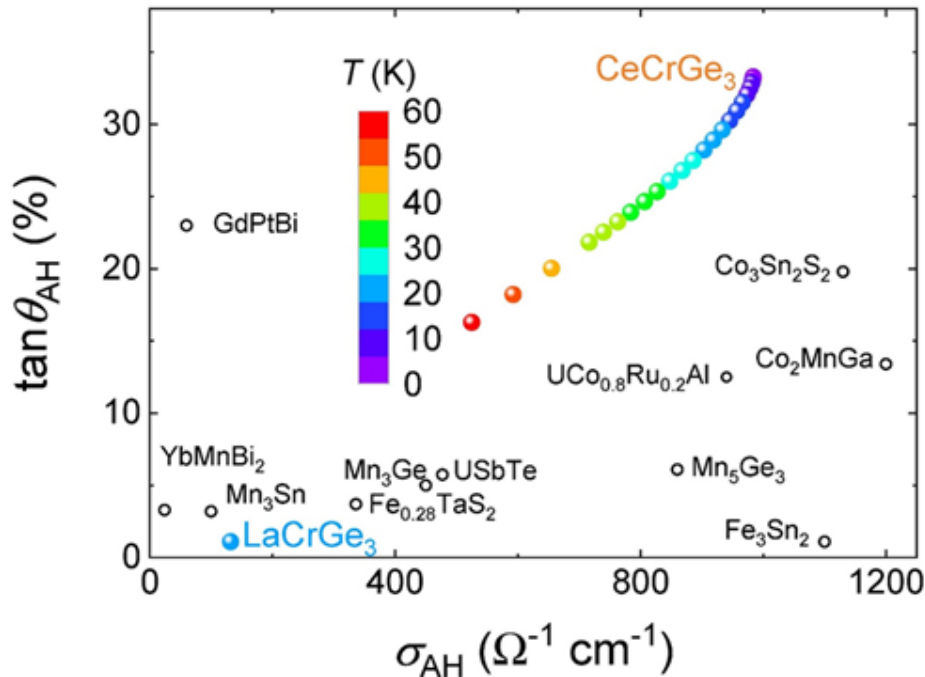


Figure 1. Giant Anomalous Hall angle ( $\tan\theta_{AH}$ ) of ferromagnetic heavy Fermion  $\text{CeCrGe}_3$ .

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- [2] L. Li et al., Science Bulletin, 2026, 71, 10.
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Vladyslav Kozii

## Nonuniform Hall conductivity, quantum geometry, and electron hydrodynamics.

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The geometry of electronic wave functions plays a fundamental role in shaping the transport and optical properties of quantum materials. A celebrated example is the intrinsic anomalous Hall effect, whose magnitude is governed by the Berry curvature of electronic bands. In this talk, I will discuss a natural extension of this concept to the nonlocal Hall conductivity, which characterizes the response of a system to spatially varying electric fields.

Focusing on the long-wavelength regime, I will show that the leading  $q^2$  contribution to the Hall conductivity, where  $q$  is the wave vector of the applied field, is determined by local geometric characteristics of the band structure. In the simplest two-band case, these include the *quantum metric*, the *Berry curvature*, and a rank-three *skewness tensor* associated with the *symplectic connection* [1].

Nonlocal transport becomes particularly important in ultraclean materials, where it can dominate conventional local responses and drive the system into the *electron hydrodynamic* regime. In this strongly interacting fluid, transport is inherently nonlocal, governed by momentum-conserving electron-electron collisions, with dissipation occurring primarily at the boundaries. I will discuss the role of nonlocal Hall conductivity in this context and its potential implications for *anomalous electron magnetohydrodynamics*, a transport regime with no classical analog [2,3].

Finally, I will present recent developments extending this framework to multiband systems. In contrast to two-band models, the intrinsic nonlocal Hall response is no longer determined solely by ground-state wave functions, but also by virtual interband processes involving excited states. This gives rise to new geometric structures, including *multistate geometric tensors*, *interband Berry connections*, and *projected shape tensors*. Together, these results establish a direct link between quantum geometry and collective transport in a strongly interacting electron fluid, leading to effects with no classical analog.

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Matteo Mitrano

## Optically driven quantum liquids in one dimension

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A key frontier of modern condensed matter is to harness light–matter interaction to coherently engineer quantum states in materials. Under optical driving, quantum materials exhibit emergent many-body phenomena, from ultrafast switching to dynamical quantum states without equilibrium analogs. Progress hinges on using light to uncover new nonequilibrium states and devise strategies to stabilize them far beyond the duration of the drive.

One-dimensional Mott insulators are particularly compelling platforms for these goals. Electron fractionalization produces highly entangled ground states that are exceptionally responsive to optical perturbations, and theory predicts exotic ordering phenomena upon photoexcitation. In this talk, I will show how ultrafast X-ray spectroscopy provides a direct, microscopic view of these dynamics by resolving charge and spin responses of optically driven phases. I will discuss our observation of a photoinduced Tomonaga–Luttinger liquid state in the one-dimensional cuprate chain  $\text{Sr}_2\text{CuO}_3$  [1]. I will then show how nonequilibrium states can be stabilized for nanosecond timescales by leveraging symmetry constraints in the parent ladder compound  $\text{Sr}_{14}\text{Cu}_{24}\text{O}_{41}$  [2,3].

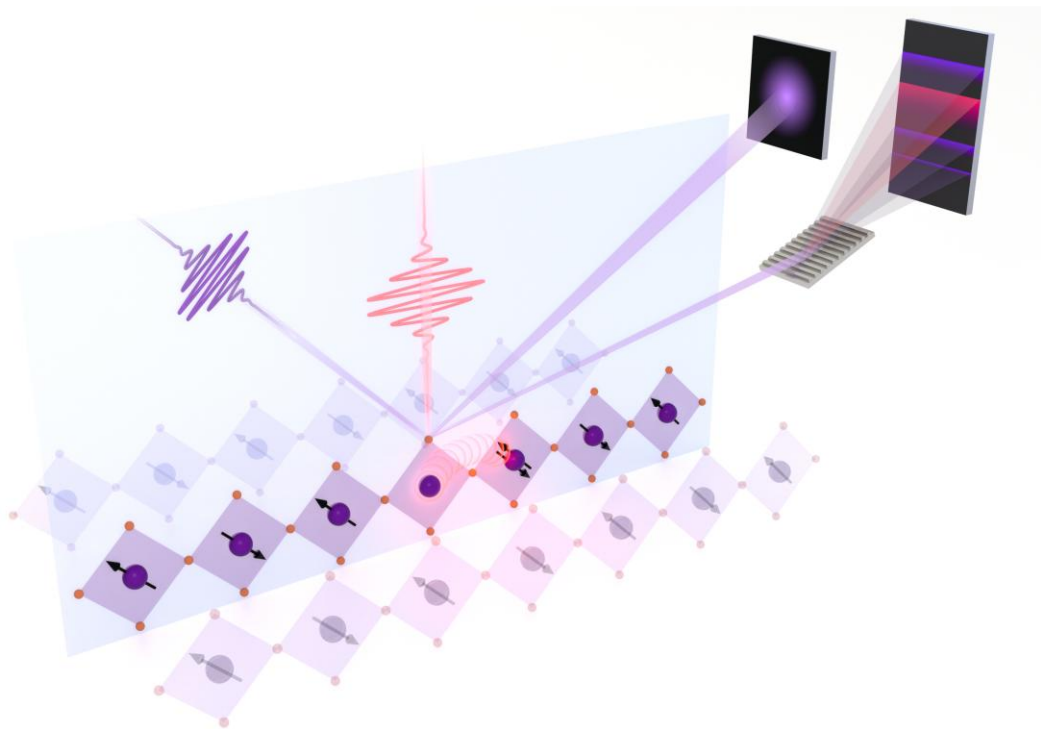


Figure 1. Ultrafast optical excitation can induce emergent charge dynamics in quasi-one-dimensional quantum materials, which can be resolved using advanced ultrafast x-ray scattering and spectroscopy techniques.

- [1] A. K. Jones, S. F. R. TenHuisen, et al. forthcoming (2026).
- [2] H. Padma et al. *Nat. Mater.* 24, 1584–1591 (2025).
- [3] H. Padma et al. *Phys. Rev. Lett.* 136, 196501 (2026).

Sid Parameswaran

## Twisted M-point materials: A new platform for strong correlations

Siddharth A. Parameswaran<sup>1</sup>

<sup>1</sup> *Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Parks Road, OX1 3PU UK*

I will discuss recent theoretical work exploring correlated phases in heterostructures generated by twisting individual 2D layers whose low-energy electronic dispersions lie at the Brillouin zone M-point [1]. The resulting moiré system has low-energy electrons with a valley-filtered anisotropy, such that each valley to good approximation is only dispersive in a single direction. Remarkably, the problem is accessible via two different sign-problem free quantum Monte Carlo algorithms along two distinct parameter axes [2,3], providing a window into the physics of strong correlations in this new family of moiré materials. These tools reveal a wealth of phenomena, ranging from correlated Mott and Wigner-Mott insulators at commensurate fillings, a strong-coupling description in terms of effective spin chains, Pomeranchuk-like thermal effects, and crossover physics that can be modelled in terms of weakly-broken U(6) local moments.

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Aline Ramires

## Structural reconstruction as the origin of the cuprate pseudogap

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High-temperature superconductivity in the cuprates emerges from an enigmatic metallic state, known as the pseudogap, characterized by a reconstructed Fermi surface, reduced carrier density, and the appearance of Fermi arcs, whose origin remains unresolved. Here, we show that these defining signatures naturally arise from a structural reconstruction, experimentally observed, that introduces a symmetry-enforced sublattice degree of freedom. In the presence of spin-orbit coupling, the Fermi surface is reconstructed into small closed pockets, effectively reducing the carrier density. The same sublattice structure gives rise to matrix-element interference in angle-resolved photoemission spectroscopy, leading to the emergence of Fermi arcs. Density functional theory calculations support this mechanism. These results demonstrate that lattice symmetry provides a unifying and experimentally verifiable framework for understanding the pseudogap regime in the cuprates.

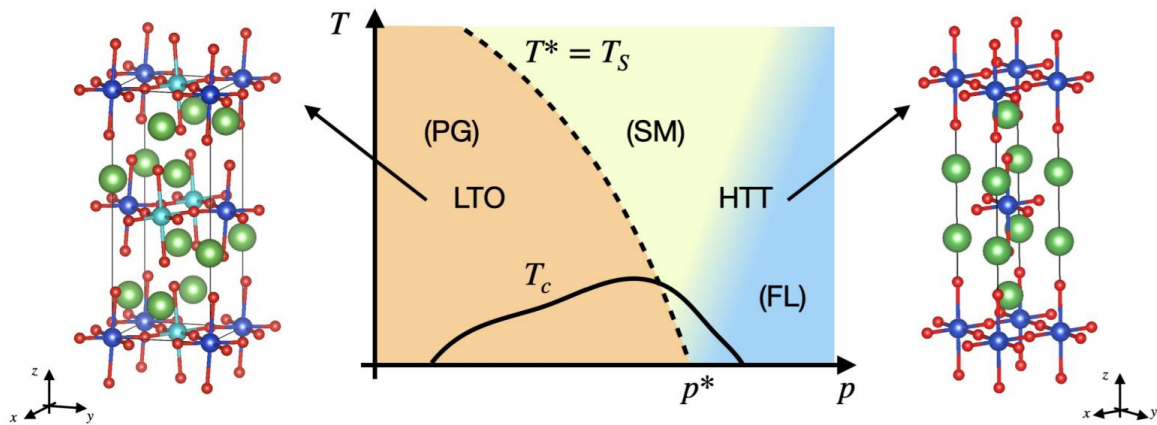


Figure 1. Structure-property relation in the pseudogap.

Sophie Beck and Aline Ramires, arXiv.2511.02508.

Inti Sodemann

## The monopole plasma resonance: a smoking gun of 3D U(1) spin liquids

Anish Koley<sup>1</sup>, Saranyo Moitra<sup>1</sup> and Inti Sodemann<sup>1</sup>

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3D U(1) quantum spin liquids feature a low-energy emergent "monopole" particle. When the spin liquid arises from a quantum spin ice manifold with dipolar nature –as argued in Ce<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> from neutron scattering experiments– these monopoles carry a physical electric charge bound to their cores. We demonstrate that at low temperatures these charged monopoles form an unusually soft electrical fluid, which is insulating when probed with DC electric fields, but displays a sharp metallic-like plasma resonance in the electrical conductivity at a low frequency much smaller than the ordinary optical and transport gaps in the material. We discuss the optimal conditions to experimentally discover this resonance, which in Ce<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> should be at around 0.6 GHz at a temperature of 25mK.

[1] Koley, Moitra, Sodemann, manuscript in preparation.

Veronika Sunko

## Magneto-optical detection of time-reversal symmetry breaking in antiferromagnets

Veronika Sunko<sup>1</sup>

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Optical probes are naturally well suited to detecting broken symmetries, including time-reversal symmetry ( $\mathcal{T}$ ), and are frequently used in this way, for example, to map ferromagnetic domains. But the conditions under which optics can detect  $\mathcal{T}$  - breaking in antiferromagnets with no net magnetization are far more subtle. The key distinction is whether the effect of  $\mathcal{T}$  can be undone by a simple translation ( $\mathcal{S}_{1/2}$ ); if it can, the product  $\mathcal{T}\mathcal{S}_{1/2}$  is a symmetry of the system and  $\mathcal{T}$  - breaking is usually invisible to bulk probes. In contrast, antiferromagnets that do not preserve  $\mathcal{T}\mathcal{S}_{1/2}$  display a range of bulk  $\mathcal{T}$ - breaking phenomena, such as the magnetoelectric and piezomagnetic effect.

But what exactly does “bulk” mean? And more specifically, are optical probes “bulk”: can they detect  $\mathcal{T}$ -breaking in  $\mathcal{T}\mathcal{S}_{1/2}$  -invariant antiferromagnets? We address these questions by comparing three antiferromagnets: non-collinear  $\text{EuIn}_2\text{As}_2$  and altermagnetic  $\text{MnTe}$  that break  $\mathcal{T}\mathcal{S}_{1/2}$  and  $\text{MnBi}_2\text{Te}_4$  that does not. In  $\text{EuIn}_2\text{As}_2$  we show how an unconventional optical probe, linear magneto-birefringence, can reveal symmetry breaking invisible to more standard measurements [1-3]. In  $\text{MnTe}$ , simultaneous measurements of linear and circular dichroism reveal microscopic orientation of the  $\mathcal{T}$  - breaking order parameter [4]. In  $\text{MnBi}_2\text{Te}_4$ , we demonstrate how perhaps the most standard optical probe of magnetism, reflection circular dichroism, can in fact detect antiferromagnetism even when  $\mathcal{T}\mathcal{S}_{1/2}$  is preserved in the bulk [5].

Together, these experiments demonstrate both the power and the versatility of optics as a probe of symmetry breaking in quantum materials.

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- [2] Donoway, E.; Trevisan, T. V.; Liebman-Peláez, A.; Day, R. P.; Yamakawa, K.; Sun, Y.; Soh, J. R.; Prabhakaran, D.; Boothroyd, A. T.; Fernandes, R. M.; Analytis, J. G.; Moore, J. E.; Orenstein, J.; Sunko, V., *Phys. Rev. X*, 14, 031013 (2024).
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## SFB Q-M&S abstracts

1. Zhanybek Alpichshev, Institute of Science and Technology Austria  
*Dynamic and kinematic resonances in nonlinear THz Kerr spectroscopy*
2. Fakher Assaad, Julius-Maximilians-Universität Würzburg  
*Mott transition of photons: quantum Monte Carlo study of Gross-Neveu criticality in a cavity*
3. Neven Barišić, Technische Universität Wien, University of Zagreb  
*Superconductivity: The case of the cuprates*
4. Karsten Held, Technische Universität Wien  
*Dawn of entanglement with the pseudogap opening*
5. Georgios Katsaros, Institute of Science and Technology Austria  
*Granular aluminum induced superconductivity in germanium for hole spin-based hybrid devices*
6. Silke Paschen, Technische Universität Wien  
*Strange metals as a platform to probe entanglement*
7. Shiva Safari, Institute of Science and Technology Austria  
*Scale-invariance and topological order in quantum spin systems*
8. Marcel Strohmaier, University of Konstanz  
*Spectroscopic evidence for nodal pairing symmetry in the non-centrosymmetric superconductor  $Nb_{18}Re_{82}$*
9. Lucia Vigiotti, Institute of Science and Technology Austria  
*Intrinsic relaxation and driven multimode dynamics in Josephson junction chains*

Zhanybek Alpichshev

## Dynamic and kinematic resonances in nonlinear THz Kerr spectroscopy

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<sup>4</sup> Dresden University of Technology, Institute of Applied Physics, Dresden, Germany

Terahertz spectroscopy is a powerful probe of low-energy excitations in complex materials. Extending it into the nonlinear regime significantly broadens its scope, providing access to interactions between lattice, electronic, and collective modes. However, interpreting nonlinear THz spectra remains challenging, as not all observed resonances directly reflect intrinsic material dynamics.

In this work, we investigate the nonlinear THz-induced Kerr effect (TKE) in the model dielectric  $\text{LaAlO}_3$ . Through a detailed analysis of the temporal oscillations in the Kerr response, we identify an  $E_g$  Raman-active phonon at 1.1 THz, excited via a two-photon process. In addition, we observe two prominent spectral features at 0.86 and 0.36 THz that do not correspond to real lattice modes. Instead, we show that these arise from phase-matching conditions between the near-infrared probe and co- and counterpropagating THz pump fields, mediated by off-resonant electronic hyperpolarizability.

These findings reveal the presence of two distinct classes of resonances in nonlinear TKE: *dynamic* resonances, associated with intrinsic excitations of the material, and *kinematic* resonances, arising from conservation laws governing the interacting optical fields. Our results highlight the crucial role of kinematic effects in shaping nonlinear THz responses and establish a general framework for interpreting multidimensional nonlinear spectroscopies in complex materials.

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Fakher Assaad

## Mott transition of photons: quantum Monte Carlo study of Gross-Neveu criticality in a cavity

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<sup>1</sup> *Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany*

The Hubbard model on the honeycomb lattice is a pristine realization of a semimetal-to-insulator Mott transition belonging to the Gross-Neveu  $O(3)$  universality class. We couple this system to a single linearly polarized cavity photon mode. The light-matter coupling is such that the photon number remains an intensive quantity as is the case for an empty cavity. For this interacting light-matter model, we formulate a negative-sign-free fermion quantum Monte Carlo algorithm that allows for bias-free results on finite system sizes. Our numerical results show that the coupling to the cavity is irrelevant at criticality, even at strong electron-photon coupling. On the other hand, we observe, and show analytically, that the photon spectral function couples to the optical conductivity of the electronic system. The cavity photons thereby undergo a Mott transition, and the photon spectral function acts as a contact-free non-invasive probe for Mott criticality [1]. We equally show how this idea can be used to detect orbital selective Mott transitions as realized by Kondo destruction quantum criticality [2],[3].

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- [2] Gaopei Pan, Fakher F. Assaad, Quantum Monte Carlo studies of  $U(1)$  lattice gauge models of Kondo breakdown, [arXiv:2512.17801](https://arxiv.org/abs/2512.17801).
- [3] Federico Mazza, Sounak Biswas, Xinlin Yan, Andrey Prokofiev, Paul Steffens, Qimiao Si, Fakher F. Assaad and Silke Paschen, Quantum Fisher information in a strange metal, [Nature Physics \(2026\)](https://doi.org/10.1038/s41567-026-0000-0).

Neven Barišić

## Superconductivity: The case of the cuprates

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<sup>2</sup> *Department of Physics, University of Zagreb, Bijenička c. 32, 10000 Zagreb, Croatia*

The experimentally established universalities in high- $T_c$  cuprates will be presented. Based on them we show that the phenomenology of cuprates across the phase diagram is fully captured by the simple charge conservation relation:

$$1 + p = n_{\text{loc}} + n_{\text{eff}}$$

Here,  $p$  is the doping while  $n_{\text{eff}}$  is the carrier density and  $n_{\text{loc}}$  is the density of localized charge within a  $\text{CuO}_2$  plaquette. The corresponding superfluid density is related to both components:

$$\rho_S = n_{\text{eff}} \cdot (O_S n_{\text{loc}}).$$

where all terms can be experimentally determined directly. The charge  $n_{\text{loc}}$  is responsible for all the strangeness of these compounds, which includes the pseudogap phenomenon and the superconducting glue [1,2].

The compound-dependent constant,  $O_S$ , is fine-tuned by the local crystal structure. It arises from the  $p$ - $d$ - $p$  fluctuation by the Cu-localized holes visiting the neighboring planar-oxygen atoms and can be determined from NMR [1,2].

[1] N. Barišić & D. K. Sunko, *J Supercond. Nov. Magn.* 35, 1781 (2022).

[2] N. Barišić & D. K. Sunko, *Phys.: Condens. Matter* 38, 053003 (2024).

Karsten Held

## Dawn of entanglement with the pseudogap opening

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Despite decades of intense theoretical and experimental investigation, the two-dimensional Hubbard model still resists a complete microscopic understanding. Here, we demonstrate how to measure operational accessible entanglement in ultracold-atom experiments [1].

Combining cold atom simulators and state-of-the-art dynamical vertex approximation, we find that entanglement is closely tied to the onset of the enigmatic pseudogap regime: spin-singlet entanglement emerges only as the pseudogap sets in and, in contrast to classical correlations, remains strictly confined to nearest-neighbours [1].

Our results explain similar findings for the quantum Fisher information in the Hubbard model and in cuprates microscopically [2].

They also largely constrain valid theories for the Fermi-Hubbard model to those that develop nearest-neighbour entangled states at the onset of the pseudogap.

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- [2] F. Bippus et al., Entanglement in the pseudogap regime of cuprate superconductors, Phys. Rev. B 112, L081110 (2025).

Georgios Katsaros

## Granular aluminum induced superconductivity in germanium for hole spin-based hybrid devices

Giorgio Fabris<sup>1</sup>, Paul Falthansl-Scheinecker<sup>1</sup>, Devashish Shah<sup>1</sup>, Daniel Michel Pino<sup>2</sup>, Maksim Borovkov<sup>1</sup>, Anton Bubis<sup>1</sup>, Kevin Roux<sup>1</sup>, Dina Sokolova<sup>1</sup>, Alejandro Andres Juanes<sup>1</sup>, Tommaso Costanzo<sup>1</sup>, Inas Taha<sup>3</sup>, Aziz Genç<sup>3</sup>, Jordi Arbiol<sup>3,4</sup>, Stefano Calcaterra<sup>5</sup>, Afonso De Cerdeira Oliveira<sup>5</sup>, Daniel Chrastina<sup>5</sup>, Giovanni Isella<sup>5</sup>, Ruben Seoane Souto<sup>2</sup>, Maria Jose Calderon<sup>2</sup>, Ramon Aguado<sup>2</sup>, Jose Carlos Abadillo-Uriel<sup>2</sup>, Georgios Katsaros<sup>1</sup>

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In superconductor-semiconductor hybrid structures superconductivity and spin-polarization are competing effects as magnetic fields break Cooper pairs. They can be combined using thin films and in-plane magnetic fields, an approach that enabled the pursuit of Majorana zero modes, Kitaev chains, and Andreev spin qubits (ASQs), but remains challenging for materials with small in-plane g-factors. Here we show that granular aluminium (grAl), composed of nanometre-scale aluminium grains embedded in an amorphous oxide matrix, can overcome this limitation [1]. By depositing grAl on Ge/SiGe heterostructures, we induce a hard superconducting gap with BCS peaks at 305  $\mu\text{eV}$  and magnetic field resilience for both the in-plane and out-of-plane direction allowing Zeeman splitting of Yu–Shiba–Rusinov (YSR) states beyond 50  $\mu\text{eV}$  (12 GHz). Leveraging this robustness, we reveal signatures of hole physics and demonstrate g-tensor tunability.

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Silke Paschen

## Strange metals as a platform to probe entanglement

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Strange metals – best known for their linear-in-temperature electrical resistivity at low temperatures instead of the Fermi liquid square-in-temperature form – are found across many materials classes [1,2]. Their full understanding is a major challenge. Heavy fermion compounds are particularly versatile model materials for studying strange metal physics because they are comparatively simple, clean, and highly tunable, and several characteristics beyond linear-in-temperature resistivity have been identified. I will give an overview and highlight recent results, including dynamical scaling of the terahertz conductivity [3] and strongly suppressed shot noise [4]. I will then show a quantum Fisher information analysis of inelastic neutron scattering data, which provides evidence of high multipartite entanglement in the strange metal state [5]. This highlights the new opportunities offered by quantum information-inspired approaches for studying correlated quantum materials.

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Shiva Safari

## Scale-invariance and topological order in quantum spin systems

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Frustrated quantum magnets host some of the most exotic states of matter, making them promising platforms for fault-tolerant quantum computation and quantum sensing. Yet, identifying and characterizing these states remains a fundamental experimental challenge, as they are often invisible to conventional probes.

I will present four years of experimental results centered on two problems. In both, we performed measurements of the magnetotropic susceptibility, which are sensitive to symmetry, phase transitions, and emergent scaling behavior across broad classes of correlated quantum materials. First, in  $\alpha$ -RuCl<sub>3</sub> we observe robust scaling behavior  $k = Tf(B/T)$  that persists well below the dominant exchange energy scale. Quantum Monte Carlo simulations match the experimental data quantitatively and identify dominant Kitaev coupling as its microscopic origin—transforming scale-invariance from an intriguing experimental observation into a theoretically-grounded diagnostic for Kitaev physics. In BaCo<sub>2</sub>(AsO<sub>4</sub>)<sub>2</sub>, a frustrated magnet without dominant Kitaev exchange, we find a clear experimental absence of this scaling, providing the first controlled test of the Kitaev hypothesis across contrasting frustrated systems. Second, by isolating single-domain monoclinic  $\alpha$ -RuCl<sub>3</sub> crystals, we resolve a longstanding controversy over stacking disorder and demonstrate that anomalies previously attributed to exotic spin-liquid phenomena instead arise from structural domain coexistence—establishing a clean thermodynamic reference and opening the path for a definitive search for Ising topological order at ultralow temperatures.

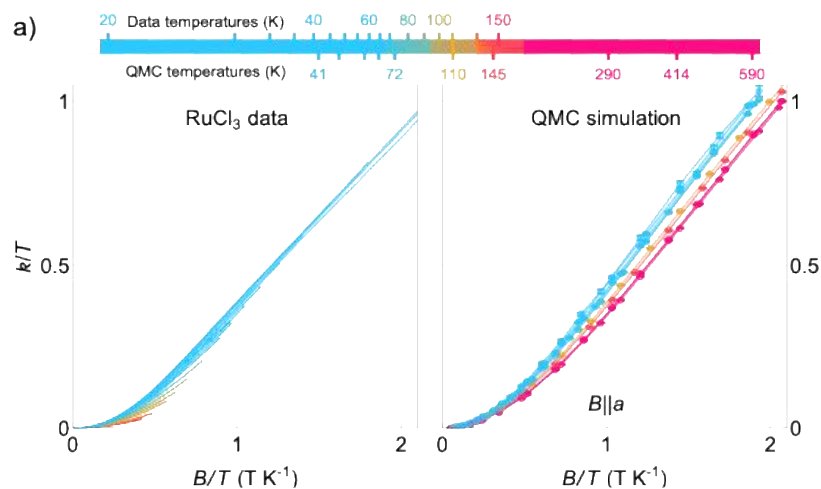


Figure 1. The magnetotropic susceptibility per Ru atom of RuCl<sub>3</sub> normalized by temperature  $k/T$  versus magnetic field normalized by temperature  $B/T$ . Left panel shows the experimental data and right panel shows QMC calculations using the model parameters.

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- [2] João C. Inácio, J. Schwab, G. Rakhmanova, S. Safari, V. Zambra, H. Nasir, S. Paschen, K. A. Modic, Fakher F. Assaad, Toshihiro Sato, “Dynamical magnetotropic susceptibility as a new probe of Kitaev materials and beyond”, *ArXiv 2605.00568*.
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Marcel Strohmeier

## Spectroscopic evidence for nodal pairing symmetry in the non-centrosymmetric superconductor Nb<sub>18</sub>Re<sub>82</sub>

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The lack of inversion symmetry in a non-centrosymmetric superconductor (NCS) can give rise to an antisymmetric spin-orbit coupling (ASOC), which facilitates the mixing of spin-singlet and spin-triplet Cooper pairs [1]. It is widely assumed that strong electronic correlations are necessary to enhance the triplet component and, therefore, to produce signatures of unconventional superconductivity that are spectroscopically resolvable, as demonstrated in heavy-fermion systems [2]. However, it remains unclear to what extent flat bands with large effective electron masses are mandatory to stabilize a triplet order parameter in the presence of ASOC.

Here, we report spectroscopic evidence for the stabilization of an unconventional superconducting order parameter in the weakly correlated NCS Nb<sub>18</sub>Re<sub>82</sub>, which has recently been suggested to host spin-triplet correlations [3]. Using low-temperature scanning tunneling spectroscopy, we probe the local density of states in Nb<sub>18</sub>Re<sub>82</sub> single crystals and observe a pronounced dependence on crystallographic direction, consistent with a complex superconducting order parameter featuring nodal directions. Supported by a theoretical model, we show that our spectra are signatures of an order parameter with coexisting even-parity spin-singlet and odd-parity spin-triplet components, in agreement with the point-group symmetry of the non-centrosymmetric crystal structure.

These results demonstrate that weakly correlated NCSs such as Nb<sub>18</sub>Re<sub>82</sub>, which can also be readily fabricated in thin-film form, intrinsically host spin-triplet components and establish their potential as dissipationless spin sources in superconducting devices.

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Lucia Vigliotti

## Intrinsic relaxation and driven multimode dynamics in Josephson junction chains

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Josephson junction chains provide a versatile platform for studying interacting bosonic excitations in one dimension, with connections to nonlinear quantum optics [1], circuit quantum electrodynamics [2], and quantum many-body physics [3]. In these systems, collective plasma modes form a multimode cavity with weak intrinsic nonlinearities, which become increasingly relevant as larger mode numbers are accessed and extrinsic losses are reduced. Understanding how these nonlinearities lead to internal relaxation and decoherence is therefore a key question in both equilibrium and driven regimes.

In this talk, I will present a combined theoretical and experimental study of plasmon kinetics in long Josephson junction chains. At thermal equilibrium, we develop a kinetic description of two-to-two plasmon scattering in a discrete, finite-size cavity with broadened modes [4]. We show that finite linewidths qualitatively modify relaxation by activating off-resonant scattering channels that dominate under experimentally relevant conditions. This leads to characteristic temperature- and frequency-dependent scaling laws for the intrinsic plasmon lifetime, providing a quantitative framework for equilibrium linewidths in multimode superconducting resonators.

We then turn to the nonequilibrium regime, where microwave driving strongly enhances multimode interactions [5]. Under coherent two-tone driving, we observe cascaded coupling and hybridization among clusters of plasma modes, reflecting strongly coupled multimode dynamics. Under broadband incoherent driving, we study plasmon population redistribution and linewidth broadening by numerically implementing a kinetic equation. At stronger driving, nonlinear interactions redistribute energy across many modes, giving rise to a dense regime of interaction-induced mode mixing where intrinsic scattering competes with dissipation.

These results establish Josephson junction chains as a controlled setting for future exploration of interaction-driven decoherence, nonclassical states engineering, and emergent many-body behavior in driven multimode quantum systems.

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# Live from ISTA

Ignacio Cirac

## Simulating the quantum world with quantum computers

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Advancements in quantum computing have enabled the development of small-scale quantum computers that operate according to the principles of quantum physics. One of the most important prospective applications of these devices is the simulation of complex quantum systems, which arise across many areas of physics and chemistry. Such simulations are notoriously difficult, if not impossible, for classical computers, even the most powerful supercomputers, due to the exponential growth of required computational resources with the number of particles in the system.

In this talk, I will first show how both analog and digital quantum devices could circumvent this limitation. Despite rapid progress, however, applications in this area remain limited, as current quantum devices are imperfect: errors accumulate and pose serious challenges for solving practically relevant problems. I will discuss how, even in the presence of such errors, near-term quantum computers can already become powerful tools for scientific discovery.

The ISTA Lecture by Ignacio Cirac is organized by [ISTA](#).

## Poster abstracts

1. Luka Akšamović, Technische Universität Wien  
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2. Nicolai Amin, Technische Universität Wien and Institut Laue-Langevin  
*Is entanglement depth related to Kondo interaction strength?*
3. Mark Arildsen, University of Vienna  
*Toward non-abelian chiral spin liquid PEPS through layered construction*
4. Serafim Babkin, Institute of Science and Technology Austria  
*Superfluid density and spin susceptibility of two-dimensional superconductor–hole-gas heterostructure*
5. Gabriele Bellomia, Technische Universität Wien  
*Absence of local quantumness in the Hubbard model*
6. Frederic Bippus, Technische Universität Wien  
*Entanglement in the Hubbard model*
7. Maksim Borovkov, Institute of Science and Technology Austria  
*Low-noise quantum dots in ultra-shallow Ge/SiGe heterostructures for prototyping hybrid semiconducting-superconducting devices*
8. Francesco G. Capone, Technische Universität Wien, University of Napoli, National Institute for Nuclear Physics  
*The Schmid transition in RSJJ: BKT universality and transport properties*
9. Francesco Domizio, Technische Universität Wien  
*Unbiased functional renormalization group study of Su-Schrieffer-Heeger phonons in the two-dimensional Hubbard model*
10. Siyar Duman, Technische Universität Wien  
*Schrödinger-Poisson solver for bilayer graphene quantum dots*
11. Henrique Fabrelli Ferreira, Technische Universität Wien  
*Search for topological semimetals in hexagonal heavy fermion compounds*
12. Lukas Fischer, Technische Universität Wien  
*Heavy fermion thin film growth by molecular beam epitaxy*
13. Ronja Fischer-Süßlin, University of Konstanz  
*Scanning tunneling spectroscopy on exfoliated NbSe<sub>2</sub> flakes*
14. Le Phuong Hoang, Institute of Science and Technology Austria  
*Charge-state-dependent restructuring of excitation and relaxation landscapes in driven NV ensembles*
15. Diana Kirschbaum, Technische Universität Wien  
*Evidence for surface-dominated transport in the Kondo insulator U<sub>3</sub>Bi<sub>4</sub>Pt<sub>3</sub>*

16. Adam Lafferty, Technische Universität Wien  
*Enhanced light-matter interactions for quantum technologies and sensing applications*
17. Gwenvredig Le Roy, Technische Universität Wien  
*Bipartite fluctuation measurements on  $\text{YbRh}_2\text{Si}_2$*
18. Monika Lužnik, Technische Universität Wien  
*Thermal and thermoelectric transport in the Weyl–Kondo semimetal  $\text{Ce}_3\text{Bi}_4\text{Pd}_3$*
19. Kazuyuki Matsumoto, Asahikawa Physics Institute  
*Phenomenology for the metamagnetism of  $\text{CeRu}_2\text{Si}_2$*
20. Federico Mazza, Technische Universität Wien  
*Quantum Fisher information in a strange metal*
21. Juan Carlos Moreno Lopez, Technische Universität Wien  
*Metal-to-insulator transition in antiferromagnetic  $\text{SrCrO}_3$  thin films*
22. Hamza Nasir, Institute of Science and Technology Austria  
*Magnetic fields in monoclinic  $\alpha\text{-RuCl}_3$  reveal rhombohedral inclusions underlying apparent oscillations*
23. Raphael Neubacher, Technische Universität Wien  
*Properties of quantum emitters in different hBN sample types*
24. Dmytro Rak, Institute of Science and Technology Austria  
*THz-gated ultrafast holographic mapping of transient electric fields*
25. Gulnaz Rakhmanova, Institute of Science and Technology Austria  
*Mobile impurity probing the FFLO phase*
26. Gergő Roósz, Technische Universität Wien  
*Nonfreeness and entropy in the two dimensional Hubbard model*
27. Mohammad Sameer, S.V. National Institute of Technology, Surat  
*The magnetotropic response of the kagome metal  $\text{CsV}_3\text{Sb}_5$  in its superconducting and metallic states*
28. Elke Scheer, University of Konstanz  
*Spin-polarized transport in copper-oxide atomic junctions revealed by anomalous shot-noise behavior in presence of the Kondo effect*
29. Nikolai Semenov, Institute of Science and Technology Austria  
*Solid-immersion-lens THz microscope for device-scale spectroscopy of 2D quantum materials*
30. Andras Szabo, Max Planck Institute for Solid State Research  
*Out-of-equilibrium intertwining via emergent collective modes*
31. Tiark Tiwary, University of Konstanz  
*Point-contact spectroscopy and fabrication of controllable atomic contacts from the non-centrosymmetric superconductor  $\text{Nb}_{18}\text{Re}_{82}$*

Luka Akšamović

## Kohler's rule in the strange metal regime of cuprates

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In the normal state of high-( $T_c$ ) cuprates, two electronic subsystems, itinerant and localized, have been identified. In the pseudo gap regime, benchmarked by the quadratic temperature dependence of the resistivity, it has been shown that the magnetoresistance of the itinerant charges obeys Kohler scaling, which is commonly regarded as a signature of Fermi-liquid behavior. Here, we address the strange-metal regime, benchmarked by the linear temperature dependence of the resistivity, and show that BSCCO, LSCO, and SLCO also exhibit such scaling. In BSCCO, Kohler's rule is restored once variations in carrier density are taken into account through the Hall coefficient. In LSCO, close to a Lifshitz transition, unusual low-field magnetoresistance is observed; however, at high magnetic fields, Kohler's rule is recovered. In SLCO, an electron-doped cuprate, Kohler scaling is likewise obeyed.

Nicolai Amin

## Is entanglement depth related to Kondo interaction strength?

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Recently, it was shown that the quantum Fisher information, a concept from quantum information science that can be used to evaluate the entanglement depth via inelastic neutron scattering (INS) experiments [1], is enhanced at a strange metal quantum critical point in  $\text{Ce}_3\text{Pd}_{20}\text{Si}_6$  [2]. Here we propose to study the isostructural heavy fermion compound  $\text{Ce}_3\text{Pd}_{20}\text{Ge}_6$ , which exhibits weaker Kondo correlations, to test whether it affects the entanglement depth. Using high-resolution INS at the cold three-axis spectrometer ThALES (ILL) complemented by previous time-of-flight measurements from LET (ISIS) and electrical resistivity data, this work aims to systematically assess what underlies high multipartite entanglement in Kondo systems and beyond. Methodologically, this work contributes to the growing use of INS for accessing model-independent quantum witnesses [3]. While these observables are directly measurable, their reliable extraction requires stringent experimental conditions. The expertise gained will support the development of best-practice standards for entanglement measurements, including quantitative figures of merit, absolute-unit protocols, and rigorous background subtraction.

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Mark Arildsen

## Toward non-abelian chiral spin liquid PEPS through layered construction

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Can chiral topological states in (2+1) dimensions be represented by Projected Entangled Pair States (PEPS)? For non-interacting fermionic PEPS, the answer is yes [1,2]. We consider instead the case of representation of chiral spin liquid (CSL) ground states by interacting PEPS (with finite bond dimension). Many PEPS are known that have properties of bona fide CSL ground states, both Abelian [3] and non-Abelian [4], but some uncertainties have remained. For instance, the half-integer spin sector of the entanglement spectrum can have two degenerate chiral branches. Meanwhile, in the non-Abelian [SU(2)-level-2] case, only two out of three topological sectors can be identified. Ref. [5] made substantial progress for the Abelian case in resolving many ambiguities (including the doubled branches) found to arise from the interplay of SU(2), point group, and translational symmetries in the PEPS. We now extend this understanding to non-Abelian CSL PEPS by building them up from Abelian chiral PEPS layers in a principled way. We analyze the resulting PEPS and are able to evaluate their ability to faithfully represent non-Abelian CSL ground states.

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Serafim Babkin

## Superfluid density and spin susceptibility of two-dimensional superconductor–hole-gas heterostructure

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Two-dimensional superconductor–hole-gas heterostructures are widely used for quantum devices and engineering of unconventional superconductivity. In these heterostructures, proximity to a superconductor substantially modifies the hole gas, however, experimentally accessing the intrinsic properties of the resulting hybridized two-dimensional hole gas (2DHG) is challenging. Here we study two probes, the superfluid density and spin susceptibility, which provide indirect access to the hole gas. Using a microscopic theory for hybridized 2DHG in an in-plane magnetic field, we demonstrate that the magnetic-field dependence of both observables exhibits distinct step-like features associated with gap closure. Additionally, we show that the angular dependence of the superfluid-density tensor provides a direct signature of unconventional superconducting pairing and cubic Rashba spin-orbit coupling in the 2DHG. Together with the step-like features, these signatures identify the hole-gas contribution to the total response of the heterostructure, thereby enabling extraction of intrinsic properties of the hybridized hole gas from experiment and opening the door to systematic experimental studies of two-dimensional superconductor–hole-gas heterostructures.

Gabriele Bellomia

## Absence of local quantumness in the Hubbard model

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We show that all local inter-particle correlations in the Hubbard model – and also its multi-orbital extensions of the density-density kind – are devoid of entanglement and quantum discord [1]. Hence, they are of fully classical nature [2]. The proof is based only on the symmetries of the system, in particular the conservation of spin (flavor) resolved charges. Thus, it applies to exact or approximate many-body eigenstates of the model, as long as the underlying  $U(1)$  group is preserved. At zero temperature, the generation of local classical correlations can be explained only by assuming the presence of *nonlocal* quantum processes involving the rest of the lattice [3]. We compare local quantum embedding approximations to both the paramagnetic and the antiferromagnetic insulating phases of the Hubbard model, at zero temperature. We find that the Mott-Hubbard insulator reaches, in the strong coupling regime, the maximum value of local correlations allowed by a classical reduced density matrix. The Neel insulator, on the other hand, realizes large local correlations only near the onset of magnetic order, and becomes asymptotically uncorrelated in the  $U \gg t$  limit. In striking contrast, numerically exact accounts of Neel phases in both the Hubbard and Heisenberg models feature long-range entanglement and quantum fluctuations, which results in a strongly-correlated local density matrix in the  $U \gg t$  limit. We ascribe the profound difference between the local quantum embedding accounts of ordered and unordered Mott insulators to the different range of nonlocal quantum correlations, which have been shown to be confined to nearest neighbors in strongly correlated unordered phases, if the quantum amplitudes associated to the hopping are removed by local superselection rules [4-6]. We propose that the noninteracting bath in the auxiliary embedding Hamiltonian is able to capture short-range nonlocal correlations due to the local interaction, but not the actual long-range entanglement associated with the development of an order parameter. Finally, we show that the symmetry constraints of this class of Hubbard systems make local reduced density matrices representable as classical mixtures of *stabilizer* states, hence devoid of *quantum magic* [7]. Like for quantum entanglement, quantum magic is instead present at the nonlocal level, suggesting that digital quantum simulations of Hubbard systems are hard to tame with Clifford-based error correction.

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Frederic Bippus

## Entanglement in the Hubbard model

Frederic Bippus<sup>1</sup>, Anna Kauch<sup>1</sup>, Gergő Roósz<sup>1</sup>, Gabriele Bellomia<sup>1,2</sup>, Thomas Chalopin<sup>3,4,5</sup>, Juraj Kršnik<sup>1,6</sup>, Titus Franz<sup>4,5</sup>, Luka Akšamović<sup>1</sup>, Motoharu Kitatani<sup>7</sup>, Antoine Georges<sup>8,9,10,11</sup>, Immanuel Bloch<sup>4,5,12</sup>, Neven Barišić<sup>1,13</sup>, Fakher Assaad<sup>14,15</sup>, Karsten Held<sup>1</sup>

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We demonstrate an enhancement of the quantum Fisher information, an established witness of multipartite entanglement, in the pseudogap regime of the Hubbard model and in cuprate experiments [1]. As for theory, we employ the dynamical vertex approximation (D $\Gamma$ A) [2], a non-local extension of dynamical mean-field theory. The pseudogap, characterized by a partially gapped electronic state, emerges near the superconducting transition in cuprate and nickelate materials, and D $\Gamma$ A properly describes it through the Hubbard model. The enhanced entanglement further motivates us to study bi-partite entanglement in the Hubbard model. To this end, we compute the two-site reduced density matrix within the D $\Gamma$ A framework [3], providing insight into the spatial structure of entanglement in strongly correlated electron systems [4]. The two-site entanglement is made experimentally measurable through super selection rules [5]. In excellent agreement with ultra cold atoms experiments, we show that nearest-neighbor spin-singlet entanglement emerges together with the onset of the pseudogap [6]. Therefore, the enigmatic pseudogap regime cannot be described by any purely classical theory.

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Maksim Borovkov

## Low-noise quantum dots in ultra-shallow Ge/SiGe heterostructures for prototyping hybrid semiconducting-superconducting devices

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Ge/SiGe heterostructures are currently the only semiconducting platform where high-coherence spin qubits and proximity-induced superconductivity have each been demonstrated. Recent research into spin qubits in Ge/SiGe has focused on increasing the thickness of the SiGe capping layer, reporting improved electrostatic noise levels. Meanwhile, heterostructures with thinner capping layers remain comparatively unexplored, despite their potential advantages for proximity-induced superconductivity. Here, we study a Ge/SiGe heterostructure with a thin SiGe cap of  $d \approx 4$  nm and investigate its viability for hosting low-noise quantum dots. To keep the thermal budget compatible with superconducting layers, low-temperature oxide deposition processes were developed and implemented for the gate dielectrics. The charge noise level of fabricated devices is estimated to be  $1.8 \pm 1.0 \mu\text{eV}/\sqrt{\text{Hz}}$ , comparable to devices fabricated on shallow heterostructures with  $d \sim 20$  nm and high-temperature deposited oxides. Low charge-noise levels, together with the straightforward integration of superconductors, make this heterostructure an attractive platform for prototyping hybrid semiconductor–superconductor devices.

Francesco G. Capone

## The Schmid transition in RSJJ: BKT universality and transport properties

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The Schmid transition is essential for modeling the resistively shunted Josephson junction (RSJJ) as a parallel circuit comprising a non-linear inductor (Josephson energy  $E_J$ ) a capacitor  $C$  (with characteristic energy  $E_C = 4e^2/2C$ ) and a shunt resistor  $R_S$ . Schmid and Bulgadaev originally foresaw an insulator-to-superconductor phase transition at  $\alpha = R_q/R_S = 1$  [1,2], where  $R_q = h/4e^2$  is the quantum resistance. Lately, however, both theoretical [3,4] and experimental [5] studies have disputed this transition's existence. This debate has sparked interest in the phenomenon and its effects on RSJJ transport properties. In this contribution, we clarify the transition's true nature by proposing a new binary order parameter  $S$ . Our findings confirm that the transition fits the Berezinskii-Kosterlitz-Thouless (BKT) universality class [6,7]. This is supported by the logarithmic decay of correlation functions near the critical point, as shown in Fig. 1.

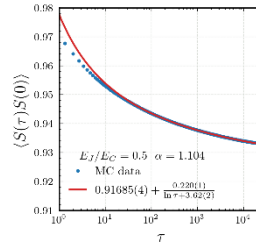


Figure 1. Logarithmic decay of the correlations  $\langle S(\tau)S(0) \rangle$  at the estimated critical point as an evidence of BKT criticality.

Moreover, using linear response theory for resistivity, we identify that the signature of the transition lies in the weight of the delta function  $D_Q$  at  $\omega = 0$  (see inset Fig. 2 (a)) [7]. Remarkably, the lack of a low-frequency Drude peak in the response function  $\Psi_{\text{reg},Q}(\omega)$  (see Fig. 2), forces the conclusion that the system's physics is entirely non-dissipative. This non-dissipative character is further corroborated by a thorough out-of-equilibrium study involving the injection of a small current.

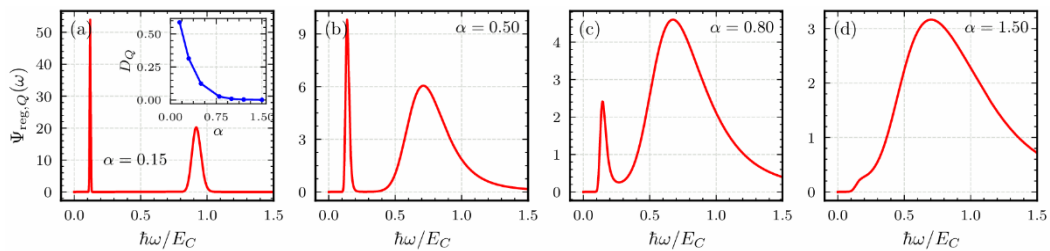


Figure 2. Analytic continuation of the resistivity response function  $\Psi_{\text{reg},Q}(\omega)$  on real frequencies via MaxEnt for (a)  $\alpha = 0.15$ , (b)  $\alpha = 0.5$ , (c)  $\alpha = 0.8$ , (d)  $\alpha = 1.5$  at  $\frac{E_J}{E_C} = 0.5$  and  $\beta E_C = 100$ . Inset (a): delta weight contribution  $D_Q$  as a function of  $\alpha$ .

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Francesco Domizio

## Unbiased functional renormalization group study of Su-Schrieffer-Heeger phonons in the two-dimensional Hubbard model

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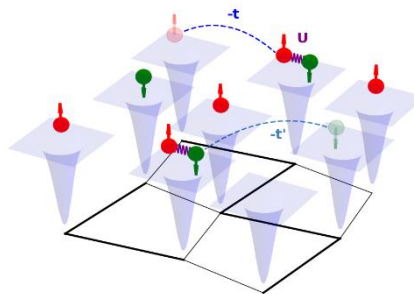
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We study the two-dimensional Hubbard model coupled to Su–Schrieffer–Heeger phonons [1,2] on the square lattice using a recently developed generalization of the single-boson exchange formalism for extended interactions [3].

The functional renormalization group description retains the full frequency dependence of the two-particle vertex and the electronic self-energy and allows for an unbiased analysis of magnetic, charge, and superconducting fluctuations.

We perform extensive parameter scans in terms of the Hubbard interaction, the electron–phonon coupling strength, and the phonon frequency, ranging from the adiabatic to the antiadiabatic regime. In the absence of the Hubbard interaction, we find that the threefold degeneracy of antiferromagnetic order, charge-density-wave order, and *s*-wave superconductivity at half filling holds for all phonon frequencies. In the adiabatic limit, however, the leading instability is a valence bond solid state. For finite values of the Hubbard interaction, the symmetry  $\mathbb{Z}_{2, \text{Shiba}}$  is lifted [4,5], leading to a competition between antiferromagnetism and valence bond order. Finally, at finite doping, the interplay between the Hubbard interaction and the Su–Schrieffer–Heeger phonons leads to an even richer picture characterized by intertwined ordering tendencies [6].



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Siyar Duman

## Schrödinger-Poisson solver for bilayer graphene quantum dots

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Bilayer graphene (BLG) has become a popular platform for various experiments investigating quantum dots, moiré superstructures, highly correlated physics such as superconductivity, and devices for manipulating individual charges with the eventual goal of BLG qubits.

The electrostatically tunable band gap allows precise experimental control, yet also causes significant theoretical challenges when simulating such experiments. In particular, the smaller number of available states compared to bulk materials and the sensitive dependence of the gap on the local electric field requires simultaneously solving the Poisson equation and the redistribution of charge due to the electrostatic potential.

These charges fall into two categories: (I) screening charges treated at local density of states approximation (qualitative agreement with recent experiment [1]) corresponding to conduction band electrons attenuating the applied gate voltages in the BLG sheet and (II) discrete quantum dot states living inside the band gap which show orbital structure, obtained by solving the single-particle BLG Hamiltonian for realistic system sizes of 100s of nm.

These charges then in turn act as a source term for Poisson's equation, rendering it and the entire problem non-linear, which we solve by a self-consistency cycle. Our results are readily applicable to other nanodevices and material platforms, of which we name several.

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In: (2025). doi: <https://doi.org/10.48550/arXiv.2509.12061>.

Henrique Fabrelli Ferreira

## Search for topological semimetals in hexagonal heavy fermion compounds

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The experimental realization of topological semimetals in heavy fermion compounds, with Weyl–Kondo semimetals representing notable examples [1], has so far been explored primarily on cubic and square-net lattices, for which several candidate compounds have been proposed [2]. Although hexagonal Bravais lattices are widely regarded as a promising platform for topological phases, including semimetallic ones [3], their realization in heavy fermion systems remains largely unexplored. Through a search of crystal-structure databases, the classification of topological band crossings, theoretical predictions from the Anderson/Kondo lattice model, and an assessment of published physical property data, we identify a candidate for topological heavy fermion compound with hexagonal crystal structures. We discuss experimental aspects relevant to their synthesis and report the successful growth of  $\text{Ce}_3\text{CuSnSe}_7$  and  $\text{Ce}_2\text{NiGe}_3$ . Temperature-dependent electrical resistivity measurements reveal semiconducting behavior in the former and semimetallic behavior in the latter, for which we also find an intrinsic contribution to the anomalous Hall effect [4].

[1] S. Dzsaber et al., Phys. Rev. Lett. 118, 246601 (2017); H.-H. Lai et al., PNAS 115, 93-97 (2018); S. Dzsaber et al., PNAS 118, e2013386118 (2021).

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Lukas Fischer

## Heavy fermion thin film growth by molecular beam epitaxy

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Heavy fermion systems provide a rich platform for exploring emergent quantum phenomena, including quantum criticality, topological effects, and unconventional transport. Synthesizing these quantum materials in thin-film form allows probing their behavior with different experimental techniques, detecting size effects, and integrating them into quantum devices via established nanofabrication techniques. This work focuses on the molecular beam epitaxy (MBE) growth of two intermetallic compounds.

$\text{YbRh}_2\text{Si}_2$  is a prototypical heavy fermion compound that hosts a Kondo destruction quantum critical point (KD QCP) [1], accessible via modest magnetic fields. Near this KD QCP, the material exhibits strange metal behavior, perhaps associated with enhanced multipartite entanglement as recently found in a related material [2]. We demonstrate that substrate temperature finely tunes growth modes, which can enhance transport properties and further improve overall film quality, which is essential to explore the nature and range of the entanglement properties in the vicinity of the KD QCP by alternative means [3].

The nonsymmorphic Weyl-Kondo semimetal  $\text{Ce}_3\text{Bi}_4\text{Pd}_3$ , which exhibits a giant nonlinear Hall effect [4], is of great interest for nonreciprocal devices based on thin films [5]. We report the first steps towards such synthesis with MBE.

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Ronja Fischer-Süßlin

## Scanning tunneling spectroscopy on exfoliated NbSe<sub>2</sub> flakes

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Scanning tunneling spectroscopy (STS) at millikelvin temperatures provides direct, spatially resolved access to the local density of states and thus enables investigation of the quasiparticle spectrum of superconductors, from which information about the energy gap and the order parameter can be drawn at the atomic scale. Since precise localization of micron-scaled two-dimensional devices under the tip is challenging due to lack of optical access, the limited scan area and thermal drifts, STS is typically performed on laterally extended films, large flakes or other sufficiently extended surfaces.

Here, we present a method for performing STS on micron-sized flakes and heterostructures. A lithographically defined grid from gold markers is presented which enables precise tip positioning over an area of  $300 \times 300 \mu\text{m}^2$  on top of the flake by scanning only  $1 \times 1 \mu\text{m}^2$  at low temperatures (300 mK). Two-dimensional nanoflakes from NbSe<sub>2</sub>, with typical size of  $10 \times 10 \mu\text{m}^2$  prepared by mechanical exfoliation, are transferred onto this predefined pattern making low-temperature STS possible.

Niobium diselenide (NbSe<sub>2</sub>) is a layered transition metal dichalcogenide that exhibits strong Ising spin-orbit coupling in the monolayer limit and has attracted significant interest as a model system for unconventional superconductivity in reduced dimensions, studied extensively using transport measurements [1]. While STS in UHV has already been applied on single-layer NbSe<sub>2</sub> grown on graphene [2] and related two-dimensional superconductors, the method presented here extends such measurements to even smaller nanoflakes and heterostructures.

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Le Phuong Hoang

## Charge-state-dependent restructuring of excitation and relaxation landscapes in driven NV ensembles

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Nitrogen-vacancy (NV) ensembles driven far from equilibrium exhibit nonlinear optical responses whose excitation and relaxation dynamics are typically studied independently. Here we combine polarization-resolved femtosecond fluorescence anisotropy and gated optical relaxometry to reveal a unified charge-state-dependent excitation–relaxation state space in driven NV ensembles. Under intense optical driving, NV<sup>-</sup> maintains a robust twofold excitation symmetry and comparatively rigid kinetic organization, whereas NV<sup>0</sup> undergoes pronounced symmetry restructuring accompanied by strong redistribution among relaxation manifolds. Despite probing distinct dynamical regimes, both measurements reveal common symmetry constraints and nonlinear crossover behavior, indicating that excitation geometry and relaxation kinetics are complementary manifestations of the same underlying driven-state organization. These results show that optical driving restructures the accessible excitation and relaxation pathways of NV ensembles in a charge-state-dependent manner and establish a unified framework for understanding nonequilibrium dynamics in solid-state defect systems.

Diana Kirschbaum

## Evidence for surface-dominated transport in the Kondo insulator $U_3Bi_4Pt_3$

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The interplay between strong correlations and topology has generated significant interest in recent years, as it can give rise to entirely new quantum phases of matter. Heavy fermion materials are particularly suitable in this context, as they naturally combine strong correlations with sizeable spin-orbit coupling (SOC), thereby providing a basis for proposals of correlated topological states in Kondo insulators and semimetals [1,2]. This has renewed interest in a family of cubic noncentrosymmetric 3-4-3 compounds, in which the prototypical Kondo insulator  $Ce_3Bi_4Pt_3$  can be driven into a topologically nontrivial Weyl-Kondo semimetal state [3,4] through isoelectronic substitution of Pt by Pd [5]. Motivated by the role of SOC in realizing such phases, we investigate whether replacing Ce with the heavier actinide U can further enhance SOC effects and stabilize a topological Kondo insulator state in  $U_3Bi_4Pt_3$ . From electrical transport, specific heat, and magnetic susceptibility measurements, we classify  $U_3Bi_4Pt_3$  as a new Kondo insulator. However, the electrical resistivity shows a strong saturation trend at low temperatures with pronounced thickness dependence, inconsistent with pure bulk transport. Instead, analysis within a parallel-conduction model indicates that the low-temperature transport is dominated by a metallic surface state [6]. This makes  $U_3Bi_4Pt_3$  a promising new platform for investigating the origin of surface conduction in Kondo insulators and its possible topological nature.

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[3] H.-H. Lai et al., *Proc. Natl. Acad. Sci. U.S.A.* 115, 93 (2018).

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Adam Lafferty

## Enhanced light-matter interactions for quantum technologies and sensing applications

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Strong light-matter interactions are important both for quantum networks and for sensing applications. Achieving such coupling has long been a challenge for conventional bulk optical platforms. Recent advances in nanofabrication have opened the door to nanophotonics as a powerful platform for enhancing light matter interaction. This poster shows how different types of nanophotonic platforms can be employed to enhance the interaction between single quantum emitters and a light field. This poster also shows that a strong light matter interaction is crucial in the wider context of environmental sensing, where we have demonstrated that we can detect and identify nanoplastic particles down to sizes of 100nm.

Phase 2.0 quantum technologies rely on the development of stable single photon emitters that work under ambient conditions. Hexagonal Boron Nitride (hBN) is a 2D wide bandgap semiconductor that hosts various atomic scale defects that act as optically active centres. These solid state defect states result in bright, stable and spectrally distinct emission of single photons under ambient conditions. hBN's layered structure and chemical robustness make it highly compatible for photonic integration and scalable quantum technologies. There are several methods of producing hBN. This poster describes the characteristics of hBN made by both CVD (Chemical Vapour Deposition) and LPE (Liquid Phase Epitaxy) and the properties of their quantum emitters [1][2].

Due to limited detection methods, the concentration of nanoplastics in the environment still remains uncertain. Defined as plastic particles smaller than 1  $\mu\text{m}$ , nanoplastics can penetrate biological barriers and have been observed to cross into the brain and placenta. Reliable techniques for their detection and characterisation are therefore essential. Surface-Enhanced Raman Spectroscopy (SERS) offers a promising detection method [3]. Implementation of this technology relies on advances in nanophotonic platform design and fabrication.

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Gwenvredig Le Roy

## Bipartite fluctuation measurements on $\text{YbRh}_2\text{Si}_2$

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Heavy fermion materials have been the playground of extensive research on quantum criticality and phases emerging from it. Because these materials are highly tunable, quantum critical points (QCPs) have been identified in many of them [1]. Of particular interest are Kondo destruction (KD) QCPs, where long-range entanglement is expected [2, 3]. Indeed, very recently, high multipartite entanglement was revealed at a KD QCP in one of these materials through quantum Fisher information experiments [4].

Here we investigate  $\text{YbRh}_2\text{Si}_2$  (YRS), a well-known heavy fermion compound that exhibits a KD QCP [1]. High-quality thin films of this material have been grown by molecular beam epitaxy [5, 6], which is essential for our experiments. We aim to witness entanglement via bipartite fluctuation measurements [7] across the phase diagram of YRS. Here we describe the setup and report on first measurements.

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Monika Lužnik

## Thermal and thermoelectric transport in the Weyl–Kondo semimetal $\text{Ce}_3\text{Bi}_4\text{Pd}_3$

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Weyl-Kondo semimetals are a novel class of materials, in which the interplay of strong correlations and metallic topology causes Weyl nodes to become part of the Kondo resonance [1-4]. As a result, Berry-curvature-driven phenomena can be strongly enhanced, as demonstrated by the giant zero-field nonlinear Hall effect observed in the Weyl–Kondo semimetal  $\text{Ce}_3\text{Bi}_4\text{Pd}_3$  [4]. Compared with weakly interacting topological semimetals of similar carrier density, its nonlinear Hall response is larger by several orders of magnitude [5]. Such an enhancement provides a promising platform for studying other Berry-curvature-driven transport phenomena, including the topological nonlinear thermal Hall and Nernst effects, which have so far received only limited experimental attention [6].

The work was supported by the European Research Council (ERC Advanced Grant 101055088 “CorMeTop”), the Austrian Science Fund (FWF grants SFB F86 “Q-M&S”, I5868-N/FOR5249 “QUAST”, 10.55776/COE1 “quantA”), and the Air Force Office of Scientific Research (AFOSR project No. FA8655-24-1-7018).

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Kazuyuki Matsumoto

Phenomenology for the metamagnetism of CeRu<sub>2</sub>Si<sub>2</sub>Kazuyuki Matsumoto<sup>1</sup><sup>1</sup> *Asahikawa Physics Institute, 078-8392 Asahikawa, Japan*

We developed the extended Landau theory for the metamagnetism of CeRu<sub>2</sub>Si<sub>2</sub> by the introduction of the  $hm^3$  term in the free energy density.[1] The magnetization and magnetic susceptibility were calculated with the use of the scaling hypothesis to correct the peak position of the susceptibility. We draw the metamagnetic boundary line in the magnetic phase diagram, which agrees with the experimental data. However, there are two additional lines that separate the magnetic phase diagram into four parts, including the former metamagnetism line.[2] These two lines are based on the observation of the double-peak structure in the specific heat of CeRu<sub>2</sub>Si<sub>2</sub>. [3] To explain these two lines, a theory that involves the expansion of free energy density due to entropy deviation within the first and third orders was also developed by the author. We obtained the double-peaks in the specific heat of CeRu<sub>2</sub>Si<sub>2</sub>. [4] The critical behavior of the specific heat as a function of the external magnetic field was also obtained within this theory. However, since this critical behavior, the divergent behavior of the specific heat, would be an artifact of the mean-field theory, this criticality should be weakened in a desirable theory.

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Federico Mazza

## Quantum Fisher information in a strange metal

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Strange metal behavior emerges across a wide range of material platforms and remains a central open problem in correlated quantum matter [1]. Beyond the hallmark linear-in-temperature electrical resistivity, it is characterized by entropy accumulation, a discontinuous change in Fermi volume, and energy-over-temperature scaling in dynamical susceptibilities [2]. The heavy-fermion compound Ce<sub>3</sub>Pd<sub>20</sub>Si<sub>6</sub> provides an ideal platform to investigate quantum criticality beyond the Landau–Ginzburg–Wilson framework [3], including access to fractional critical exponents and emerging concepts such as multipartite entanglement [4]. Here, we present inelastic neutron scattering measurements at a strange-metal quantum critical point in Ce<sub>3</sub>Pd<sub>20</sub>Si<sub>6</sub>. Our analysis reveals dynamical scaling behavior, quantifies the entanglement depth via the quantum Fisher information density  $f_Q$ , and establishes a direct comparison with quantum Monte Carlo simulations [5].

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Juan Carlos Moreno Lopez

## Metal-to-insulator transition in antiferromagnetic SrCrO<sub>3</sub> thin films

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Materials that exhibit the rare combination of antiferromagnetism (AF) and metallic behavior are highly sought after for spintronic devices. The AF spin dynamics allow for more efficient magnetic manipulation, while their metallic characteristics facilitate the readout of magnetic states. Among various candidates, SrCrO<sub>3</sub> has captured our attention as a largely unexplored system, known for its challenging synthesis. In this study, we demonstrate our capability to grow high-quality epitaxial SrCrO<sub>3</sub> thin films using out-of-axis magnetron sputtering on substrates that impose strain ranging from -1.82% to 3.18%. Our measurements reveal remarkable insights into the transport properties of SrCrO<sub>3</sub>, including a strain-driven metal-to-insulator transition, as well as an intriguing upturn in resistivity accompanied by a change in the sign of charge carriers. By combining muon spin relaxation experiments ( $\mu$ SR) with x-ray magnetic circular and linear dichroism (XMCD and XMLD) measurements, we demonstrate that SrCrO<sub>3</sub> films exhibit a magnetic transition towards a disordered AF state at  $\sim 150$  K, regardless of strain. Remarkably, this transition temperature is over 100 K higher than in bulk SrCrO<sub>3</sub>. Our findings not only establish the AF character of SrCrO<sub>3</sub> thin films but also suggest that *they* could serve as promising candidates for the emergence of altermagnetism.

Hamza Nasir

## Magnetic fields in monoclinic $\alpha$ -RuCl<sub>3</sub> reveal rhombohedral inclusions underlying apparent oscillations

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$\alpha$ -RuCl<sub>3</sub> is a leading candidate for Kitaev material, a class of systems predicted to host a quantum spin liquid with fractionalized excitations and has potential applications in topological quantum computation. Magnetic fields suppress the zigzag antiferromagnetic (AFM) order and may drive  $\alpha$ -RuCl<sub>3</sub> toward a Kitaev-dominated regime. However, the interpretation of field-induced phenomena remains controversial because  $\alpha$ -RuCl<sub>3</sub> exhibits a temperature-dependent structural transition and is highly sensitive to stacking disorder. Recent studies have shown that the low-temperature crystal structure depends strongly on crystal size and sample quality, motivating a reassessment of the magnetic phase diagram in structurally well-defined samples [1].

Here, we investigate nanogram-scale  $\alpha$ -RuCl<sub>3</sub> crystals that remain in the monoclinic C2/m structure down to low temperature [2]. Using resonant torsion magnetometry, we measure the magnetotropic susceptibility,  $k = \partial^2 F / \partial \theta^2$ , as a function of temperature, magnetic field strength, and field orientation. The resulting phase diagram closely resembles that of rhombohedral crystals but is systematically shifted to higher Néel temperatures and larger critical fields. Angular measurements reveal additional weak anomalies near the out-of-plane direction. By comparing their angular dependence and critical fields with known monoclinic and rhombohedral phase boundaries, we identify these features as originating from small rhombohedral inclusions embedded within an otherwise monoclinic crystal. Our results demonstrate that transitions previously interpreted as signatures of field-induced non-magnetic phases can instead arise from multiple shifted AFM phase boundaries associated with structural inhomogeneity. These findings highlight the critical role of crystal symmetry, stacking order, and sample homogeneity in determining the magnetic-field response of  $\alpha$ -RuCl<sub>3</sub>. More generally, they show that the structural inhomogeneity in quasi-two-dimensional van der Waals quantum materials can masquerade as exotic field-induced states.

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Raphael Neubacher

## Properties of quantum emitters in different hBN sample types

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Hexagonal boron nitride (hBN) is a two-dimensional material that hosts a range of defect types with optically active properties. Certain defects exhibit single-photon emission and show sensitivity to magnetic field strength and orientation, making hBN a relevant platform for investigations in quantum photonics and defect-based quantum systems. Previous studies have also demonstrated ODMR in hBN emitters [1].

This work investigates the optical properties of quantum emitters in hBN samples fabricated using different preparation techniques. The examined sample types include chemical vapor deposition (CVD) monolayers, stacked trilayer CVD structures, liquid phase exfoliated (LPE) samples prepared by drop-casting and drop-touch methods, as well as exfoliated flakes subjected to ion bombardment. Trilayer structures were fabricated to reduce bleaching effects by embedding emitters within inner layers [2].

Characterization was performed using a confocal microscope setup enabling fluorescence excitation microscopy, fluorescence spectroscopy, Raman spectroscopy, and second-order correlation measurements. Fluorescence and reflectance imaging were obtained by scanning the sample with a piezo-controlled stage while collecting emitted light using single-photon counting modules [2].

Distinct optical characteristics were observed for the different sample types. Several samples showed localized emitters with sharp fluorescence peaks and clear antibunching dips in the second-order correlation measurements, indicating single-photon emission behaviour. Broad fluorescence spectra and multi-emitter signatures were also identified in some LPE samples. Density functional theory (DFT) calculations were used for comparison with experimentally observed spectra in order to support defect assignment [3].

The results demonstrate that fabrication and post-processing methods significantly influence emitter stability, spectral characteristics, and emission behaviour in hBN [3]. These findings contribute to the identification and optimization of hBN defect systems for future nanophotonic and quantum optical applications.

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Dmytro Rak

## THz-gated ultrafast holographic mapping of transient electric fields

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Electric fields determine electronic transport and collective electron dynamics. Beyond externally applied bias, these include transient, spatially inhomogeneous internal fields arising from dynamic charge redistribution. However, direct observation of such fields in solids has remained challenging due to the lack of experimental probes capable of resolving their spatial and temporal structure. Here, we overcome this limitation by combining ultrafast optical interferometry, which provides sub-micron spatial resolution, with intense sub-cycle THz pulses that act as an ultrafast gate, converting instantaneous internal electric-field profiles into measurable optical signals.

To demonstrate the capability of this approach, we focus on directly observing internal electric fields generated by charge separation in a non-equilibrium hot electron–hole plasma. Normally, Coulomb interactions suppress charge inhomogeneities on timescales set by the plasma frequency. In standard metals, these timescales lie in the sub-femtosecond regime, precluding access by table-top ultrafast optical methods. We circumvent this limitation by focusing instead on high-mobility semiconductor quantum wells, where reduced dimensionality, lower plasma frequency, and the large kinetic energy of optically excited carriers enable transient separation of electrons and holes over macroscopic, micron-scale distances. In this regime, Coulomb attraction is temporarily overcome, allowing charge inhomogeneities to persist long enough to be directly resolved.

Using our method, we observe in real time the buildup and decay of internal electric fields associated with this hot carrier separation, providing direct access to a regime of transient, micron-scale charge separation and broken local charge neutrality. This work opens a route to exploring nonequilibrium many-body dynamics in solids beyond the assumption of local charge neutrality that underpins standard descriptions of collective charge behavior in condensed matter.

Gulnaz Rakhmanova

## Mobile impurity probing the FFLO phase

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The Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state is a superconducting phase in which Cooper pairs carry a finite center-of-mass momentum, giving rise to a spatially modulated order parameter [1, 2]. Experimental identification of this phase remains challenging because it exists only within a narrow parameter regime, and its spatial modulation is difficult to detect using conventional bulk probes. Mobile impurities have emerged as sensitive microscopic probes of ultracold gases, as their quasiparticle properties and spectral response are strongly affected by the surrounding medium [3]. Ultracold atomic gases therefore provide a clean and highly tunable platform for exploring FFLO physics. In this work, we study a mobile impurity coupled to a spin-imbalanced Fermi superfluid and examine its response across the BCS-FFLO-normal phase diagram. The host medium is described within Fulde-Ferrell mean-field theory, and the impurity is treated using a variational ansatz that leads to a closed set of three coupled integral equations. We find that finite pairing momentum qualitatively modifies the impurity excitation branch: the polaron pole evolves from a bound state below the continuum in the BCS regime into a resonance embedded within the continuum in the FFLO regime. This resonance acquires a finite decay width, corresponding to a reduced quasiparticle lifetime, due to the opening of decay channels into the two-quasiparticle continuum. Furthermore, as shown in Fig. 1, the polaron energy and quasiparticle residue exhibit discontinuous jumps across the first-order BCS-to-FFLO transition, while varying smoothly through the FFLO-to-normal transition. These features provide clear impurity-based signatures of FFLO pairing that can be experimentally accessed using Ramsey spectroscopy.

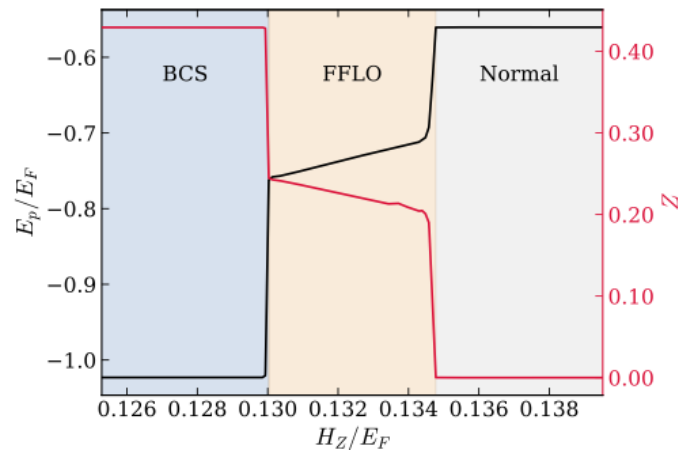


Figure 1. Impurity energy (black) and residue (red) across the BCS-FFLO-normal phase evolution at  $1/(k_F a_{\text{ff}}) = -1$ .

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Gergő Roósz

### Nonfreeness and entropy in the two dimensional Hubbard model

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We investigate the entropy and the nonfreeness (the relative entropy compared to the closest uncorrelated state) of the 2D Hubbard model as the function of the interaction strength, temperature and filling, using DGammaA at finite temperature and cluster DMFT at zero temperature.

We compare the entropy calculated from Parquet DGammaA with Monte -Carlo simulations from the literature, and found good agreement.

Using the nonfreeness one can quantify the strength of the correlations independently from the correlation functions or basis choice, and draw the boundaries of the strongly correlated regime, where an approximate Gaussian description is impossible. At the zero temperature the nonfreeness changes abruptly at the Mott transition is higher in the localized phase.

Based on the nonfreeness we define a witness, which is equal to the difference of the magnetic and charge structure factors, and detect quantum correlations between the particles.

Mohammad Sameer

### The magnetotropic response of the kagome metal CsV<sub>3</sub>Sb<sub>5</sub> in its superconducting and metallic states

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The kagome superconductor CsV<sub>3</sub>Sb<sub>5</sub> ( $T_c \approx 2.5$  K) hosts a  $2 \times 2 \times 2$  charge-density-wave phase below 94 K [1], and signatures of electronic nematicity and time-reversal-symmetry breaking near 30 K. The interplay of these orders with its superconducting state and Fermi-surface topology remains an open question.

Using resonant torsion magnetometry, we investigate CsV<sub>3</sub>Sb<sub>5</sub> single crystals between 0.7–35 K and 0–14 T. The technique measures the angular curvature of the free energy via resonant-frequency shifts  $\Delta f(B, T, \theta)$ .

Angular sweeps from out-of-plane to in-plane orientations resolve clear de Haas–van Alphen oscillations superimposed on the uniaxial magnetotropic background. Field sweeps below  $T_c$  reveal a pronounced peak within the superconducting state. The field positions of this peak define a phase boundary  $H_1(T)$  internal to the superconducting region, distinct from published  $H_{c2}$  curves. At fields above  $H_{c2}$ , the magnetotropic response exhibits an anomalous change in temperature dependence near 25 K, whose origin remains unclear.

In-plane angular measurements are currently underway to determine whether nematicity is an intrinsic bulk property of CsV<sub>3</sub>Sb<sub>5</sub> and to determine whether additional symmetry-breaking phenomena emerge below 35 K.

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Elke Scheer

## Spin-polarized transport in copper-oxide atomic junctions revealed by anomalous shot-noise behavior in presence of the Kondo effect

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Noise measurements provide a valuable tool for revealing spin polarization effects in the electronic transport through quantum coherent conductors. We present an extension of the Landauer description of shot noise to include energy-dependent transmission functions and apply it to explore local magnetic correlations in air-oxidized copper contacts and chains [1], for which first-principle studies have predicted the emergence of ferromagnetic ground states, attributing certain atomic configurations with spin filtering capabilities [2]. By means of low-temperature transport measurements, we provide comprehensive experimental evidence, including hysteretic magnetoresistance [3] and zero-bias anomalies (ZBAs) [4] attributed to the Kondo effect [5], for the presence of local magnetism. The analysis of the anomalous shot noise in the presence of ZBAs allows us to determine the spin polarization of the current which may reach even full polarization, confirming the spin-filtering capability of copper oxide atomic contacts.

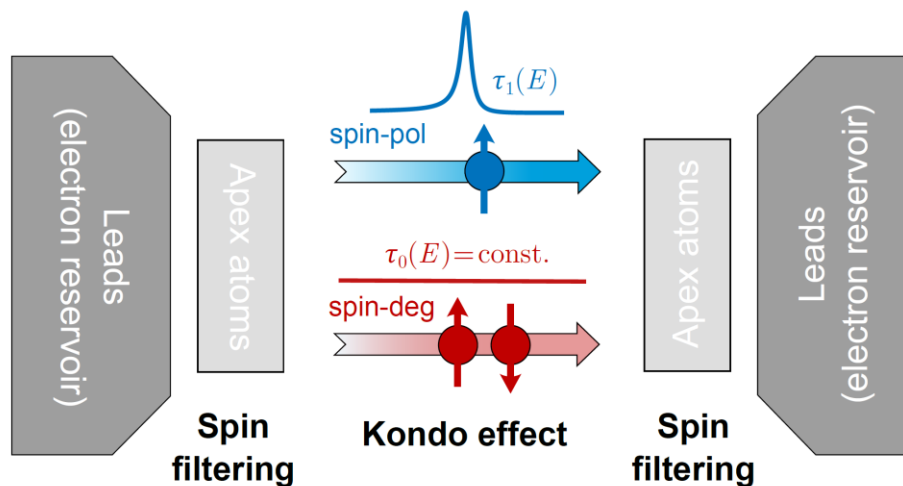


Figure 1. Cartoon of the transport properties of CuO atomic contacts.

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Nikolai Semenov

## Solid-immersion-lens THz microscope for device-scale spectroscopy of 2D quantum materials

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Correlated electronic phases in two-dimensional quantum materials are often realized in micron-scale, gate-tunable heterostructures, while conventional terahertz (THz) spectroscopy averages over diffraction-limited areas that are orders of magnitude larger. This mismatch is particularly limiting for distinguishing interaction-driven electron solids, such as Wigner-crystal-like phases in transition-metal dichalcogenides, from disorder-localized or fluid regimes. Their most direct signatures are expected in the complex optical conductivity  $\sigma(\omega)$  through pinned collective modes, spectral-weight transfer, and non-equilibrium depinning dynamics.

I will present the development of a cavity-free THz microscope based on solid-immersion-lens optics for broadband, phase-resolved spectroscopy of device-scale 2D materials. A high-refractive-index hemispherical lens placed close to the sample compresses the THz focus to the  $\sim 30$   $\mu\text{m}$  scale, enabling efficient coupling to gated van der Waals devices while avoiding resonant artifacts associated with on-chip cavities. The planned instrument combines THz time-domain spectroscopy, cryogenic sample environments, and electrostatic gate tuning to extract the complex sheet conductivity over the sub-THz to few-THz range.

The poster will discuss the optical design, expected spatial and spectral performance, and the measurement workflow for converting field-resolved THz transmission into  $\sigma(\omega)$  of micron-scale devices. As a target application, I will focus on gate-tunable transition-metal dichalcogenide heterostructures, where density- and temperature-dependent THz spectra can test for pinned collective resonances and map the crossover between electron-solid and conducting-fluid responses. The same platform is designed to support future THz pump–THz probe and optical pump–THz probe experiments, allowing field-driven depinning, photo-induced melting, and recovery kinetics of correlated electronic order to be measured directly.

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Andras Szabo

## Out-of-equilibrium intertwining via emergent collective modes

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Symmetry enlargement between microscopically distinct ordered phases appears in a variety of correlated systems, as exemplified by the  $SO(5)$  and pseudospin  $SU(2)$  symmetries of the Hubbard model. New collective excitations emerge near the enlarged-symmetry manifold, including soft modes connecting the different symmetry sectors. Here, we consider a theory of emergent collective excitations in the vicinity of an  $O(N) \times O(M) \rightarrow O(N+M)$  symmetry enlargement under periodic driving. We show that drives inducing dynamical symmetry reduction generate an oscillating mass for the inter-sector Goldstone mode. Through parametric resonance with this emergent energy scale, the driven system develops out-of-equilibrium intertwined orders in the form of stable limit-cycle solutions. We further elucidate their interplay with the Higgs scale. Finally, we discuss a state-of-the-art tunable quantum-engineered matter-cavity platform, which realizes the minimal scenario with  $N=M=1$  [2], providing a potential experimental route toward observing the proposed phenomenology.

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Tiark Tiwary

## Point-contact spectroscopy and fabrication of controllable atomic contacts from the non-centrosymmetric superconductor Nb<sub>18</sub>Re<sub>82</sub>

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The non-centrosymmetric superconductor Nb<sub>18</sub>Re<sub>82</sub> (Nb-Re) has become of great interest in recent years, as it reveals various properties of unconventional superconductivity. A key feature is the absence of inversion symmetry which is causing a Rashba-type spin-orbit coupling. Theoretically, this lack of symmetry allows for an admixture of spin-singlet and spin-triplet states. While previous measurements [1] on point contacts with Nb-Re single crystals stated the existence of two distinct BCS-like superconducting energy gaps, measurements on Nb-Re thin films [2] suggest a single s-wave gap. To address these inconsistencies, we applied the mechanically controlled break junction (MCBJ) technique to characterise Nb-Re atomic contacts.

MCBJs feature a suspended nanobridges of the material, the cross section of which can be adjusted at low temperature by stretching and relaxing the nanowire. Two fabrication routes have been established: A modified version of the standard lift-off fabrication method [3] as well as subtractive patterning by dry etching have been developed. The sample characterisation involves the determination of the preferred conductance values of atomic-size contacts and their statistical analysis in conductance histograms. These reveal a strong bias dependence unknown for Nb atomic contacts [4]. To understand both aspects, the development of a fabrication method for Re MCBJs is currently ongoing.

On Nb-Re MCBJs, we observe the typical features of Andreev reflections and multiple Andreev reflections [5] for atomic contacts with high transmission as well as tunnelling spectra for contacts with low transmission. As a result, the two distinct gaps observed in [1] can be reproduced. While the temperature dependencies of both gaps follow a BCS-like behaviour, the magnetic field dependent measurements clearly differ from the one of conventional type II BCS-superconductors.

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