Correlations and Dynamics in Low-Dimensional Quantum Systems

Argentinian-German WE-Heraeus-Seminar

23 Mar - 29 Mar 2025
at the Gran Hotel Panamericano,
San Carlos de Bariloche, Argentinia

The WE-Heraeus Foundation supports research and education in science, especially in physics.
The Foundation is Germany's most important private institution funding physics.

WILHELM UND ELSE
HERAEUS-STIFTUNG

Introduction

The Wilhelm und Else Heraeus-Stiftung is a private foundation that supports research and education in science with an emphasis on physics. It is recognized as Germany's most important private institution funding physics. Some of the activities of the foundation are carried out in close cooperation with the German Physical Society (Deutsche Physikalische Gesellschaft). For detailed information see https://www.we-heraeus-stiftung.de

Aims and scope of the Argentinian-German WE-Heraeus-Seminar:

This first "Argentinian-German Wilhelm and Else Heraeus Seminar" aims at bringing together scientists from Argentina and Germany to discuss outstanding challenges in investigation of correlation effects and out-of-equilibrium dynamics in low-dimensional quantum systems. In recent years, the study of correlations and dynamics in low-dimensional quantum systems has witnessed a remarkable expansion, spanning a wide range of applications that range from superconducting qubits and circuits made from those, via artificially generated heterostructures and interfaces, edge-states in topological matter, all the way to strongly anisotropic bulk materials. The key theme of the meeting is to identify and discuss common physical principles in these diverse, but closely related physical platforms. These phenomena are at the heart of condensed matter physics but also found relevance in scientific domains such as quantum information science and material engineering.

Scientific Organizers:

Prof. Dr. Liliana Arrachea	Centro Atómico Bariloche, San Carlos de Bariloche, Argentina E-mail: larrachea@unsam.edu.ar
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Introduction

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Venue:

Gran Hotel Panamericano
Av. Exequiel Bustillo 22900
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More information about the venue are available here:
https://www.ghpanamericano.com/

Registration:

At the Hotel,
Sunday (17:00 h – 21:00 h)
Monday (08:15 h – 08:50 h)

Program

Program

Sunday, March 23, 2025

17:00 – 21:00	Registration	
20:00	*DINNER / Informal get together*	

Monday, March 24, 2025

07:30 – 08:50	*BREAKFAST*	
08:15 – 08:50	Registration	
08:50 – 09:00	Scientific organizers	**Opening and welcome**
09:00 – 09:35	**Roderich Moessner** MPI-PKS Dresden	**Lifting topological censorship : where the current flows in a Chern insulator**
09:35 – 10:10	**Alexander Mirlin** KIT Karlsruhe	**Measurement-induced phase transitions in fermionic systems**
10:10 – 11:20	*COFFEE BREAK*	
11:20 – 11:55	**Flavia Argentina Gomez Albarracín** Natl. Univ. of La Plata	**Topological phases in magnetic systems : models, simulations and machine learning**
11:55 – 12:30	**Stefan Jorda** WEH Foundation	**About the Wilhelm and Else Heraeus Foundation**
12:30 – 14:00	LUNCH	
14:00 – 14:35	**Alexander Altland** Univ. of Cologne	**Statistical field theory approach to quantum thermalization**
14:35 – 15:00	**Horacio Miguel Pastawski** Natl. Univ. of Cordoba	**The global out-of-time-order correlators as a signature of the ballistic scrambling of local information in a 3D crystal under Double Quantum Hamiltonian.**

Program

Monday, March 24, 2025

15:00 – 16:00	**Participants with poster**	**1 min. flash presentations (one slide)**
16:00 – 19:30	*COFFEE BREAK* at 16:00 h **Discussions group**	
20:00	*DINNER*	

Program

Tuesday, March 25, 2025

07:30 – 09:00	*BREAKFAST*	
09:00 – 09:35	**Bella Lake** Helmholtz Center Berlin	**Excitations of quantum spin chain antiferromagnets with Heisenberg-Ising anisotropy**
09:35 – 10:10	**Luis Manuel** Natl. Univ. of Rosario	**Fractionalized Excitations in Triangular Lattice Antiferromagnets**
10:10 – 11:20	*COFFEE BREAK*	
11:20 – 11:55	**Elena Gati** MPI-CPFS Dresden	**Elastocaloric effect of strain-tuned frustrated magnets**
11:55 – 12:30	**Santiago Grigera** Natl. Univ. of La Plata	**Topological transitions and hidden order in a frustrated magnet**
12:30 – 14:00	*LUNCH*	
14:00 – 17:00	**Poster Session** *COFFEE BREAK* at 15:30 h	
17:00 – 17:35	**Matthias Scheurer** Univ. Stuttgart	**Adatom-engineered and fractionalized altermagnetism**
17:35 – 18:00	**Thomas Schäfer** MPI-FKF Stuttgart	**Correlations and geometric frustration - a happy marriage?**
18:00 – 18:25	**Ignacio Hamad** Natl. Univ. of Rosario	**Singlet polaron theory of low-energy optical excitations in $NiPS_3$**
18:25 – 18:50	**Gustavo Pastor** Univ. of Kassel	**Tracking angular momentum flow during the laser-induced ultrafast demagnetization of ferromagnetic transition metals**
20:00	*DINNER*	

Program

Wednesday, March 26, 2025

07:30 – 09:00	*BREAKFAST*	
09:00 – 09:35	**Roser Valenti** Univ. of Frankfurt	**Designing flat bands, localized and itinerant states in van der Waals platforms**
09:35 – 10:10	**Bernd Buechner** IFW-Dresden	**Topological superconductivity in $PtBi_2$**
10:10 – 11:20	*COFFEE BREAK*	
11:20 – 11:55	**Yanina Fasano** Centro Atómico Bariloche	**Surface superconductivity in the topological Weyl semimetal t-$PtBi_2$**
11:55 – 12:30	**Jorge Facio** Centro Atómico Bariloche	**Obstructed Peierls instabilities and their relevance for the electronic topology of $PtBi_2$**
12:30 – 14:00	*LUNCH*	
14:00	**Excursion**	

Program

Thursday, March 27, 2025

07:30 – 09:00	*BREAKFAST*	
09:00 – 09:35	**Alejandro Lobos** Univ. de Cuyo	**A Large-N Approach to Magnetic Impurities in Superconductors**
09:35 – 10:10	**Organizers**	**Tools to foster German / Argentinian collaborations**
10:10 – 11:20	*COFFEE BREAK*	
11:20 – 11:55	**Christoph Strunk** Univ. Regensburg	**Inductance measurements as a versatile probe of spin-orbit effects in hybrid 2D-superconductors**
11:55 – 12:30	**Leandro Tosi** Centro Atómico Bariloche	**Hybrid Quantum Circuits based on two-dimensional Al/InAs heterostructures**
12:30 – 14:00	*LUNCH*	
14:00 – 17:00	**Poster session** *COFFEE BREAK* at 15:30 h	
17:00 – 17:35	**Frank Pollmann** TU Munich	**Probing Quantum Phases of Matter on Quantum Processors**
17:35 – 18:10	**María José Sánchez** Centro Atómico Bariloche	**Landau Zener Stückelberg Interferometry as a tool to control superconducting qubits**
18:10 – 18:35	**Alejandro Ferron** Univ. Nacional d. Nordeste	**Electric quantum control of on-surface spins using Landau–Zener–Stückelberg-Majorana interference**
20:00	*DINNER*	

Program

Friday, March 28, 2025

07:30 – 09:00	*BREAKFAST*	
09:00 – 09:35	**Igor Gornyi** KIT-Karlsruhe	**Steering and cooling of quantum systems.**
09:35 – 10:10	**Cecilia Cormick** Univ. de la Rep. Uruguay / CONICET	**Optomechanics with ions in an optical cavity**
10:10 – 11:20	*COFFEE BREAK*	
11:20 – 11:55	**Armando Aligia** Centro Atómico Bariloche	**Topological charge pumping in the interacting Rice-Mele model, theory and experiment (+ other collaborations)**
11:55 – 12:30	**Karen Hallberg** Centro Atómico Bariloche	**Physical properties of confined fermionic chains in a Wannier-Stark potential**
12:30 – 14:00	*LUNCH*	
14:00 – 17:00	**Discussion groups** *COFFEE BREAK* at 15:30 h	
17:00 – 17:35	**Gonzalo Usaj** Centro Atómico Bariloche	**The Streda Formula for Floquet Systems: Topological Invariants and Quantized Anomalies from Cesaro Summation**
17:35 – 18:10	**Felix von Oppen** FU-Berlin	**Random fields in the Floquet quantum Ising model**
18:10 – 18:35	Scientific organizers	**Poster prize and closing**
20:00	*DINNER*	

End of seminar

Program

Saturday, March 29, 2025

07:30 – 09:00	*BREAKFAST*
09:00	**Departure**

Posters

Posters

Lourdes Amigó	**Negative c-axis longitudinal magnetoresistance in FeSe**
Leandro Arancibia	**Towards electrical domain-wall control in polyacetylene-based electronic nano-devices**
Selena Barragán	**Advancing Topological Electronics with dual-gated Quantum Spin Hall Devices based on III-V Semiconductors**
Julia Besprosswanny	**Topological Fermi Arcs and Surface Superconductivity in t-$PtBi_2$**
Muriel Bonetto	**Local thermometry for non-equilibrium vibrational states of an ion chain**
Geronimo Jesus Caselli	**Two interacting qubits as a thermal machine**
Victor Correa	**Quantum oscillations evidence of sixfold fermions in the cubic Dirac semimetal β-$PtBi_2$**
Sebastian Esteban Deghi	**Second-order adiabatic expansion in quantum transport: corrections to the isolated mass due to electron forces**
Jose Tomas Este Jaloveckas	**Superconducting circuit architecture supporting multi-mode qubits**
Niclas Heinsdorf	**Higher Berry Curvature from Matrix Product States**
Nohora Alejandra Hernandez Cepeda	**Nagaoka Ferromagnetism in finite-size arrays: Shaped by Connectivity, Disrupted by Fields.**
Juan Herrera Mateos	**Nonlocal thermoelectricity in quantum wires as a signature of Bogoliubov-Fermi points**
Iksu Jang	**Elastic Quantum Criticality in Nematics and Altermagnets via the Elasto-Caloric Effect**

Posters

Oleg Janson	**Weakly coupled triangles in a S=1/2 star lattice of an organic-inorganic cuprate**
Erika Mehring	**Hysteresis and effective reciprocity breaking due to current-induced forces**
Gonzalo Alfredo Mogensen	**Near 2D limit in FeSe by single crystal exfoliation**
Avedis Neehus	**Genuine topological Anderson insulator from impurity induced chirality reversal**
Adelina Orlandini	**Non-trivial entanglement structure across a local topological quantum phase transition**
Andrei Pavlov	**Topological transitions in quantum jump dynamics: Hidden exceptional points**
Lucila Peralta Gavensky	**The Středa Formula for Floquet Systems**
Ihor Poboiko	**Measurement-induced Lévy flights of quantum information**
Ignacio Luciano Pomponio	**Two-spinon bound states evolution in the magnetic spectrum of triangular antiferromagnets**
Lucas Pupim	**Adatom engineering magnetic order in superconductors: Applications to altermag- netic superconductivity**
Kelvin Julinio Ramos Villalobos	**Development of photon detectors based on granular aluminum superconducting resonators**
Corina Révora	**Superposition of n squeezed states for quantum metrology and for encoding quantum information**
Maurice Indrian Rieger	**Towards quantum many-body physics in two dimensions with highly magnetic atoms of Dysprosium**

Posters

Gabriel Fernando Rodriguez Ruiz	**Superconductivity in two-dimensional heterostructures with spin-orbit coupling**
Adrian Rubio Lopez	**Stochastic resonant behaviours and steady state control in harmonic systems**
Daniel Schultz	**Electric field control of a quantum spin liquid in weak Mott insulators**
Thibault Scoquart	**Scaling of many-body localization transitions: Correlations and dynamics in Fock space and real space**
Veronika Stangier	**Pauli Limiting near a Quantum Critical Point**
Charles Steward	**Dynamic paramagnon-polarons in altermagnets**
Piotr Surowka	**Non-equilibrium charge-vortex duality at finite temperature**
Davide Valentinis	**Interplay between quantum criticality, superconductivity, and magnetic fields in exactly solvable models for strange metals**
Cecilia Ileana Ventura	**MODELING Bi-based LAYERED SUPERCONDUCTORS: Electronic Properties**
Carolina Vlatko	**Vibrational dynamics in ultracold ion systems**

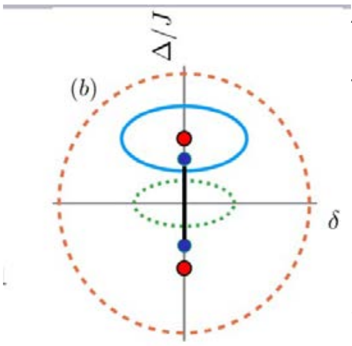
Abstracts of Lectures

(in alphabetical order)

Topological charge pumping in the interacting Rice-Mele model, theory and experiment + other collaborations

Armando A. Aligia
Centro Atómico Bariloche, INN, CNEA, CONICET

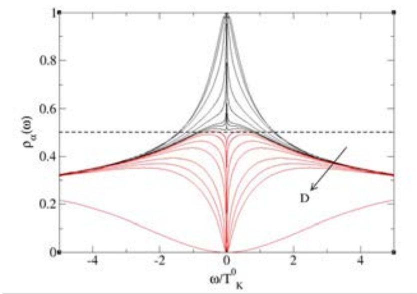
The topological charge pumping or Thouless pump has been a subject of great interest in the last years. It consists in quantified charge transport in a unit cell after an adiabatic cycle in the parameters of a Hamiltonian is completed.
Recently, relevant experiments were done in the interacting Rice-Mele model (a Hubbard model with alternating hopping t+(-)δ and on-site interactions +(-)Δ) by the ETH group [1] but choosing cycles in which the interaction *U* destroys the charge pumping.



Almost at the same time, in a collaboration between German and Argentine researchers, we have shown that it is possible to choose alternative cycles that do not encircle the point δ=Δ=0 and allow charge transport for any value of the interaction [2].

More recently both groups collaborated to verify this, and show that for some cycles charge pumping is induced by the interaction [3]. After the first pump cycle, adiabaticity is lost due to charge-spin interaction. Possible solutions to this problem are discussed.

I will briefly mention other topics: 1) the topological quantum phase transition transition to a "non-Landau" Fermi liquid in a two-channel spin-1 Kondo (or Anderson) model with anisotropy $D(S_z)^2$, in which the spectral density at the Fermi level jumps abruptly [4]. The model has found experimental relevance in several systems studied with scanning-tunneling microscopy [5-7]. 2) research on topological superconductors [8-10], in collaboration with Argentine and German researchers.



References
[1] A.-S. Walter et al. Nature Physics 19, 1471 (2023).
[2] E. Bertok, F. Heidrich-Meisner, and A. A. Aligia, Phys. Rev. B 106, 045141 (2022).
[3] K. Viebahn, A.-S. Walter, E. Bertok, Z. Zhu, M. Gächter, A. A. Aligia, F. Heidrich-Meisner, and T. Esslinger, Phys. Rev. X 14, 021049 (2024).
[4] G. G. Blesio et al., Phys. Rev. B 98, 195435 (2018), Phys. Rev. B 100, 075434 (2019).
[5] R. Žitko, G. G. Blesio, L. O. Manuel, and A. A. Aligia, Nature Commun. 12, 6027 (2021).
[6] G. G. Blesio, R. Žitko, L. O. Manuel, and A. A. Aligia, SciPost Phys. 14, 042 (2023).
[7] G. G. Blesio and A. A. Aligia, Phys. Rev. B 108, 045113 (2023).
[8] A. Camjayi, L. Arrachea, A. Aligia and F. von Oppen, Phys. Rev. Lett. 119, 046801 (2017).
[9] A. A. Aligia, D. Pérez Daroca, and L. Arrachea, Phys. Rev. Lett. 125, 256801 (2020).
[10] G. F. Rodríguez Ruiz, M. A. Rampp, A. A. Aligia, Jörg Schmalian, and L. Arrachea, Phys. Rev. B 106, 195415 (2022).

Statistical field theory approach to quantum thermalization

Alexander Altland[1], Tobias Micklitz[2]

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[2]) Centro Brasileiro de Pesquisas Físicas, Rua Xavier Sigaud 150, 22290-180, Rio de Janeiro, Brazil

The evolution of complex random quantum systems is governed by the buildup of entanglement and entropy, generically terminating in an ergodic final state. In this talk, we introduce a real-time field theory approach capable of describing such 'thermalization' dynamics for a variety of system classes from first principles. This theory describes how quantum thermalization generically starts with the fast entanglement of initially independent ('single particle') states to strongly correlated randomly evolving many-body states. Depending on the presence of conservation laws (such as energy, in Hamiltonian dynamics), this is followed by the slower relaxation of locally conserved densities. As examples, we will discuss this type of evolution for unitarily coupled 'circuits' and arrays of quantum dots subject to capacitive interactions.

Topological superconductivity in PtBi2

Bern Buechner

Leibniz Institut für Festkörper und Werkstoffforschung Dresden, Germany

Due to their intrinsic topology, Weyl semimetals are potential candidates for to pological superconductivity, but so far have always been connected with bulk s uperconductivity, leaving the possibility of intrinsic superconductivity of their to pological surface states, the Fermi arcs, practically without attention, even fro m the theory side. By means of angle-resolved photoemission spectroscopy (A RPES) we identified topological Fermi arcs on two opposing surfaces of the no n-centrosymmetric Weyl material trigonal PtBi2. We show these states becom e superconducting at temperatures of about 10 K. Superconductivity is also fo und in our STM measurements showing in addition spatial inhomogeneity of th e superconducting gap. In some samples superconducting gaps as large as 2 0 meV and transition temperatures at about 40 K are revealed by STM resemb ling the phenomenology found in high-Tc superconductors. By extending our h igh resolution ARPES measurements we can extract a k dependence of the su perconducting gaps and the data clearly show nodes of the gap implying topol ogical surface superconductivity in PtBi2.

Optomechanics with ions in an optical cavity

C. Cormick 1,2

1 Instituto de Física Enrique Gaviola, UNC-CONICET, Córdoba, Argentina 2 Instituto de Física de la Facultad de Ingeniería, UdelaR, Montevideo, Uruguay

A crystal of ions trapped inside a pumped optical cavity can be used to implement condensed-matter models with tunable features. When the cavity and the ions are off-resonance, the cavity field couples with the positions of the ions forming an optomechanical system. We study the stationary states in a case when nonlinearities are specially relevant, namely, in the vicinity of the so-called sliding-pinned transition. Using a semiclassical treatment, we find that the cavity leads to the appearance of parameter regions where both of the competing phases are stable, while mirror losses provide a non-invasive means to monitor the dynamics and to cool the chain vibrations. We also explore the relation between spatial structure and multipartite entanglement for a small system of three ions. Finally, we address the limitations of our treatment and discuss alternative numerical techniques for more challenging parameter regimes.

Obstructed Peierls instabilities and their relevance for the electronic topology of $PtBi_2$

Santiago Palumbo[1], Manuel Alonso Lemos[1], Pablo S. Cornaglia[1,2], Jorge I. Facio[1,2]

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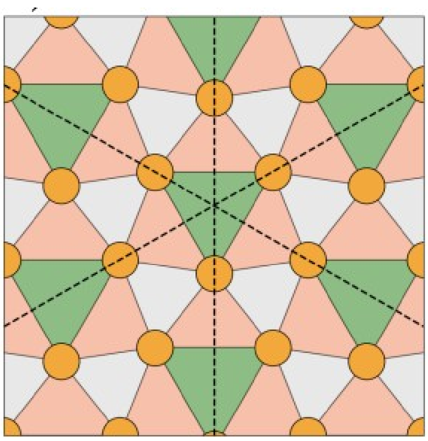
[2]Centro Atomico Bariloche, Instituto de Nanociencia y Nanotecnologia (CNEA-CONICET), Av. Bustillo, 9500, Argentina

The coupling between electronic and lattice degrees of freedom is often crucial for understanding the emergence of electronic and structural order in complex materials. A textbook example is the Peierls transition, where a one-dimensional (1D) lattice undergoes a dimerization instability that reduces its translational symmetry. The fundamental connection between symmetry and topological phases in electronic systems naturally raises the question of how electronic topology is affected when translational symmetry is broken. Here, we explore Peierls-like instabilities in systems with triangular lattice symmetry and show that in higher dimensions, such distortions can give rise to a rich variety of topological phases. This framework provides a unified perspective on the electronic topology of graphene and kagome systems, as well as materials derived from them. As a concrete example, we demonstrate how the topological properties of trigonal $PtBi_2$ emerge as a direct consequence of its broken translational symmetries, offering new insight into its electronic structure.



Decomposition of 2D space into alternating large and small triangles, forming a tiling that preserves certain symmetries of the underlying, distorted triangular Bravais lattice.

Surface superconductivity in the topological Weyl semimetal t-$PtBi_2$

Yanina Fasano [1,2], Sebastian Schimmel [2,3], Sven Hoffmann [2,3], Julia Besproswanny [2,3], Laura Teresa Corredor Bohorquez [2], Joaquín Puig [1,2], Bat-Chen Elshalem [4], Beena Kalisky [4], Grigory Shipunov [2], Danny Baumann [2], Saicharan Aswartham [2], Bernd Büchner [2,5] & Christian Hess [2,3]

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5. Institute of Solid State and Materials Physics and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, Dresden, Germany.

Topological superconductivity is a promising concept for generating fault-tolerant qubits. Early experimental studies looked at hybrid systems and doped intrinsic topological or superconducting materials at very low temperatures. However, higher critical temperatures are indispensable for technological exploitation. Recent angle-resolved photoemission spectroscopy results have revealed that superconductivity in the type-I Weyl semimetal—trigonal $PtBi_2$ (t-PtBi2)—is located at the Fermi-arc surface states, which renders the material a potential candidate for intrinsic topological superconductivity. Here we show, using scanning tunnelling microscopy and spectroscopy, that t-$PtBi_2$ presents surface superconductivity at elevated temperatures (5 K). The gap magnitude is elusive: it is spatially inhomogeneous and spans from 0 to 20 meV. In particular, the large gap value and the shape of the quasiparticle excitation spectrum resemble the phenomenology of high-Tc superconductors. To our knowledge, this is the largest superconducting gap so far measured in a topological material. Moreover, we show that the superconducting state at 5 K persists in magnetic fields up to 12 T.[1]

[1] S. Schimmel, Y. Fasano *et al.*, Nature Communications **15**, 9895 (2024).

Electric quantum control of on-surface spins using Landau–Zener–Stückelberg-Majorana interference

Santiago Rodríguez(1), Sergio Gómez(1), Joaquín Fernández-Rossier(2), Alejandro Ferrón(1)

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(2) International Iberian Nanotechnology Laboratory (INL), Av. Mestre José Veiga, 4715-330 Braga, Portugal.

Quantum control techniques play a crucial role in manipulating and harnessing the properties of different quantum systems, including isolated atoms and arrays of atoms. Here, we propose to achieve quantum control over a single on-surface atomic spin using Landau-Zener-Stuckelberg-Majorana (LZSM) interferometry implemented with Scanning Tunneling Microscopy (STM). Specifically, we investigate how the application of time-dependent, non-resonant AC electric fields across the STM tip-surface gap makes it possible to achieve precise quantum state manipulation in an isolated Fe atom on a MgO/Ag(100) surface. The proposed experiments can be implemented with actual ESR-STM instrumentation, opening a new venue in the research of on-surface single spin control. At the end of the talk, we will discuss some details about possible experimental implementations and the possibility of generalizing these experiments with different magnetic atoms and more complex arrays of atoms.

Elastocaloric effect of strain-tuned frustrated magnets

Elena Gati

Max-Planck-Institute for Chemical Physics of Solids, 01187 Dresden, Germany

As a result of experimental advances to control uniaxial stress with unprecedented precision in situ at low temperatures, uniaxial pressure has emerged as a promising tool to control lattice symmetries and modify competing interactions in correlated quantum materials. This aspect is particularly relevant for frustrated Mott insulators, where uniaxial pressure provides an excellent opportunity for high-precision tuning of the frustration strength. Mapping experimental phase diagrams as a function of strain to theoretical model calculations as a function of frustration is highly desirable to advance our understanding of its effects in real materials.

In this talk, we will demonstrate that experimentally achievable strains are sufficient to tune materials that serve as model systems for frustrated magnetism, and show that the newly discovered method of elastocaloric effect measurements is highly suited to determine their phase diagrams as a function of uniaxial pressure. In particular, we will emphasize how these measurements can pinpoint instances where entropy extrema, such as those associated with maximum frustration, are crossed by strain tuning.

Topological phases in magnetic systems: models, simulations and machine learning

F. A. Gómez Albarracín [1,2], H. D. Rosales [1,2]

[1] Instituto de Física de Líquidos y Sistemas Biológicos, La Plata, Argentina

[2] Depto. de Ciencias Básicas, Fac. de Ingeniería, Universidad Nacional de La Plata, La Plata, Argentina

Magnetic skyrmions have attracted a lot of attention in the last years, given their intriguing properties and potential technological applications. We will focus on our recent work combining analytical and numerical techniques in systems where frustration plays a key role in the stabilization of exotic skyrmion textures. We will also discuss particular cases where the presence of these topological phases is linked to algebraic and spiral spin liquids. Finally, we will give a brief overview on our work applying machine learning techniques to these systems and models.

Steering and cooling of quantum systems

<u>Igor Gornyi</u>

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Last years have witnessed an extreme surge of interest in phenomena driven by quantum measurements, particularly in view of related challenges in the context of quantum information processing. This talk will overview measurement-induced steering (preparation and manipulation) and cooling of quantum states. Steering exploits the backaction of projective measurements performed on detectors coupled to the system, which arises from entanglement generated during their joint evolution. This framework encompasses two key paradigms. *Passive steering* [1,2,3] refers to protocols that are predesigned and implemented independently of the specific sequence of detector readouts. This framework of so-called *blind measurements* [1] is further extended by including an active-decision choice of the system-detector interactions, which can be viewed as "navigation in many-body Hilbert space" based on the information extracted through measurements. This approach of *active steering* [4,5] utilizes protocols that adapt dynamically, with each step determined by the real-time readout history of the system's evolution. For steerable systems, where sufficiently local measurements can drive the system into its ground state, steering is equivalent to cooling. Remarkably, even for passively unsteerable models, repetitive measurements can significantly reduce the system’s energy [6], thus mimicking zero-temperature environments in cooling quantum systems.

References

[1] S. Roy, J.T. Chalker, I.V. Gornyi, and Y. Gefen, Phys. Rev. Research **2**, 033347 (2020).

[2] E. Medina-Guerra, P. Kumar, I. V. Gornyi, and Y. Gefen, Phys. Rev. Research **76**, 023159 (2024).

[3] J. Langbehn, K. Snizhko, I. Gornyi, G. Morigi, Y. Gefen, and C. P. Koch, PRX Quantum **5**, 030301 (2024).

[4] Y. Herasymenko, I. V. Gornyi, and Y. Gefen, PRX Quantum **4**, 020347 (2023).

[5] S. Morales, Y. Gefen, I. Gornyi, A. Zazunov, and R. Egger, Phys. Rev. Research **6**, 013244 (2024).

[6] J. Langbehn *et al.*, to appear (2025).

Topological transitions and hidden order in a frustrated magnet

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Spin ice is well-known for being a host to 2D and 3D Kasteleyn transitions. In the latter case, a field-polarized state along one of the principal axes can be abruptly destabilizes due to a sudden proliferation of system-spanning strings of flipped spins. In this talk, I will present experimental evidence of such a transition in one of the canonical spin-ice materials, Dy2Ti2O7. Additionally, I will discuss a variation of this phenomenon in a modified spin ice system, characterized by degenerate ground states composed of densely packed monopole configurations. Under an applied [111] field, the system undergoes a thermodynamic phase transition, as evidenced by features like specific heat. However, unlike the standard Kasteleyn transition, this transition lacks a local order parameter to distinguish between the two phases. In the monopole-liquid ground state manifold, short loops are allowed even under very strong fields. As the field strength decreases, these loops progressively grow longer, eventually proliferating across all sizes, including system-spanning loops at the transition. While this behavior is not reflected in the magnetization, it leaves distinct signatures in topological and string order parameters, highlighting the system as a rare example of perfectly hidden order in a three-dimensional classical model. Instead of the traditional `3/2'-order kink associated with a Kasteleyn transition, the system shows critical scaling expected near a 3D Ising transition. Interestingly, the magnetic response scales with the critical exponent not of the susceptibility, but of the \textit{specific heat}.

Physical properties of confined fermionic chains in a Wannier-Stark potential

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We study interacting fermions on a finite chain in a Wannier-Stark linear potential using the density matrix renormalization group numerical technique. For the generalized extended Hubbard model, we find that the ground state exhibits a staircase of (quasi) plateaus in the average local site density along the chain, decreasing from being doubly filled to empty as the potential increases. These "plateaus" represent locked-in commensurate phases of charge density waves together with band and Mott insulators. These phases are separated by incompressible regions with incommensurate fillings, as observed from dynamical properties. We suggest that experimental variations of the slope of the potential and the range of the repulsive interactions will produce such a coexistence of phases.
We also study the effect of correlations on the localisation length of an extended spinless model with nearest neighbour repulsion and compare with exact analytical results.

Singlet polaron theory of low-energy optical excitations in $NiPS_3$ [1]

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We develop a theory that explains the low-energy optical excitations near 1.5 eV observed by optical experiments in $NiPS_3$ [2]. Using ab initio methods, we construct a two-band Hubbard model for two effective Ni orbitals. The dominant effective hopping corresponds to third-nearest neighbours. This model exhibits triplet-singlet excitations of energy near two times the Hund exchange. We derive an effective model for the movement of two singlets in an antiferromagnetic background, that we solve using a generalized self-consistent Born approximation, disentangling the nature of these novel excitations, which move coherently as "singlet polarons."

References

[1] I. J. Hamad, C. S. Helman, L. O. Manuel, A. E. Feiguin, and A. A. Aligia, "Singlet Polaron Theory of Low-Energy Optical Excitations in $NiPS_3$," Phys. Rev. Lett., vol. 133, no. 14, p. 146502, 2024. doi:10.1103/PhysRevLett.133.146502.

[2] Soonmin Kang, Kangwon Kim, Beom Hyun Kim, Jonghyeon Kim, Kyung Ik Sim, Jae Ung Lee, Sungmin Lee, Kisoo Park, Seokhwan Yun, Taehun Kim, Abhishek Nag, Andrew Walters, Mirian Garcia-Fernandez, Jiemin Li, Laurent Chapon, Ke Jin Zhou, Young Woo Son, Jae Hoon Kim, Hyeonsik Cheong, and Je Geun Park, "Coherent many-body exciton in van der Waals antiferromagnet $NiPS_3$," Nature, vol. 583, pp. 785–789, 2020. doi:10.1038/s41586-020-2520-5.

Excitations of quantum spin chain antiferromagnets with Heisenberg-Ising anisotropy

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The antiferromagnetic spin-1/2 spin chain with Heisenberg-Ising (XXZ) anisotropy is a rich source of novel phenomena. Good physical realizations are the compounds $SrCo_2V_2O_8$ and $BaCo_2V_2O_8$ where the Co^{2+} ions have effective spin-1/2 and are coupled by antiferromagnetic interactions into chains while collinear long-range magnetic order occurs below T_N ~ 5 K due to weak interchain coupling. The fundamental excitations are spinons which have quantum spin number S=1/2 unlike conventional spin-waves (S=1) – as a consequence they can only be created experimentally in multiple pairs and are observed in neutron scattering as a spinon continuum spread over energy and wavevector in contrast to well-defined spin-wave modes. Below the Neel temperature the spinons can no longer move freely but become confined into pairs and the continuum is replaced by a series of sharp spinon-pair modes corresponding to different spinon-pair separations. In a longitudinal magnetic field applied along the easy axis, the magnetic order is suppressed and we find the evidence for complex bound states of magnetic excitations, known as Bethe strings. Furthermore, the characteristic energy, scattering intensity and linewidth of the observed string states exhibit excellent agreement with precise Bethe ansatz calculations. Our results confirm the existence of the long-sought Bethe string excitations predicted almost a century ago. Application of transverse magnetic field along the direction perpendicular to the easy axis induces a quantum phase transition where the antiferromagnetic order is destroyed at a three-dimensional quantum critical point. The evolution of the excitations is investigated as a function of field revealing a complex series of modes and continuua. At a particular field still within the antiferromagnetically ordered phase we find a sequence of excitations whose energies match the lightest three E8 particles corresponding to the maximal exceptional Lie E8 algebra.

A Large-N Approach to Magnetic Impurities in Superconductors

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Quantum spin impurities coupled to superconductors are under intense investigation for their relevance to fundamental research as well as the prospects to engineer novel quantum phases of matter. Here we develop a large-N mean-field theory of a strongly coupled spin-$\tfrac{1}{2}$ quantum impurity in a conventional s-wave superconductor. The approach is benchmarked against Wilson's numerical renormalization group (NRG). While the large-N method is not applicable in the weak-coupling regime where the Kondo temperature T_K is smaller than the superconducting gap Δ, it performs very well in the strong coupling regime where $T_K \gtrsim \Delta$, thus allowing us to obtain a reasonably accurate description of experimentally relevant quantities. The latter includes the energy of the Yu-Shiba-Rusinov subgap states, their spectral weight, as well as the local density of continuum states. The method provides a reliable analytical tool that complements other perturbative and non-perturbative methods, and can be extended to more complex impurity models for which NRG may not be easily applicable.

Fractionalized Excitations in Triangular Lattice Antiferromagnets

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Recent experimental and theoretical studies have significantly advanced our understanding of quantum magnetism in triangular lattice antiferromagnets (TLAFs), revealing novel phenomena such as spin liquid phases and spinon excitations. This talk will discuss three recent investigations providing new insights into these complex systems.

First, inelastic neutron scattering (INS) on $Ba_3CoSb_2O_9$ reveals strong deviations from semiclassical theories, which can be explained by a parton Schwinger boson framework beyond the saddle-point approximation. The magnon dispersion is well reproduced by two-spinon bound states, while the observed continuum suggests a free spinon gas as a useful starting point for studying magnetically ordered phases near a quantum critical point. Similarly, studies on the spin-1/2 delafossite $KYbSe_2$ reveal a proximate Heisenberg quantum spin-liquid state. The observed spin dynamics include a broad continuum with a sharp lower bound, indicative of fractionalized excitations. Applying entanglement witnesses to the data suggests the presence of multipartite quantum entanglement, while Schwinger boson and tensor network calculations confirm the material's proximity to a gapped Z2 spin-liquid phase. Finally, in $Ba_2La_2CoTe_2O_{12}$, strong easy-plane XXZ anisotropy leads to an excitation spectrum dominated by a high-energy continuum, with spectral weight exceeding single-magnon modes. This suggests a spinon confinement length much larger than the lattice spacing, even in the presence of strong anisotropy.

Together, these studies highlight the intricate interplay between frustration, anisotropy, and quantum entanglement in TLAFs. They establish key experimental signatures of excitation fractionalization and quantum phase transitions, providing a foundation for future exploration of exotic magnetic states in frustrated quantum materials.

Measurement-induced phase transitions in fermionic systems

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We develop [1-4] a theory of measurement-induced phase transitions (MIPT) for d-dimensional lattice fermions subject to random measurements of local site occupation numbers. Our analytical approach is based on the Keldysh path-integral formalism and replica trick. For free fermions, we derive a non-linear sigma model (NLSM) as an effective field theory of the problem. Its replica-symmetric sector is a U(2)/U(1)xU(1) NLSM corresponding to observables linear in the density matrix; it describes diffusive behavior of average density fluctuations. The most interesting is the replica-asymmetric sector corresponding to observables that are non-linear in the density matrix. In particular, it describes propagation of quantum correlations of charge and of quantum information in a system. It is given by a (d+1)-dimensional isotropic NLSM defined of a chiral symmetry class AIII or BDI, with the target manifold SU(R) or SU(2R)/USp(2R), depending on presence of an additional effective time-reversal symmetry, with a replica limit R → 1. This establishes a close relation between MIPT and Anderson transitions. On the Gaussian level, the NLSM predicts diffusive behavior, implying that the entanglement entropy grows with system size as logarithm times area. However, the renormalization-group analysis shows that, for d=1, the "weak localization of information" develops asymptotically into strong localization, implying that the system is in the area-law phase even for a small measurement rate [1]. The corresponding localization length is however exponentially large for rare measurements (as localization length for Anderson localization in 2D). For d>1, we obtain a MIPT between the "diffusive" and "localized" phases of information and charge correlations [2]. The charge covariance G (linked to mutual information) in our theory is a counterpart of conductance in Anderson transitions. The "metallic" phase is characterized by "universal conductance fluctuations" of G and the critical point by scale-invariant distribution of G and by multifractality of two-point "conductance" [4]. Including interaction between fermions induce additional terms in the NLSM that affect the physics in a dramatic way [3]. First, this leads to the "information-charge separation": charge cumulants get decoupled from entanglement entropies. Second, the interaction stabilizes the volume-law phase for the entanglement. Third, for spatial dimensionality d=1, the interaction stabilizes the phase with logarithmic growth of charge cumulants. All analytical results are supported by numerical simulations [1-4].

References

[1] I. Poboiko, P. Pöpperl, I.V. Gornyi, A.D. Mirlin, Phys. Rev. X **13**, 041046 (2023)
[2] I. Poboiko, I.V. Gornyi, A.D. Mirlin, Phys. Rev. Lett. 132, 110403 (2024)
[3] I. Poboiko, P. Pöpperl, I.V. Gornyi, A.D. Mirlin, Phys. Rev. B 111 (2025)
[4] I. Poboiko, I.V. Gornyi, A.D. Mirlin, in preparation

Lifting topological censorship: where the current flows in a Chern insulator

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The discovery of the quantum Hall effect has established the foundation of the field of topological condensed matter physics. An amazingly accurate quantization of the Hall conductance, now enshrined in quantum metrology, is stable against any reasonable perturbation due to its topological protection. Conversely, the latter implies a form of censorship by concealing any local information from the observer. The spatial distribution of the current in a quantum Hall system is such a piece of information, which, thanks to spectacular recent advances, has now become accessible to experimental probes. It is an old question whether the original and intuitively compelling theoretical picture of the current, flowing in a narrow channel along the sample edge, is the physically correct one. Motivated by recent experiments locally imaging quantized current in a Chern insulator [Rosen et al., Phys. Rev. Lett. 129, 246602 (2022); Ferguson et al., Nat. Mater. 22, 1100-1105 (2023)], we theoretically demonstrate the possibility of a broad "edge state" generically meandering away from the sample boundary deep into the bulk. Further, we show that by varying experimental parameters one can continuously tune between the regimes with narrow edge states and meandering channels, all the way to the charge transport occurring primarily within the bulk. This accounts for various features observed in, and differing between, experiments. Overall, our findings underscore the robustness of topological condensed matter physics, but also unveil the phenomenological richness, hidden until recently by the topological censorship, most of which we believe remains to be discovered.

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The global out-of-time-order correlators as a signature of the ballistic scrambling of local information in a 3D crystal under Double Quantum Hamiltonian.

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The characterization of the scrambling of quantum information across a system requires techniques as Loschmidt Echoes (LE) and Out-of-Time-Order Correlators (OTOCs). Although these methods emerged in different fields, they essentially equivalents as both involve a “backward evolution”, i.e. a time reversal procedure. This disentangles the information by using perturbations that mark how far each part has scrambled and spread. In NMR, LEs and OTOCs have long been used to measure correlations among spins. However, a significant challenge arises because NMR experiments typically rely on global measurements—considering all spins together—rather than focusing on local ones, which is the approach taken in most theoretical and numerical studies. Most experimental implementations of OTOCs to probe information scrambling rely on indirect measurements based on global observables, using techniques such as Loschmidt echoes and multiple quantum coherences, via time-reversal evolutions **[1]**. In this article, we establish a direct connection between OTOCs with global and local observables in the context of NMR experiments. Our basic hint is that the global echo arises from averaging many local echoes whose strengths depend on the sudden perturbation after the scrambling dynamics. Importantly, the primary contribution to the global echo comes from local excitations returning to their original sites, while contributions from neighboring spins tend to cancel out due to the intricate interferences developed during evolution.

Our numerical analysis quantifies the differences in the evolution of both magnitudes, evaluating the excitation dynamics in spin ring systems with 8 to 16 spins, using a many-body Hamiltonian and long-range interactions. Our analysis decomposes the global echo into a sum of local echoes and cross-contributions, leading to local and global OTOCs **[2]**. After an initial transient period, local OTOCs determine the global ones as the difference between the average of local OTOCs and the global one, as well as their fluctuations, becomes negligible as the system size increases. This demonstrates that in large and complex systems, after a transient initial evolution, results obtained from global measurements are equivalent to those from local measurements. This insight strengthens and validates the interpretation of recent NMR experiments on fundamental issues such as localization of excitation from multispin interactions and the emergence of intrinsic irreversibility in large quantum systems. Since we incorporate a new detection procedure that involves Dynamical Decoupling, we are able to confirm that in Adamantane crystal under Double Quantum Hamiltonian, the scrambling is ballistic, i.e. that the wave-front grows linearly with time.

[1] T. Zhou and B. Swingle, Nat. Commun. **14**, 3411 (2023).
https://www.nature.com/articles/s41467-023-39065-5
[2] F.S.Lozano-Negro, C.M.Sánchez, A.K.Chattah, G.A.Alvarez and H.M.Pastawski, Phys.Rev. A **110**, 042410 (2024)
https://journals.aps.org/pra/abstract/10.1103/PhysRevA.110.042410

Tracking angular momentum flow during the laser-induced ultrafast demagnetization of ferromagnetic transition metals

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The dynamics of the electronic and lattice degrees of freedom, triggered in femtosecond-laser excitation of ferromagnetic (FM) transition metals, is investigated using a many-body model of itinerant magnetism that accounts for electron delocalization, local Coulomb interactions, and spin-orbit (SO) coupling on an equal footing. An exact numerical solution of the electronic time evolution reveals that the experimentally observed ultrafast demagnetization unfolds through three concatenated microscopic processes:
1. Initial electron-hole pair creation: The pumping laser pulse generates electron-hole pairs, enabling effective intra-atomic spin-orbit (SO) transitions.
2. Spin-orbit driven angular momentum transfer: Local angular momentum is transferred from the spin degrees of freedom $\vec{s}_i$ to the orbital electronic degrees of freedom $\vec{l}_i$. This occurs on a characteristic timescale of $\hbar/\xi \simeq 10$ fs, where ξ is the SO coupling strength, and leads to a breakdown of the FM spin correlations $\langle \vec{s}_i \cdot \vec{s}_j \rangle$ among highly stable local magnetic moments $\langle s_i^2 \rangle$.
3. Quenching of orbital angular momentum: A rapid quenching of the electronic orbital angular momentum takes place at the same time as it is transferred from the increasingly disordered spin degrees of freedom. This process takes place on the much shorter timescale of interatomic electronic hoppings t_{ij}, on the order of $\hbar/t_{ij} \simeq 1$ fs. As orbital moment quenching results from electron-lattice interactions, it leads to an increase in lattice angular momentum, ensuring total angular momentum conservation.
The role of electron correlations in the dynamics is discussed, particularly in relation to the nature of the demagnetized electronic state. The consequences of the angular momentum transfer —from spin, through orbital, to lattice degrees of freedom— are analyzed by computing the mechanical strain torques and the asymmetries in the Franck-Condon factors arising from angular momentum absorption by the lattice. The results are compared to recent experimental observations.

Probing Quantum Phases of Matter on Quantum Processors

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Quantum fluctuations and interactions give rise to exotic phases of matter with remarkable properties, pushing the boundaries of our understanding of many-body quantum systems. Solving these problems is notoriously difficult on classical computers due to the exponential complexity of quantum many-body physics. Quantum processors, on the other hand, provide a powerful new way to explore these systems, offering a more direct and potentially groundbreaking approach. In this talk, we will first discuss how to prepare the ground state of the toric code Hamiltonian using an efficient quantum circuit on a superconducting quantum processor [1]. The measures topological entanglement entropy is near the expected value of $\log 2$, and we simulate anyon interferometry to extract the braiding statistics of the emergent excitations. We will then investigate a class of novel, highly entangled quantum phases that exist only in non-equilibrium settings and demonstrate how to probe their stability using a quantum processor [2].

[1] Satzinger, Liu, Smith, et al., Knap, FP, Roushan, Science 374, 1237 (2021)
[2] Will, Cochran, Rosenberg, Jobst, Eassa, Smith, Roushan, Knap, FP,
arXiv:2501.18461 (2025)

Landau Zener Stückelberg Interferometry as a tool to control superconducting qubits

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Superconducting circuits (SC) based on Josephson junctions are promising candidates as qubits for implementation of quantum technologies, due to their microfabrication techniques, downscalability and continuous improvements in performances such as coherence times and gate fidelities.
Most protocols implemented so far for controlling and manipulating SC qubits rely on small-amplitude and/or resonant Rabi-based driving schemes. However, the Landau-Zener-Stückelberg (LZS) protocol which consists of driving the qubit with a large amplitude non-resonant periodic signal, has been recently established as a versatile tool to manipulate SC driven by harmonic signals.

In this talk, I will present some examples of LZS protocols in SC qubits, with particular emphasis on the analysis of the fluxonium spectrum and its non-trivial resonance patterns.
The implementation of LZS interferometry for entanglement protocols, fast single and two-qubits gates will also be discussed.

Correlations and geometric frustration - a happy marriage?

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The phase diagrams of quasi two-dimensional organic superconductors display a plethora of fundamental phenomena associated with strong electron correlations, such as unconventional superconductivity, metal-insulator transitions, frustrated magnetism and spin liquid behavior.

We analyze a minimal model for these compounds, the Hubbard model on an anisotropic triangular lattice, using cutting-edge quantum embedding methods respecting the lattice symmetry. We demonstrate the existence of unconventional superconductivity by directly entering the symmetry-broken phase. We show that the crossover from the Fermi liquid metal to the Mott insulator is associated with the formation of a pseudogap. The predicted momentum-selective destruction of the Fermi surface into hot and cold regions provides motivation for further spectroscopic studies. Our theoretical results agree with experimental phase diagrams of κ-BEDT organics.

H. Menke, M. Klett, K. Kanoda, A. Georges, M. Ferrero, and T. Schäfer, Phys. Rev. Lett. **133**, 136501 (2024)

Adatom-engineered and fractionalized altermagnetism

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Abstract:
Altermagnetism refers to a class of magnets that, as opposed to ferromagnets, have a vanishing total magnetic moment. The symmetry behind this cancellation is not translational symmetry, like in antiferromagnets, but is based on point symmetries instead. Originally driven by their direct relevance to spintronics, altermagnets have attracted enormous attention in recent years, way past the spintronic community. After a short introduction to the field, I will first discuss how deliberate placement of non-magnetic adatoms on surfaces of unconventional superconductors can be used to stabilize superlattice pairing states with altermagnetic symmetries in the orbital channel [1]. These "orbital altermagnetic superconductors" are characterized by current loop patterns, staggered magnetic moments, and Berry curvature quadrupole moments. Adding spin-orbit coupling induces an altermagnetic texture in the intra-unit-cell spins. In the second part, we will analyze what happens when frustration-driven quantum fluctuations become significant in altermagnets and study proximate spin-liquid phases [2]. In some of these spin liquids there are remnants of the altermagnet in the sense that, while spin-rotation invariance is restored, symmetries are broken in the orbital channel. This includes what we dub "altermagnetic spin liquid" – similar to the abovementioned altermagnetic superconductor, it features altermagnetic orbital currents. We finally discuss the electronic spectral function in such a fractionalized system which exhibits "fractionalized spin orbit coupling", i.e., the spectral function is reminiscent of that with spin-orbit coupling although spin-rotation invariance is preserved. As such, individual peaks at fixed momentum are associated with half an electron (per spin).

[1] Pupim & Scheurer, arXiv:2411.02489
[2] Sobral, Mandal, & Scheurer, arXiv:2410.10949

Inductance measurements as a versatile probe of spin-orbit effects in hybrid 2D-superconductors

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Rashba-superconductors are expected to feature prominent spin-orbit effects when exposed to a parallel magnetic field [1]. At the Ginzburg-Landau level, spin-orbit interaction is incorporated by so far elusive Lifshitz-invariant terms in the free energy. We investigate epitaxial Al/InAs heterostructures as *synthetic* Rashba superconductors.
When exposed to a small perpendicular magnetic field, thin superconducting films feature a large inductance which originates from oscillations of pinned vortices around their pinning centers. The vortex inductance is inversely proportional to the curvature of pinning potential.

Unexpectedly, the pinning potential strongly *increases* when a parallel field is applied in addition. When the field is rotated within the sample plane, the vortex inductance turns out to be anisotropic and provides a tomography of the order parameter profile in the vortex cores. This result can be understood as a manifestation of Lifshitz invariants in our non-centrosymmetric heterostructure [2]. We observe similar effects in several different material systems such as thin Al films on $SrTiO_3$ and single crystalline $CoSi_2$.

[1] M. Smidman et al., Rep. Prog. Phys. **80**, 036501 (2017).
[2] L. Fuchs *et al.*, Phys. Rev. X **12**, 041020 (2022).

Hybrid Quantum Circuits based on two-dimensional Al/InAs heterostructures

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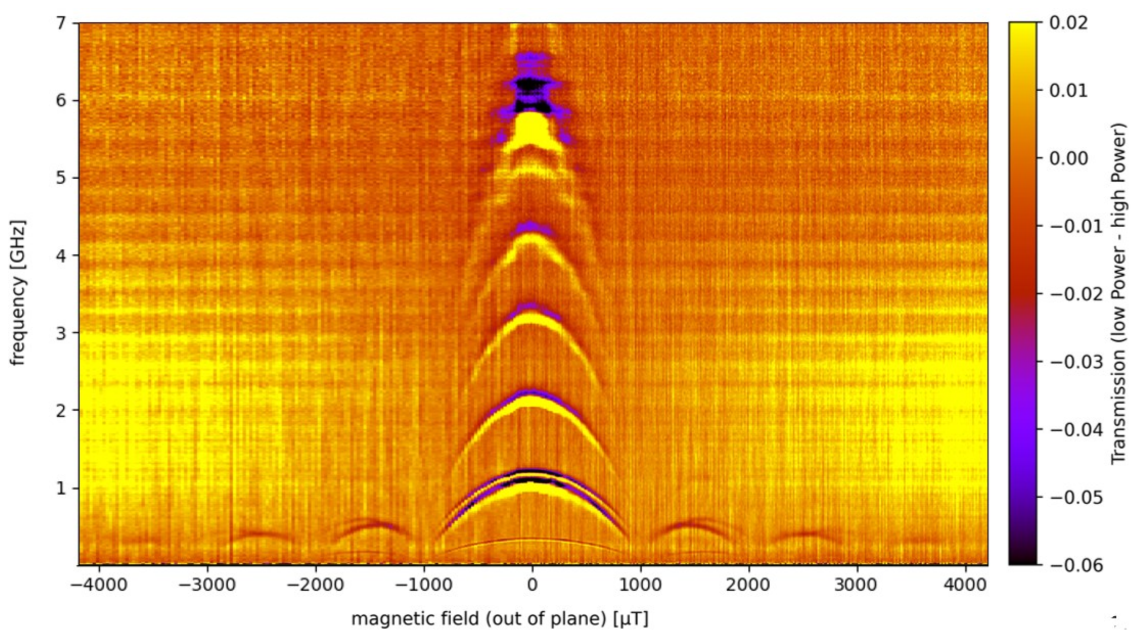
We present three different experiments with devices fabricated out of two-dimensional epitaxial Al/InAs heterostructures which combine strong spin-orbit coupling and induced superconductivity. i) We have fabricated lumped element resonators which are very sensitive to an in-plane magnetic field and present anisotropic features in their supercurrent response consistent with the effect of spin-orbit interaction in the presence of disorder and the emergence of Bogoliubov Fermi surfaces. ii) We have also fabricated and characterized gate and magnetic-field tunable resonators with planar Josephson junctions, which will be employed to realize parametric amplification. iii) We have performed the microwave characterization of planar 1D Josephson junction arrays, where we probe the lowest energy plasmonic modes. We show the effect of in-plane and out-of-plane magnetic field in the spectrum and discuss the role of junctions' transparency.



The Streda Formula for Floquet Systems: Topological Invariants and Quantized Anomalies from Cesaro Summation

Gonzalo Usaj

In this talk I will introduce a general theoretical framework [1] which expresses the topological invariants of two-dimensional Floquet systems in terms of tractable response functions: building on the Sambe representation of periodically-driven systems, and inspired by the Středa formula for static systems, we evaluate the flow of the unbounded Floquet density of states in response to a magnetic perturbation. This Floquet-Středa response, which is a priori mathematically ill-defined, is regularized by means of a Cesàro summation method. As a key outcome of this approach, we relate all relevant Floquet winding numbers to simple band properties of the Floquet-Bloch Hamiltonian. These general relations indicate how the topological characterization of Floquet systems can be entirely deduced from the stroboscopic time-evolution of the driven system. Importantly, we identify two physically distinguishable contributions to the Floquet-Středa response: a quantized flow of charge between the edge and the bulk of the system, and an 'anomalous' quantized flow of energy between the system and the driving field, which provides new insight on the physical origin of the anomalous edge states. As byproducts, our theory provides: a general relation between Floquet winding numbers and the orbital magnetization of Floquet-Bloch bands; a local marker for Floquet winding numbers, which allows to access Floquet topology in inhomogeneous samples; an experimental protocol to extract these Floquet winding numbers from density-measurements in the presence of an engineered bath; as well as general expressions for these topological invariants in terms of the magnetic response of the Floquet density of states, opening a route for the topological characterization of interacting Floquet systems.

[1] L. Peralta Gavensky, G. Usaj and N. Goldman,
https://doi.org/10.48550/arXiv.2408.13576

Designing flat bands, localized and itinerant states in van der Waals platforms

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Stacking, twisting and straining van der Waals materials provide a powerful tool to design quantum matter and engineer electron correlated phases. Some prominent examples are twisted bilayer graphene, heterostructures of graphene with Kitaev-like magnets or multilayered Mott insulating and metallic transition metal dichalcogenides. In this talk I will discuss the microscopic modelling of some exemplary heterostructures by a combination of first principles methods and many-body techniques and will compare with experimental results.

Random fields in the Floquet quantum Ising model and level statistics

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Motivated by an experiment on a superconducting quantum processor [1], we study level pairings in the many-body spectrum of the random-field Floquet quantum Ising model [2]. The pairings derive from Majorana zero and π modes when writing the spin model in Jordan-Wigner fermions. Both splittings have log-normal distributions with random transverse fields. In contrast, random longitudinal fields affect the zero and π splittings in drastically different ways. While zero pairings are rapidly lifted, the π pairings are remarkably robust, or even strengthened, up to vastly larger disorder strengths. We explain our results within a self-consistent Floquet perturbation theory and study implications for boundary spin correlations. The robustness of π pairings against longitudinal disorder may be useful for quantum information processing. Time permitting, the talk may also address further extensions to quasiperiodic driving [3] and Floquet time crystals [4].

References

[1] X. Mi et al., Science **378**, 785 (2022)
[2] H. Schmid, A.-G. Penner, K. Yang, L.I. Glazman, F. von Oppen, Phys. Rev. Lett. **132**, 210401 (2024)
[3] H. Schmid, Y. Peng, G. Refael, F. von Oppen, arXiv:2410.18219 (2024)
[4] A.-G. Penner, H. Schmid, L.I. Glazman, F. von Oppen, arXiv:2501.18760 (2025)

Abstracts of Posters

(in alphabetical order)

Negative *c*-axis longitudinal magnetoresistance in FeSe

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Below the structural transition occurring at T_s=90K, FeSe exhibits positive transverse magnetoresistance when the current is applied parallel to the *ab*-plane. In this study, we show that, in contrast, when both the magnetic field and the current are aligned along the *c*-axis, the magnetotransport changes significantly. In this configuration, FeSe develops a sizable negative longitudinal magnetoresistance (~15% at T=10K and $\mu_0 H$=16T) in the nematic phase. We attribute this finding to the effect of the applied magnetic field on the scattering from spin fluctuations. Our observations reflect the intricate interplay between spin and orbital degrees of freedom in the nematic phase of FeSe.

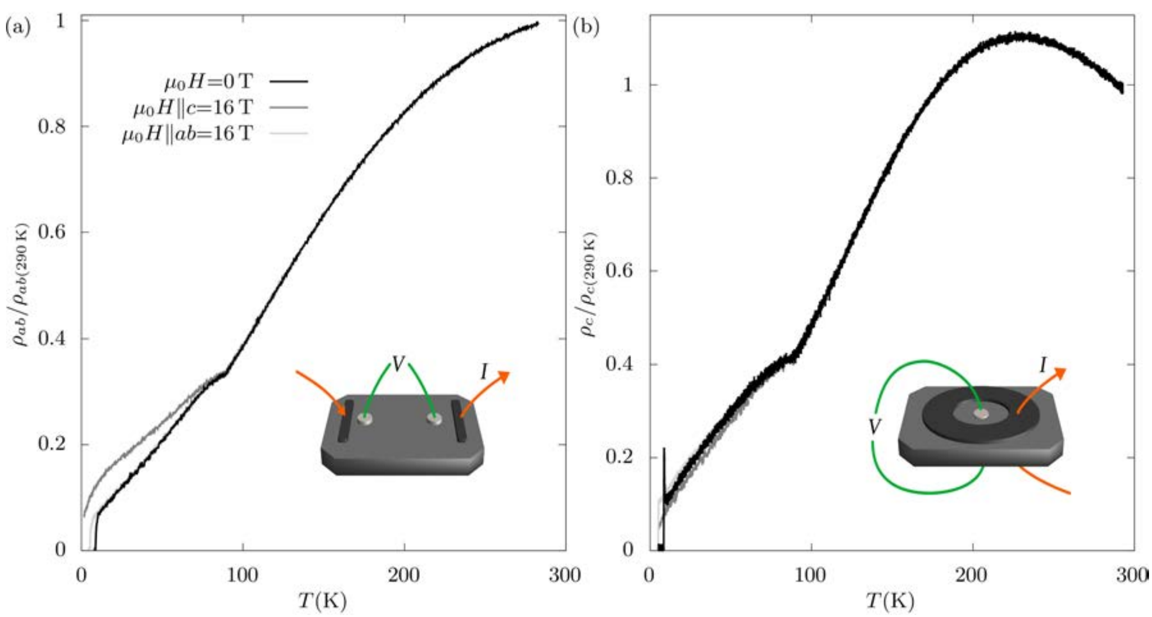

FIG. 1: Temperature dependence of the normalized resistivity with the current applied (a) in the *ab*-plane and (b) along the *c*-axis for $\mu_0 H$=0T and 16T, parallel or perpendicular to the *ab*-plane. A sketch of the contacts configuration is presented as an inset in each figure.

Towards electrical domain-wall control in polyacetylene-based electronic nano-devices

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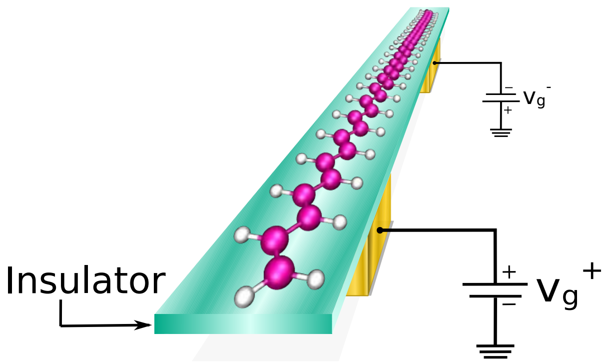
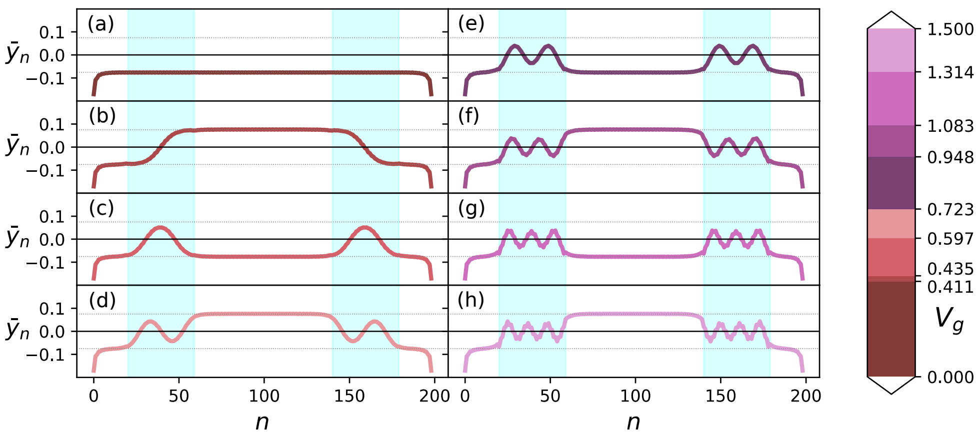
We theoretically propose a polymer-based nano-device consisting of a single transpolyacetylene (tPA) molecule capacitively coupled to external gate voltages. We model the integrated device using a Su-Schrieffer-Heeger (SSH)-like Hamiltonian, and solve the self-consistent problem of coupled electronic and lattice degrees of freedom in the presence of the gate voltages. Interestingly, we demonstrate the emergence of multiple topological kinks or domain walls in the lattice distortion patterns, which can be externally controlled at the region of the gates. The local symmetry-breaking induced by the gates gives access to the different topological sectors of the SSH model characterized by a Z topological invariant, and allows the emergence of quantized charges at the gates, associated to the topological kinks solutions. Given their topological origin, these solutions are remarkably stable as functions of the external gate voltage, except at specific values where topological transitions between different multi-kink solutions occur, and where the electronic subgap spectrum of the device is completely reconstructed in order to accomodate the extra charge. In practice, the device can be considered as a polymer-based organic quantum dot where charge quantization is inherently topological and robust, a fact that may be useful for potential technological applications.





Advancing Topological Electronics with dual-gated Quantum Spin Hall Devices based on III-V Semiconductors

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Over 40 years ago, the discovery of the Quantum Hall Effect marked a breakthrough as the first experimental realization of a topologically non-trivial state in two dimensions (2D). In 2005, the Quantum Spin Hall Effect (QSHE) was proposed in graphene [1] and later demonstrated in 2007 in HgTe quantum wells (QWs) [2,3]. With spin-polarized, dissipationless edge states, QSHE materials hold promise for low-power electronics and quantum information science. Among proposed QSHE platforms [4,5], InAs/GaSb bilayer quantum wells (BQWs) stand out due to their tunable topological phase transitions via electric fields or illumination [6,7]. However, their small inverted bandgap limits performance. Strained InAs/GaInSb BQWs [8,9] and trilayer quantum wells (TQWs) achieve larger bandgaps up to 60 meV [10], with recent results showing conductance quantization up to T = 60 K. While TQWs offer a larger bandgap, temperature-independent band ordering, and tunability, challenges include developing reliable gate dielectrics to prevent leakage and designing a functional back gate for dual-gated operation at elevated temperatures. Here, we present a well-controlled fabrication process for topological insulators (TIs) based on InAs/GaInSb QW heterostructures, enabling dual-gated topological electronic devices. The top gate incorporates a high-k HfO_2 dielectric deposited via plasma-enhanced atomic layer deposition (PE-ALD), providing high insulation and reducing the required gate voltage for Fermi level tuning. Additionally, an AlAs/AlSb superlattice (SL) is implemented to insulate the back gate and prevent leakage currents through the substrate. Hence, this work establishes a reliable fabrication strategy for integrating III-V semiconductors into dual-gated topological electronic devices, paving the way for scalable and tunable topological field-effect transistors operating at elevated temperatures.

References:

[1] C. Kane, E. Mele, Phys. Rev. Lett. 95, 226801 (2005) [2] B. Bernevig, et al., Science 314, 1757–1761 (2006) [3] M. König et al., Science 318, 766–771 (2007) [4] S. Wu et al., Science 359,76–79 (2018) [5] L. Du et al., Phys. Rev. Lett. 114, 096802 (2015). [6] F. Qu et al., Phys. Rev. Lett. 115, 036803 (2015). [7] M. Meyer et al., Phys. Rev. B 109, L121303 (2024). [8] M. Meyer et al., Phys. Rev. B 104, 085301 (2021). [9] H. Irie et al., Phys. Rev. Mater. 4, 104201 (2020). [10] S. Krishtopenko, F. Teppe., Sci. Adv. eaap7529, (2018).

Topological Fermi Arcs and Surface Superconductivity in t-$PtBi_2$

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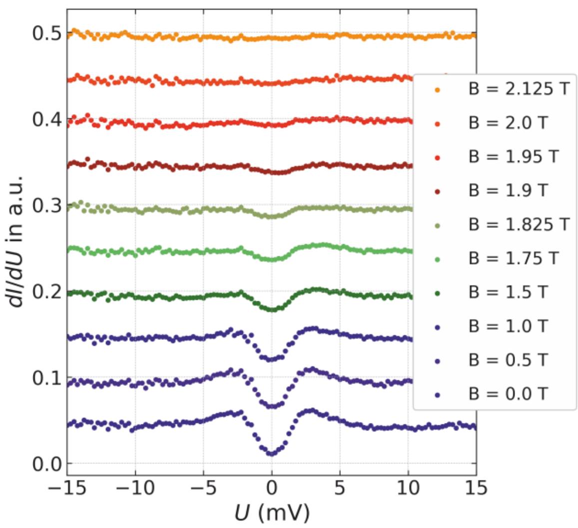
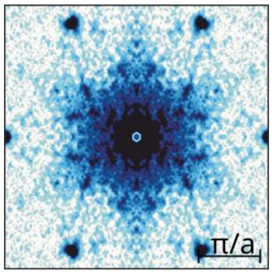
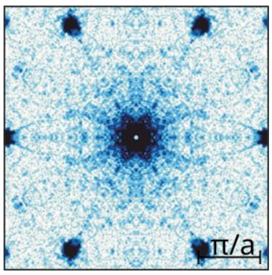
Trigonal PtBi2 is a topological Weyl semimetal, as evidenced by band structure and quasiparticle interference (QPI) investigations [1]. It also exhibits unconventional surface superconductivity [2, 3], with ARPES revealing a superconducting energy gap only on the Fermi arc states [3]. Low-temperature scanning tunneling microscopy and spectroscopy (STM/STS) reveals locally varying sample-dependent superconductivity evidenced by the energy gap. In some cases the scale of the gap suggests BCS critical temperatures as high as 70-130 K. We study the temperature and magnetic field dependence of the energy gap, demonstrating its persistence up to 45 K. Furthermore, QPI measurements in the superconducting state indicate an interplay between topological Fermi arcs and superconductivity.





$B = 0$ T $< B_c$



$B = 2.5$ T $> B_c$

References

[1] S. Hoffmann et. al.; Adv. Phys. Res. **2400150** (2024).
[2] S. Schimmel et. al.; nature communications **15**, 9895 (2024).
[3] A. Kuibarov et. al.; nature **626**, 294-299 (2024).

Local thermometry for non-equilibrium vibrational states of an ion chain

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The accurate simulation of vibrational energy transport and quantum thermodynamics with trapped ions requires good methods for the estimation of temperatures. One valuable tool with this purpose is based on the fit of dark resonances in the fluorescence spectrum; however, the reliability of this technique remains uncertain. In this work, we evaluate several simplified dynamical equations for simulating the spectrum of a trapped ion undergoing thermal motion, highlighting the strengths and limitations of each method. Additionally, we analyze the applicability of this approach to measure local temperatures in a chain of trapped ions. Our study includes a detailed experimental proposal for measuring non-equilibrium profiles of the effective temperatures in this system, supported by numerical simulations of the dynamics and the measurement process.

Two interacting qubits as a thermal machine

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In the last decade, advances in quantum sciences and technologies have motivated the study of energy manipulation and conversion in quantum devices [1,2]. This and other related phenomena form the field of study known as *quantum thermodynamics*. Experimentally, one research direction focuses on the study of the energy dynamics of superconducting qubits in quantum circuits [3]. These systems operate at very low temperatures, ensuring the coherence conditions necessary to observe quantum effects such as interference and entanglement.

We have studied the operation of a qubit as a thermal machine functioning between two reservoirs at the same temperature, performing a cycle driven by an external mechanism. The calculation of the associated transport coefficients is carried out using master equations [4,5,6], specifically employing the Lindblad equation. We have verified that it is possible to achieve net heat pumping by appropriately selecting the contacts, and we have identified the protocol that achieves the Landauer limit k_B T log(2).

Currently, we are investigating an analogous system in which the thermal machine consists of two interacting qubits. We have already verified the Landauer limit in the case without interaction. Our primary interest now is to understand how the interaction affects dissipation, with the goal of maximizing the figure of merit defined by the ratio of pumping to dissipation.

References

[1] Vinjanampathy S and Anders J (2016), *Contemporary Physics* 57, 545.
[2] Goold J et al. (2016) *J. Phys. A: Math. Theor.* 49, 143001.
[3] Pekola JP and Karimi B (2021) *Rev. Mod. Phys.* 93, 041001.
[4] Bhandari B, Alonso PT, Taddei F, von Oppen F, Fazio R, and Arrachea L (2020) *Phys. Rev. B* 102, 155407.
[5] Alonso PT, Abiuso P, Perarnau-Llobet M, and Arrachea L (2022) *PRX Quantum* 3, 010326.
[6] Arrachea L (2023) *Rep. Prog. Phys.* 86, 036501.

Quantum oscillations evidence of sixfold fermions in the cubic Dirac semimetal β-$PtBi_2$

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February 21, 2025

Abstract

The exploration of materials exhibiting multiple band crossings near the Fermi energy is a very active area of research. Here we report an experimental study of de Haas-van Alphen oscillations in high-quality single crystals of cubic β-$PtBi_2$. Combined with density functional theoretical calculations, we identify quantum oscillations from all the calculated Fermi surfaces in the system. Our results reveal three small double-degenerate electron pockets centered at a sixfold band touching point which occurs $\sim 25\,\mathrm{meV}$ below the Fermi level at the R point of the Brillouin zone. Our work is in line with recent ARPES results and firmly establish the existence of sixfold fermions in close proximity to the Fermi energy of β-$PtBi_2$.

Second-order adiabatic expansion in quantum transport: corrections to the isolated mass due to electron forces

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Due to their quantum behavior, nanoelectromechanical devices have attracted the attention of researchers from different fields. Quantum transport theory, through the non-equilibrium Green's functions approach (NEGF), can explain the origin of the forces responsible for the dynamics of this type of device. For nanometric-sized systems, the flow of electric charges is the main cause of these forces. In this context, it is convenient to introduce two-time scales with different dynamic regimes. The first of the scales is associated with a fast time, which characterizes the electronic dynamics; while the second describes classical variables, whose movement is considerably slower. This timescale separation results useful in the theoretical study of these devices since it allows us to perform an adiabatic expansion of the current-induced forces (CIFs). The first term of the expansion consists of the adiabatic force, while the second contains the electronic friction [1]. However, higher-order terms have not yet been sufficiently explored [2]. In our work, we investigate the next term of the expansion, which involves a correction to the isolated mass due to electronic effects. To understand the role of these terms, we use the NEGF formalism to study the forces and dynamics of an atomic mass (which can be carbon or hydrogen) connected to an electron reservoir [3]. We used a minimal model given by the standard Goodwin, Skinner and Pettifor representation [4], which comprises a tight-binding chain.

References

[1] N. Bode, S. V. Kusminskiy, R. Egger, and F. von Oppen, Beilstein Journal of Nanotechnology 3, 144 (2012).
[2] S. E. Deghi and R. A. Bustos-Marún, Phys. Rev. B 110, 115409 (2024).
[3] S. E. Deghi, L. J. Fernández-Alcázar, H. M. Pastawski, and R. A. Bustos-Marún, Journal of Physics: Condensed Matter 33, 175303 (2021).
[4] C. H. Xu, C. Z. Wang, C. T. Chan, and K. M. Ho, Journal of Physics: Condensed Matter 4, 6047 (1992).

Superconducting circuit architecture supporting multi-mode qubits

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Superconducting circuits offer great opportunities for quantum information processing and simulation with high fidelity. Even though partial noise protection is possible in superconducting circuits with a single quantum degree of freedom, by extending the Hilbert space to higher dimensions, degenerate ground states can be realized in which the wave functions of two different eigenstates have disjoint support exhibiting intrinsic protection against decoherence [1].

We study a high kinetic inductance Josephson junction array [2] in a ring configuration with 4 loops supporting long-lived fluxon excitations. The low-energy spectrum of this system is mapped to a tight-binding model with fluxons tunnelling between neighbouring sites in the limit of dominating Josephson energies. The theoretical analysis in both the hard and soft parameter regimes will help guide the experimental realisation to develop a mutli-mode, noise-resilient qubit.

References :

[1] A. Gyenis. A. Di Paolo, J. Koch, A. Blais, A. A. Houck, D. I. Schuster. "Moving beyond the Transmon: Noise-Protected Superconducting Quantum Circuits". PRX Quantum 2, 030101

[2] A. Petrescu, H. E. Türecei, A. V. Ustinov, I. M. Pop. "Fluxon-based quantum simulation in circuit QED". Phys. Rev. B 98, 174505

Title: Higher Berry Curvature from Matrix Product States

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The higher Berry curvature is the generalization of Berry curvature to infinite systems. We show that a family of translationally invariant matrix product states over some discretized parameter space can be used to compute the Higher Berry Curvature and its topological invariants. These invariants are "strong", i.e. they do not require the presence of any symmetry and unlike the many-body generalizations of conventional invariants, they are inherently interacting. We demonstrate our algorithm for interacting bosonic and fermionic systems. Further, we make use of the Kunneth formula to compute even higher invariants like second Chern numbers in one-dimensional fermionic chains.

References:
K. Shiozaki, N. Heinsdorf, S. Ohyama, Higher Berry curvature from matrix product states, arXiv:2305:08109

Nagaoka Ferromagnetism in finite-size arrays: Shaped by Connectivity, Disrupted by Fields.

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The advancement of quantum dot platforms for quantum simulators has recently allowed the first observation of Nagaoka Ferromagnetism (NFM) in a 2x2 array of quantum dots after Nagaoka's prediction in 1966. However, the finite-size cluster characteristics that maximize the spin in the ground state when there is one hole away from half-filling, as well as the robustness of NFM under external magnetic field perturbations, remain to be studied. Employing exact diagonalization of the Hubbard Hamiltonian, we study the inter-dot connectivity conditions and external perturbations affecting NFM in finite-size arrays. We find that NFM appears if the array is 1) biconnected (i.e., the array remains connected after removing one site), and 2) formed by elementary loops of four sites. We focus on the role of external magnetic fields in affecting NFM in square arrays. Applying a perpendicular magnetic field that induces a Peierls phase, we find a critical phase at which NFM can be destroyed even in the limit of infinite interactions, since the phase decreases linearly with the ratio of hopping t to the onsite repulsion U for 2x2 and larger NxN arrays. Additionally, when Peierls and Zeeman effects are combined, NFM is destroyed immediately, although a trivial ferromagnetic phase is recovered after one Peierls phase cycle. Our results illustrate how NFM depends on the array's connectivity and leads to the counterintuitive conclusion that ferromagnetism can be destroyed by applying a magnetic field.

Nonlocal thermoelectricity in quantum wires as a signature of Bogoliubov-Fermi points

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We study nonlocal thermoelectricity in a superconducting wire subject to spin-orbit coupling and a magnetic field with a relative orientation θ between them. We calculate the current flowing in a normal probe attached to the bulk of a superconducting wire, as a result of a temperature difference applied at the ends of the wire. We focus on the linear response regime, corresponding to a small temperature bias. We find that the nonlocal thermoelectric response is strongly dependent on the angle θ and occurs in ranges which correspond to the emergence of Bogoliubov Fermi points in the energy spectrum of the superconducting wire [1].

[1] Nonlocal thermoelectricity in quantum wires as a signature of Bogoliubov-Fermi points, Juan Herrera Mateos, Leandro Tosi, Alessandro Braggio, Fabio Taddei, and Liliana Arrachea, Phys. Rev. B 110, 075415 (2024)

Elastic Quantum Criticality in Nematics and Altermagnets via the Elasto-Caloric Effect

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(Dated: February 18, 2025)

The coupling between electronic nematic degrees of freedom and acoustic phonons is known to significantly alter the universality class of a nematic quantum critical point (QCP). While non-Fermi-liquid behavior emerges in the absence of lattice coupling, the inclusion of interactions with acoustic phonons results in observables such as heat capacity and single-particle scattering rate exhibiting only subleading non-analytic corrections to dominant Fermi-liquid terms. In this work, we demonstrate that the elastocaloric effect (ECE) - the adiabatic temperature change under varying strain - and the thermal expansion deviate from this pattern. Despite lattice coupling weakening the singularity of the ECE, it preserves a dominant non-Fermi-liquid temperature dependence. By drawing analogies between nematic systems and field-tuned altermagnets, we further show that similar responses are expected for the ECE near altermagnetic QCPs. We classify the types of piezomagnetic couplings and analyse the regimes arising from field-tuned magnetoelastic interactions. Our findings are shown to be consistent with the scaling theory for elastic quantum criticality and further emphasize the suitability of the ECE as a sensitive probe near QCPs.

Weakly coupled triangles in a $S = \frac{1}{2}$ star lattice of an organic-inorganic cuprate

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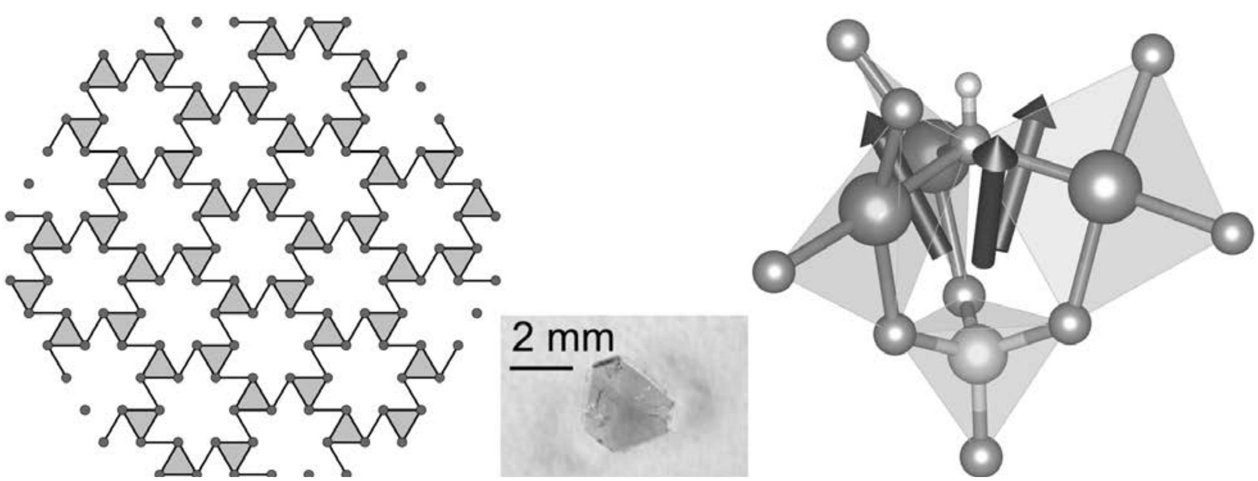
The organic-inorganic copper sulfate $[(CH_3)_2(NH_2)]_3[Cu_3(OH)(SO_4)_4]\cdot 0.24H_2O$ has been proposed as a material realization of the $S = \frac{1}{2}$ star lattice model [1]. High-field magnetization measured on powder samples shows a broad $\frac{1}{3}$-plateau; full saturation is reached at about 105 T in a destructive pulsed-field experiment. Low-field and low-temperature measurements on single crystals show no indications of magnetic ordering and reveal a drastically anisotropic magnetization [2]. Density-functional-theory (DFT) calculations indicate the relevance of two inequivalent exchanges J_{T} and J_{D} with $J_{\mathrm{T}} \gg J_{\mathrm{D}}$, placing this material in the limit of weakly coupled triangles. Anisotropic components of J_{T}, in particular the Dzyaloshinskii-Moriya (DM) coupling, were estimated by noncollinear DFT+U calculations. Surprisingly, a simple model of isolated triangles with DM anisotropy accounts for the thermodynamic behavior of this compound [2]. Long-range magnetic ordering can be addressed by including the weak coupling between spin triangles on the level of an effective model – the $S = \frac{1}{2}$ XXZ model on a honeycomb lattice [3].



References

[1] M. Sorolla *et al.*, J. Am. Chem. Soc. **142**, 5013 (2020).
[2] H. Ishikawa *et al.*, Phys. Rev. B **109**, L180401 (2024).
[3] M. Georgiou *et al.*, in preparation.

Hysteresis and effective reciprocity breaking due to current-induced forces

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Directed transport plays a crucial role in various applications such as nanoscale heat management, current rectification, source protection, and energy harvesting. In quantum transport, we explore the use of nonlinear effects from current-induced forces (CIFs) to break charge and heat transport reciprocities. Specifically, we study a model with a mobile quantum dot (QD) coupled to two leads, where the charge or heat current shows asymmetric behavior under voltage or temperature bias inversion, thus creating a quantum diode. We also find multiple stable positions for the QD and demonstrate that useful work can be extracted by modulating nonequilibrium sources along hysteresis loops. Finally, we consider a scenario where CIF nonlinearity is used to pump heat or charge, even in systems preserving inversion symmetry. This unexpected behavior arises from a spontaneous breaking of inversion symmetry due to the system's intrinsic dynamics.

[1] E. L. Mehring, R. A. Bustos-Marún, and H. L. Calvo, Phys. Rev. B 109, 085418 (2024).

Near 2D limit in FeSe by single crystal exfoliation

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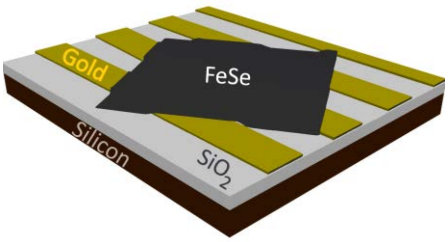
The FeSe superconductor exhibits one of the simplest crystal structures among the Fe based superconductors, consisting of layers bonded by Van der Waals forces. This layer structure makes it feasible to approach the two-dimensional (2D) limit through exfoliation, similar to the methodology applied for graphene. However, FeSe crystals are inherently unstable in ambient conditions, resulting in inconsistent findings reported in the literature [1,2]. To mitigate this instability, significant efforts have been made to grow FeSe films in ultra-high vacuum, achieving a critical temperature (Tc) of approximately 100 K in monolayers grown on $SrTiO_3$ substrates [2]. These findings suggest that the observed physical properties arise from lattice parameter mismatches and interfacial effects, to which FeSe is particularly sensitive.

In our laboratory, we have systematically investigated the stability of FeSe single crystals under ambient conditions [3]. Building upon this understanding, we are currently producing thin flakes of FeSe through mechanical exfoliation. Our work includes Raman spectroscopy, electrical resistance analysis, and optical contrast measurements and calculations. We will present a selection of these results to contribute to the broader understanding of the material's behavior in reduced dimensions.



References

[1] R. Yang, at al., IEEE Transactions on Nanotechnology 18, 37-41 (2018).

[2] D. Huang, and J.E. Hoffman, Annual Review of Condensed Matter Physics 8(1), 311-336 (2017).

[3] L. Lanoël, Doctoral dissertation at Instituto Balseiro - Universidad Nacional de Cuyo (2023), Title: *"Origen, propiedades y efectos del avejentamiento en la superficie de monocristales del superconductor β-FeSe (Doctoral dissertation, Universidad Nacional de Cuyo)"*.

Genuine topological Anderson insulator from impurity induced chirality reversal

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We investigate a model of Dirac fermions with topological mass impurities which open a global topological gap even in the dilute limit. Surprisingly, we find that the chirality of this mass term, i.e., the sign of the Chern number, can be reversed by tuning the magnitude of the single-impurity scattering. Consequently, the disorder induces a phase disconnected from the clean topological phase, i.e., a genuine topological Anderson insulator. In seeming contradiction to the expectation that mass disorder is an irrelevant perturbation to the Dirac semimetal, the tri-critical point separating these two Chern insulating phases and a thermal metal phase is located at zero impurity density and connected to the appearance of a zero energy bound state in the continuum corresponding to a divergent topological mass impurity. Our conclusions based on the T-matrix expansion are substantiated by large scale Chebyshev-Polynomial-Green-Function numerics. We discuss possible experimental platforms.

Non-trivial entanglement structure across a local topological quantum phase transition

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A quantum phase transition between two topological distinct local Fermi liquids takes places in the two-channel spin-1 Kondo impurity model as a function of the single-ion anisotropy. In this work, we numerically study the entanglement properties of the systems across this quantum phase transition. We find that the non-Landau Fermi liquid, present for higher anisotropies, displays a non-trivial entanglement structure: while the impurity is distangled from the rest of the system due to the Kondo effect destruction by the anisotropy, the two conductions channels, that are coupled only through the impurity, become highly entangled between them. Our results shows that a magnetic impurity can passively mediate the entanglement between spatially separated conduction bands.

References:

[1] R. Žitko, G. G. Blesio, L. O. Manuel, and A. A. Aligia. Nature Comm. 12, 6027 (2021).

[2] A. A. Orlandini, "Kondo cloud and entanglement in multiorbital magnetic impurities", MSc Thesis, Universidad Nacional de Rosario (2022).

[3] G. G. Blesio, L. O. Manuel, P. Roura-Bas, and A. A. Aligia, Phys. Rev. B 98, 195435 (2018).

Topological transitions in quantum jump dynamics: Hidden exceptional points

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Complex spectra of dissipative quantum systems may exhibit degeneracies known as exceptional points (EPs). At these points the systems' dynamics may undergo drastic changes. Phenomena associated with EPs and their applications have been extensively studied in relation to various experimental platforms, including, i.e., the superconducting circuits. While most of the studies focus on EPs appearing due to the variation of the system's physical parameters, we focus on EPs emerging in the full counting statistics of the system. We consider a monitored three level system and find multiple EPs in the Lindbladian eigenvalues considered as functions of a counting field. These "hidden" EPs are not accessible without the insertion of the counting field into the Linbladian, i.e., if only the density matrix of the system is studied. Nevertheless, we show that the "hidden" EPs are accessible experimentally. We demonstrate that these EPs signify transitions between different topological classes which are rigorously characterized in terms of the braid theory. Furthermore, we identify dynamical observables affected by these transitions and demonstrate how experimentally measured quantum jump distributions can be used to spot transitions between different topological regimes. Additionally, we establish a duality between the conventional Lindbladian EPs (zero counting field) and some of the "hidden" ones. Our findings allow for easier experimental observations of the EP transitions, normally concealed by the Lindbladian steady state, without applying postselection schemes. These results can be directly generalized to any monitored open system as long as it is described within the Lindbladian formalism.

The Středa Formula for Floquet Systems

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The Středa formula is a fundamental thermodynamic relation linking the topological Hall conductivity of insulating states of matter to their density response under a probe magnetic field. I will present our recent generalization of the Středa formula to out-of-equilibrium Floquet systems [1], where topological properties are engineered by means of a time-periodic driving. Such phases can host "anomalous" chiral edge channels that defy the conventional topological classification of static systems. Building on elementary notions of spectral flow, which lie at the backbone of the Středa relation, we are able to derive strikingly elegant and physically insightful formulas for Floquet topological invariants, expressed entirely in terms of bulk properties of the Floquet-Bloch bands. Our formalism unveils a key mechanism operating in the anomalous regime: a magnetic-field-induced quantized transfer of energy and angular momentum between the system and the driving environment. Furthermore, our results naturally lead to the construction of real-space resolved versions of the Floquet winding numbers, which can be used to access topological properties locally in inhomogeneous or disordered samples.

References

1. **L. Peralta Gavensky**, G. Usaj and N. Goldman, The Středa Formula for Floquet Systems: Topological Invariants and Quantized Anomalies from Cesàro Summation, arXiv:2408.13576 (2024)

Measurement-induced Lévy flights of quantum information

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We explore a model of free fermions in one dimension, subject to frustrated (non-commuting) local measurements across adjacent sites, which resolves the fermions into non-orthogonal orbitals, misaligned from the underlying lattice. For maximal misalignment, superdiffusive behavior emerges from the vanishing of the measurement-induced quasiparticle decay rate at one point in the Brillouin zone, which generates fractal-scaling entanglement entropy $S \sim l^{1/3}$ for a subsystem of length l. We derive an effective non-linear sigma model with long-range couplings responsible for Lévy flights in entanglement propagation, which we confirm with large-scale numerical simulations. When the misalignment is reduced, the entanglement exhibits, with increasing l, consecutive regimes of superdiffusive, $S \sim l^{1/3}$, diffusive, $S \sim \ln(l)$, and localized, $S = \text{const}$, behavior. Our findings show how intricate fractal-scaling entanglement can be produced for local Hamiltonians and measurements

References

[1] Measurement-induced Lévy flights of quantum information, I. Poboiko et al., arXiv:2501.12903

Two-spinon bound states evolution in the magnetic spectrum of triangular antiferromagnets

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In recent years, the increasing synthesis of triangular antiferromagnets and the advancement of high-resolution inelastic neutron scattering have driven efforts to theoretically describe their dynamical spin structure factors. Materials such as Cs_2CuCl_4, $Ba_3CoSb_2O_9$, and $KYbSe_2$, which are frustrated and exhibit a two-dimensional character in their exchange interactions, show anomalies in their magnetic spectra. These anomalies include an extended magnon lifetime and a high-energy continuum of excitations, which cannot be explained by conventional spin wave theory.

In this work, we develop an SU(2) Schwinger boson theory to study the Heisenberg model on triangular lattices. The natural excitations in this framework are bosonic spinons, which pair up due to emergent gauge field fluctuations arising from Gaussian fluctuations of the effective action around the saddle point. Low-spin states result in low-energy magnon-like excitations coexisting with a high-energy continuum of quasi-free spinons. In contrast, the theory reproduces linear spin-wave magnon bands for large-spin states.

We analyze the evolution of the magnetic spectrum by tuning the spin (at zero temperature) and the temperature (for spin-½). As the temperature rises, we find that the binding between spinons weakens and disappears completely at the Néel temperature, allowing us to define the *Terminated Goldstone Regime*, where the magnetic order is weakened by thermal fluctuations, and collective excitations are well-defined only within a limited region around the Goldstone modes. Additionally, we decompose the excitations into their transverse and longitudinal contributions at zero temperature and examine how semiclassical magnon bands emerge while the excitation continuum vanishes as the spin value increases.

Adatom engineering magnetic order in superconductors: Applications to altermagnetic superconductivity

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Engineering heterostructures is a versatile method to obtain non-trivial phases. Here, we study theoretically how superlattices based on adatoms on surfaces of unconventional superconductors can be used to engineer novel pairing states that break time-reversal symmetry and exhibit non-trivial magnetic point symmetries. In particular, we explore a square-lattice Hubbard model with d-wave superconductivity and a subleading s-wave state as an example. An "orbital-altermagnetic superconductor" phase is stabilized through an adatom superlattice with square-lattice symmetries. In this state, we find loop current patterns and associated orbital magnetic moments, which preserve superlattice translations but are odd under four-fold rotations. We further characterize this state through a finite Berry curvature quadrupole moment and, upon including spin-orbit coupling, by an altermagnetic spin splitting of the bands and non-trivial spin textures in the superlattice unit cell, with zero net spin moment.

Development of photon detectors based on granular aluminum superconducting resonators

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High kinetic inductance materials are increasingly important for superconducting circuit applications, particularly in the development of super-inductors. This property is also essential for increasing the sensitivity of a KID photon detector [1]. A KID consists of a microwave resonator, made of a superconducting material, whose frequency is sensitive to changes in kinetic inductance. In particular, its operating principle allows the detection of photons with energy greater than twice the superconducting gap. In this work we present measurements of high quality factor microwave resonators fabricated with granular aluminum films with different degrees of disorder [2]. Using a theoretical framework based on Mattis-Bardeen theory, we analyzed the dependence of resonance frequency and quality factor on temperature and power, enabling us to extract the kinetic inductance fraction of the films and identify the predominant loss mechanisms. Finally, we will discuss the sensitivity of our detectors to 1550 nm single photons.

References

[1] Day PK et al, Nat. 425 (2003) 6960
[2] Grünhaupt L et al, Phys. Rev. Lett. 121 (2018) 117001

Superposition of *n* squeezed states for quantum metrology and for encoding quantum information

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We present a method to systematically characterize highly non-classical states obtained by superposing *n* states that are squeezed along different directions. These states can be useful both for metrology, as they are highly sensitive to perturbations, and for encoding quantum information in a continuous variable system. We compare the results obtained for *n*=3 and *n*=4 with those arising from recent experiments performed with cold trapped ions, where so-called trisqueezed and quadsqueezed states have been prepared.

Towards quantum many-body physics in two dimensions with highly magnetic atoms of Dysprosium

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Ultracold quantum gases achieve exquisite platforms to explore few- and many-body phenomena with extreme control. Being the most magnetic element of the periodic table, dysprosium presents strong interatomic dipolar interactions. In contrast to the standard contact interactions, the dipolar interactions are long-range and anisotropic.

The relative strength between both types of interactions can be tuned by magnetically modifying the scattering length near Feshbach resonances[1]. Within the last years, these properties led to exciting novel discoveries. Some of these arising exotic phenomena are supersolidity, topological ordering and the formation of droplets or droplet crystals[2],[3].

Our experiment aims in particular to a reduction of the dimensionality of the dysprosium quantum gas by restricting it to two dimensions. For this, an accordion lattice for tailorable quasi 2D traps and an objective setup to probe and perturb the atomic cloud with sub-micron resolution are currently being implemented.

The overall goal is to explore and understand not only which exotic phases form in quantum gases under the influence of dipolar interactions in lower dimensional space, but also: How these orders arise? What are the underlying phase transitions and how do the states evolve dynamically when crossing them? How do these states behave far from equilibrium? How do they equilibrate? And with particular interest: What is the role of the topological defects that the exotic states can host in the various aspects of these behaviours?

With my contribution “Towards quantum many-body physics in two dimensions with highly magnetic atoms of Dysprosium” I give insights into the experimental realization and a theoretical perspective on exotic phases in lower dimensional quantum gases.

References:

[1] Lauriane Chomaz et al. “Dipolar physics: A review of experiments with magnetic quantum gases.” In: Reports on Progress in Physics (2022).

[2] Alexander L Fetter and Anatoly A Svidzinsky. “Vortices in a trapped dilute Bose-Einstein condensate”. In: Journal of Physics: Condensed Matter 13.12 (2001), R135.

[3] Barbara Goss Levi. “From Superfluid to Insulator: Bose–Einstein Condensate Under goes a Quantum Phase Transition”. In: Physics Today 55.3 (2002), pp. 18–20.

Superconductivity in two-dimensional heterostructures with spin-orbit coupling

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A magnetic field parallel to the plane of a 2DEG with Rashba Spin-orbit-coupling in proximity to a superconductor may lead to a topological phase with antichiral edge states of copropagating Majorana fermions localized at the edges perpendicular to the magnetic field. We study the Josephson phase-current relation in junctions made of such topological superconductors, in order to look for signatures of this topological phase.

References

[1] Ruiz, G et. al. (2022). Josephson junctions of two-dimensional time reversal invariant superconductors: Signatures of the topological phase.Physical Review B,106(19), 195415.

[2] Ruiz, G. et.al. (2024). Binding zero modes with fluxons in Josephson junctions of time-reversal invariant topological superconductors.arXiv preprint arXiv:2403.14277

Stochastic resonant behaviours and steady state control in harmonic systems

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Brownian motion and parametric resonance are two paradigmatic phenomena particularly taking place on harmonic dynamical systems, covering a plethora of branches in science. While the former gives a pathway to include dissipation and noise (additive noise) in a system, the latter stands for a physical mechanism that supplies energy to a system by exploiting the resonant variation of the characteristic frequency. Both aspects find their syncretism in the so-called stochastic resonance, where the competition between dissipation and the strength of the fluctuations in the characteristic frequency of the system (multiplicative noise) defines whether the system undergoes exponential growth (as in parametric resonance) or stabilises in a steady state in the long-time limit[1]. Typically, the impact of this competition is neglected due to relatively high dissipation rates that overcome resonant effects. However, the development of harmonic systems with increasingly quality factors makes this competition to come into play, raising as a potential limiting factor but also as a possibility for a novel control mechanism. In this talk, I will introduce the basics of the mentioned dynamical phenomena to quantify its impact on experimental setups, such as optically levitated nanoparticle. Moreover, I will also show how these concepts enter interacting harmonic systems, giving place to enhanced resonant behaviours in the steady state. The latter can be exploited, for instance, for heat transport and thermalisation[2].

[1] B. J. West, K. Lindenberg and V. Seshadri, Physica 102A, pp. 470-488 (1980).
[2] A. E. Rubio Lopez and F. Herrera, *Stochastic resonant behaviours and steady state control in harmonic systems*, in preparation.

Electric field control of a quantum spin liquid in weak Mott insulators

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The triangular lattice Hubbard model at strong coupling, whose effective spin model contains both Heisenberg and ring exchange interactions, exhibits a rich phase diagram as the ratio of the hopping t to onsite Coulomb repulsion U is tuned [1]. This includes a chiral spin liquid (CSL) phase. Nevertheless, this exotic phase remains challenging to realize experimentally because a given material has a fixed value of t/U which is difficult to tune with external stimuli. One approach to address this problem is applying a DC electric field, which renormalizes the exchange interactions as electrons undergo virtual hopping processes; in addition to creating virtual doubly occupied sites, electrons must overcome electric potential energy differences. Performing a small t/U expansion to fourth order, we derive the ring exchange model in the presence of an electric field and find that it not only introduces spatial anisotropy but also tends to enhance the ring exchange term compared to the dominant nearest-neighbor Heisenberg interaction. Thus, increasing the electric field serves as a way to increase the importance of the ring exchange at constant t/U. Through density matrix renormalization group calculations, we compute the ground state phase diagram of the ring exchange model for two different electric field directions. In both cases, we find that the electric field shifts the phase boundary of the CSL towards a smaller ratio of t/U. Therefore, the electric field can drive a magnetically ordered state into the CSL. This explicit demonstration opens the door to tuning other quantum spin systems into spin liquid phases via the application of an electric field[2].

[1] T. Cookmeyer, J. Motruk and J.E. Moore, Phys. Rev. Lett. 127, 087201 (2021).
[2] D.J. Schultz, A. Khoury, F. Desrochers, O. Tavakol, E.Z. Zhang, and Y B Kim, Phys. Rev. B 109, 214423 (2024).

Scaling of many-body localization transitions: Correlations and dynamics in Fock space and real space

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Typical models for many-body localization (MBL) can be represented as tight-binding models over the many-body Hilbert space (Fock space), where sites correspond to non-interacting basis states, and possible hoppings depend on interaction. In this representation, the disordered model is fully specified by the joint distributions and correlations for on-site energies as well as hopping matrix elements.

In this poster, I will present our conclusions regarding the scaling of the MBL critical disorder $W_c(n)$ in three different single-spin-flip disordered spin-$\frac{1}{2}$ models which share the same distributions of diagonal (energy) and off-diagonal (hopping) Fock-space matrix elements but differ by their Fock-space correlations. These include the one-dimensional (1D) chain with nearest-neighbor interactions, the quantum dot (QD) model with all-to-all pair interactions, and the quantum random energy model (QREM). The QD and 1D models differ essentially by the structure of their many-body energy correlations, which reflect the real-space spatial structure of the latter, while the QREM has no Fock-space correlations. We analytically predict, and check numerically using exact diagonalization that $W_c \sim n$ for the QD model, $W_c(n) \sim$ const for the 1D model and $W_c \sim n^{1/2} \ln n$ for QREM, where n is the system size [1].

These results are corroborated by our study of the dynamics of the generalized imbalance [2], that characterizes propagation in Fock space out of an initial basis state. Our numerics for the time-resolved average imbalance demonstrate that its quantum and mesoscopic fluctuations provide excellent indicators for the position of the MBL transition. Combining these findings with the results of [1], we determine phase diagrams of the MBL transitions in the n-W plane. We also determine the scaling of the transition width $\Delta W(n)/W_c(n)$ and estimate the system size n needed to study the asymptotic scaling behavior.

References:

[1] T. Scoquart, I. Gornyi and A. Mirlin, Role of Fock-space correlations in many-body localization, Phys. Rev. B **109**, 214203,(2024)

[2] T. Scoquart, I. Gornyi and A. Mirlin, Scaling of many-body localization transitions: Quantum dynamics in Fock space and real space, *to appear soon on arxiv*, (2025)

Pauli Limiting Near A Quantum Critical Point

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Applying a magnetic field to a superconductor reduces the critical temperature and eventually leads to the break down of the superconducting phase. Usually, this is caused by orbital coupling of the electrons to the magnetic fields. However, in systems where these orbital effects do not play a role, the superconducting phase is instead destroyed by Zeeman coupling. In a conventional superconductor this is referred to as Pauli limiting.

Near a quantum critical point, a conflicting effect occurs and the superconducting transition temperature is enhanced. Naturally, the question arises of what happens if these two effects compete.

In this work, we look at Zeeman coupling in a superconductor near a quantum critical point within the framework of Eliashberg theory. We consider a singlet superconductor where the electrons are coupled by a boson that is based on the γ-model[1]. In this way our analysis is applicable to several types of quantum critical points, e.g. nematic or antiferromagnetic. Solving both the linearized and non-linearized gap equations we discuss the emergence and break down of several superconducting phases induced by the magnetic field.

[1] A. Abanov, A. V. Chubukov, Phys. Rev. B **102.2** (2020).

Dynamic paramagnon-polarons in altermagnets

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The combined rotational and time-reversal symmetry breakings that define an altermagnet lead to an unusual d-wave (or g-wave) magnetization order parameter, which in turn can be modeled in terms of multipolar magnetic moments. Here, we show that such an altermagnetic order parameter couples to the dynamics of the lattice even in the absence of an external magnetic field. This coupling is analogous to the nondissipative Hall viscosity and describes the stress generated by a time-varying strain under broken time-reversal symmetry. We demonstrate that this effect generates a hybridized paramagnon-polaron mode, which allows one to assess altermagnetic excitations directly from the phonon spectrum. Using a scaling analysis, we also demonstrate that the dynamic strain coupling strongly affects the altermagnetic phase boundary, but in different ways in the thermal and quantum regimes. In the ground state for both 2D and 3D systems, we find that a hardening of the altermagnon mode leads to an extended altermagnetic ordered regime, whereas for nonzero temperatures in 2D, the softening of the phonon modes leads to increased fluctuations that lower the altermagnetic transition temperature. In 3D even at finite temperatures, the dominant effect is the suppression of quantum fluctuations [1].

[1] C.R.W Steward, R.M. Fernandes, J. Schmalian, Phys. Rev. B. **108**, 144418 (2023).

Non-equilibrium charge-vortex duality at finite temperature

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We provide an in-depth exploration of the evolving field of dipole moment preserving quasiparticles characterized by restricted mobility and their connections to elasticity and fluid mechanics. We examine fracton-elasticity dualities, using examples to highlight their significance. We first review recent advancements in quantum field theory dualities, particularly the boson-vortex duality in 2+1 dimensions, which link superfluid dynamics to an Abelian Maxwell theory. We propose a generalization of these developments to non-equilibrium conditions at finite temperatures, providing new insights into the non-perturbative behaviors of fluids. A dual low-energy effective action that emphasizes the interactions between the superfluid phase and the normal fluid component is proposed.

Interplay between quantum criticality, superconductivity, and magnetic fields in exactly solvable models for strange metals

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Exactly solvable models for non-Fermi liquid (NFL) states provide controlled framework to investigate the physics of strange metals [1]. In this work, we obtain the exact solution of the spatially disordered Yukawa-Sachdev-Ye-Kitaev (SD-YSYK) model, in the normal [2,3] and superconducting states [4]. The SD-YSYK theory assumes dispersive fermions and bosons in two spatial dimensions, dynamically coupled through spatially random contact interactions and random two-body potentials [2]. After disorder averaging, in the normal state the fermions realize a marginal Fermi liquid (MFL) with linear-in-temperature DC resistivity, concomitant with critical soft bosons [2,3], while the latter also mediate superconductivity below a finite critical temperature T_c, with finite phase stiffness that anticorrelates with T_c at strong coupling near criticality [4]. We apply this model to DC and AC strange-metal charge transport [4], as well as to orbital magnetotransport [3]. Consistently with recent experiments on cuprates, the optical conductivity displays universal ω/T scalings as a function of frequency ω and temperature T [5], while the cyclotron resonance frequency in the conductivity shifts linearly with magnetic field B and is renormalized by disordered interactions [6].

[1] D. Chowdhury et al., Rev. Mod Phys. **94**, 035004 (2022)
[2] A. A. Patel et al., Science **381**, 790 (2023)
[3] H. Guo et al., Phys. Rev. B **109**, 075162 (2024)
[4] C. Li et al., Phys. Rev. Lett. **133**, 186502 (2024)
[5] B. Michon et al, Nat. Comm.**14**, 3033 (2023)
[6] A. Legros et al., Phys. Rev. B **106**, 195110 (2022)

MODELING Bi-based LAYERED SUPERCONDUCTORS:
ELECTRONIC PROPERTIES

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Superconductivity in layered BiS2-based compounds was discovered in 2012. Though the crystal structure of the BiS2 layers is similar to that of: CuO2 planes in cuprate superconductors; Fe2An2 (An: Se, Te, S) layers in Fe chalcogenide superconductors; or FeAs planes in iron pnictides, other properties are different. There are experimental indications that electron-phonon coupling is weak, pointing to an unconventional pairing mechanism, but the origin and nature of the superconductivity is not yet clear in layered bismuth sulphides.They are also characterized as multi-band superconductors. Electron correlations are generally believed to be moderate in these Bi-based compounds.

We focus on the normal state properties of Bi-sulphide superconductors and analize the effect of electron correlations: having started with the spectral properties, and the topology of the Fermi surface. Through an analytical treatment for a minimal model consisting of two correlated effective bands proposed to describe bismuth sulphides, we determined the temperature-dependent electron Green's functions, from which we obtained the spectral density function,[1], improving the description of ARPES results by including moderate electron correlations. We studied the dependence on doping and temperature, predicting also the k-dependence of the spectral density. We described the Fermi-surface topological transition at a critical doping value. To complete our study, more recently (in yet unpublished results) we determined the normal-state electrical conductivity (resistivity) and the Hall coefficient, using the Kubo formalism, comparing our results with experimental data available, again obtaining improved descriptions of the experimental transport data with the inclusion of moderate electron correlations. We also evaluated thermal transport properties: Seebeck, electronic thermal conductivity, the power factor, and ZT figure of merit.

[1] J.Querales, C. I.Ventura, R. Citro & J.J. Rodríguez Núñez, Physica B 488, 32-42 (2016).

Vibrational dynamics in ultracold ion systems

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Our research proposal focuses on the vibrational dynamics of small trapped ion crystals, combining theoretical modeling and experimental implementation at the Cold Ions and Atoms Laboratory (LIAF). Initial efforts target the characterization of vibrational states in individual ions under the Gaussian approximation, including coherent and squeezed states. These techniques will be extended to small ion chains to study entanglement dynamics in systems coupled to engineered baths via laser beams.

References

[1] Cecilia Cormick and Juan Pablo Paz. Observing different phases for the dynamics of entanglement in an ion trap. *Phys. Rev. A*, 81:022306, Feb 2010.