PROGRAM AND ABSTRACT BOOKLET

WORKSHOP ON COMPLEX QUANTUM MATTER

University of Évora, Portugal, 27-31 October 2025

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The Workshop

This workshop is supported by several European and US projects and research centers. Our aim is to generate a lively exchange of ideas between researchers working in distinct but interrelated fields. Advances in recent years have witnessed an exciting and promising confluence of the areas of strongly correlated many-body quantum systems, including computational condensed matter physics and quantum information theory.

Topics to be discussed at the workshop will include: quantum critically; quantum transport; entanglement transitions; quantum spin liquids; nonequilibrium quantum statistics; quantum many-body chaos; topological phases of matter; novel properties of graphene; quantum integrability; and superconductivity. On the theoretical side, analytical as well as computational approaches will be highlighted. On the experimental side, a few talks will focus on problems directly related to the workshop topics. The workshop will bring together a number of established experts, as well as many talented young scientists, to further explore, develop, and exploit the connections between these forefront areas of research.

Previous Workshops

Previous Évora workshops have an established tradition and have been highly successful in drawing together leading researchers and young scientists in a lively and engaging intellectual environment. A UNESCO World Heritage city, beautiful medieval town of Évora is the capital of Portugal's south-central Alentejo region, and the month of October is an ideal period for local excursions to explore both the city and its surroundings.

Information on previous Évora workshops of the present series may be found at:

2008: http://hawk.fisica.uminho.pt/ccqm/
2010: http://hawk.fisica.uminho.pt/qcmca/
2012: http://hawk.fisica.uminho.pt/ccqs/
2014: http://hawk.fisica.uminho.pt/cccqs/
2016: http://www.cicqs.uevora.pt
2019: http://www.odcqs.uevora.pt
2023: https://www.cdnbqs.uevora.pt

Workshop site

The workshop will take place at:

Anfiteatro 131-A
Edifício do Espírito Santo
Universidade de Évora.

Approximate location:
https://maps.apple.com/?ll=38.573402,-7.904735&q=Dropped%20Pin&t=m

The entrance to the old University building is through Rua do Cardeal Rei.

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FCT Project - Quantum Non-equilibrium excitons in two-dimensional semiconductors
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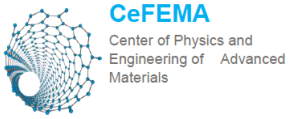

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Through FCT-Portugal Grant No. UID/00618/2023

Câmara Municipal de Évora

PROGRAM

The lengths of both invited and contributed talks include at least 5 minutes of discussion.

Monday, 27 October

8:30 – 9:00 Registration

9:00 – 9:10 Welcome

9:10 – 9:45 Invited: **Guido Pupillo**
Exact results for long-range hopping models in reduced dimensions

9:45 – 10:05 Contributed: **Chris Bühler**
Quantum phase slips and transport in one-dimensional supersolids

10:05 – 10:25 Contributed: **João Costa**
Emergence of universality in transport of noisy free fermions

10:25 – 10:50 Coffee break

10:50 – 11:25 Invited: **Daniel Podolsky**
Can antiferromagnetism survive lattice melting?

11:25 – 11:45 Contributed: **Sebastian Eggert**
Anyonic phase transitions in the 1D extended Hubbard model

11:45 – 12:20 Invited: **Raquel Queiroz**
Quantum Geometry and the scales it imprints in electronic systems

12:20 Lunch break

15:00 – 16:00 Invited Colloquium: **Aharon Kapitulnik**
Optical control of orbital magnetism in magic angle twisted bilayer graphene

16:00 – 16:20 Contributed: **Ricardo Oliveira**
Tensor network approach to real-space superconductivity in quasicrystals

16:20 – 16:45 Coffee break

16:45 – 17:20 Invited: **José González**
The route of shear to Ising superconductivity in bilayer graphene

17:20 – 17:55 Invited: **Miguel Sánchez**
Many-body renormalization of twisted bilayer graphene

17:55 – 18:15 Contributed: **Grigorii A. Starkov**
Conductivity peak at small T as a signature of tomographic dynamics

Tuesday, 28 October

9:00 – 9:35 Invited: **Francisco Guinea**
Superconductivity in graphene stacks

9:35 – 9:55 Contributed: **Thomas Stegmann**
Controlling the current flow in 2D quantum materials

9:55 – 10:15 Contributed: **Maksim Ulybyshev**
Quantum Monte Carlo simulations of electronic hydrodynamics in graphene

10:15 – 10:40 Coffee break

10:40 – 11:15 Invited: **Jed Pixley**
Controlling chaos on classical and quantum computers

11:15 – 11:35 Contributed: **Federico Escudero**
Twisted and Strained bilayer graphene: A platform for manipulating flat bands

11:35 – 11:55 Contributed: **Pierre A. Pantaléon**
Designing flat bands and pseudo-Landau levels in GaAs with patterned gates

11:55 – 12:30 Invited: **Chandra Varma**
Loop-currents in normal and superconducting states of some metals

12:30 Lunch break

15:00 – 16:00 Invited Colloquium: **Eva Andrei**
Moiré, moiré of moiré, and more: periodic and quasiperiodic crystals in twisted graphene/hBN Heterostructures

16:00 – 16:35 Invited: **Mikito Koshino**
Moiré-of-moiré superlattices: from domain formation to emergent topological states

16:35 – 17:00 Coffee break

17:00 – Poster presentations (2 minutes each) and poster session
(Poster frame size: 180cm height from the ground x 120cm width)

Wednesday, 29 October

9:00 – 9:35 Invited: **Bruno Bertini**
Quantum and classical dynamics with random permutation circuits

9:35 – 9:55 Contributed: **Pavel Orlov**
Circuits built from pairwise difference conserving gates: from loop symmetries to localization transitions

9:55 – 10:30 Invited: **Enej Ilievski**
Eigenstate thermalization hypothesis: lessons from the minimal model

10:30 – 10:55 Coffee break

10:55 – 11:30 Invited: **Eugene Bogomolny**
Peculiar random matrix ensembles

11:30 – 11:50 Contributed: **Lucas L. Sá**
Theory of irreversibility of quantum many-body systems

11:50 – 12:25 Invited: **Shiwei Zhang**
Learning and understanding phases in two-dimensional Coulomb systems with neural wave functions

12:25 Lunch break

15:00 Social Program

19:30 Banquet

Thursday, 30 October

9:00 – 9:35 Invited: **Hai-Qing Lin**
Exploring gapless SPT phases in 1D systems: theory, simulation, and experiment

9:35 – 9:55 Contributed: **Roopayan Ghosh**
Quantum Liang information flow probe of causality across critical points

9:55 – 10:15 Contributed: **Michael Potthoff**
Bound states and local topological phase diagram of classical impurity spins coupled to a Chern insulator

10:15 – 10:40 Coffee break

10:40 – 11:15 Invited: **Jonathan D'Emidio**
Entanglement entropy at deconfined and Gross-Neveu critical points

11:15 – 11:35 Contributed: **Henrique P. Veiga**
Markov inequality as a tool for a linear-scaling estimation of local observables

11:35 – 12:10 Invited: **Pontus Laurell**
Witnessing entanglement and quantum correlations in condensed matter

12:10 – 12:30 Contributed: **Yigal Meir**
Observation of detector-induced Anderson orthogonality catastrophe in quantum dots

12:20 Lunch break

15:00 – 16:00 Invited Colloquium: **Ralph Claessen**
Surfaces go topological – atomic monolayers as 2D quantum materials

16:00 – 16:35 Invited: **Bogdan A. Bernevig**
New platforms for Moiré systems

16:35 – 17:00 Coffee break

17:00 – Poster presentations (2 minutes each) and poster session
(Poster frame size: 180cm height from the ground x 120cm width)

Friday, 31 October

9:00 – 9:35 Invited: **Xi-Wen Guan**
Confined and deconfined spin kinks in quasi-one-dimensional materials

9:35 – 9:55 Contributed: **Hetényi Balázs**
Applications of the generalized Bloch theorem formalism: from detecting Majorana fermions to understanding non-Hermitian impurities

9:55 – 10:30 Invited: **Johanna Zijderveld**
Scattering theory of higher order topological phases

10:30 – 10:55 Coffee break

10:55 – 11:30 Invited: **Karlo Penc**
Chiral states in classical and quantum spin models

11:30 – 11:50 Contributed: **José Luís Martins**
Precise quantum-geometric electronic properties from first principles

11:50 – 12:10 Contributed: **Bo Peng**
Molecular quantum materials from first principles

12:10 – 12:40 Summary and closing remarks

POSTERS

Poster Session I (28/10/2025)

	Name	Title
1	Mariana Abreu	Relevance of Electronic Interactions at Quasiperiodicity-Driven Localization Transitions
2	Yuliy Bludov	Polariton-assisted second-harmonic generation in graphene
3	Abdiel de Jesus Espinosa Champo	Hyperbolic Plasmon dispersion and Optical Conductivity of Holey Graphene: signatures of flat-bands
4	Raúl Liquito	Enhancement of low frequency optical conductivity of the Aubry-André model}
5	Thomas Seligman	Symmetry and Spontaneous Symmetry Breaking in Molecules: Selected Aspects
6	Tiago Jorges	Transport Through a Critical Magnetic Quantum Dot Away From Equilibrium
7	Danna Liu	Optoelectronic superlattices based on 2D transition metal dichalcogenides
8	Anselmo Marques	Impurity Flat Band States in the Diamond Chain
9	Luís Miguel Martelo	Graphene under lateral spin-orbit superlattices: symmetry-protected Dirac cones and hot spots of spin Berry Curvature in 2D van der Waals metamaterials.
10	João Manuel Pinho	Analytical results for the quantum dynamics of electrons under strong fields with dissipation
11	Thomas Seligman	Symmetry and spontaneous symmetry breaking in molecules: selected aspects
12	Helena Dias da Silva	Non-Linear Hall Effect: From theory to experiment
13	João Silva	Bulk Impurities/Vacancies in Nodal Loop Semimetals

POSTERS

Poster Session I (28/10/2025)

	Name	Title
14	G. Parra-Martínez	Polarized phases and chiral superconductivity in multilayer graphene
15	M. Sarkar	Floquet-Enhanced Binding and Exotic Pairing States in Doped Mott Insulators, and Quantum State Transfer via Fermionic Chains
16	J. P. C. Ferreira	Treatment of electromagnetic perturbations on crystals through a spatial mode analysis
17	I. M. Vasilevskiy	Exact Hartree-Fock band structure for twisted trilayer graphene

POSTERS

Poster Session II (30/10/2025)

	Name	Title
1	Gabriel Almeida	Universality, Robustness, and Limits of the Eigenstate Thermalization Hypothesis in Open Quantum Systems
2	José Maria Cruz	Generalized Dimer Physics in Multi-Level Rydberg Atom Arrays
3	Simon Fell	Quantum doubles in symmetric blockade structures
4	Ryan Flynn	Strongly First Order Neél-VBS transition in the SU(N) X-Q Model
5	Jacopo Gliozzi	Domain coarsening with multipole conservation: cascade of critical exponents
6	Engo Guan	One-dimensional hard-core anyons under dephasing
7	Zhi Lin	Scaling Dimensions via Operator Covariance in a S=1/2 Quantum Spin Chain
8	Dragan Marković	Chaos and operator dependent anomalous transport in semiclassical Bose-Hubbard chains
9	Guilherme Moreira	Guided quantum state transfer on an asymmetric two-dimensional Su-Schrieffer-Heeger model via domain walls
10	Júlio Oliveira	Variational Monte-Carlo Powered By Neural Quantum States
11	Afonso Leitão Sousa Ribeiro	Dissipative quantum spin ice
12	Nicolau Sobrosa	Local Density of States as a Universal Probe of Multifractality in Quantum Materials
13	Rafael Carreira Torres	Tricriticality in 4D U(1) Lattice Gauge Theory
14	Kazuki Yamamoto	Universal subsystem fluctuations of quantum jump statistics in postselection-free many-body dynamics under continuous monitoring

POSTERS

Poster Session II (30/10/2025)

	Name	Title
15	Henrique C. Prates	Bloch-Landau-Zener oscillations and dynamical management of BECs in a quasiperiodic potential
16	Pedro S. Gil	Localization of Bose-Einstein condensates enabled by incommensurate optical lattice and photon-atom interactions
17	P. Kofman	Measurement-Induced Phase Transitions in Monitored Collective Spin Models
18	Yue-Yue Chang	Magnon, doublon and quarton excitations in 2D S=1/2 trimerized Heisenberg models

ABSTRACTS OF THE INVITED COLLOQUIA, INVITED TALKS, AND CONTRIBUTED TALKS

Monday, 27 October

EXACT RESULTS FOR LONG-RANGE HOPPING MODELS IN REDUCED DIMENSIONS

G. Pupillo

University of Strasbourg and CNRS, CESQ and ISIS (UMR 7006), 67000 Strasbourg, France

We present results for bosonic systems with long-range hopping decaying as $1/r^{\alpha}$ in the weak long-range regime $1 < \alpha \leq 3$, using large-scale quantum Monte Carlo simulations. In one dimension, we show that both interaction-driven and disorder-induced localization transitions are scale-invariant and distinct from the Berezinskii-Kosterlitz-Thouless type, defining new universality classes of quantum criticality which we characterize by computing the critical exponents. In two dimensions, we demonstrate that long-range hopping can stabilize supersolid order in mesoscopic excitonic materials, providing a new microscopic route to the coexistence of crystalline and superfluid phases. These results offer quantitative benchmarks for theories and experiments of long-range quantum criticality in reduced dimensions.

9h10
Mon
1

QUANTUM PHASE SLIPS AND TRANSPORT IN ONE-DIMENSIONAL SUPERSOLIDS

A. Biselli, C. Bühler, H. P. Büchler

Institute for Theoretical Physics III and Center for Integrated Quantum Science and Technology, University of Stuttgart, DE-70550 Stuttgart, Germany

9h45 Mon 2

Quantum fluctuations in one dimension prevent the appearance of long-range order for a continuous symmetry even at zero temperature. Furthermore, the nucleation of quantum phase slips can have significant influence on the phase diagram and transport properties. Here, we study the influence of quantum phase slips on the phase diagram of a one-dimensional supersolid as they can be realized with dysprosium atoms. We demonstrate the appearance of a novel quantum phase transition from the supersolid to the superfluid phase and study in detail its influence on transport properties.

EMERGENCE OF UNIVERSALITY IN TRANSPORT OF NOISY FREE FERMIONS

J. Costa[1,2], P. Ribeiro[1], A. De Luca[2]

1 CeFEMA, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
2 Laboratoire de Physique Théorique et Modélisation, CY Cergy Paris Université, CNRS, F-95302 Cergy-Pontoise, France

We analyze the effects of various forms of noise on one-dimensional systems of non-interacting fermions. In the strong noise limit, we demonstrate, under mild assumptions, that the statistics of the fermionic correlation matrix in the thermodynamic limit follow a universal form described by the recently introduced quantum simple symmetric exclusion process (QSSEP). For charge transport, we show that QSSEP, along with all models in its universality class, shares the same large deviation function for the transferred charge as the classical SSEP model. The method we introduce to derive this result relies on a gauge-like invariance associated with the choice of the bond where the current is measured. This approach enables the explicit calculation of the cummulant generating function for both QSSEP and SSEP and establishes an exact correspondence between them. These analytical findings are validated by extensive numerical simulations. Our results establish that a wide range of noisy free-fermionic models share the same QSSEP universality class and show that their transport properties are essentially classical.

10h05
Mon
3

CAN ANTIFERROMAGNETISM SURVIVE LATTICE MELTING?

D. Podolsky

Physics Department, Technion - Israel Institute of Technology

10h50 Mon 4

In an antiferromagnet, spins tend to align in directions opposite to their neighbors, a pattern that typically depends on a regular underlying lattice. In this talk, I will explore a scenario where a form of antiferromagnetism persists even when the lattice melts. I will present a colloidal system where this phenomenon may be realized, and discuss the associated antiferromagnetic order parameter, highlighting close connections with concepts from quantum error correction.

ANYONIC PHASE TRANSITIONS IN THE 1D EXTENDED HUBBARD MODEL WITH FRACTIONAL STATISTICS

S. Eggert[1], M. Bonkhoff[1,2], K. Jägering[1], S. Hu[1,3], A. Pelster[1], and I. Schneider[1]

1 Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, 67663 Kaiserslautern, Germany
2 I. Institut für Theoretische Physik, Universität Hamburg, 22607 Hamburg, Germany
3 Beijing Computational Science Research Center, Beijing 100193, China

Recent advances in quantum technology allow the realization of "lattice anyons", which have enjoyed large interest as particles which interpolate between bosonic and fermionic behavior. We now study the interplay of such fractional statistics with strong correlations in the one-dimensional extended Anyon Hubbard model at unit filling by developing a tailored bosonization theory and employing large-scale state-of-the-art numerical simulations [1]. The resulting phase diagram shows several distinct gapped and superfluid phases, which display an interesting transition through a multicritical point as the anyonic exchange phase is tuned from bosons to fermions. The universality of the phase transitions is discussed.

11h25
Mon
5

1. M. Bonkhoff, K. Jägering, S. Hu, A. Pelster, S. Eggert and I. Schneider
Phys. Rev. Lett. **135**, 036601 (2025)

QUANTUM GEOMETRY AND THE SCALES IT IMPRINTS IN ELECTRONIC SYSTEMS

Raquel Queiroz

Department of Physics, Columbia University, New York, NY 10027, USA

11h45 Mon 6

We will discuss how the quantum geometry of Bloch wavefunctions naturally imprints a separation of scales in electronic systems, which is reflected in their correlated states. I will introduce the concept of cell natural orbitals as a natural and convenient basis to study multiband systems, properly accounting for wavefunction geometry, including in moiré continuum models.

OPTICAL CONTROL OF ORBITAL MAGNETISM IN MAGIC ANGLE TWISTED BILAYER GRAPHENE

Aharon Kapitulnik[1,2,3] and Eylon Persky[1,2]

[1]*Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA*
[2]*Department of Applied Physics, Stanford University, Stanford, California 94305, USA*
[3]*Department of Physics, Stanford University, Stanford, California 94305, USA*

Flat bands in graphene-based moiré structures host a wide range of emerging strongly correlated and topological phenomena. Optically probing and controlling them can reveal important information such as symmetry and dynamics, but have so far been challenging due to the small energy gap compared to optical frequencies. In this talk we focus on the optical interrogation of a stack of magic angle twisted bilayer graphene (MATBG) and monolayer WSe_2 device, which clearly exhibits orbital magnetism and associated anomalous Hall effects (AHE) near select moiré integer fillings [1]. Circular photogalvanic effect (CPGE) measurements above the magnetic transitions reveal a finite response as a function of band filling, confirming the alluding to the finite Berry connection embedded in the band structure. At low temperatures we show that the AHE phases, such as hysteresis and amplitude, can be controlled by circularly polarized light. By modulating the light helicity, we observe periodic modulation of the transverse resistance in a wide range of fillings, indicating light induced orbital magnetization through an anomalously large inverse Faraday effect associated with the flat band.

15h00
Mon
7

Work done in collaboration with: Léonie Parisot, Minhao He, Jiaqi Cai, Takashi Taniguchi, Kenji Watanabe and Xiaodong Xu.

1. Eylon Persky, Minhao He, Jiaqi Cai, Takashi Taniguchi, Kenji Watanabe, Xiaodong Xu, Aharon Kapitulnik, “Optical control of orbital magnetism in magic angle twisted bilayer graphene,” arXiv:2503.21750 [cond-mat.str-el].

TENSOR NETWORK APPROACH TO REAL-SPACE SUPERCONDUCTIVITY IN QUASICRYSTALS

Ricardo Oliveira[1], Yitao Sun[2], Tiago V. C. Antão[2], Jose L. Lado[2], Eduardo V. Castro[1], Bruno Amorim[1]

1 Centro de Física das Universidades do Minho e Porto, LaPMET, Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto, 4169-007 Porto, Portugal
2 Department of Applied Physics, Aalto University, 02150 Espoo, Finland

16h00
Mon
8

The recent discovery of superconductivity in quasiperiodic twisted trilayer graphene (tTLG) underscores the complex interplay between quasiperiodicity and interactions in moiré materials [1]. Furthermore, previous work by the authors [2] has shown that quasiperiodicity can lead to an enhancement of superconductivity in one-dimensional quasiperiodic models. However, a proper theoretical description of superconductivity in quasiperiodic moiré materials is still lacking, due to the lack of translational invariance that implies that real-space numerical methods must be necessarily employed to study moiré systems such as twisted bilayer graphene (tBLG), requiring the simulation of system sizes in the order of millions of atoms [3]. We propose a real-space tensor network approach to study s-wave superconductivity in two-dimensional quasicrystals with eightfold rotational symmetry. Building on the tensor network kernel polynomial method combined with the quantics tensor cross interpolation method (QTCI) to represent ultra-large real-space Hamiltonians [4, 5], we can obtain real-space mean-field solutions for on-site pairing across systems exceeding one million sites. This scalable approach enables computation of the local density of states and the spatially resolved superconducting pairing, revealing how eightfold symmetry and the quasiperiodic structure of the system shapes the texture of s-wave order. Our work opens a path towards quantitative real-space characterization of superconductivity in quasiperiodic moiré systems that require large-scale simulations.

1. A. Uri et al., Nature 620 (2023) 762-767.
2. R. Oliveira et al., arXiv preprint (2023) 2303.17656.
3. Miguel Gonçalves et al., 2D Mater 9 (2021) 011001.
4. Yitao Sun et al., arXiv preprint (2025) 2503.04373.
5. Tiago V. C. Antão et al., arXiv preprint (2025) 2506.05230.

THE ROUTE OF SHEAR TO ISING SUPERCONDUCTIVITY IN BILAYER GRAPHENE

J. González[1], T. Stauber[2]

1 Instituto de Estructura de la Materia, CSIC, Madrid, Spain
2 Instituto de Ciencia de Materiales de Madrid, CSIC, Madrid, Spain

We show that the application of shear to graphene bilayers can be used to engineer flat low-energy bands for sufficiently large moiré supercells. In this regime, the interacting system becomes prone to develop broken-symmetry phases, with valley symmetry breaking as the dominant pattern. The strong signal of symmetry breaking favors the onset of a pairing instability in which the electrons with opposite spin projections in the Cooper pair live in different valleys. The Fermi lines become distorted due to the repulsive Coulomb interaction, which makes the screening highly anisotropic, leading easily to attraction in some of the interaction channels. We also show that the sheared graphene bilayers offer the possibility to realize the combined breakdown of parity and valley symmetry, making them very suitable to study the interplay between correlations and topology in a two-dimensional electron system.

16h45
Mon
9

MANY-BODY RENORMALIZATION OF TWISTED BILAYER GRAPHENE

Miguel Sánchez Sánchez[1], José González[2], Tobias Stauber[1]

1 Instituto de Ciencia de Materiales de Madrid ICMM-CSIC. Madrid (Spain)
2 Instituto de Estructura de la Materia IEM-CSIC. Madrid (Spain)

17h20 Mon 10

We employ an atomistic tight-binding model to address basic properties of the normal state of magic-angle twisted bilayer graphene. Within Hartree-Fock theory, we obtain this normal state at the charge neutrality point [1], revealing a nontrivial renormalization of the band structure and a associated shift in the value of the magic angle. We then extract the parameters of a generalized Bistritzer-MacDonald model, thereby establishing a low-energy description that incorporates many-body effects from high-energy states. Additionally, we introduce a novel set of local order parameters that capture the symmetry-breaking patterns of various correlated states in real space [2]. Finally, we discuss the implications of our findings for experiments.

1. M. Sánchez Sánchez, J. González, T. Stauber. *Phys. Rev. B* **111**, 205133 (2025).
2. M. Sánchez Sánchez, I. Díaz, J. González, T. Stauber. *Phys. Rev. Lett.* **133**, 266603 (2024).

CONDUCTIVITY PEAK AT SMALL T AS A SIGNATURE OF TOMOGRAPHIC DYNAMICS

G. A. Starkov[1,2], B. Trauzettel[1,2]

1 Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany
2 Würzburg-Dresden Cluster of Excellence ctd.qmat, Germany

The reduced dimensionality in 2D materials allows us to selectively address electron flow regimes dominated by electron-electron scattering. This is the main driving force of interest to study electron transport in such materials. Recent theoretical studies suggest however that our common understanding of the electron-electron collision processes in 2D is incomplete: Due to phase-space constraints, odd deformations of the electron distribution function relax much slower than the even ones. These studies also predict that the resulting novel "tomographic" regime of the electron flow should be characterized by particular flow profiles and scale-dependent viscosities. Determination of the scale exponent in either case requires a rather sophisticated experimental setup. In light of this, it is important to look for other possible signatures of the "tomographic" flow. Moreover, bridging the gap between the theory and experiment in principle requires the analysis of more realistic models, than the ones considered up to this moment. These are precisely the problems that we address in our work.

We consider a model of 2D electron channels with realistic boundary scattering. Using both analytical calculations in the form of the perturbation theory and supplementing them by the first-principles numerical computations, we predict unique transport signatures stemming from the long-lived odd modes: The number of the odd modes shrinks with increasing temperature. As we demonstrate, the sign of the conductance correction is sensitive to this number, which results in a non-monotonic temperature dependence of the conductance: the latter exhibits a peak at small temperatures.

17h55
Mon
11

1. G. A. Starkov, B. Trauzettel, Anomalous Knudsen effect signaling long-lived modes in 2D electron gases, arXiv:2502.04880 (2025)

Tuesday, 28 October

SUPERCONDUCTIVITY IN GRAPHENE STACKS

F. Guinea[1,2]

1 IMDEA Nanscience, Faraday 5, 28015 Madrid, Spain
2 Donostia International Physics Center, Manuel Lardizabal 4, 20018, /San Sebastian, Spain

Superconductivity in twisted and untwisted graphene stacks is investigated. The role of the screened long range repulsive Coulomb interaction in the superconducting pairing is studied in detail, as it is the largest electron-electron interaction in twisted bilayers.
Screening includes electron-hole excitations, plasmons, and longitudinal acoustic phonons, all included via the RPA dielectric function. A significant contribution to pairing in twisted bilayer graphene comes from moiré assisted processes.
Superconductivity in fully spin and valley polarized systems is also studied. The long range Coulomb interaction reasonably describes observed trends in superconducting graphene stacks. It marks a significant difference between a twisted graphene bilayer and other moiré systems, such as twisted double bilayers, and helical trilayers.
Pairing in untwisted bilayers and trilayers is weaker than in twisted bilayer graphene. The superconducting order parameter in twisted bilayer graphene can be f-wave like, that is, there are full gaps with opposite signs in the two valleys. The superconducting order parameter in other graphene stacks usually shows nodes at the Fermi surface.

9h00
Tue
1

CONTROLLING THE CURRENT FLOW IN 2D QUANTUM MATERIALS

S. Galván y García[1], J. A. Sánchez-Sánchez[1], Y. Betancur-Ocampo[2], F. Sánchez-Ochoa[2], J. E. Barrios-Vargas[3], T. Stegmann[1]

1 Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México, Cuernavaca, México,
2 Instituto de Física, Universidad Nacional Autónoma de México, Ciudad de México, México,
3 Facultad de Química, Universidad Nacional Autónoma de México, Ciudad de México, México

In this talk, we explore various strategies to manipulate and control the electronic transport in 2D quantum materials. We show that the current flow in graphene can be guided on atomically-thin current pathways by the engineering of Kekulé distortions. A grain boundary in these distortions separates the system into topologically distinct regions and induces a ballistic domain-wall state. The state is independent of the orientation of the grain boundary with respect to the graphene sublattice and permits guiding the current on arbitrary paths, as illustrated in the figure below, where the current forms the letters of our institue 'ICF-UNAM' [1]. When considering a graphene bilayer, we demonstrate that it is possible to steer the current by twisting one layer relative to the other. The observed steering gives rise to a non-local Hall resistance and can be explained by the trigonal shape of the energy bands due to the Moiré interference pattern [2]. Additionally, we discuss the emergence of anomalous edge states in this system, which open new possibilities for transport control [3].

9h35
Tue
2

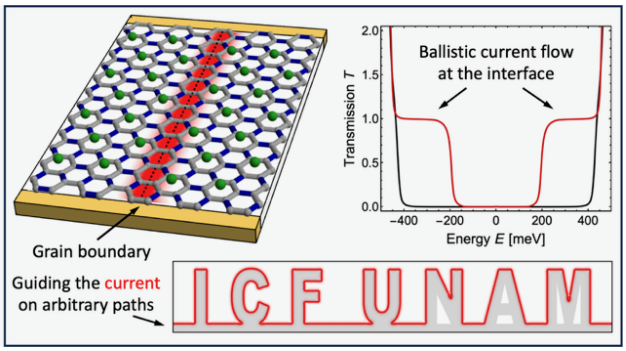

Fig. 1: Current flow in graphene with Kekulé-type distortions. A grain boundary in these distortions allows the current to be guided on well-defined atomically-thin paths, forming for example the letters of our institute 'ICF-UNAM'.

1. Galván y García, et al., Nano Lett. **24**, 2322 (2024).
2. Sánchez-Sánchez, et al., J. Phys. Mater. **5**, 024003 (2022).
3. Sánchez-Sánchez, et al., Phys. Rev. B **110**, 205432 (2024).

QUANTUM MONTE CARLO SIMULATIONS OF ELECTRONIC HYDRODYNAMICS IN GRAPHENE

A. Reingruber[1],K. Pongsangangan[2], F. Assaad[1], M. Ulybyshev[1]

1 Institute for theoretical physics and astrophysics, University of Wuerzburg, Germany
2 Department of Physics, Faculty of Science, Mahidol University, Bangkok, Thailand

The emergence of hydrodynamic behavior in electronic flow within clean, particle-hole-symmetric systems at half filling is a nontrivial problem. Navier-Stokes (NS) equations describe the momentum flow, while experimental measurements typically capture the current flow profiles. However, in particle-hole-symmetric systems, electric current and momentum flow are entirely decoupled, because electrons and holes move in opposite directions with equal distribution functions. This makes it challenging to link NS equations to observed flow patterns. In order to resolve this discrepancy, we perform the numerically exact Quantum Monte Carlo (QMC) simulations of clean graphene samples with disordered edges using the microscopic model previously verified by comparing the computed renormalization of the Fermi velocity with experimental data. Since we can reach system sizes of up to 20,000 sites, such simulations can essentially serve as an alternative to experiments for studying the transport properties of strongly correlated electronic systems, providing data in a flexibly tunable and highly controllable environment. QMC results show that the hydrodynamic behavior of the charge current at half filling can emerge despite the absence of momentum flow. We interpret the numerical results using the Boltzmann transport and show that NS-type equations can be derived directly for the charge current, eliminating the need for any additional mechanism coupling the velocity field and charge current in explaining the experimentally observed hydrodynamic flow profiles in graphene at half filling. We show that a new transport quantity – the current diffusion coefficient – replaces viscosity.

9h55
Tue
3

1. A. Reingruber, K. Pongsangangan, F. Assaad, M. Ulybyshev, Phys. Rev. Lett. **134**, 206303 (2025).
2. M. Ulybyshev, S. Zafeiropoulos, C. Winterowd, F. Assaad, arXiv:2104.09655.

CONTROLLING CHAOS ON CLASSICAL AND QUANTUM COMPUTERS

Jed Pixley

Department of Physics and Astronomy, Rutgers, The State University of New Jersey, 136 Frelinghuysen Road, Piscataway, NJ 08854-8019 USA

10h40 Tue 4

Chaotic evolution, the exponential sensitivity to initial conditions, underpins a great deal of everyday phenomena. In certain settings, it is possible to control the chaotic evolution by pushing the system towards an unstable fixed point of the dynamics, which drives the system through an absorbing state transition. Recent efforts have shown how to embed this dynamics into a quantum many body system, which requires using measurements and feedback to design the control operation. In the quantum setting this drives a measurement induced phase transition that may or may not coincide with the absorbing state transition depending on the structure of the feedback operation. We will discuss the current theoretical understanding of feedback driven transitions in quantum many-body systems and will present data on realizing this system on IBM's superconducing quantum processor with over 100 qubits.

TWISTED AND STRAINED BILAYER GRAPHENE: A PLATFORM FOR MANIPULATING FLAT BANDS

Federico Escudero[1], Dong Wang[2], Shengjun Yuan[2], Pierre A. Pantaleón[1], Francisco Guinea[1,3], Zhen Zhan[1]

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2 Key Laboratory of Artificial Micro- and Nano-structures of Ministry of Education and School of Physics and Technology, Wuhan University, Wuhan 430072, China
3 Donostia International Physics Center, Paseo Manuel de Lardizábal 4, 20018 San Sebastián, Spain

Moiré heterostructures have emerged as a promising platform to study unconventional superconductivity and strongly correlated phases of matter [1,2]. The most prominent example is twisted bilayer graphene, where strong electronic correlations have been observed in numerous experiments around the so-called "magic-angle". An additional tune parameter, beyond the twist angle, comes from the presence strain in the samples, which generally distort the layers and can lead to many possible, non-hexagonal moiré patterns [3]. Although small strains are known to arise randomly during the fabrication of the samples, recent experimental advances have opened the possibility to precisely control and engineer external strain [4,5]. This could lead to rich electronic properties can be tuned by the interplay between the twist and strain.

In this work, we investigate twisted and strained bilayer graphene using atomistic tight-binding simulations and strain-extended continuum models. For the tight binding model we construct commensurate superlattices for different combinations of twist and uniaxial, biaxial and shear strain, considering rigid and relaxed lattices. The obtained results are in excellent agreement with those from the continuum model. In particular, we find that the strain-induced gauge potential, coming from the change in the hopping energies, is essential to capture the tight binding band structure and the appearance of multiple Van Hove singularities. By then analyzing different twist and strain configurations, we show that the magic angle of minimum bandwidth shifts as the strain magnitude increases, with a nontrivial dependence on the strain direction. Taking further into account electrostatic interactions, we find that the increase of bandwidth due to the strain competes with the corresponding decrease of the Hartree potential. As a result, the renormalized bandwidth with strain can become comparable to that with only twist. Our results establish twisted and strained bilayer graphene as a versatile platform for engineering flat bands and exploring correlated phases.

11h15
Tue
5

1. E.Y. Andrei and A.H. MacDonald, Nat. Mater. **19**, 1265-1275 (2020).
2. DM. Kennes et al., Nat. Phys. **17**, 155-163 (2021).
3. F. Escudero et al., Phys. Rev. Res. **6**, 023203 (2024).
4. T. Peña et al., Appl. Phys. Lett. **122**, 143101 (2023).
5. M. Kapfer et al., Science **381** , 677 (2023).

DESIGNING FLAT BANDS AND PSEUDO-LANDAU LEVELS IN GAAS WITH PATTERNED GATES

P. A. Pantaleón[1], Z. Zhan[1], S. E. Morales[2], G. G. Naumis[2]

[1] *Imdea Nanoscience, Faraday 9, 28015 Madrid, Spain*
[2] *Depto. de Sistemas Complejos, Instituto de Física, Universidad Nacional Autónoma de México (UNAM), Apdo. Postal 20-364, 01000 México D.F., México*

11h35 Tue 6

In this talk I will present our recent studies in the electronic properties of two-dimensional electron gases (2DEGs) subjected to a periodic patterned gate. By incorporating the superlattice (SL) potential induced by patterning into the Schrödinger equation, we develop a methodology for obtaining exact analytical solutions. These solutions enable us to construct a comprehensive phase diagram illustrating the emergence of narrow bands and pseudo-Landau levels driven by the SL potential. To complement the analytical approach, we employ a standard plane-wave formalism to track the evolution of the band structure as the SL strength increases. By breaking the inversion symmetry of the SL potential, we found a nontrivial Berry curvature. Furthermore, we introduce a self-consistent Hartree screening to account for the interplay between the SL potential and electronic interactions. Our findings not only reveal the emergence of a non-trivial quantum geometry and a competition between SL strength and electron-electron interactions, but also highlight the value of exact analytical solutions for understanding and engineering electronic phases in patterned 2DEG systems.

LOOP-CURRENTS IN NORMAL AND SUPERCONDUCTING STATES OF SOME METALS

Chandra Varma

University of California, Riverside, USA

I will briefly review the physical principles of loop-current order, with emphasis on its observation in cuprates, kagome lattice, and in various forms of graphene. The special conditions required to have an anomalous Hall effect in the normal state due to loop-currents which is inherited to get topological superconductivity, which in turn leads to a spontaneous non-reciprocal critical currents in the superconducting states, will be discussed.

11h55
Tue
7

MOIRÉ, MOIRÉ OF MOIRÉ, AND MORE: PERIODIC AND QUASIPERIODIC CRYSTALS IN TWISTED GRAPHENE/HBN HETEROSTRUCTURES

Eva Andrei

Department of Physics and Astronomy, Rutgers University, United States

15h00
Tue
8

Twisting atomically thin crystals creates moiré potentials that profoundly reshape their electronic behavior. Extending this concept to three stacked layers reveals an even richer landscape of structural and electronic phenomena. Using scanning tunneling microscopy and spectroscopy, we map the double-moiré structures that arise when twisted bilayer graphene is overlaid on hexagonal boron nitride. The resulting phase-diagram encompasses both commensurate periodic and incommensurate quasiperiodic moiré crystals. Remarkably, the 1:1 commensurate structure, predicted to occur only at one phase-diagram point, emerges over a wide range of angles, revealing a self-alignment mechanism that stabilizes extended domains bounded by one-dimensional chiral edge states. Among the incommensurate phases, we identify quasiperiodic quasicrystals, which exhibit forbidden rotational symmetries, and intercrystals, which are quasiperiodic but symmetry-permitted. The quasiperiodic crystals host flat electronic bands that, when aligned with the Fermi level, give rise to correlated electronic states.

1. Moiré periodic and quasiperiodic crystals in heterostructures of twisted bilayer graphene on hexagonal boron nitride X. Lai, G.Li, A. M. Coe, J. H. Pixley, K.Watanabe, T.Taniguchi & E. Y. Andrei, Nature Materials, 24, 1019-1026 (2025)

MOIRÉ-OF-MOIRÉ SUPERLATTICES: FROM DOMAIN FORMATION TO EMERGENT TOPOLOGICAL STATES

Mikito Koshino

University of Osaka, Toyonaka, 560-0042 Japan

Moiré superlattices in twisted van der Waals materials have emerged as a rich platform for exploring novel quantum phenomena. While most efforts have focused on bilayer systems, moiré systems with three or more layers are now experimentally accessible, where multiple moiré patterns interfere to form quasi-periodic structures. These systems host structural and electronic properties that go well beyond the bilayer paradigm. In this talk, I will present a comparative theoretical study on the structural relaxation and electronic structures of such multi-moiré systems. In twisted trilayer graphene, the two moiré patterns arising from layers 1,2 and 2,3 interfere to generate a higher-order 'moiré-of-moiré' pattern with length scales of tens to hundreds of nanometers. Relaxation drives the formation of commensurate domains where the two periodicities locally align [1]. In helical trilayers, the moiré vertices repel each other, giving rise to nontrivial topological boundary modes, while in alternating trilayers they attract, leading to distinct domain textures. In twisted trilayer TMDs, such as WSe_2, relaxation also induces domain formation but with qualitatively different consequences for the electronic structure [2]. Here, the intralayer moiré potential dominates over interlayer hybridization, resulting in layer-polarized states near the valence band edge. In helical stacking, this mechanism produces an emergent kagome lattice potential with flat bands characteristic of kagome physics, whereas alternating stacking yields deep triangular quantum wells. Furthermore, we show that a moderate perpendicular electric field can switch the layer polarization and control interlayer hybridization, enabling external tuning of the band structure.

16h00
Tue
9

1. N. Nakatsuji, T. Kawakami, and M. Koshino, Phys. Rev. X 13, 041007 (2023)
2. N. Nakatsuji, T. Kawakami, and M. Koshino, arXiv:2504.20449 (2025).

Wednesday, 29 October

QUANTUM AND CLASSICAL DYNAMICS WITH RANDOM PERMUTATION CIRCUITS

Bruno Bertini

Physics East, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

Understanding thermalisation in quantum many-body systems is among the most enduring problems in modern physics. A particularly interesting question concerns the role played by quantum mechanics in this process, i.e. whether thermalisation in quantum many-body systems is fundamentally different from that in classical many-body systems and, if so, which of its features are genuinely quantum. I will discuss this question by considering minimally structured many-body systems that are only constrained to have local interactions, i.e. local random circuits. In particular, I will introduce random permutation circuits (RPCs), which are circuits comprising gates that locally permute basis states, as a counterpart to random unitary circuits (RUCs), a standard toy model for generic quantum dynamics.

9h00
Wed
1

CIRCUITS BUILT FROM PAIRWISE DIFFERENCE CONSERVING GATES: FROM LOOP SYMMETRIES TO LOCALIZATION TRANSITIONS

P. Orlov[1,2], Y. Kasim[1], C. Jonay[1], T. Prosen[1,3]

1 Physics Department, Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
2 Nanocenter CENN, Jamova 39, SI-1000 Ljubljana, Slovenia
3 Institute of Mathematics, Physics, and Mechanics, Jadranska 19, SI-1000 Ljubljana, Slovenia

9h35
Wed
2

We introduce a new class of models: circuits constructed from special local gates that we dubbed pairwise difference conserving (PDC) gates. These circuits can be defined on graphs of arbitrary dimension and for both quantum and classical spins. A key consequence of the PDC construction is the emergence of an extensive set of loop charges, associated with closed walks of even length on the graph. These charges exhibit a one-dimensional character reminiscent of 1-form symmetries and lead to strong Hilbert-space fragmentation: the dynamics decomposes into exponentially many disconnected sectors, each labeled by charge values.

As a concrete realization, we analyze a classical cellular automaton belonging to this family, defined on the square lattice. In this model, we uncover a localization-delocalization phase transition in information spreading, controlled by loop charges. The transition is continuous and characterized by critical scaling of a Hamming-distance order parameter and a diverging correlation length, placing it in close analogy with equilibrium second-order phase transitions.

Together, these results establish PDC circuits as a versatile platform for exploring symmetry-induced fragmentation, constrained dynamics, and emergent phase transitions across quantum and classical settings.

EIGENSTATE THERMALIZATION HYPOTHESIS: LESSONS FROM THE MINIMAL MODEL

P. Orlov[1], R. Sharipov[1], E. Ilievski[1]

1 Department of Physics, University of Ljubljana, Ljubljana, Slovenia

Eigenstate thermalization hypothesis is a cornerstone principle for our modern understanding of thermalization phenomena in quantum many-body systems. In the talk, I will critically assess the validity of the standard ETH ansatz by examining its refined version on a simple, exactly solvable quantum field theory.

9h55
Wed
3

PECULIAR RANDOM MATRIX ENSEMBLES

E. Bogomolny

Université Paris-Saclay, CNRS, LPTMS, 91405 Orsay, France

10h55 Wed 4

Matrices with random or pseudo-random elements are omnipresent in physics and mathematics. The best known example is invariant ensembles (GOE, GUE, GSE) where all correlation functions are known analytically. The topic of this talk concerns much less understood low complexity (structured) matrices characterised by a finite displacement rank. Many named matrices belong to this category: Cauchy, Toeplitz, Hankel, etc. When elements of such matrices are random, the statistics of their eigenvalues are, in a sense, intermediate between the spectral statistics of invariant random matrix ensembles (used to describe chaotic systems) and the Poisson statistics (typical for integrable models). Such type of statistics were observed in the Anderson model at the metal-insulator transition point and in pseudo-integrable billiards, besides others. Various examples of structured random matrices with intermediate spectral statistics are briefly surveyed in the talk. For certain models related with the Lax matrices of integrable systems analytical results are available, for others one is limited to construct Wiener-like surmises in a good agreement with numerics. A special attention is given to Cauchy-like random matrices appeared in the exact quantisation of barrier billiards which is the only to-day known example of pseudo-integrable billiards accessible to analytical treatment.

THEORY OF IRREVERSIBILITY OF QUANTUM MANY-BODY SYSTEMS

Lucas Sá[1], Takato Yoshimura[2,3]

1 TCM Group, Cavendish Laboratory, Ray Dolby Centre, University of Cambridge, JJ Thomson Avenue, Cambridge, CB3 0US UK
2 All Souls College, Oxford OX1 4AL, U.K.
3 Rudolf Peierls Centre for Theoretical Physics, University of Oxford, 1 Keble Road, Oxford OX1 3NP, U.K.

We advance the theory of quantum Ruelle-Pollicott (RP) resonances and their connection with irreversible relaxation. We relate the spectral form factor to the sum of ensemble-averaged autocorrelation functions and, in generic many-body lattice systems without conservation laws, argue that all quantum RP resonances converge inside the unit disk, highlighting the role of nonunitary and the thermodynamic limit. While we conjecture this picture to be general, we analytically prove the emergence of irreversibility in the random phase model (RPM), a paradigmatic quantum circuit model. To this end, we couple it to arbitrary external local baths and compute the exact time evolution of autocorrelation functions, the dissipative form factor and its partial counterpart, out-of-time-order correlation functions, and operator size. Although the results are valid for any dissipation strength, we then focus on weak dissipation to clarify the origin of irreversibility in the unitary system. When the dissipationless limit is taken after the thermodynamic limit, the unitary quantum map develops an infinite tower of quantum RP resonances inside the unit disk. We trace their microscopic origin to the entropic cost of domain walls in the configuration space of the many-body system. Finally, we demonstrate how conservation laws, many-body localization, and nonlocal interactions cause the leading RP resonance to merge with the unit circle, thereby suppressing the relaxation of the quantities it couples to.

11h30
Wed
5

1. T. Yoshimura and L. Sá, Robustness of Quantum Chaos and Anomalous Relaxation in Open Quantum Circuits, Nat. Commun. 15, 9808 (2024).
2. T. Yoshimura and L. Sá, Theory of Irreversibility in Quantum Many-Body Systems, Phys. Rev. E 111, 064135 (2025).

LEARNING AND UNDERSTANDING PHASES IN TWO-DIMENSIONAL COULOMB SYSTEMS WITH NEURAL WAVE FUNCTIONS

Shiwei Zhang

Flatiron Institute/Center for Computational Quantum Physics, New York, USA

11h50
Wed
6

I will report on our recent work to determine and understand phases in two-dimensional (2D) materials, using quantum Monte Carlo (QMC) and machine learning methods. We investigate the ground state of the 2D electron gas (2DEG) under the effect of one or more of the following: moire potential, metallic gates, disorder, and topology. The use of neural networks have in many of these cases greatly raised the accuracy and predictive power of the computation, as I will demonstrate from systematic benchmarks against previous best QMC results on the 2DEG [1], and direct comparisons with STM images [2]. A rich set of phases are seen in the presence of moire potentials [3]. The effects of metallic gates on detecting the Wigner crystal in 2DEG are quantified [4]. I will also briefly discuss on-going work to study anormalous Hall crystals and electron-hole bilayers.

1. C. Smith, Y. Chen, R. Levy, Y. Yang, M.A Morales, S. Zhang, Phys. Rev. Lett. **79**, 266504 (2024).
2. Zhehao Ge, Conor Smith, Zehao He, *et. al.*, to be published.
3. Y. Yang, M. A Morales, S. Zhang, Phys. Rev. Lett. **132**, 076503 (2024); ibid **133**, 266501 (2024).
4. A. Valenti, V. Calvera, Y. Yang, M. A. Morales, S. A. Kivelson, I. Esterlis, S. Zhang, arXiv:2501.16430

Thursday, 30 October

EXPLORING GAPLESS SPT PHASES IN 1D SYSTEMS: THEORY, SIMULATION, AND EXPERIMENT

Hai-Qing Lin

Institute for Advanced Study in Physics and School of Physics, Zhejiang University, Hangzhou, China

9h00
Thu
1

Topological phases, characterized by nonlocal order and exotic entanglement structures, hold profound implications for quantum technologies and fundamental physics. While traditionally associated with gapped systems, recent advances have revealed that gapless critical points or phases can sustain stable topological edge modes, challenging conventional wisdom. In this talk, I will present our recent progress in exploring the interplay between topology and criticality across equilibrium and non-equilibrium settings, alongside experimental validation of these phenomena. Using large-scale numerics and field theory, we demonstrate that one-dimensional (1D) gapless symmetry-protected topological (gSPT) states host topologically protected edge degeneracy encoded in their entanglement spectra, establishing a universal bulk-edge correspondence [1]. Beyond equilibrium, we generalize gSPT physics to critical steady states in measurement-only quantum circuits [2], uncovering a symmetry-enriched percolation criticality characterized by edge modes and nonlocal string operators. Experimentally, we employ programmable superconducting quantum processors to directly probe gapless topology [3]. By preparing critical states and measuring the boundary g-function and bulk entanglement spectrum, we observe a nontrivial $g = \sqrt{2}$ and twofold degeneracy in the entanglement spectrum for the critical cluster-Ising chain, verifying previous theoretical predictions. Furthermore, we construct a concrete 1D lattice model where deconfined criticality manifests as a gapless topological state with robust edge modes near the boundary [4]. Our work underscores the universality of topology in quantum critical systems, bridging theory, simulation, and experiment to advance the exploration of complex quantum matter.

1. Xue-Jia Yu, Sheng Yang, Hai-Qing Lin, and Shao-Kai Jian, Phys. Rev. Lett. **133**, 026601 (2024).
2. Xue-Jia Yu, Sheng Yang, Shuo Liu, Hai-Qing Lin, and Shao-Kai Jian, arXiv:2501.03851
3. Ziqi Tan, Ke Wang et al., arXiv:2501.04679
4. Sheng Yang, Fu Xu, Da-Chuan Lu, Yi-Zhuang You, Hai-Qing Lin, and Xue-Jia Yu, arXiv:2503.01198

QUANTUM LIANG INFORMATION FLOW PROBE OF CAUSALITY ACROSS CRITICAL POINTS

Roopayan Ghosh[1,2], Bin Yi[2,3], Sougato Bose[2]

1 School of Basic Sciences, Indian Institute of Technology, Bhubaneswar, 752050, India
2 Department of Physics and Astronomy University College London, *Gower Street*, *London*, *WC1E 6BT*, *United Kingdom*
3 Institute of Fundamental and Frontier Sciences, *University of Electronic Science and Technology of China*, *Chengdu 610051*, *China*

Investigating causation in the quantum domain is crucial. Despite numerous studies of correlations in quantum many-body systems, causation, which is very distinct from correlations, has hardly been studied. We address this by demonstrating the efficacy of the newly established causation measure, quantum Liang information flow, in quantifying causality across phase diagrams of quantum many-body systems. We focus on quantum criticality, which are highly non-classical points. We extract causation behavior across a spectrum-wide critical point and a ground state second-order phase transition in both integrable and non-integrable systems. Across criticality, each case exhibits distinct hallmarks, different from correlation measures. We also deduce that quantum causation qualitatively follows the quasiparticle picture of information propagation in integrable systems but exhibits enhanced quantum non-locality near criticality. At times significantly larger than the spatial separation, it extracts additional features from the equilibrium wavefunction, leading to a peak just before the critical point for near boundary sites.

9h35
Thu
2

1. R. Ghosh, B. Yi and S. Bose , Phys. Rev. Lett. **134**, 150202 (2025).
2. B. Yi and S. Bose , Phys. Rev. Lett. **129**, 020501 (2022).

BOUND STATES AND LOCAL TOPOLOGICAL PHASE DIAGRAM OF CLASSICAL IMPURITY SPINS COUPLED TO A CHERN INSULATOR

S. Michel[1], A. Fünfhaus[2], R. Quade[1], R. Valentí[2], M. Potthoff[1,3]

1 Department of Physics, University of Hamburg, Hamburg, Germany
2 Goethe University Frankfurt, Frankfurt am Main, Germany
3 The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

9h55
Thu
3

We consider magnetic impurities modeled as classical unit-length spins that are exchange coupled to the spinful Haldane model and study the spectral flow of bound states with the coupling strength J. In addition to conventional k-space topology, an additional, spatially local topological feature is available, based on the space of impurity-spin configurations. Global k-space and local S-space topology are represented by different Chern invariants. We demonstrate that there is a local S-space topological transition as a function of J associated with a change in the spin-Chern number and work out the implications for the J-dependent local electronic structure close to the impurities and, in particular, for in-gap bound states. The critical exchange couplings' dependence on the parameters of the Haldane model, and thus on the k-space topological state, is obtained numerically to construct local topological phase diagrams for systems with R = 1 and 2 impurity spins.

1. Simon Michel, Axel Fünfhaus, Robin Quade, Roser Valentí, and Michael Potthoff, Phys. Rev. B **109**, 155116 (2024).

ENTANGLEMENT ENTROPY AT DECONFINED AND GROSS-NEVEU CRITICAL POINTS

Jonathan D'Emidio

Department of Physics and Astronomy, University of Tennessee, Knoxville

The structure of entanglement underpins much of our understanding of modern condensed matter physics. The most basic measure, the entanglement entropy, displays universal properties that offer a unique characterization of quantum many-body systems. In this talk I will introduce a new technique for computing entanglement entropy in quantum Monte Carlo simulations, based on the concept of nonequilibrium work to compute free energy differences, which allows for precise calculations of unprecedented size. As an application of this approach, I will present results on a two-dimensional quantum spin model for deconfined criticality, where emergent symmetry is observed at the critical point between two disparate ordered phases. Finally, I will show how this methodology can be successfully adapted to study two-dimensional models of interacting fermions. This is applied to the Hubbard model on the honeycomb lattice, which realizes a Dirac semi-metal phase separated by a Gross-Neveu transition from an antiferromagnetic Mott insulator. I will present results throughout the phase diagram and at the critical point of this model, where universal logarithmic terms of the entanglement entropy are observed for the first time.

10h40
Thu
4

1. J. D'Emidio, Phys. Rev. Lett. **124**, 110602 (2020).
2. J. D'Emidio, R. Orús, N. Laflorencie, F. de Juan, Phys. Rev. Lett. **132**, 076502 (2024).
3. J. D'Emidio, A. W. Sandvik, Phys. Rev. Lett. **133**, 166702 (2024).

MARKOV INEQUALITY AS A TOOL FOR A LINEAR-SCALING ESTIMATION OF LOCAL OBSERVABLES

H. P. Veiga[1], D. R. Pinheiro[1], J. P. Santos Pires[1], J. M. Viana Parente Lopes[1]

1 Centro de Física das Universidades do Minho e do Porto (CF-UM-UP) and Laboratório de Física para Materiais e Tecnologias Emergentes LaPMET, University of Porto, 4169-007 Porto, Portugal

11h15 Thu 5

Probing local observables in quantum systems has become a cornerstone of modern condensed matter physics. Spatially resolved quantities, such as the local density of states, magnetization textures or local currents, offer crucial insights on disordered phases and critical phenomena. We introduce a stochastic method, the random vector fluctuation algorithm (RVFA), that computes entire maps of local observables in large quantum lattice systems. Starting by diagonal matrix elements, we show how the construction of positive-definite estimators rigorously bound statistical errors. Later we generalize this approach to non-diagonal matrix elements. The substantial improvements over conventional approaches are demonstrated on the πs-flux model on the square lattice, subject to both isolated and clustered point defects.

WITNESSING ENTANGLEMENT AND QUANTUM CORRELATIONS IN CONDENSED MATTER

Pontus Laurell[1,2]

1 Department of Physics and Astronomy, University of Missouri, Columbia, Missouri, USA
2 Materials Science and Engineering Institute, University of Missouri, Columbia, Missouri, USA

Entanglement and other nonclassical correlations are ubiquitous in quantum many-body systems, representing resources for quantum information applications and playing a prominent role in the theory of important condensed matter phenomena, such as novel phases of matter. Yet there has been a distinct lack of viable methods to *experimentally* detect these correlations in the solid state, impeding our ability to identify suitable materials and to unravel their secrets. In this talk, I will describe recent progress towards finding and applying suitable measures of these properties in materials, by making use of information “hidden” in spectroscopic data. By employing entanglement witnesses – quantities akin to order parameters for certain classes of entangled states – bi- and multi-partite entanglement has now been observed in a range of condensed matter systems [1]. Such quantum information-theory-informed approaches offer new quantitative insights into many-body states and can provide hints for modeling of enigmatic states in quantum materials.

11h35
Thu
6

1. P. Laurell, A. Scheie, E. Dagotto, and D. A. Tennant, "Witnessing Entanglement and Quantum Correlations in Condensed Matter: A Review", Adv. Quantum Technol. **8**, 202400196 (2025).

OBSERVATION OF DETECTOR-INDUCED ANDERSON ORTHOGONALITY CATASTROPHE IN QUANTUM DOTS

S. Sankar[1,2], J. Folk[1], E. Sela [2], and Y. Meir[1]

1 Department of Physics, Ben Gurion University of the Negev, Beer Sheva 84105, Israel
2 School of Physics and Astronomy, Tel Aviv University, Tel Aviv 6997801, Israel
3 Department of Physics and Astronomy, University of British Columbia, Vancouver, British Columbia, Canada

12h10
Thu
7

We demonstrate unambiguous direct observation of Anderson orthogonality catastrophe (AOC) effects in a quantum dot coupled to a charge detector. We develop a theoretical approach that allows estimation the strength of the AOC power-law exponent α, using easy-to-measure observables, which have a robust dependence on α in the non-equilibrium regime. We show experimental data that, in agreement with the theoretical predictions, allows direct probe of the interaction between the detector and the system

1. S. Sankar et al., https://arxiv.org/pdf/2507.03763
2. J. Folk et al., in preparation.

SURFACES GO TOPOLOGICAL – ATOMIC MONOLAYERS AS 2D QUANTUM MATERIALS

R. Claessen

Physikalisches Institut and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, Würzburg, Germany

Confining electrons to two dimensions (2D) is known to enhance electronic correlations and promote non-trivial topological phases. Atomic monolayers on semiconductor substrates represent the ultimate 2D limit of such confinement and thus have recently come into focus as third-generation 2D designer quantum materials, following the examples of graphene and monolayer transition metal dichalcogenides. Here I will focus on atomic monolayers as 2D topological insulators (2D-TIs) which host 1D metallic and spin-polarized edge states as hallmark of the quantum spin Hall (QSH) effect. My examples range from bismuthene (Bi/SiC(0001)) [1-3], the 2D-TI with the largest band gap realized to date, to indenene (In/SiC(0001)), a triangular lattice of In atoms with emergent honeycomb physics [4,5]. Using ARPES as well as STM/STS we have studied their electronic structure and especially their topological edge states, revealing interesting insights into their protection (or loss thereof) against single particle backscattering. I will further demonstrate how the non-trivial topological character of these monolayers can also be derived from spectroscopic information on the *bulk* (rather than edge) states [4,6]. Finally, I will discuss the stabilization of these monolayers in ambient conditions via van der Waals capping [6,7], paving the way towards *ex situ* experiments and the realization of transport devices.

15h00
Thu
8

1. Science **357**, 287 (2017).
2. Nat. Phys. **16**, 47 (2020).
3. Nat. Commun. **13**, 3480 (2022).
4. Nat. Commun. **12**, 5396 (2021).
5. asrXiv:2503.11497.
6. Phys. Rev. Lett. **132**, 196401 (2024).
7. Nat. Commun. **15**, 1486 (2024).
8. arXiv:2502.01592; Adv. Mat. (accepted).

NEW PLATFORMS FOR MOIRÉ SYSTEMS

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3 IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

16h00
Thu
9

I will show that materials whereby the M and not the K point is twisted lead to an entirely new class of quantum Hamiltonians. Unlike the K point twisting of twisted bilayer graphene or TMD's, the M symmetries act differently, and distinct valence bond solids and spin liquids can show up as ground states. We should that materials, which have been already exfoliated and twisted, can support these states.

Friday, 31 October

CONFINED AND DECONFINED SPIN KINKS IN QUASI-ONE-DIMENSIONAL SPIN MATERIALS

Xi-Wen Guan[1], Fa-Kai Wen[2], Jun Zhao[3], Hai-Qing Lin [4]

1 Innovation Academy for Precision Measurement Science and Technology, Chinese Academy of Sciences
2 Department of Physics, Yunnan Normal University, China
3 Department of Physics, Fudan University, China
4 School of Physics, Zhejiang University, China

9h00
Fri
1

In the one-dimensional (1D) antiferromagnetic spin-1/2 chain, the elementary excitation is known as the continuum of two spinons, fractionalized quasiparticles responsible for spin fluctuation. Spinons behave as a Tomonaga-Luttinger liquid at low energy, and service as rich resources in quantum metrology. On the other hand, in recent years there have been great deal of interest in confinement of such quasiparticles in spin-1/2 Ising-like quasi-1D antiferromagnets, leading to the exotic emergent E8 massive spectra in compounds CoNb2O6 and BaCo2V2O8. In this talk I will first briefly discuss historical growth of interest in confined and deconfined spin kinks and recent development of thermodynamics of the 1D Heisenberg spin chains. Then I will present in detail a many-body perturbation theory for analytical calculation of the spin dynamical structure factor (DSF) of the confined quasiparticles in two quasi-1D compounds Sr/BaCo2V2O8. Our results reveal significant microscopic origin of the confined kinks and further describe the experimental observation of the DSFs of the E8-like spectra in these compounds.

APPLICATIONS OF THE GENERALIZED BLOCH THEOREM FORMALISM: FROM DETECTING MAJORANA FERMIONS TO UNDERSTANDING NON-HERMITIAN IMPURITIES

B. Hetényi[1,2], A. Lászlóffy[2], K. Penc[2], B. Újfalussy[2], and B. Dóra[3]

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2 Quantum Materials Research Group, HUN-REN Wigner Research Centre for Physics, Budapest, Hungary
3 MTA-BME Lendület "Momentum" Open Quantum Systems Research Group, Institute of Physics, Budapest University of Technology and Economics, Műegyetem rkp. 3., H-1111, Budapest, Hungary

Recently an interesting generalization of the Bloch theorem was developed [1,2]: a formalism was derived to analyze the localization of edge states in systems in which there are repeating unit cells, but the translational symmetry is broken by the boundaries. Around the same time, a formalism for non-Hermitian systems was also developed [3,4] to understand localization effects unique to such systems, for example the non-Hermitian skin effect. We will chronicle the strong connections between these two formalisms. We then use the formalism to generize the Zak phase to a system with open boundaries. We then analyze the numerical detection of Majorana fermions at the edge of a Kitaev wire or around a bond impurity. We also present our results for a simple Hermitian tight-binding model with a single non-Hermitian bond impurity. We show that a non-Hermitian skin effect develops near the impurity, and it persists even when the "thermodynamic limit" is taken, meaning that the size of the Hermitian host lattice is taken to infinity.

9h35
Fri
2

1. A. Alase, E. Cobanera, G. Ortiz, and L. Viola, "Exact Solution of Quadratic Fermionic Hamiltonians for Arbitrary Boundary Conditions", *Phys. Rev. Lett.* **117** 076804 (2016).
2. A. Alase, E. Cobanera, G. Ortiz, and L. Viola, "Generalization of Bloch's theorem for arbitrary boundary conditions: Theory", *Phys. Rev. B* **96** 195133 (2017).
3. S. Yao and Z. Wang, "Edge States and Topological Invariants in Non-Hermitian Systems", *Phys. Rev. Lett.* **121** 086803 (2018).
4. K. Yokomizo and S. Murakami, "Non-Bloch Band Theory of Non-Hermitian Systems"", *Phys. Rev. Lett.* **123**, 066404 (2019).
5. B. Hetényi, A. Lászlóffy, K. Penc, and B. Újfalussy, "Topological indicators for systems with open boundaries: Application to the Kitaev wire" *Phys. Rev. B* **112** 075115 (2025).
6. B. Hetényi and B. Dóra, "Localized states and skin effect around non-Hermitian impurities in tight-binding models", *Phys. Rev. B* **112** 075123 (2025).

SCATTERING THEORY OF HIGHER ORDER TOPOLOGICAL PHASES

R. Johanna Zijderveld[1], Isidora Araya Day[1,2], Anton R. Akhmerov[1]

1 Kavli Institute of Nanoscience, Delft University of Technology, 2600 GA Delft, The Netherlands
2 QuTech, Delft University of Technology, Delft 2600 GA, The Netherlands

9h55 Fri 3

Intrinsic higher order topological insulators (HOTIs) have edge states protected by the global symmetry of the sample. We advance the understanding of HOTIs by developing a theory of scattering topological invariants. Because our approach utilizes the global symmetry properties, it establishes the bulk-edge correspondence. Our work makes it possible to study intrinsic HOTIs in the presence of disoder as well as quasi-crystalline and amorphous HOTIs. In this talk, I will demonstrate the logic behind the general approach by using $C_4\mathcal{T}$ symmetry as an example.

CHIRAL STATES IN CLASSICAL AND QUANTUM SPIN MODELS

Judit Romhányi[1], Péter Kránitz[2,3,4], Yasir Iqbal[3], Karlo Penc[2,3]

1 University of California, Irvine, USA
2 HUN-REN Wigner Research Centre for Physics, Budapest, Hungary
3 Indian Institute of Technology Madras, Chennai, India
4 Budapest University of Technology and Economics, Budapest, Hungary

Frustrated magnets provide fertile ground for unconventional orders and emergent excitations. In particular, chiral states break time-reversal symmetry and host emergent gauge fluxes that can endow quasiparticles with nontrivial topology [1,2,3]. Here, we explore two complementary aspects: topological magnon transport and exactly solvable spin models.

On the triangular lattice, we study a spin-1/2 isotropic Heisenberg model with further-neighbor exchanges and ring exchange. The four-site ring exchange stabilizes a chiral four-sublattice noncoplanar order, which generates finite Berry curvature in the magnon bands and produces a thermal Hall effect even without Dzyaloshinskii–Moriya interactions. Using variational methods, we further show that this ordered phase can melt into a chiral spin liquid, continuously connected to the $U(1)$ Dirac spin liquid in the absence of ring exchange.

10h55
Fri
4

In parallel, we construct a class of SU(2)-symmetric spin-S Hamiltonians whose ground states form an extensively degenerate manifold of chiral product wave functions. These exact ground states arise from spin-coherent states obeying a four-coloring rule on tetrahedral units. The construction naturally generalizes to a broad family of four-site Hamiltonians, applicable to lattices of corner- or edge-sharing tetrahedra such as the pyrochlore [4] and the fcc lattices, to the honeycomb lattice with first- and second-neighbor interactions built from distorted tetrahedra, and even to the triangular lattice mentioned above. This framework provides a versatile platform for exploring chiral and multipolar orders across both two- and three-dimensional frustrated magnets.

1. H. Katsura, N. Nagaosa, and P. A. Lee, Phys. Rev. Lett. **104**, 066403 (2010).
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3. A. Mook, J. Henk, and I. Mertig, Phys. Rev. B **89**, 134409 (2014).
4. D. Lozano-Gómez, Y. Iqbal, and M. Vojta, Nat. Commun. **15**, 10162 (2024).

PRECISE QUANTUM-GEOMETRIC ELECTRONIC PROPERTIES FROM FIRST PRINCIPLES

José Luís Martins[1,2], Carlos L. Reis[2], Ivo Souza[3,4]

1 Departamento de Física, Instituto Superior Técnico, Lisboa, Portugal
2 INESC MN, Lisboa, Portugal
3 Centro de Física de Materiales, Universidad del País Vasco, San Sebastían, Spain
4 Ikerbasque Foundation, Bilbao, Spain

11h30 Fri 5

The direct calculation of quantum-geometric quantities, Berry curvature, quantum metric, orbital magnetic moment and effective masses, was implemented in a pseudopotential plane-wave code. The starting point was the derivative of the wave-function $\psi(k)$ with respect to the wave-vector k obtained with perturbation theory. The case of degenerate levels, where the quantum-geometric quantities are tensors with two spatial indexes and two orbital indexes, was taken into account. The method was tested with calculations for gapped graphene and tellurium. Comparison of effective masses calculated by perturbation theory for silicon and gallium arsenide with convergence tests of numerical second derivatives of band energies, and with convergence of $k.p$ methods with matrix size, confirm the precision of the procedure. The open source code is available at https://github.com/jlm785/cpw2000.

MOLECULAR QUANTUM MATERIALS FROM FIRST PRINCIPLES

J. Wu[1], L. W. Pingen[2], A. Sanders[3], R. Yuan[3], T. K. Dickens[1], M. Pizzochero[4], B. Peng[3]

[1] *Peterhouse, University of Cambridge, UK*
[2] *Trinity College, University of Cambridge, UK*
[3] *Theory of Condensed Matter Group, Cavendish Laboratory, University of Cambridge, UK*
[4] *Department of Physics, University of Bath, UK*

Molecular building blocks provide a versatile platform for exploring exotic quantum phases and complex many-body physics. Here we demonstrate a showcase system based on pure-carbon, charge-neutral fullerene networks, which can be constructed from a molecular synthon with quantised spins due to the resonance structures. We report a rich variety of condensed matter models that are challenging to realise, including (1) antiferromagnetic spin-1/2 chains in Janus fullerene nanoribbons, (2) ferromagnetic Haldane fullerene monolayers, and (3) altermagnetic Shastry-Sutherland fullerene networks that can be continuously tuned into a quantum spin liquid phase. Our findings open a new frontier for exploring quantum phenomena based on scalable, chemically-stable, molecular building units that can potentially operate at room temperature.

1. L. Hou, *et al.* Nature **606**, 507 (2022).
2. E. Meirzadeh, *et al.* Nature **613**, 71 (2023).
3. B. Peng, J. Am. Chem. Soc. **144**, 19921 (2022).
4. C. Jones & B. Peng, J. Phys. Chem. Lett. **14**, 11768 (2023). Front Cover.
5. J. Wu & B. Peng, J. Am. Chem. Soc. **147**, 1749 (2025). Front Cover.
6. D. Shearsby, J. Wu, D. Yang & B. Peng*, *Nanoscale (invited)* **17**, 2616 (2025).
7. T. Wang, *et al.* Angew. Chem. Int. Ed. **62**, e202311352 (2023).
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9. D. Kayley & B. Peng, Comput. Mater. Today (invited) **6**, 100030 (2025).
10. A. Shaikh, J. Wu & B. Peng, Phys. Rev. Lett. (doi: 10.1103/tck2-78dx).
11. J. Wu, L. W. Pingen, T. K. Dickens & B. Peng, arXiv:2508.18125.
12. B. Peng & M. Pizzochero, Chem. Commun. (invited Feature) **61**, 10287 (2025).
13. B. Peng & M. Pizzochero, ACS Nano **19**, 29637 (2025).
14. B. Peng & M. Pizzochero, arXiv:2508.18849.
15. L. W. Pingen, J. Wu & B. Peng, arXiv:2508.19849.
16. J. Wu, A. Sanders, R. Yuan & B. Peng, arXiv:2508.21056.

11h50
Fri
6

ABSTRACTS OF THE POSTER PRESENTATIONS

Poster session I

RELEVANCE OF ELECTRONIC INTERACTIONS AT QUASIPERIODICITY-DRIVEN LOCALIZATION TRANSITIONS

Mariana Abreu[1], Pedro Ribeiro[1,2], Bruno Amorim[3]

1 CeFEMA, Instituto Superior Técnico, University of Lisbon
2 Department of Physics, Instituto Superior Técnico
3 Department of Physics, University of Minho

The effect of incommensurate/quasiperiodic modulations in crystals can dramatically change the nature of the quantum wavefunction. Upon increasing the strength of quasiperiodicity, electronic wave-functions can become localized/confined to a specific spatial region, in contrast with pristine crystals, where they extend throughout the system in the form of plane waves. The simplest model that captures the transition between extended and localized phases at a critical strength of quasiperiodic modulation is the celebrated Aubry-André model. This is a one-dimensional model of non-interacting tight-binding fermions in a cosine potential that is incommensurate with the lattice, which has a remarkable duality between localized and delocalized states. In a series of works, we showed that this duality, previously thought to be fine-tuned, is actually generic for many families of models but "hides" near the localization/delocalization transition [1, 2]. Recently, we extended our study to localization transitions in one-dimensional systems of interacting spinless fermions. Interestingly, we showed that interactions of this type are irrelevant around the transition [3]. Furthermore, we found in this case the same scenario of hidden dualities that underlies non-interacting localization transitions. We achieved these results using a combination of numerical methods, finite-size scaling of correlation functions (Chalker scaling [4]), and renormalization group arguments. In this project, we study the role of electronic (i.e. spinful) interactions at the delocalization transition. Our goal is to determine if this type of interactions become relevant at the transition, as observed in disorder-driven transitions at higher dimensions [5], or if it remains irrelevant, as in the spinless case. We will also study whether hidden dualities emerge around this transition, and try to generalize our renormalization group method to this crucial case. The outcome of this work will allow us to understand if quasiperiodicity-driven localization transitions can always be well described by a non-interacting theory or if interactions may change the nature of this quantum phase transition.

PSI
1

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5. D. Belitz and T. R. Kirkpatrick, Rev. Mod. Phys. 66, 261 (1994)

POLARITON-ASSISTED SECOND-HARMONIC GENERATION IN GRAPHENE

João M. Alendouro Pinho[1], Simão S. Cardoso[2], Yuliy V. Bludov[2], João Viana Lopes[1], Vladimir V. Konotop[3], Joel D. Cox[4,5], Nuno M. R. Peres[2,4,6]

1 Centre of Physics of the Universities of Minho and Porto, Laboratory of Physics for Materials and Emergent Technologies (LaPMET), and Faculty of Science, University of Porto, Campo Alegre, 4169-007, Porto, Portugal
2 Centre of Physics of the Universities of Minho and Porto, Laboratory of Physics for Materials and Emergent Technologies (LaPMET), and Department of Physics, University of Minho, Campus of Gualtar, 4710-057, Braga, Portugal
3 Department of Physics, Center for Theoretical and Computational Physics, University of Lisbon, Campo Grande, C8, 1749-016, Lisbon, Portugal
4 POLIMA—Center for Polariton-driven Light–Matter Interactions, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark
5 Danish Institute for Advanced Study, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark
6 International Iberian Nanotechnology Laboratory (INL), Av. Mestre José Veiga, 4715-330 Braga, Portugal

PSI
2

We present a theoretical examination of second harmonic generation (SHG) in a graphene monolayer integrated within an attenuated total internal reflection (ATR) configuration. By embedding graphene in this optical setup, we explore the enhancement in nonlinear optical response, particularly focusing on the efficiency of SHG. Our analysis reveals that the excitation of surface plasmon-polaritons (SPPs) plays a central role in significantly boosting the efficiency of SHG. The unique electronic properties of graphene, combined with the resonant characteristics of SPPs, create a synergistic effect that amplifies the nonlinear optical signals. This enhancement is attributed to the strong field confinement and the resonant nature of SPPs, which effectively increase the interaction between the incident light and the graphene monolayer. Furthermore, we analyse the underlying mechanisms that govern this process, providing a comprehensive theoretical framework that elucidates the interplay between graphene's electronic structure and the optical fields. Our findings suggest that the ATR scheme not only facilitates the excitation of SPPs but also optimizes the conditions for SHG.

HYPERBOLIC PLASMON DISPERSION AND OPTICAL CONDUCTIVITY OF HOLEY GRAPHENE: SIGNATURES OF FLAT-BANDS

A. de J. Espinosa-Champo[1], G. G. Naumis[1,2]

[1] *Posgrado de Ciencias Físicas, Universidad Nacional Autónoma de México, Apartado Postal 20-364, 01000 Ciudad de México, México.*
[2] *Depto. de Sistemas Complejos, Instituto de Física, Universidad Nacional Autónoma de México (UNAM), Apdo. Postal 20-364, 01000 CDMX, México.*

PSI
3

Holey graphene (HG) is a two-dimensional (2D) material that has attracted considerable attention due to its electrical, thermal, and mechanical properties. The recent discovery of flat bands in HG has garnered significant interest. In this work, we systematically investigate the tunable plasmonic modes and optical conductivity of HG at or near the flat band condition by changing the holes radii and periodic configuration. It is found that HG presents nearly flat plasmonic bands in configurations with larger hole radii. Hyperbolic plasmons are found due to the breaking of the graphene's bipartite sublattice symmetry induced by the holes. Such an effect is also confirmed by looking at the optical conductivity that also presents a marked anisotropy. The material's marked optical anisotropy leads to hyperbolic plasmons, making it a promising platform for nanophotonic applications.

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2. A. de J. Espinosa-Champo and G. G. Naumis, *arXiv:2507.23103* (2025).

ENHANCEMENT OF LOW FREQUENCY OPTICAL CONDUCTIVITY OF THE AUBRY-ANDRÉ MODEL

Raul Liquito[1], Miguel Gonçalves[2], Eduardo V. Castro[1,3]

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2 Princeton Center for Theoretical Science, Princeton University, Princeton NJ 08544, USA
3 Beijing Computational Science and Research Center, Beijing 100084, China

Moiré materials, such as, Twisted Bilayer Graphene (tBLG), exhibit exotic physical properties, such as delocalized eigenstates in momentum and real space in the narrow band regime, unconventional superconductivity, and other intriguing, strongly correlated phases.
Moiré materials derive their name from the characteristic moiré pattern that emerges due to lattice misalignment. However, these systems are inherently quasiperiodic, lacking true atomic periodicity. This quasiperiodicity poses a significant computational and theoretical challenge as reciprocal-space models fail to capture it, necessitating real-space approaches. Furthermore, large-scale simulations of these materials require handling systems with billions of atoms.
This work studies two 1D quasiperiodic models at the single particle level: the prototypical Aubry-André model and a model hosting a flat band. The quasiperiodic potential introduces a 1D Moiré pattern, mimicking atomic quasiperiodicity. Our objective is to identify unique signatures of quasiperiodicity in experimentally accessible observables. Specifically, we analyzed the temperature-dependent Drude weight and the terahertz conductivity using Kubo formalism, comparing results between quasiperiodic and periodic regimes - akin to tuning tBLG to commensurate twist angles [1]. At low temperatures ($\approx 10mK$, exhibits a clear signature of a multi-band metal, characterized by multiple peaks and optical gaps at finite frequency. However, a clear distinction is observed in the metal-insulator transition of both models: in quasiperiodic models, transport properties are rapidly suppressed, even at finite frequencies, whereas their periodic counterparts retain metallic behavior. At higher temperatures ($\approx 50K$), a single peak emerges at finite frequency, which is exponentially suppressed after the transition.
As a natural extension of this work, we aim to explore how these quasiperiodic effects translate into 2D moiré materials. In particular, recent results [2] show that sub-ballistic states appear in the narrow-band regime of tBLG, highlighting the need for quantities capable of distinguishing between perfectly periodic and atomic quasiperiodic systems. We aim to implement Kernel Polynomial method with Quantics Tensor Cross interpolation to calculate optical responses of quasiperiodic moiré materials with billions of atoms [3,4].

PSI
4

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SYMMETRY AND SPONTANEOUS SYMMETRY BREAKING IN MOLECULES: SELECTED ASPECTS

T. H. Seligman, A. Jalboud, P. Majari, Y. P. Ortiz, and K. Uriosteguí

Centro Internacional de Ciencias, Cuernavaca, México

We discuss some little-known facts about symmetry breaking in graphene flakes and chains. In particular, we shall show DFT calculations for static and dynamic behaviour for the adsorption of Li to these surfaces[1,2]. On the other hand, the behaviour of graphene strips under symmetry breaking is illustrated by forming both normal rings and Möbius rings from polyacene strips. The degeneracies of these strips are known, but for the rings, we find that the degeneracies for even and odd numbers of benzene rings are radially different, and this difference persists in the infinite limit. [3] Finally, some recent results on transport through triangulene are shown [4].

PSI
5

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TRANSPORT THROUGH A CRITICAL MAGNETIC QUANTUM DOT AWAY FROM EQUILIBRIUM

Tiago Jorge[1], Pedro Ribeiro[1], Jens Paaske[2]

1 CeFEMA-LaPMET, Departamento de FÃsica, Instituto Superior TÃ©cnico, Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal
2 Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

Systems out of thermal equilibrum, like electronic transport setups, bring novel paradigms for studying quantum matter and its phases transitions, with properties not possible under equilibrium conditions. While a comprehensive body of work has addressed the so-called Markovian regime where the memory of the environment is much shorter than the typical system's time scales, the non-Markovian regime remains widely unexplored. The current project aims to fill in some of these gaps by investigating non-equilibrium phase transitions in a voltage-biased magnetic quantum dot. This model is directly relevant to understanding the transport and magnetic properties of quantum spintronic devices in systems near criticality.
Using a Keldysh path integral approach, we develop a theoretical framework describing the dots' collective degrees of freedom as they undergo a quantum phase transition under an applied bias voltage, connecting the equilibrium and Markovian (high temperature/bias) regimes. We analytically derive a mean-field phase diagram revealing both first and second order phase transitions out of equilibrium. By analyzing fluctuations, we find we can extend the fluctuation-dissipation theorem to define an effective temperature to describe the system. However, this picture breaks down when we look at late-time correlations, which are described by a power-law oscillating decay, unique to the quantum out-of-equilibrium phases. Finally, we develop a ϕ^4 theory for the system and a corresponding stochastic semi-classical equation of motion, uncovering dissipative order parameter dynamics under an effective free energy.

OPTOELECTRONIC SUPERLATTICES BASED ON 2D TRANSITION METAL DICHALCOGENIDES

D.-N. Liu[1], Y. Guo[1]

[1] *Department of Physics and State Key Laboratory of Low-Dimensional Quantum Physics, Tsinghua University, Beijing 100084, P.R. China*

PSI 7

Optoelectronic superlattices are proposed based on two-dimensional transition metal dichalcogenides, which can be realized by periodically superimposed, interlaced, or alternate modulations of the gate voltage and the off-resonant right circularly polarized light. Owing to the huge band gap and spin-orbit coupling, the propagation of electrons through the gate-tunable WSe_2 superlattice under the optical field becomes highly valley-dependent, i.e., the transmission and conductance are suppressed for the K valley but enhanced remarkably for the K' valley. Moreover, it is shown that the properties of the line-type resonant peaks are extremely sensitive to the valley and spin degrees of freedom, the period number of the superlattice, and the mode of modulated external fields, and can be further drastically adjusted by the width of the modulated region. This work may shed light on potential applications of the optoelectronic superlattices in the fields of valleytronics and spintronics.

IMPURITY FLAT BAND STATES IN THE DIAMOND CHAIN

A. M. Marques[1], D. Viedma[2], V. Ahufinger[2], R. G. Dias[1]

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2 Departament de Física, Universitat Autònoma de Barcelona, Bellaterra, Spain

Flat band systems, characterized by dispersionless energy bands and compact localized states (CLSs), exhibit intriguing physical properties when subject to local perturbations [1,2]. In this work, we study a diamond chain pierced by a finite magnetic flux per plaquette, featuring a gapped mid-spectrum flat band composed of non-orthogonal CLSs. We develop a general framework for projecting operators onto non-orthogonal bases [3] and apply it to the analysis of local impurities introduced at the midchain plaquette. Analytical solutions are derived for impurity-induced states, which are validated through numerical simulations [1].
We show that for equal impurities, disorder averaging leads to an effective robustness of impurity states against diagonal disorder, consistent with the central limit theorem [1]. For a single impurity, the system enters an exotic topological phase characterized by a half-integer winding number and a $\pi/2$-quantized Zak phase, revealing a refined bulk-boundary correspondence manifested by a single in-gap edge state in a mapped two-dimensional Lieb lattice [1], with the momentum along the periodic direction playing the role of the flux. These results provide the first example of a Hermitian system displaying half-integer topological invariants, opening new paths for the exploration of flat-band and impurity-induced topological phenomena [2].

PSI
8

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GRAPHENE UNDER LATERAL SPIN-ORBIT SUPERLATTICES: SYMMETRY-PROTECTED DIRAC CONES AND HOT SPOTS OF SPIN BERRY CURVATURE IN 2D VAN DER WAALS METAMATERIALS.

L. M. Martelo[1,2], A. F. Ferreira[3]

1 Departamento de Engenharia Química e Biológica, Área de Engenharia Física, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
2 Centro de Física do Porto, Rua do Campo Alegre, 687, 4169-007 Porto, Portugal
3 School of Physics, Engineering and Technology and York Centre for Quantum Technologies, University of York, YO10 5DD, York, United Kingdom

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Proximity effects in two-dimensional materials have provided unique opportunities for basic condensed matter physics to obtain an understanding of emergent electronic properties that otherwise are unachievable. Here, we present a route to realize tunable relativistic band structures based on the lateral patterning of proximity-induced spin-orbit coupling. The concept is illustrated on lateral superlattice fabricated from graphene and transition metal dichalcogenide monolayers, where the spatially periodic spin-orbit coupling induces a rich mini-band structure featuring massless and massive Dirac bands carrying large spin Berry curvature [1]. The envisaged superlattices support robust and gate-tunable spin Hall responses driven by the quantum geometry of mini-bands, which can be tailored through metasurface fabrication methods and twisting effects. These fndings open pathways to two-dimensional quantum material design and low-power spintronic applications.

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ANALYTICAL RESULTS FOR THE QUANTUM DYNAMICS OF ELECTRONS UNDER STRONG FIELDS WITH DISSIPATION

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The theory of open quantum systems is one of the most essential tools for the development of quantum technologies. A particular area of interest is in the optical response of solid-state systems, where dissipation is introduced phenomenologically through the relaxation-time approximation and its effects are usually gauged perturbatively [1–4]. Here, we obtain the analytical solution for a general single-band tight-binding system under the influence of a generic uniform, time-dependent electric field under the relaxation-time approximation. We explore the effects of dissipation in two limiting cases: a monochromatic field, where we analytically deduce the effect of dissipation on high-harmonic generation [5], and a constant electric field, where a generalization of the Esaki–Tsu [6] equation is presented for any single-band tight-binding system. We apply the results to a two-dimensional tilted square lattice with nearest neighbours. The validity of perturbation-theory results for vanishing dissipation is also analyzed against our exact result. We conclude that divergences present in first-order current response are purely artifacts of perturbation theory and do not reflect physical behaviour.

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SYMMETRY AND SPONTANEOUS SYMMETRY BREAKING IN MOLECULES: SELECTED ASPECTS

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We discuss some little-known facts about symmetry breaking in graphene flakes and chains. In particular, we shall show DFT calculations for static and dynamic behaviour for the adsorption of Li to these surfaces [1,2]. On the other hand, the behaviour of graphene strips under symmetry breaking is illustrated by forming both normal rings and Möbius rings from polyacene strips. The degeneracies of these strips are known, but for the rings, we find that the degeneracies for even and odd numbers of benzene rings are radially different, and this difference persists in the infinite limit [3]. Finally, some recent results on transport through triangulene are shown [4].

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NON-LINEAR HALL EFFECT: FROM THEORY TO EXPERIMENT

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The Non-Linear Hall Effect (NLHE) represents a novel class of Hall-like phenomena that emerge without the need for time-reversal symmetry breaking, distinguishing it from conventional Hall effects. It consists of a transverse electric response which has a second-order contribution on the applied longitudinal current and arises from both intrinsic and extrinsic contributions. The intrinsic contribution is connected to the dipole moment of the Berry curvature in momentum space, while the extrinsic contribution arises from the scattering sources in the system. This study aims to explore how this second-order response manifests in time-reversal invariant and inversion-breaking materials when subjected to an external electric field. Using semiclassical Boltzmann transport theory within the framework of the tilted 2D massive Dirac model, we investigate the influence of impurity scattering, as well as electron-phonon scattering, allowing us to study the effect of temperature variation. Experimentally, a modified conventional Hall setup with an AC current and lock-in amplifiers is employed to study Bi_2Se_3 samples. This study opens new pathways for investigating the topological and symmetry properties of emergent quantum materials.

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BULK IMPURITIES/VACANCIES IN NODAL LOOP SEMIMETALS

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Weyl nodal loop semimetals are topological semimetals where the valence and conduction bands linearly touch along one dimensional loops in momentum space. A manifestation of their non-trivial topology is the presence of zero energy surface states, induced by chiral symmetry, on surfaces parallel to the loop plane. Unlike their insulator counterparts, these exotic phases may be unstable to small perturbations that respect their topology-protecting symmetries. Results for symmetry-breaking disorder have been reported [1]. However, vacancies preserve chiral symmetry, and remain a largely open problem.

Here, we will discuss the effects of impurities and vacancies in the bulk of a Weyl nodal loop semimetal [1]. In an effective low energy model for a nodal loop, an analytical approach is tractable. We focus on the changes in the density of states (DOS), computed via a projected Green's function formalism, and study the localization of the impurity-induced bound states. We have found that a single cell-impurity induces a peak in the DOS, which traverses zero energy as its strength increases, becoming sharper near the Fermi level, in line with known literature [2]. Contrary to Weyl point semimetals and graphene, our results are consistent with the existence of a finite critical impurity strength that lifts the DOS at zero energy. Moreover, the impurities create bound states, with tails decaying as $\sim r^{-4}$.

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A single cell-vacancy creates broad peaks on both sides of the Fermi level, while the system remains a semimetal. Orbital-vacancies induce a sharp peak at zero energy. Lastly, we also look at the linear optical response of the nodal loop semimetal in the presence of vacancies.

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POLARIZED PHASES AND CHIRAL SUPERCONDUCTIVITY IN MULTILAYER GRAPHENE

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Rhombohedral multilayer graphene systems feature an abundance of correlated phases and superconducting states in experimental measurements. Some of the superconducting pockets can emerge from, or close to, one of these correlated states. This exotic superconductivity emerging from a spin-and-valley-polarized metallic phase has been recently discovered in four-, five-, and six-layer rhombohedral graphene [1,2].
In this work, Hartree–Fock calculations have been performed to build the phase diagram of rhombohedral graphene for different numbers of layers, in the presence of long-range Coulomb interactions. By varying the external displacement field and carrier density, a cascade of metallic partially isospin-polarized phases that spontaneously break spin and/or valley (flavor) symmetries is found [3]. In addition, these states can present nematicity, stabilized by electron–electron interactions, exhibiting rich internal complexity. Polarized states are more stable for electron doping, and they are found for systems with up to 20 layers.
Though mean-field Hartree–Fock correctly predicts the isospin flavors and reproduces the experimental phase diagram, it overestimates the band renormalization near the Fermi energy and suppresses superconducting instabilities. To address this, we introduce a physically motivated scheme that includes internal screening in the Hartree–Fock calculation. Using this formalism, we find superconductivity arising from the spin–valley polarized phase on the electron-doped side. Our findings reproduce the experimental observations and reveal a *p*-wave, finite-momentum, time-reversal-symmetry-broken superconducting state, encouraging further investigation into exotic phases in graphene multilayers.

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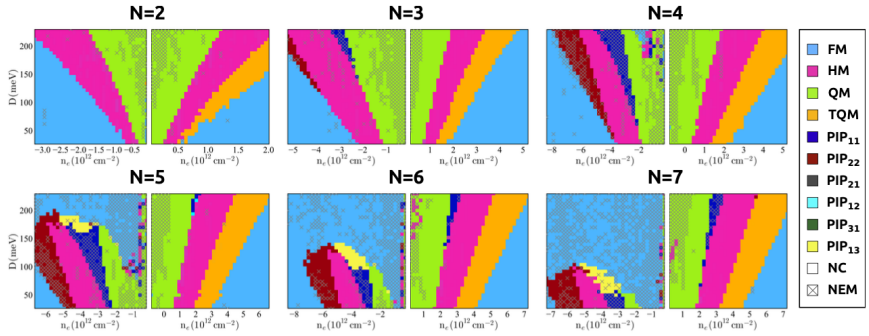

Figure 1: Hartree-Fock phase diagrams for rhombohedral multilayer graphene with different number of layers N.

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FLOQUET-ENHANCED BINDING AND EXOTIC PAIRING STATES IN DOPED MOTT INSULATORS, AND QUANTUM STATE TRANSFER VIA FERMIONIC CHAINS

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We investigate the emergence of bound states in doped Mott insulators, mediated by spin and η-pairing fluctuations in both two-leg ladder and two-dimensional systems. To effectively describe the photo and chemically doped state on the same footings, we employ the Schrieffer-Wolff transformation, resulting in a generalized t-J model. Our findings show that the binding energies and localization lengths are comparable in both doping regimes, with η-pairing fluctuations playing a negligible role. Furthermore, we show that manipulating the binding is possible through external periodic driving, a technique known as Floquet engineering, leading to significantly enhanced binding energies. We also roughly estimate the lifetime of photo-doped states under periodic driving conditions based on the Fermi golden rule.
In the same photo-doped ladder system we identify a novel doublon-holon pairing phase characterized by quasi-long-range correlations with a d-wave-like structure. This phase emerges between the spin-singlet and charge-density-wave η-pairing regimes and reveals rich interplay among charge, spin, and η-spin degrees of freedom. Finally, we look at another aspect of the Fermi-HUbbard model, where we employ it for quantum state transfer between distant spin qubits using engineered spin chains as quantum channels.

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TREATMENT OF ELECTROMAGNETIC PERTURBATIONS ON CRYSTALS THROUGH A SPATIAL MODE ANALYSIS

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In this work, the nonlinear optical response of crystals under a homogeneous electromagnetic perturbation is studied. It is first shown that by applying a gauge transformation to the tight-binding Hamiltonian in the velocity gauge [1], the Hamiltonian becomes periodic in the reciprocal lattice. As a consequence, in this new gauge, all relevant operators can be expanded in a Fourier series. Furthermore, due to the gauge transformation, the phenomenological Bloch equation for the density matrix [2] acquires a new term analogous to the length gauge potential [3]. By expanding the density matrix in a Fourier expansion, we obtained an equation for the spatial Fourier modes of the density matrix in which all modes are coupled. We discuss the procedure to compute the current by simulating a finite number of Fourier modes of the density matrix and estimate the required number of modes necessary to accurately simulate the current by analyzing the time delay between the electromagnetic pulse and the response of the spatial modes. The dependence of this estimation on the energy gap between bands is also examined. Lastly, we compare the optical response obtained from our method with results from direct time integration of the Bloch equations in the velocity gauge [3] and with the predictions made by perturbation theory for first- and second-order conductivities [4]. We wish to thank UID/04650 - Centro de Física das Universidades do Minho e do Porto for financing this work.

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EXACT HARTREE-FOCK BAND STRUCTURE FOR TWISTED TRILAYER GRAPHENE

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Moiré systems have attracted considerable attention due to the many exotic phenomena they exhibit at the so-called magic angles, making them an excellent platform for exploring fundamental questions in physics [1]. The observation of superconductivity in stacks beyond twisted bilayer graphene, namely with three, four and five layers, highlights the relevance of these configurations for further investigation [2].
In order to cover a wider parameter space, we study trilayers with alternating twist angle under hydrostatic pressure at which flat bands appear for angles around 3.5^o. We consider the non-interacting band structure for various hydrostatic pressures with and without relaxation by using the atomistic tight-binding model. Electron interactions are then incorporated via the Hartree-Fock approximation, and the resulting phase diagram is examined as a function of the filling factor, the short-ranged Hubbard and the long-ranged Coulomb interactions, and the interlayer bias. In this analysis, we follow the density-matrix reduction procedure described in Ref. [3].

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Poster session II

UNIVERSALITY, ROBUSTNESS, AND LIMITS OF THE EIGENSTATE THERMALIZATION HYPOTHESIS IN OPEN QUANTUM SYSTEMS

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The eigenstate thermalization hypothesis (ETH) underpins much of our modern understanding of the thermalization of closed quantum many-body systems. Here, we investigate the statistical properties of observables in the eigenbasis of the Lindbladian operator of a Markovian open quantum system. We demonstrate the validity of a *Lindbladian ETH ansatz* through extensive numerical simulations of several physical models. To highlight the robustness of Lindbladian ETH, we consider what we dub the dilute-click regime of the model, in which one postselects only quantum trajectories with a finite fraction of quantum jumps. The average dynamics are generated by a non-trace-preserving Liouvillian, and we show that the Lindbladian ETH ansatz still holds in this case. On the other hand, the no-click limit is a singular point at which the Lindbladian reduces to a doubled non-Hermitian Hamiltonian and Lindbladian ETH breaks down.

GENERALIZED DIMER PHYSICS IN MULTI-LEVEL RYDBERG ATOM ARRAYS

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Many physical systems with local constraints can effectively be described using a dimer model approach. The active degrees of freedom are represented by dimers that live on links connecting sites and the local constraints translate to dimer constraints that limit the number of dimers touching each site. This implies that, unlike say regular quantum spin models, the total Hilbert space cannot be written as a tensor product state of local Hilbert spaces.Â One platform in which dimer models have been proposed to be relevant is Rydberg atom arrays. Rydberg atoms interact predominantly via a dipole-dipole coupling which, in certain regimes, leads to the Rydberg blockade effect [1]. As a result of this effect, two atoms near one another cannot simultaneously occupy a Rydberg excited state. It is then straightforward to make a connection between Rydberg atom arrays and dimer models. Each atom can be interpreted as a dimer and the blockade effect generates the dimer constraints.
Beyond the conventional setup, there are also three-level Rydberg atom arrays [2], and dual species platforms [3], which motivate the study of generalized dimer models, the focus of this work. An extra "color" degree of freedom can be associated with each dimer allowing for a connection with the generalized Rydberg atom arrays. Here, we study a simple toy 2-color dimer model on a 1D ladder lattice, including the possibility of Ising-like color interactions between parallel dimers. Using a mix of exact diagonalization and DMRG numerical methods the full phase diagram of this toy model was obtained in terms of the dimer potential V and Ising coupling J_z. The limiting behaviours of the model were compared with the results of perturbation theory. For the ferromagnetic case ($J_z = -1$) two phases were found, and the model effectively reduces to the conventional (single color) dimer model [4]. For the antiferromagnetic case ($J_z = +1$) four phases were found. For large negative V the theory can be mapped to the 1D spin-1/2 XXZ model. For large positive V we find non-trivial antiferromagnetic order driven by interactions generated at fourth-order in perturbation theory. In addition, two intermediate phases were discovered. One is likely to be connected to a decoupled plaquette phase, while the other may be continuously connected to the phase at large negative V.
To make this toy model more realistic the next steps will be to include a more realistic van der Waals interaction [1]. An extension to quasi two-dimensional lattices is also planned, to explore the impact of lattice geometry and frustration.

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QUANTUM DOUBLES IN SYMMETRIC BLOCKADE STRUCTURES

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Exactly solvable models of topologically ordered phases with non-abelian anyons typically require complicated many-body interactions which do not naturally appear in nature. This motivates the “inverse problem” of quantum many-body physics: given microscopic systems with experimentally realistic two-body interactions, how to design a Hamiltonian that realizes a desired topological phase? We solve this problem on a platform motivated by Rydberg atoms, where elementary two-level systems couple via simple blockade interactions. Within this framework, we construct Hamiltonians that realize topological orders described by non-abelian quantum double models. We analytically prove the existence of topological order in the ground state, and present efficient schemes to prepare these states. We also introduce protocols for the controlled adiabatic braiding of anyonic excitations to probe their non-abelian statistics. Our construction is generic and applies to quantum doubles G for arbitrary groups G. We illustrate braiding for the simplest non-abelian quantum double S_3.

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STRONGLY FIRST ORDER NÉEL-VBS TRANSITION IN THE SU(N) X-Q MODEL

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We study the Néel-Valence Bond Solid (VBS) transition in square-lattice SU(N) quantum antiferromagnets using Stochastic Series Expansion quantum Monte Carlo. The Deconfined Quantum Criticality (DQC) scenario predicts a generically continuous transition between these phases [1], going beyond the conventional Landau-Ginzburg paradigm. Recent numerical studies of the prototypical J-Q and J1-J2 models indicate that the transition is weakly first order for SU(2) [2], but approaches continuity as N increases [3]. Here, we introduce the X-Q model as a new candidate for exploring near-critical DQC behavior in SU(N) systems. In this model, X represents a plaquette next-nearest-neighbor permutation operator. While the transition in the X-Q model remains weakly first order for SU(2), it becomes strongly first order for $N > 2$, contrary to conventional expectations that increasing N should weaken discontinuities. We present these results and discuss their implications for future numerical studies of DQC.

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DOMAIN COARSENING WITH MULTIPOLE CONSERVATION: CASCADE OF CRITICAL EXPONENTS

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We study the dynamics of domain growth in systems where multipole moments of the order parameter are conserved. We focus on the non-equilibrium dynamics following a quench into the ordered phase of the Ising model, where domains expand in a self-similar manner. In the absence of conserved quantities (Glauber dynamics), the linear size of domains grows diffusively in time as $t^{1/2}$. When the order parameter is conserved (Kawasaki dynamics), the domains grow more slowly, as $t^{1/3}$. Additional multipole symmetries, such as conserving the center of mass of the order parameter, impose further kinetic contraints on the dynamics. We distinguish between a regime in which domain growth is frozen entirely and a regime in which growth is merely anomalously slow. In the latter case, we analytically and numerically show that m-pole conservation causes domains to grow as $t^{1/(2m+3)}$. This cascade of dynamical critical exponents characterizes a new nonequilibrium universality class for fractonic systems.

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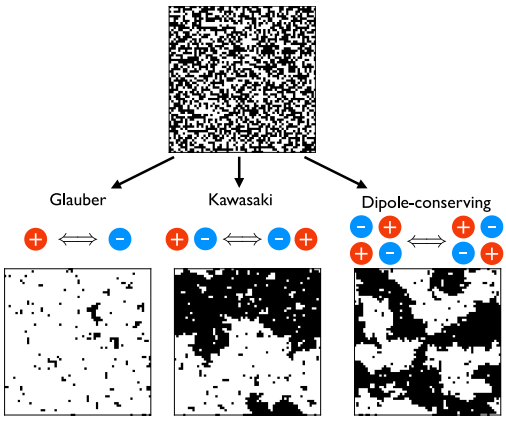

Fig. 1: Spin dynamics in the kinetic Ising model following a quench from $T = \infty$ (top) to $T < T_c$. Late time snapshots of the domains are shown on the bottom for non-conserving (left), spin-conserving (middle), and spin and dipole-conserving (right) dynamics.

ONE-DIMENSIONAL HARD-CORE ANYONS UNDER DEPHASING

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We present a Bethe ansatz solvable dissipative model of one-dimensional hard-core anyons under dephasing, where the particles obey fractional statistics. We establish an exact mapping between the Liouvillian and a non-Hermitian Hubbard model with special twisted boundary conditions. With the help of string hypothesis, we rigorously calculate the finite-size corrections and the Liouvillian gap in terms of the statistical parameter, total particle number, lattice size, and dissipation strength. Our results shed light on the Liouvillians of exactly solvable dissipative models of anyonic particles that obey the fractional statistics.

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SCALING DIMENSIONS VIA OPERATOR COVARIANCE IN A S=1/2 QUANTUM SPIN CHAIN

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In critical lattice models, the real-space two-point function of a local lattice operator consists of a sum of power laws, $\sum_i c_i r^{-2\Delta_i}$, where each Δ_i is the scaling dimension of a continuum field operator with the same quantum numbers as the lattice operator. When several fields contribute significantly within a given symmetry sector, leading-dimension fits become unstable. Here we implement a covariance-matrix-based approach, previously used for classical models [1], in which the distance-dependent eigenvalues of a covariance matrix built from multiple symmetry-adapted lattice operators isolate individual scaling dimensions, including primaries and low-lying descendants. We apply this framework to the spin-$1/2$ JQ_2 chain, which adds four-spin interactions to the SU(2)-symmetric Heisenberg model and can drive the system to a dimerized state. Using Quantum Monte Carlo simulations at the critical dimerization point, we can extract primary scaling dimension as well as descendant scaling dimensions that are difficult to resolve with single-operator analysis. The same framework extends to imaginary-time correlations, which exhibit crossover between short-τ power-law decay and long-τ exponential decay set by the finite-size gap. We can extract scaling dimensions from either the power-law window or the exponential tail. These results demonstrate covariance-diagonalization as an enhancement of standard correlation functions.

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CHAOS AND OPERATOR DEPENDENT ANOMALOUS TRANSPORT IN SEMICLASSICAL BOSE-HUBBARD CHAINS

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We investigate anomalous transport and chaotic dynamics in the semiclassical one-dimensional Bose–Hubbard chain using the Truncated Wigner Approximation with quantum corrections. At early times, the system exhibits robust superdiffusion characterized by universal, quantized exponents governed primarily by the initial state, largely independent of model parameters or the strength of chaos. This anomalous regime persists even in long chains and reflects a special scaling symmetry of the Hamiltonian. At later times, a crossover to normal diffusion emerges, which is most stable when nonintegrability is strong, leading to homogeneous states; for weaker nonintegrability, long-lived oscillations and inhomogeneities survive despite strong chaos. The coexistence of fast (angle) and slow (action) variables provides a natural framework to interpret the transport properties through free energy functionals: while quenched ensembles fail to equilibrate, annealed ensembles capture the effective late-time behavior. Together, these results highlight anomalous diffusion as a universal, early-time phenomenon distinct from prethermalization, smoothly evolving into conventional hydrodynamic transport at long times.

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GUIDED QUANTUM STATE TRANSFER ON AN ASYMMETRIC TWO-DIMENSIONAL SU-SCHRIEFFER-HEEGER MODEL VIA DOMAIN WALLS

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Quantum state transfer is an essential ingredient a quantum computer must possess. Due to the symmetry protection of the boundary states of topological insulators, many transfer protocols in these systems have been developed to counter the decoherence of qubits. One such implementation has been proposed recently that focuses on the fragmentation of a one-dimensional topological insulator into smaller domains that expedites the transfer exponentially [1]. In this work, we generalize the approach of these authors and propose a novel protocol in an asymmetric two-dimensional Su-Schrieffer-Heeger model [2] with an arbitrary number of domains. Through adiabatic state preparation and weak local potential applications, our protocol allows a state totally localized in a corner site of the lattice to be transferred to another through an arbitrarily chosen path [3]. Our studies also revealed high transfer fidelities and resilience of the topologically protected states against certain disorder regimes.

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VARIATIONAL MONTE-CARLO POWERED BY NEURAL QUANTUM STATES

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The ability to compute the ground state (GS) of a many-body Hamiltonian is essential to solve problems in both condensed matter and high-energy physics. Unfortunately, more often than not, that computation becomes untractable because of an exponential barrier in the memory needed to store the GS. Variational Monte-Carlo circumvents that barrier by approximating the true GS by a parametrized ansatz. Neural quantum states (NQS) [1] are a class of ansätze that use neural networks to approximate the map between the space configurations of a quantum system and the probability amplitude of that configuration. NQS have been tested in either purely bosonic [2] or purely fermionic systems [3]. We are interested in extending NQS to systems with coexisting fermions and bosons, more specifically supersymmetric (matrix) quantum mechanics.

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DISSIPATIVE QUANTUM SPIN ICE

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Coupling of a many-body system to external degrees of freedom can drastically alter the nature of the phase diagram. Motivated by recent works on the effect of dissipation on quantum liquid phases [1,2], we study the stability of quantum spin ice against environment-induced dissipation.
For this purpose, we develop a quantum Monte-Carlo method in the continuous-time path-integral formalism with worm update scheme. The use of the recently introduced wormhole updates [3] allow us to simulate quantum systems where each site is locally coupled to one or more bosonic bath. In this work, we simulate the XXZ model on the pyrochlore lattice where, on each site, a U(1)-symmetric two-bath couples to the system spin operators. We map the phase diagram of the dissipative XXZ model for the ohmic and sub-ohmic bath cases. This is done by inspecting the structure factors $\langle S^z(k)S^z(-k)\rangle$ and $\langle S^x_\mu(k)S^y_\mu(-k)\rangle$ and the finite-size XY correlation length estimator as a function of bath coupling. We conclude that quantum spin ice is stable to the environment up to finite bath coupling. For higher couplings, the bath induces a transition into the 3D XY ordered phase.

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To understand the numeric results, we look into the effect of the bath-induced terms in the 4D compact QED description of quantum spin ice. Using the usual Villain approximation, we find that the bath simply renormalizes the coupling in the Coulomb gas dual action. The quantum spin ice to 3D XY ordered transition is then driven by the same deconfinement-confinement transition of the topological charges as in the usual XXZ model on the pyrochlore.
Finally, we analyse the stability of classical spin ice as a function of the bath exponent and relate our results to the two-bath spin-boson model [4].

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LOCAL DENSITY OF STATES AS A UNIVERSAL PROBE OF MULTIFRACTALITY IN QUANTUM MATERIALS

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Moiré materials and twisted layered heterostructures provide an unprecedented platform for exploring correlated and topological quantum phases, ranging from superconductivity to nontrivial magnetic states. A central challenge in these systems is the characterization of electronic states that often display nontrivial spatial patterns. In particular, the recently discovered intercrystal and quasicrystal phases in heterostructures composed by twisted bilayer graphene and hexagonal boron nitride showcase the importance of such detailed study [1]. Multifractal analysis of the local density of states (LDOS) has been extensively developed in the study of Anderson localization due to disorder, where it serves as a cornerstone for identifying critical phases. In this work, we extend this framework to quasiperiodic moiré systems as a natural description of moiré-induced electronic structures [2,3]. We test this approach on a one-dimensional model with a quasiperiodic potential and long-range hoppings, which captures key features of moiré interference such as narrow bands. Our results demonstrate clear distinctions in the multifractal spectra between extended and critical states, validating the sensitivity of the method [4]. Importantly, this methodology is not model-dependent: it can be directly applied to STM data, uncovering multifractal signatures in any material where they emerge, without the need for additional assumptions or system-specific adaptations. This establishes a versatile framework for probing critical phases in correlated moiré materials and beyond.

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TRICRITICALITY IN 4D U(1) LATTICE GAUGE THEORY

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The 4D compact U(1) gauge theory has a well-established phase transition between a confining and a Coulomb phase. In this work, we revisit this model using state-of-the-art Monte Carlo simulations on anisotropic lattices. We map out the coupling-temperature phase diagram and determine the location of the tricritical point, $T/K_0 \simeq 0.19$, below which the first-order transition is observed. We find the critical exponents of the high-temperature second-order transition to be compatible with those of the three-dimensional O(2) model. Our results at higher temperatures can be compared with literature results and are consistent with them. Surprisingly, below $T/K_0 \simeq 0.05$ we find strong indications of a second tricritical point where the first-order transition becomes continuous. These results suggest an unexpected second-order phase transition extending down to zero temperature, contrary to the prevailing consensus. If confirmed, these findings reopen the question of the detailed characterization of the transition including a suitable field-theory description.

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UNIVERSAL SUBSYSTEM FLUCTUATIONS OF QUANTUM JUMP STATISTICS IN POSTSELECTION-FREE MANY-BODY DYNAMICS UNDER CONTINUOUS MONITORING

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We reveal a nontrivial crossover of subsystem fluctuations of quantum jumps in continuously monitored many-body systems, which have a trivial maximally mixed state as a steady-state density matrix [1]. While the fluctuations exhibit the standard volume law $\propto L$ following Poissonian statistics for sufficiently weak measurement strength, anomalous yet universal scaling law $\propto L^{\alpha}$ ($\alpha \sim 2.7$) indicating super-Poissonian statistics appears for strong measurement strength. This drastically affects the precision of estimating the rate of quantum jumps: for strong (weak) measurement, the estimation uncertainty is enhanced (suppressed) as the system size increases. We demonstrate that the anomalous scaling of the subsystem fluctuation originates from an integrated many-body autocorrelation function and that the transient dynamics contributes to the scaling law rather than the Liouvillian gap. The measurement-induced crossover is accessed only from the postselection-free information obtained from the time and the position of quantum jumps and can be tested in ultracold atom experiments.

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BLOCH-LANDAU-ZENER OSCILLATIONS AND DYNAMICAL MANAGEMENT OF BECS IN A QUASIPERIODIC POTENTIAL

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We consider the dynamics of Bose-Einstein condensates (BECs) in a tilted quasiperiodic optical lattice, with the excited states having energies below the mobility edge, and thus being localized in space. The observed oscillatory behaviour is enabled by tunnelling between the initial state and a state (or several states) determined by a selection rule consisting of the condition of their spatial proximity and a condition of quasi-resonances occurring at avoided crossings of the energy levels. The effect of the inter-atomic interactions on the dynamics is also predicted on the bases of the developed theory. In spin-orbit coupled BECs, resonant driving of the linear force gives rise to additional phenomena, such as spin-switching, coherent transport across the lattice, and the formation of dark states with multiple localised states. The frequency and amplitude of the linear force provide direct control over oscillation rates and population transfer, offering versatile protocols for coherent manipulation of spinor wavefunctions.

LOCALIZATION OF BOSE-EINSTEIN CONDENSATES ENABLED BY INCOMMENSURATE OPTICAL LATTICE AND PHOTON-ATOM INTERACTIONS

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We consider a Bose-Einstein condensate loaded into an optical cavity subject to the combined action of an external potential and a cavity mode with mutually incommensurate periods. This configuration enables the localization of matter waves even in the absence of attractive two-body interactions. We analyze the families of the corresponding localized modes for both red- and blue-detuned atomic and cavity resonances in relatively shallow lattices. The parameter regimes supporting localization are identified. The system is found to exhibit multistability, previously discussed in terms of bistability, manifesting as distinct photon numbers under otherwise identical conditions. In addition, the system may display "strict" bistability, characterized by two different atomic density distributions corresponding to the same photon number. The stability of the localized modes is examined. Furthermore, we show that, owing to long-range interactions, the two-mode system effectively mimics the operation of an XOR gate.

MEASUREMENT-INDUCED PHASE TRANSITIONS IN MONITORED COLLECTIVE SPIN MODELS

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Measurement-induced phase transitions (MIPTs) were originally discovered in random qubit lattices subjected to local projective measurements [1]. These transitions manifest as sharp changes in the scaling of entanglement entropy in quantum trajectories: from volume-law growth to area-law suppression [2], controlled by the measurement rate.

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In this work, we investigate the emergence of MIPTs in a paradigmatic model of collective quantum dynamics–the Lipkin-Meshkov-Glick (LMG) spin model under continuous monitoring. Building on recent observations of monitored atomic ensembles [3], we analyze how measurement backaction drives transitions in entanglement and dynamical spreading. By combining entanglement entropy with the inverse participation ratio as complementary diagnostics, we uncover the nature of these transitions and characterize the structure of quantum trajectories in this collective setting.

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MAGNON, DOUBLON AND QUARTON EXCITATIONS IN 2D S=1/2 TRIMERIZED HEISENBERG MODELS

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We study magnetic excitations in two-dimensional trimerized spin-1/2 Heisenberg models on several representative lattices. Using large-scale quantum Monte Carlo combined with stochastic analytic continuation, complemented by cluster perturbation theory, we identify three types of quasiparticle excitations: low-energy magnons, intermediate-energy doublons, and high-energy quartons. Our results demonstrate how these excitations evolve with varying inter- and intratrimer couplings, revealing clear spectral separation in the weak-coupling regime and broad continua at stronger coupling. The findings provide theoretical predictions relevant to inelastic neutron and resonant inelastic X-ray scattering experiments, offering guidance for understanding novel excitations in trimerized quantum magnets.

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Évora and how to reach it

Évora is located in the south of Portugal, about 130 km east of Lisbon. The monumental feature of Évora - together with its picturesque aspect - made UNESCO include its historic centre in its list of cultural heritage of mankind.

Follow this link to find more:
https://whc.unesco.org/en/list/361

Find below information about the connections Lisbon-Évora and Évora-Lisbon both by train or bus.

By bus:

From the Lisbon International Airport you should take the metro red line, which is the only line available, to the end of the line (São Sebastião station). There you should change to the blue line, Amadora Este direction, and leave at Sete Rios Station (two metro stations).

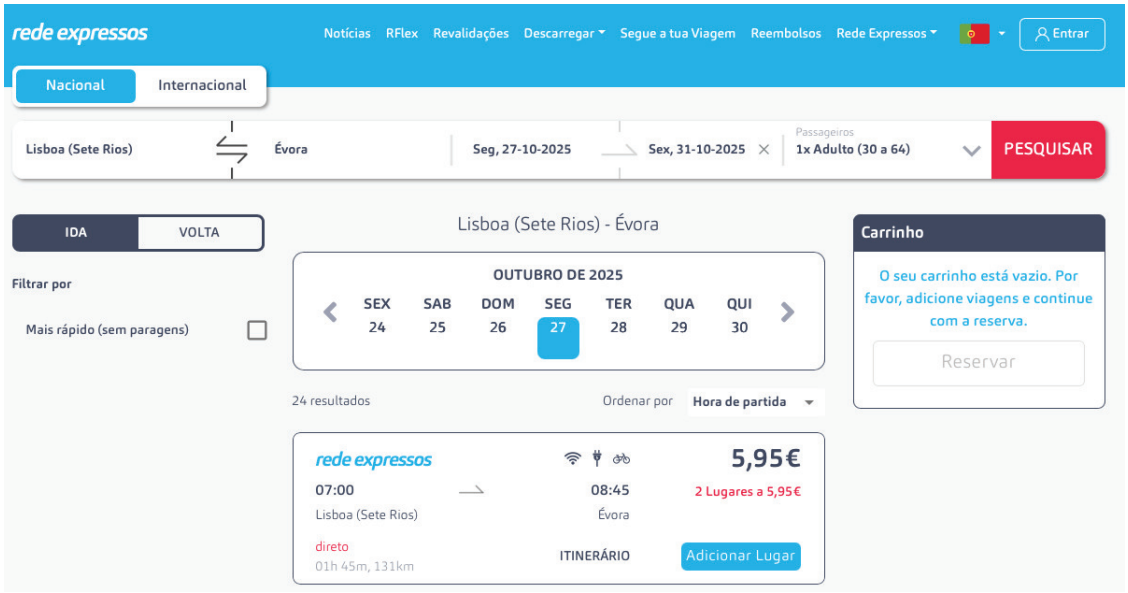
At the bus station in Sete Rios you can take a direct bus to Évora. The journey will last approximately 1h40. This is the address of the Bus Station:

RNE - Rede Nacional de Expressos, Lda
Terminal Rodoviario de Sete Rios
Praça Marechal Humberto Delgado - Estrada das Laranjeiras
1500-423 LISBOA

Bus Timetables

In the link below you will find departure and arrival timetables to and from Évora:

https://rede-expressos.pt/pt/horarios-bilhetes



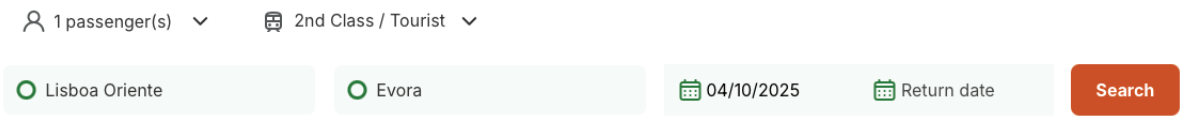
By train:

From the Lisbon International Airport you should take the metro red line, which is the only line available, to the Oriente metro station (three metro stations). At the Oriente Railway Station you can take an intercity train to Évora. The journey will last approximately 1h.30.

Train Timetables

In the link below you will find departure and arrival timetables to and from Évora:

https://www.cp.pt/sites/passageiros/en/train-times



Wireless

HOW TO CONNECT TO WIRELESS NETWORK:

1st STEP:

1- Enable **Wireless connection**

2- Manually add **Wireless Network or Network Profile**

3- Configurations:

network's name: **FWUE**
security: **None** or **No Authentication (Open)**
select: **Start this connection automatically**
select: **Connect even if the network is not broadcasting**

2nd STEP:

Turn on your web browser.

The first time you enter FWUE the Internet access is disabled. When trying to access any page will be redirected to the following page:

The access credentials are::

USERNAME: cqm
PASSWORD: cqm

After entering the credentials a second screen appears. It is not strictly necessary to restart the browser, it is only a recommendation to ensure compability.

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