Talks

Waseem Akbar, Academic Centre for Materials and Nanotechnology, AGH University of Krakow
Contributed talk

Title: *Effect of intersite coulomb interaction on superconductivity in twisted transition metal dichalcogenide homobilayer and Heterobilayer*

Abstract: We study the effect of intersite coulomb repulsion (V) in the case of twisted WSe2 homobilayer and WS2-WSe2 heterobilayer utilizing the Gutzwiller approach within single-band t-J-V and t-J-U-V models supplemented with Dzyaloshinskii-Moriya term. Our findings indicate that inclusion of the V-term suppresses the superconducting pairing. Nevertheless, superconductivity still survives for a relatively large values of V in both twisted homobilayer and heterobilayer structures. As we show, spin-singlet symmetry is contributing more in WSe2 homobilayer compared to triplet for D=0.4 V/nm. However, opposite situation is observed in the case of WS2-WSe2 heterobilayer. As we show, by changing the displacement field, one can tune the balance between the singlet and triplet contributions to the pairing for the homobilayer case. Our findings provide valuable insights for design and engineering of novel quantum materials with tailored electronic functionalities.

Rodrigo Arouca, Uppsala University
Organizer (contributed) talk

Title: *A thermodynamic approach to topological phase transitions*

Abstract: I will discuss an approach initiated by Cristiane’s group to understand topological phase transitions by their critical properties. In special, in this approach, the bulk-boundary correspondence is manifest in different orders of phase transitions in the bulk and surface of topological models.

Pantelis Bampoulis, University of Twente
Invited talk

Title: *Topological Phase Transition in Germanene Nanoribbons: from 1D to 0D Topological States*
Abstract: Investigating topological phases and phase transitions is crucial for discovering new quantum states and enhancing the functionality of topological insulators. Here, we delve into the critical yet unexplored area of how two-dimensional (2D) topological insulators transition into 1D topological insulators, revealing their potential to host 0D states crucial for topological quantum computing. We fabricated arrays of zigzag-terminated germanene nanoribbons with large topological bulk gaps and metallic edges, creating a high density of parallel and straight 1D topological edge states. By systematically investigating the nanoribbon's electronic properties as a function of their width, we observed the evolution of their topological characteristics. We identified a topological phase transition from a 2D to 1D topological insulator below a critical width of approximately 2 nm. This transition is marked by the vanishing of 1D edge states and the emergence of distinct 0D end states. Our experimental and theoretical findings reveal that the topological behavior of germanene nanoribbons is rich and complex, depending in a non-monotonic way on ribbon width, spin-orbit coupling, and staggered mass.

Gordon Baym, University of Illinois
Invited talk

Title: *Exploring high density nuclear matter with cold atoms*
Abstract: Cold atom systems are promising for both simulating as well as being analogs for high density nuclear matter, as occurs in neutron stars. A range of model problems can begin to give one insight into the interplay of nucleonic and quark degrees of freedom in dense matter. In this talk I will focus on two such experimentally accessible systems, time permitting. The first is a mixture of Bose and Fermi atoms to create an analog of the transition from nuclear matter (Bose-Fermi molecules) to a liquid of quarks and diquarks (unbound fermionic and bosonic atoms). The second, looking at the formation of bosonic pairs in an imbalanced sea of two fermionic states, is the analog of how a neutron liquid becomes a quark sea consisting of diquarks (bound atomic fermion pairs) mixed with free quarks (unpaired atoms). While in the BCS limit, such an imbalanced system of paired fermions with excess free fermions is unfavorable, in the dilute BEC regime, such imbalance is achievable.

Dario Bercioux, Donostia International Physics Center
Invited talk

Title: *Spectral Properties of Non-Hermitian Systems Featuring Impurities and Flat Bands*

Abstract: In this talk, I will present our recent findings on non-Hermitian lattices featuring flat bands and impurities. We investigate the Diamond chain with two distinct non-reciprocal dimerization configurations. Our analysis demonstrates that these configurations are equivalent to the non-Hermitian Su-Schrieffer-Heeger (SSH) model in non-reciprocal and PT-symmetric forms, with an added flat band at zero energy. Additionally, we examine the Hatano-Nelson model in the presence of impurities. Our results reveal that for specific values of the impurity strength relative to the non-reciprocal hopping parameters, the non-Hermitian skin effect associated with the impurity mode can counterbalance the overall skin effect of the Hatano-Nelson model. These insights contribute to a deeper understanding of non-Hermitian systems and their unique properties, potentially paving the way for novel applications in various fields.

Emil Bergholtz, Stockholm University
Tutorial

Title: *Beyond Quantum Connections*
Abstract: I'll present work that connects to Cristiane in various ways; through imported and exported students -- and to joint work.

Wouter Beugeling, Julius-Maximilians-Universitat Wurzburg
Invited talk

Title: *Finding signatures of the parity anomaly in a topological insulator: Theory, numerics, and experiment*

Abstract: The surface states of topological insulators are, in hindsight, equivalent to the massless surface states predicted by Volkov and Pankratov in the 1980s. These surface states realize two-dimensional Dirac fermions, which means that they are subject to the parity anomaly known from 2+1D quantum electrodynamics. While these surface states thus seem an interesting platform for an experimental

realization of the parity anomaly, finding its signature is challenging because the contributions from opposite surfaces naturally cancel. We have combined theoretical, numerical, and experimental techniques and show evidence for parity anomaly in the Hall conductance of a high-mobility heterostructure based on HgTe, a three-dimensional topological insulator. We observe a remarkable re-entrant quantum Hall effect, that we identify as a signature of spectral asymmetry for a single surface state, that is intimately linked to the parity anomaly. A complicating factor is the coexistence of the topological surface states with massive (trivial) surface states. We have tackled this problem by making intelligent use of the top and bottom gates in the device and by realistic simulations of the Landau spectra with our custom built numerical package 'kdotpy'. In this talk, I will highlight the state-of-the-art techniques used in this project and I will show how Cristiane continues to be a major influence and inspiration for my present day work.

Amir Caldeira, Universidade Estadual de Campinas - UNICAMP
Invited talk

Title: *Effective momentum-momentum coupling in a correlated electronic system: the diamagnetism of benzene*.

Abstract: A well-known property of aromatic molecules is their highly anisotropic response to an external magnetic field. This phenomenon is rationalized as a consequence of the delocalization of the itinerant electrons that populate the aromatic ring. In this presentation, we revisit the magnetism of aromatic molecules through the study of simple Hubbard rings, and argue that if the itinerant electrons are described by an extended Hubbard Hamiltonian with an effective momentum-momentum interaction between them, a large enhancement of the molecule diamagnetic response takes place. We show that the presence of this new term is due to the reincorporation of part of the effects of the localized bonding electrons on the dynamics of their itinerant counterparts in Hubbard ‚Äì like Hamiltonians. Going beyond the adiabatic approximation, we show that the net effect of virtual transitions of bonding electrons between their ground and excited states is to furnish the itinerant electrons with an effective interelectronic momentum ‚Äì momentum interaction. Although we have applied these ideas to the specific case of rings, our assumptions can be generalized to higher-dimensional systems sharing the required properties of which we have made use herein.

Robert Canyellas Nunez, Radboud University

Contributed talk

Title: *Topological edge and corner states in bismuth fractal nanostructures*

Abstract: Topological materials hosting metallic edges characterized by integer-quantized conductivity in an insulating bulk have revolutionized our understanding of transport in matter. The topological protection of these edge states is based on symmetries and dimensionality. While integer-dimensional effects on topological properties have been studied extensively, the interplay of topology and fractals, which may have a non-integer dimension, remains largely unexplored. Here we demonstrate that topological edge and corner modes arise in fractals formed upon depositing thin layers of bismuth on an indium antimonide substrate. Our scanning tunnelling microscopy results and theoretical calculations reveal the appearance and stability of nearly zero-energy modes at the corners of Sierpinski triangles, as well as the formation of outer and inner edge modes at higher energies. This work opens the perspective to extend electronic device applications in real materials at non-integer dimensions with robust and protected topological states.

Erica Carlson, Purdue University
Invited talk

Title: *Universal Features of Emergent Electronic Fractals in Quantum Materials*

Abstract: Electrons inside of many quantum materials spontaneously form clumpy patterns on multiple length scales. By importing techniques from disordered statistical mechanics into the field of quantum materials, we have defined new conceptual frameworks for understanding and controlling this electronic inhomogeneity. This allows us to use the rich information available from spatially resolved probes to diagnose criticality from the spatial structure alone, without the need of a sweep of temperature or external field. These new methods have enabled the discovery of universal, fractal electronic textures across a variety of quantum materials. For instance, scanning tunneling microscopy on BSCO reveals that the orientations of electronic stripes in that material form fractal, self similar patterns displaying power law behavior throughout the superconducting doping range [1], leading to a connected scaffolding on which superconductivity can arise. Surprisingly similar structures are also found in antiferromagnetic domains in NdNiO3 and the Mott metal-insulator transition in VO2. In NdNiO3, scanning resonant magnetic X-ray scattering reveals a highly textured magnetic fabric, establishing a self-similar network of antiferromagnetic domains [2]. In VO2, both scanning near-field optical microscopy and far-field optical microscopy have revealed that as opposed to transitioning from insulator to metal all at once, VO2 forms an intricate, fractal network of metallic puddles that extend like filigree over a wide range of temperatures [3]. This identification opens the door to using hysteresis effects to sculpt the filigree, in order to improve the function of VO2 in novel electronic applications such as neuromorphic devices and quantum sensing. The universal features of these fractal electronic textures across a disparate collection of quantum materials hints at a common origin. We show that this emergent electronic complexity is the result of proximity to a critical point arising from the combined effects of quenched disorder and interactions. [1] Nature Commun. 14, 2622 (2023). [2] Nature Commun. 10, 4568 (2019). [3] Phys. Rev. B 107, 205121 (2023)

Monica Conte, Utrecht University
Contributed talk

Title: *The Fractal-Lattice Hubbard Model*

Abstract: The Hubbard model is the prototypical model to describe strongly correlated electrons hopping in a lattice. It has been studied numerically in several dimensions, but not in fractal dimensions. We explore this model on a fractal lattice, specifically focusing on the Sierpinski triangle with a Hausdorff dimension of 1.58. Using numerical methods such as exact diagonalization, mean-field Hartree-Fock, and Auxiliary-Field Quantum Monte Carlo, we have identified a phase of matter that is both metallic and magnetic, which has been an ongoing pursuit within the framework of the Hubbard model. Our findings also include the discovery of compact localized states in the tight-binding limit, that we understood in terms of symmetry and linked to the formation of a ferrimagnetic phase at weak interaction. Moreover, simulations at half-filling revealed the persistence of this type of magnetic order for every value of interaction strength and a Mott transition. Finally, we found a remarkable dependence on the Hausdorff dimension regarding the number of compact localized states in different generations, the scaling of the total many-body ground-state energy in the tight-binding limit, and the density of the states at the corners for specific values of electronic filling.

Charles Creffield, Universidad Complutense
Invited talk

Title: *Floquet engineering without shaking*

Abstract: Floquet engineering has proved to be a powerful and highly controllable method of manipulating the properties of quantum systems. The most common approach is to periodically drive an external potential - a scheme that is often referred to as “shaking” the system. In principle, however, any term in the Hamiltonian can be driven. In this talk I will consider two alternative methods, the first being periodic driving of the interaction energy, and the other being periodic variation of the intersite tunnelling, or ,”kinetic driving”. Applying these schemes to the Bose-Hubbard model, we will see how they can be used to induce and control assisted tunnelling processes, and thereby to create exotic superfluid ground states and unusually stable cat-states.

Marco Di Liberto, Università di Padova
Tutorial

Title: Quantum simulation: overview and perspectives

Abstract: TBA

Ricardo Doretto, University of Campinas
Invited talk

Title: *Flat-band ferromagnetism and spin waves in the Haldane-Hubbard model*

Abstract: In this talk, we will discuss the flat-band ferromagnetic phase of the spinfull Haldane-Hubbard model on a honeycomb lattice within a bosonization scheme for flat-band Chern and topological insulators. We will consider the Haldane-Hubbard model with the noninteracting lower bands in a nearly-flat band limit and at 1/4-filling of its corresponding noninteracting limit. Within the bosonization scheme, the Haldane-Hubbard model is mapped into an effective interacting boson model, whose quadratic term allows us to determine the spin-wave spectrum at the harmonic approximation. We will show that, for the correlated Chern insulator, the spin-wave spectrum has two branches with a Goldstone mode at the center of the first Brillouin zone and Dirac points at the K and K' points. For the correlated topological insulator, we will show that the spin-wave spectrum also has two branches, but it is gapped, with an energy gap between the lower and the upper bands at the K and K'points. We will also comment on the effects on the spin-wave spectrum due to an energy offset in the on-site Hubbard repulsion energies and due to the presence of an

staggered on-site energy term, both quantities associated with the two triangular sublattices.

Andrea Gauzzi, Sorbonne Universite
Tutorial

Title: *Tuning topological Dirac states using correlated d-electrons in the Ba(Co,Ni)S2 system*

Abstract: The topological properties of Dirac fermions lead to unique physical phenomena combined with extremely high charge mobilities, which suggests novel concepts of electronic devices. One prerequisite of these developments is the manipulation of the position and of the filling of Dirac bands, which is very challenging in the solid state and previous reports are very limited as they are either theoretical [1,2] or experimental in optical lattices [3]. Here we show that an effective tuning of these bands may be achieved in the quasi-2D Mott system BaNiS2, where the nonsymmorphic symmetry and the inherent correlated properties of d-electrons lead to the formation of Dirac points whose location in k-space can move along the -M symmetry line, instead of being pinned at symmetry points, as commonly found in graphene and other Dirac materials. By means of ARPES supported by ab initio calculations, we show that both the k-position and dispersion of these Dirac bands can be tailored using a variety of control parameters: i) a partial substitution of Ni for Co [4], which controls the strength of the electronic correlations and the Mott transition; ii) the carrier density induced by K ad-atoms deposited onto the surface [5]; iii) femtosecond light pulses that induce out-of-equilibrium electronic states [6]. In this talk, we shall present and discuss these results which indicate that BaNiS2 is a model system to test the possibility of tuning Dirac states at surfaces, interfaces and heterostructures and to explore the effects of electronic correlations on the topological properties of materials. [1] V.M. Pereira, A.H. Castro Neto, and N.M.R. Peres, ‚ÄúTight-binding approach to uniaxial strain in graphene‚Äù, Phys. Rev. B 80, 045401 (2009). https://doi.org/10.1103/PhysRevB.80.045401 [2] C. Hua, S. Li, Z.-A. Xu, Y. Zheng, S.A. Yang and Y. Lu, ‚ÄúTunable topological energy bands in 2D dialkali-metal monoxides‚Äù, Advanced Science 7, 1901939 (2020). https://doi.org/10.1002/advs.201901939 [3] L. Tarruell, D. Greif, T. Uehlinger, G. Jotzu, and T. Esslinger. ‚ÄúCreating, moving and merging Dirac points with a Fermi gas in a tunable honeycomb lattice‚Äù, Nature 483, 302 (2012). https://doi.org/10.1038/nature10871 [4] N. Nilforoushan, M. Casula, A. Amaricci, M. Caputo, J. Caillaux, L. Khalil, E. Papalazarou, P. Simon, L. Perfetti, I. Vobornik, P. K. Das, J. Fujii, A. Barinov, D. Santos-Cottin, Y. Klein, M. Fabrizio, A. Gauzzi, and M. Marsi, ‚ÄúMoving Dirac nodes by chemical substitution‚Äù, Proc. Natl. Acad. Sci.18, e2108617118 (2021). https://doi.org/10.1073/pnas.2108617118 [5] J. Zhang, T.D.P. Sohier, M. Casula, Z. Chen, J. Caillaux, E. Papalazarou, L. Perfetti, L. Petaccia, A. Bendounan, A. Taleb-Ibrahimi, D. Santos-Cottin, Y. Klein, A. Gauzzi, and M. Marsi, ‚ÄúManipulating Dirac States in BaNiS2 by Surface Charge Doping,Äù Nano Lett. 23, 1830 (2023). https://doi.org/10.1021/acs.nanolett.2c04701 [6] N. Nilforoushan, M. Casula, M. Caputo, E. Papalazarou, J. Caillaux, Z. Chen, L. Perfetti, A. Amaricci, D. Santos-Cottin, Y. Klein, A. Gauzzi, and M. Marsi, ‚ÄúPhotoinduced renormalization and electronic screening of quasi-two-dimensional Dirac states in BaNiS2,Äù, Phys. Rev. Research 2, 043397 (2020). https://doi.org/10.1103/PhysRevResearch.2.043397

Mark Oliver Goerbig, Laboratoire de Physique des Solides, CNRS, Universite Paris-Saclay
Organizer (contributed) talk

Title: *Magnetospectroscopy of topological surface states*

Abstract: TBA

Nathan Goldman, LKB-ENS / ULB
Invited talk

Title: *On the edge of interacting topological matter*

Abstract: TBA

Vladimir Gritsev, Institute for Theoretical Physics, University of Amsterdam
Tutorial

Title: *Geometry and topology of quantum states*

Abstract: I will discuss some of the recent advances in our understanding of the geometry-based approach to quantum systems.

Thors Hans Hansson, Stockholm University
Invited talk

Title: *Classical mechanics of identical particles*

Abstract: Starting from the quantum theory of identical particles, I show how to define a classical mechanics that retains information about the quantum statistics, and explain the connection to quantum Hall physics. I discuss both statistical mechanics and review recent work on the dynamics of two and three particle systems

----

Andreas Hemmerich, University Hamburg
Invited talk

Title: *Dissipative time crystals in an atom-cavity system*

Abstract: Discrete (DTCs) and continuous (CTCs) time crystals are dynamical many-body states, showing robust self-sustained oscillations, emerging via spontaneous breaking of discrete or continuous time translation symmetry, respectively. DTCs are periodically driven systems that oscillate with a subharmonic of the drive, while CTCs are driven continuously and oscillate with a system inherent frequency. I will show experimental realizations of continuous and discrete time crystals in Bose-Einstein condensates of rubidium atoms strongly coupled to a high finesse optical cavity. I will discuss how these two dynamical many-body phases are connected via a subharmonic injection locking process.

Patric Holmvall, Uppsala University
Contributed talk

Title: *Josephson effect in a Fibonacci quasicrystal*

Abstract: Quasiperiodicity has recently been proposed to enhance superconductivity and its proximity effect. At the same time, there has been significant experimental progress in the fabrication of quasiperiodic structures, also in reduced dimensions. Motivated by these developments, we use microscopic tight-binding theory to investigate the DC Josephson effect through a ballistic Fibonacci chain attached to two superconducting leads. The Fibonacci chain is one of the most studied examples of quasicrystals, hosting a rich multifractal spectrum, containing topological gaps with

different winding numbers. We study how the Andreev bound states (ABS), current-phase relation, and the critical current depend on the quasiperiodic degrees of freedom, from short to long junctions. While the current-phase relation shows a traditional 2pi sinusoidal or sawtooth profile, we find that the ABS obtain quasiperiodic oscillations and that the Andreev reflection is qualitatively altered, leading to quasiperiodic oscillations in the critical current as a function of junction length. Surprisingly, despite earlier proposals of enhanced superconductivity, we do not in general find an enhanced critical current. However, we find significant enhancement for reduced interface transparency due to the modified Andreev reflection. Furthermore, by varying the chemical potential, e.g. by an applied gate voltage, we find a fractal oscillation between superconductor-normal metal-superconductor (SNS) and superconductor-insulator-superconductor (SIS) behavior. Finally, we show that the winding of the subgap states leads to an equivalent winding in the critical current, such that the winding numbers, and thus the topological invariant, can be determined. [1] A. Sandberg, O. A. Awoga, A. M. Black-Schaffer, P. Holmvall, "Josephson effect in a Fibonacci quasicrystal", arXiv:2405.05660 (2024).

Wojciech Jankowski, University of Cambridge
Contributed talk

Title: *Quantised responses in multi-gap topological phases*

Abstract: Quantised electromagnetic responses are rare smoking-gun probes constituting a hallmark for non-trivial topology in quantum materials. Following the discovery of the quantum Hall effect [1], it was shown that Chern insulators exhibit quantised bulk Hall currents [2], whereas Weyl semimetals can support quantised injection currents [3]. We show that certain 3D multi-gap topological insulators can host quantised integrated shift photoconductivities due to bulk invariants defined under PT (spatiotemporal inversion) symmetry [4,5]. We recast the quantisation in terms of quantum-geometric torsion tensors, connecting them to real Chern-Simons forms, and to virtual multiband optical transition amplitudes. [1] K.V. Klitzing, et al., Phys. Rev. Lett. 45, 494‚Äì497 (1980). [2] F. D. M. Haldane, Phys. Rev. Lett. 61 (2015). [3] F. De Juan, et al., Nat. Commun. 8, 15995 (2017). [4] W.J. Jankowski, et al., arXiv:2402.13245. [5] W.J. Jankowski, et al., arXiv:2405.17305.

W. Vincent Liu, University of Pittsburgh
Invited talk

Title: *Orbital symmetry, order and topology in synthetic quantum materials*

Abstract: Orbital physics has been a long-standing topic that extends impact across physics subdisciplines from condensed matter to cold atom physics and back, for which Dr. Morais Smith has published creative, pioneer, and inspiring works. Orbital is a fascinating degree of freedom independent of charge and spin. It is known to play a rudimentary role in understanding the nature of superfluid pairings, such as s-, p-, and d-wave. In condensed matter, through its coupling to spin and charge, orbital order intertwines superconductivity, magnetism, and other quantum phenomena. The advanced spatiotemporal control of cold atoms provides new opportunities to explore orbital physics beyond standard quantum regimes, complementary to studies in condensed matter. In this talk, I will report on theoretical and experimental progress in orbital superfluidity, highlighting unique phases of matter emerging from the interplay of novel spatial lattice geometry and emerging orbital symmetries in artificial quantum simulators for fundamental physics.

Eduardo Marino, Federal University of Rio de Janeiro
Invited talk

Title: *A Successful Theory for High-Tc Superconductivity in Cuprates*
Abstract: After almost 40 years of the discovery of superconductivity in cuprates many theories have been proposed to explain its underlying mechanism. Almost all of them, however, fail in providing quantitative predictions that could be compared to the experimental data, being, therefore not testable. We propose a comprehensive microscopic theory for High-Tc superconductivity in cuprates, which makes quantitative predictions for Tc(x), T*(x), Tmax(P), TNeel(x), TSpinGlass(x), TCDW(X), rho(T), rho(H), among other observable quantities, which are in excellent agreement with the experimental data for several cuprate materials including LSCO, YBCO, Hg1201, Hg1212, Hg1223, Bi2201, Bi2212, Bi2213. Our theory, besides being testable, has successfully explained numerous experimental results and thereby allowed us to obtain analytical expressions for the whole T vs. Doping phase diagram of several cuprates. The pairing is produced by the intermediation of the ferromagnetic component of the magnetic quantum fluctuations of the Kondo-like interaction that exists between the doped holes and the localized Cu ions. The Pseudogap is produced by exciton condensation, while the main resistivity mechanism consists of hole-exciton scattering References [1] E. C. Marino et al, Supercond. Sci. Tech. 33, 035009 (2020). [2] E. C. Marino, R. Arouca, Supercond. Sci. Tech. 34, 085008 (2021) [3] R. Arouca, E. C. Marino, Supercond. Sci. Tech. 34, 035004 (2021) [4] E. C. Marino, New J. of Phys. 24, 063009 (2022) [5] E. C. Marino,

SciPost Phys. Proc. 11, 004 (2023) [6] E. C. Marino, arXiv 2405.17683 in cond-mat.supr-con .

Carolina Martinez Strasser, Max Planck Institute for the Science of Light
Contributed talk

Title: *Topological Properties of a Non-Hermitian Quasi-1D Chain with a Flat Band*

Abstract: The spectral properties of a non-Hermitian quasi-1D lattice in two of the possible dimerization configurations are investigated. Specifically, it focuses on a non-Hermitian diamond chain that presents a zero-energy flat band. The flat band originates from wave interference and results in eigenstates with a finite contribution only on two sites of the unit cell. To achieve the non-Hermitian characteristics, the system under study presents non-reciprocal hopping terms in the chain. This leads to the accumulation of eigenstates on the boundary of the system, known as the non-Hermitian skin effect. Despite this accumulation of eigenstates, for one of the two considered configurations, it is possible to characterize the presence of non-trivial edge states at zero energy by a real-space topological invariant known as the biorthogonal polarization. This work shows that this invariant, evaluated using the destructive interference method, characterizes the non-trivial phase of the non-Hermitian diamond chain. For the second non-Hermitian configuration, there is a finite quantum metric associated with the flat band. The two non-Hermitian diamond chains can be mapped into two models of the Su-Schrieffer-Heeger chains, either non-Hermitian, or Hermitian, both in the presence of a flat band. This mapping allows to draw valuable insights into the behaviour and properties of these systems.

Anouar Moustaj, Utrecht University
Contributed talk
Title: *Topological Phase of the interacting SSH model*

Abstract: The interacting SSH model provides an ideal ground to study the interplay between topologically insulating phases and electron-electron interactions. We study the polarization density as a topological invariant and provide an analytic treatment of its behavior in the low-energy sector of the one-dimensional interacting SSH model. By formulating the topological invariant in terms of Green's functions, we use the low-energy field theory of the model, the Thirring model, to derive the behavior of the polarization density. We show that the polarization density in the continuum theory describes the usual topological insulating phases, but it contains an extra

factor coming from the scaling dimensions of the fields in the low-energy quantum field theory. We interpret this as a measure of the modified charge of the new excitations in the system. We find two distinct contributions: a renormalization of the electronic charge e of a Fermi liquid, because of quasiparticle smearing, and an additional contribution coming from the topological charge of the soliton arising in the bosonized version of the Thirring model, the sine-Gordon model.

Lorena Niggli, Radboud University, Institute for Molecules and Materials
Contributed talk

Title: *Dynamic heterogeneity in the pattern spin glass elemental neodymium*

Abstract: Structurally homogeneous liquids approaching the glass transition display a slowing down of structural relaxation, while local dynamics become increasingly spatially heterogeneous [1]. This so-called dynamic heterogeneity is observed in almost all disordered systems with glassy dynamics ranging from structural glasses to colloids and granular media [1], while the situation in magnetic systems, i.e. spin glasses, is more subtle. Theoretical models describing spin glasses identify two key ingredients for glassiness, quenched disorder and frustration [2]. Accordingly, traditional spin glasses possess heterogeneous dynamics in the form of a wide distribution of relaxation timescales, arising directly due to the random nature of the interactions, while being only weakly correlated in space. Recently, we discovered that the low temperature magnetic phase of elemental neodymium behaves like a proposed self-induced spin glass [3,4]. Namely, a magnetic state that exhibits short-range order as well as aging behavior (pattern spin glass), but relies solely on spin frustration in the absence of disorder [5,6]. Here, we investigate the magnetization dynamics of Nd(0001) in its self-induced spin phase directly in real space. We observe that zero-field cooling freezes a specific set of metastable states into the pattern spin glass and find a structured transition towards a distinct set of states with magnetic field ramping. Local magnetization dynamics reveal a coexistence of heterogeneous dynamics correlated in space giving rise to the first experimental observation of dynamic heterogeneity in a spin glass system based on the original picture of structural glasses. [1] L. Berthier et al., Dynamical Heterogeneities in Glasses, Colloids, and Granular Media, Oxford University Press (2011) [2] Vincent et al., Complex Dynamics of Glassy Systems 492, 184 (1997) [3] Kamber et al., Science 368, 6494 (2020) [4] Verlhac et al., Nature Physics 18, 905-911 (2022). [5] Principi, Katsnelson, PRL 117, 137201 (2016). [6] Principi, Katsnelson, PRB 93, 054410 (2016).

Giandomenico Palumbo, Dublin Institute for Advanced Studies
Invited talk

Title: *Higher-Spin Modes in the Fractional Quantum Hall Effect*

Abstract: In this talk, I will introduce and discuss higher-spin modes in the fractional quantum Hall effect (FQHE). Recently, a groundbreaking experimental work has finally proved the existence of a massive spin-2 mode, also known as magneto-roton, in the FQHE that was originally theorised several decades ago. The corresponding emergent quantum geometry plays a central role in our understanding of the incompressibility of the fractional quantum Hall states. However, there are clear numerical and theoretical indications that higher-spin modes (i.e. collective modes with spin higher than two) should emerge along with the spin-2 mode. I will present a novel theoretical approach to understand the existence of these massive higher-spin modes starting from the generalisation of nematic phases, known as p-atic phases. Within this theoretical framework, I will present a non-relativistic quantum-field-theory description of the higher-spin modes in terms of higher-spin Schroedinger actions by generalising some previous results found for the magneto-roton.

Lucila Peralta Gavensky, Universite Libre de Bruxelles (ULB)
Contributed talk

Title: *The Widom-Streda Formula and its Remarkable Consequences: From Strongly Correlated to Topological Floquet Systems*

Abstract: In this talk, I will discuss recent theoretical advances that were made possible thanks to a remarkable thermodynamic relation known as the Widom-Streda formula, which relates the quantized Hall conductivity of an insulator to its density response under an external probe magnetic field. I will explain how this non-perturbative relation allowed us to derive a fundamental connection between the failure of Luttinger's theorem and the classification of correlated quantum Hall phases with winding numbers built from single-particle Green's functions [1]. I will also present our more recent findings on the generalization of this formula for topological Floquet systems [2]. [1] Lucila Peralta Gavensky, Subir Sachdev, and Nathan Goldman, ‚ÄúConnecting the Many-Body Chern Number to Luttinger's Theorem through Streda's Formula,‚Äù Phys. Rev. Lett. 131, 236601 (2023). [2] To appear in ArXiv.

Gloria Platero, Spanish research Council (CSIC)
Invited talk

Title: *Long range quantum transfer in one dimensional systems mediated by topological edge states*

Abstract: The recent fabrication and control of semiconductor quantum dot arrays open the possibility to use these systems as quantum links for transferring quantum information between distant sites, an indispensable part of large-scale quantum information processing [1]. Also, the recent implementation of long quantum dot arrays has shown their feasibility as quantum simulators of complex lattices [2]. Recently, it has been shown how to imprint non trivial topology in a quantum dot array by means of Floquet engineering [3].
In this talk I will first review the different protocols to directly transfer particles and quantum states in quantum dot arrays between distant sites.
Then I will discuss an alternative way to transfer information with high fidelity using protected topological edge states in systems with non-trivial topology [4,5].
I will discuss the long-range particle dynamics mediated by edge states in different atomic array configurations and the role of topological domain walls to speed up the particle transfer [6]. I will first consider the simplest topological insulator, the SSH chain, in which the domain walls are induced by changing the hopping amplitude dimerization. Finally, I will discuss the Creutz-Ladder model [6,7], where the domain walls can hold two topological states. It allows to use one as a quantum memory while the other transfers information through the wall, allowing for complex transfer operations between topological states. It opens efficient avenues for quantum state transfer protocols in low dimensional topological lattices.
[1] D. Fernández-Fernández et al., Phys. Rev. App. 8, 054090 (2022)
[2] M. Kiczynski et al., Nature, 606, 694 (2022); C.J. van Diepen et al., PRX, 11, 041025 (2021)
[3] B. Pérez-González et al., Phys. Rev. Lett. 123, 126401 (2019)
[4] N. Lang et al., npj, QI., 3,47 (2017); F. Mei et al., Phys Rev A, 98, 012331 (2018)
[5] J. Zurita et al.,, Quantum, 5, 591 (2021)
[6] J. Zurita et al., Quantum,7, 1043 (2023)
[7]Y. He et al., Physical Review Letters 126, 103601 (2021).

Gautam Rai, I. Institute of Theoretical Physics, Universitat Hamburg
Contributed talk

Title: *Dynamical correlations and order in twisted bilayer graphene*

Abstract: When two layers of graphene are stacked on top of each other with a small rotational misalignment---the honeycomb in the upper layer is twisted relative to the honeycomb in the lower layer---the long-wavelength interference pattern between the two layers gives rise to surprising emergent long-wavelength electronic physics. At a twist-angle of around 1.1 degrees (the magic angle), the low temperature phase diagram of TBLG shows a variety of diverse tunable strong correlation phases as a function of temperature and doping, exhibiting correlated insulating, orbital ferromagnetic, strange metallic, and superconducting behaviour. We use dynamical mean-field theory on the topological heavy Fermion model of magic-angle twisted bilayer graphene (TBLG) to investigate the interplay of electronic correlations and long-range order in the non-superconducting phase of this system. Our work [1, 2] identifies three central events in the filling-temperature plane: (i) the formation of local spin and valley isospin moments at around 100K, (ii) the ordering of these local isospin moments at around 10K, and (iii) a cascadic redistribution of charge between localized and delocalized electronic states upon doping. These three phenomena underpin some of the most puzzling aspects of data from scanning tunneling spectroscopy, transport, and compressibility experiments. In my talk, I will show you what we have learned about the nature of the emergent insulating and metallic states, the doping- and temperature-induced transitions between them, the so-called cascade transitions in local density and compressibility, and the microscopic mechanism behind the isospin Pomeranchuk effect in TBLG. [1] arXiv:2309.08529 [2] Phys. Rev. Lett. 131, 166501 (2023)

Theo Rasing, Radboud University
Invited talk

Title: *All Optical Control of Magnetism*

Abstract: Since our demonstration of magnetization reversal by a single 40 femtosecond laser pulse, the manipulation of spins by ultra-short laser pulses has developed into an alternative and energy efficient approach to magnetic recording. Though originally thought to be due to an optically induced effective field, later studies demonstrated that the switching occurred via a strongly non-equilibrium state, exploiting the exchange interaction between the spins. Recent work also shows how magnetic textures like skyrmions are generated via a non-equilibrium phase. While for a long time, all-optical switching (AOS) was exclusively observed in ferrimagnetic alloys, more recent work demonstrated AOS in a broad range of ferromagnetic multilayer materials, though here a large number of pulses were required. By studying the dynamics of this switching process, we have discovered

that this switching is a 2-step process, which led us to the subsequent demonstration that highly efficient AOS can be achieved by using pairs of femto/pico-second laser pulses. Combining optical laser excitation with in situ magnetic force microscopy we recently found that the nucleation and switching process evolves via a stochastic network of domains, but a detailed understanding is still missing.
Acknowledgement(s): Support from the Dutch Research Council (NWO) and the European Research Council ERC grant agreement no.856538 (3D-MAGiC) is acknowledged.

Federico Roccati, Columbia University
Contributed talk

Title: *Hermitian and non-Hermitian topology from photon-mediated interactions*

Abstract: As light can mediate interactions between atoms in a photonic environment, engineering it for endowing the photon-mediated Hamiltonian with desired features, like robustness against disorder, is crucial in quantum research. We provide general theorems on the topology of photon-mediated interactions in terms of both Hermitian and non-Hermitian topological invariants, unveiling the phenomena of topological preservation and reversal, and revealing a system-bath topological correspondence. Depending on the Hermiticity of the environment and the parity of the spatial dimension, the atomic and photonic topological invariants turn out to be equal or opposite. Consequently, the emergence of atomic and photonic topological boundary modes with opposite group velocities in two-dimensional Hermitian topological systems is established. Owing to its general applicability, our results can guide the design of topological systems.

Bitan Roy, Lehigh University
Invited talk

Title: *Topological insulators on fractal lattices: A general principle of construction*

Abstract: Fractal lattices, featuring the self-similarity symmetry, are often geometric descents of parent crystals, possessing all their discrete symmetries (such as rotations and reflections) except the translational ones. Here, we formulate three different general approaches to construct real space Hamiltonian on a fractal lattice starting from the Bloch Hamiltonian on the parent crystal, fostering for example strong and crystalline topological insulators resulting from the interplay between the nontrivial geometry of the underlying electronic wavefunctions and the crystal symmetries. As a demonstrative example, we consider a generalized square lattice Chern insulator model, and within the framework of all three methods we successfully showcase incarnations of strong and crystalline Chern insulators on the Sierpinski carpet fractal lattices. The proposed theoretical framework thus lays a generic foundation to build a tower of topological phases on the landscape of fractal lattices.

Peter Schmelcher, University of Hamburg
Invited talk

Title: *Local and latent symmetries and their generalization to control localization*

Abstract: Following up on a brief review on local symmetries we will address latent symmetries and isospectral reduction techniques in graph theory with applications to physical setups. We show that flat bands can be generated from a hidden symmetry of the lattice unit cell. This allows us to construct them by using a latently symmetric unit cell and multiplet interconnections. We demonstrate that the resulting flat bands are tunable and preserve the latent symmetry. The developed framework may offer fruitful perspectives to analyze and design flat band structures in a variety of physical systems, including cold atoms, optical and acoustic wave setups.

Kareljan Schoutens, Institute of Physics and QuSoft, University of Amsterdam
Invited talk

Title: *Fermionic bricks in the wall*

Abstract: We analyze brick wall quantum circuits with free fermionic (matchgate) building blocks and analyze the spectral structure of two distinct hamiltonian limits, paying special attention to topological phases.

Marlou R. Slot, NIST & CU Boulder

Invited talk

Title: *A quantum ruler for orbital magnetism in moire quantum matter*

Abstract: For almost a century, magnetic oscillations have been a powerful “quantum ruler” for measuring Fermi surface topology. In this talk, I will present Landau-level spectroscopy as a complete quantum ruler to unravel the energy-resolved valley-contrasting orbital magnetism and large orbital magnetic susceptibility in twisted double-bilayer graphene [1]. These orbital magnetism effects lead to substantial deviations from the standard Onsager relation, manifesting as a breakdown in scaling of Landau-level orbits. The substantial magnetic responses emerge from the nontrivial quantum geometry of the electronic structure and the large length scale of the moire lattice potential. Going beyond traditional measurements, Landau-level spectroscopy performed with a scanning tunneling microscope offers a quantum ruler that resolves the full energy dependence of orbital magnetic properties in moire quantum matter. [1] M. R. Slot et al., Science 382, 81-87 (2023)

Shan-Wen Tsai, University of California Riverside
Invited talk

Title: *Quantum simulators for strongly correlated systems and lattice gauge theories*

Abstract: The goal of quantum simulations is to provide answers to open and relevant questions that cannot be answered using classical computers. I will discuss how programmable neutral atom arrays have been used to create a quantum floating phase and other correlated many-body states. I will also discuss a gauge-invariant approach for quantum simulating lattice gauge theory models.

Van Sergio Alves, Universidade Federal do Para
Invited talk

Title: *Thermal Effects on Fermi Velocity and Energy Gap for two dimensional Dirac-like Electrons*

Abstract: We describe the Fermi velocity and the mass renormalization due to the two-dimensional Coulomb interaction in the presence of a thermal bath. We consider an anisotropic version of pseudo quantum electrodynamics (PQED), within a perturbative approach in the fine-structure constant α. We use the so-called imaginary-time formalism to include the thermal bath. In the limit $T\rightarrow 0$, we calculate the renormalized mass $m^R(\mathrm p)$ and compare this result with the experimental findings for the energy band gap in monolayers of transition metal dichalcogenides, namely, WSe$_2$ and MoS$_2$. In these materials, the quasi-particle excitations behave as a massive Dirac-like particles in the low-energy limit, hence, its mass is related to the energy band gap of the material. In the low-temperature limit $T\ll v_F \mathrm p $, where $v_F \mathrm p$ is taken as the Fermi energy, we show that $m^R(\mathrm p)$ decreases linearly on the emperature, i.e, $m^R(\mathrm p,T)-m^R(\mathrm p,T\rightarrow 0)\approx -A_\alpha T +O(T^3)$, where A_α is a positive constant. On the other hand, for the renormalized Fermi velocity, we find that $v^R_F(\mathrm p,T)-v^R_F(\mathrm p,T\rightarrow 0)\approx -B_\alpha T^3 +O(T^5)$, where B_α is a positive constant. We also perform numerical tests which confirm our analytical results.

Jasper van Wezel, University of Amsterdam
Invited talk

Title: *Protected degeneracies and the concentric Wilson loop spectrum*

Abstract: TBD

Daniel Vanmaekelbergh, Debye Institute for Nanomaterials Science, Gravity Program Materials for the Quantum Age, University of Utrecht
Invited talk

Title: *Atom-by-atom made lattices as simulators for real materials*

Abstract: In real “natural” materials, the band structure is determined by the nature of the elements in the solid, the chemical binding and crystal structure, spin-orbit coupling, and interactions. In natural materials, all factors emerge at once. This means that it is often difficult to systematically study the effect of one factor, e.g., the strength of intrinsic spin orbit coupling or the electronic coupling in a given lattice, and keep all other factors constant. This impedes a systematic study of the electronic properties in relation to (two-dimensional) crystal structures. Using, artificial hand-made two-dimensional lattices, our (and other) group(s) went for a study of the relation between the lattice geometry and electronic properties, more

specifically for the honeycomb, deformed honeycomb, kagome and Lieb lattices; also studying geometric limits that are not available in natural materials. Experimentally, we used a scanning tunneling microscope to prepare the lattice and characterize the band structure. We prepare lattices by placing electron-repelling CO-molecules on a Cu(111) surface in a certain geometry, molding the natural surface state into a specific lattice. The electron repelling CO's determine the artificial atoms as potential-energy valleys, and the electronic coupling between these. With scanning tunneling microscopy we studied the geometry of the lattice. With scanning tunneling spectroscopy, we measure the LDOS(E,x,y). We compare the experimental LDOS(E,x,y) with the result of tight-binding lattice models and derive the single-particle band structure. In this, we have a strong collaboration with the group of Cristiane Morais Smith. I will provide some highlights. e.g., the honeycomb lattice with decoupled s-orbital and in-plane p-orbital bands, showing orbital-specific Dirac and flat bands, and what happens if we could introduce SOC in such a lattice. I will also give an outlook: The above ,"analog quantum emulations" (Feynmann) could be extended to materials in which spin-orbit coupling or interactions are important. Otherwise, novel engineered electronic materials could be prepared by transferring these concepts to a two-dimensional electron gas in a state-of-the-art quantum well that can be patterned into a lattice by modern lithography. Finally, the results obtained with artificial lattices should help to understand those obtained with natural materials; for instance two-dimensional Bi2Se3 quantum spin Hall insulators.

XiaoYun Xu, Shanghai Jiao Tong University
Invited talk

Title: Quantum simulation based on three-dimensional photonic chips

Abstract: Integrated photonic technology offers a promising platform for compact, stable, and scalable quantum information processing. Femtosecond laser direct writing technology is known for its three-dimensional fabrication capability, which enables us to construct complex integrated photonic lattices and photonic circuits. This talk will begin with the underlying technology and briefly introduce our technical progress in implementing large-scale three-dimensional photonic chips. Subsequently, I will present our quantum simulation research based on the three-dimensional photonic chips, including the studies of quantum phenomena in periodic and aperiodic photonic lattices.

Posters

Ayan Banerjee, Max-Planck-Institute for the Science of Light (MPL)
Poster

Title: *Controlling Non-Hermitian Topological Phases Through Floquet Engineering*

Abstract: In case of open systems the system might exchange energy/particles (or other degrees of freedom) among the subsystems. In that case, each subsystem encounters an overall growth or decay in energy or probability norm. Such energy non-conserving or dissipative systems can be modeled through the adoption of complex energy eigenvalues and a non-Hermitian (NH) Hamiltonian [1]. Interestingly, NH topological systems show a distinct class of spectral degeneracies, known as exceptional points (EPs), where not only eigenvalues but also eigenvectors coalesce and result in the Hamiltonian becoming non-diagonalizable [2]. Enclosing such an EP yields a quantized topological invariant, revealing its underlying topological nature governed by NH topological band theory [3]. On the other hand, Floquet engineering, the control of quantum systems using periodic driving, is a very useful tool to manipulate quantum matter [4]. The study of periodically driven NH systems opens up an avenue to explore new features of NH topological phases [5].Motivated by these rapid developments, we combine the two ideas and propose to use Floquet engineering to create and control tunable NH phases [6,7]. We use analytical as well as numerical calculations to illustrate the topological properties and map out the topological phase transitions arising from the application of circularly polarized laser light [6]. We demonstrate our proposal using various NH models and show that by using illumination with light, one can engineer the positions and stability of EPs. We support our numerical studies with an analytic expression for the Floquet Hamiltonian (H_F) computed within a Floquet–Magnus (FM) expansion theory. Next, we turn on the light to observe the effect of light on the open boundary spectra as well as stable zero energy modes. We find that the stability of zero energy modes is destroyed on introduction of light as they move away from zero energy. Additionally, we show that driving can destabilize the higher-order EPs and NH skin modes with increasing laser intensity. Furthermore, we demonstrate that applying driving forces can effectively generate exceptional contours (ECs) in NH multi-Weyl semimetals when exposed to circularly polarized light. We also investigate how these ECs divide charges using an NH generalization of Berry curvature and explore the resulting Lifshitz transitions [7]. Our proposal is amenable to realization in cold atom and waveguide setups. We are hopeful that our findings will motivate further theoretical and experimental studies of these intriguing topological systems.
References: [1] N. Moiseyev, Non-Hermitian quantum mechanics (Cambridge University Press, 2011). [2] D. Heiss, Nature Physics 12, 823 (2016). [3] H. Shen, B.

Zhen, and L. Fu, Phys. Rev. Lett. 120, 146402 (2018). [4] T. Oka and H. Aoki, Physical Review B 79, 081406 (2009). [5] L. Zhou and D. Zhang, Entropy, 25, 10 (2023). [6] A. Banerjee and A. Narayan, Phys. Rev. B 102, 205423 (2020). [7] D. Chowdhury, A. Banerjee, and A. Narayan, Phys. Rev. A 103, L051101 (2021).

Carlos Camacho, University of Birmingham
Poster

Title: *Non-abelian lattice gauge field systems using feedback-coupled oscillators*

Abstract: Non-abelian lattice gauge fields show exotic behaviour that cannot be captured by an abelian counterpart. This is due to the existence of Wilson loops with the same starting spatial position that do not commute in the non-abelian case. These systems are described by a complete knowledge of all Wilson loops allowed by the geometry of the system. We simulate both Hermitian and non-Hermitian models and demonstrate the ability to measure objects related to Wilson loops using a system of feedback-coupled mechanical oscillators. Furthermore, we can obtain experimental signatures of both genuine non-abelian behaviour and non-Hermitian non-abelian systems.

Thibaut Desort, Laboratoire de Physique des Solides, Universite Paris-Saclay
Poster

Title: *Exploring Topological Invariants and Quantum Geometry when adding Electronic Interactions*

Abstract: I try to find an object that would reproduce the properties of Berry curvature in 2D systems when the system is interacting. In this poster, I introduce a simple situation where we can identify a local geometry in reciprocal space.

Julius Gohsrich, Max Planck Institute for the Science of Light
Poster

Title: *Exceptional points of any order in a generalized Hatano-Nelson model*

Abstract: Exceptional points (EPs) are truly non-Hermitian degeneracies where matrices become defective. The order of such an EP is given by the number N of coalescing eigenvectors. While there is good understanding of low- and high-order EPs, with $N<5$ or N scaling with system size, respectively, there was little to no progress regarding EPs of orders in between. On my poster about [arXiv:2403.12018], I show how to bridge this gap and generate EPs of arbitrary order in a generalized Hatano-Nelson model, and show remarkable physical features related to those EPs.

Banan Kerdi, LPS-ENSTA
Poster

Title: *Evidence of large Dzyaloshinskii-Moriya interaction at the cobalt/hexagonal boron nitride interface*

Abstract: A large Dzyaloshinskii-Moriya interaction (DMI) has been predicted to occur at the interface of Co with hexagonal boron nitride (h-BN) [1], despite h-BN being a van der Waals insulator composed of light elements. I will present how clean Co/h-BN interfaces were obtained by combining ultra-high vacuum growth and mechanical exfoliation. In addition, DMI and PMA were measured using Brillouin light scattering spectroscopy on a series of samples of varying Co thickness grown on Pt or Au and covered with h-BN or Cu. By comparing the h-BN-covered samples with their corresponding control Cu-covered samples, the effect of the Co/h-BN interface was extracted. We thus deduced a

----

Lorenzo Maffi, University of Padua
Poster

Title: *Vortex dynamics in strongly interacting superfluid*

Abstract: Interactions can play a determinant role in low dimensions for topological and chiral states of matter by giving rise to interesting emergent phenomena such as quasiparticle fractionalization and quantum phase transitions. In particular, near criticality, the system exhibits effective relativistic invariance leading to the emergence of concepts typical of high-energy physics. The recent advances in control and tunability of local quantum degrees of freedom allow to explore such questions in several experimental platforms, as part of the analog quantum simulation programs. In particular, we studied the dynamical properties of excitations, such as vortices, within bosonic systems and focus on their fate under the presence of interactions close to transitions.

Dennis Klaassen, University of Twente
Poster

Title: *Quantum Spin Hall States and Topological Phase Transition in Germanene*

Abstract: We provide experimental evidence of a topological phase transition in the monoelemental quantum spin Hall insulator, germanene. Low low-buckled epitaxial germanene on buffer-layer/Ge2Pt is a quantum spin Hall insulator with a large bulk gap and robust metallic edges. The topological edge states have distinct dispersion characteristics depending on their termination. Particularly, we observe a pronounced variance in Fermi velocity, with armchair edges exhibiting a velocity higher than zigzag edges by about an order of magnitude. Moreover, we demonstrate that the application of a critical perpendicular electric field closes the topological gap and makes germanene a Dirac semimetal. Increasing the electric field further results in the opening of a trivial gap and the disappearance of the metallic edge states. This electric field-induced switching of the topological state and the sizable gap make germanene suitable for room-temperature topological field-effect transistors, which could revolutionize low-energy electronics.

Xinyang Li, Utrecht University
Poster

Title: *Topological structures of fractal-related systems*

Abstract: I will introduce a new kind of fractal and the non-trivial properties of the crystals that are built according to different generations of the fractal.

Miguel Mojarro, Ohio University
Poster

Title: *Intertwined electronic pairing and topological states by uniaxial strain in the kagome lattice*

Abstract: We study the interplay of attractive electron interactions and topological states in strained kagome lattices with spin-orbit coupling via a Hubbard Hamiltonian in the mean-field approximation. In the unstrained lattice, there is a topological phase transition from a quantum spin Hall state to a charge density wave (CDW) with increasing interaction strength. Upon applying a uniform uniaxial strain to the lattice, we find a new phase with coexisting CDWs and topological states. For increasing interaction strength or strain, the system is driven into a pure CDW, signaling topological phase transitions. The directionality (nematicity) of the CDW is controlled by the direction of the applied strain. When s-wave electronic pairing is allowed, the system develops a superconducting order beyond a threshold attraction, which is totally suppressed by the onset of a CDW with increasing interaction. Most interestingly, moderate strain allows the coexistence of superconductivity and CDWs for a range of interaction values. This illustrates how electronic interactions and single-particle topological structures compete to create unusual correlated phases in kagome systems.

Corentin Morice, Laboratoire de Physique des Solides
Poster

Title: *Gravitational horizons in quantum matter*

Abstract: We propose a class of lattice models, including Weyl semimetals, realizable in condensed matter systems whose low-energy dynamics exactly reduces to Dirac fields subjected to gravitational backgrounds. Wave-packets propagating on the lattice exhibit eternal slowdown, signalling the formation of black hole event horizons. We show that the semiclassical wave packets trajectories coincide with the geodesics on (1+1)D dilaton gravity, paving the way for new and experimentally feasible routes to mimic black hole horizons and realize (1+1)D spacetimes as they appear in certain gravity theories.

Diego Felipe Munoz Arboleda, Utrecht University
Poster

Title: *Thermodynamics and entanglement entropy of the non-Hermitian SSH model*

Abstract: Topological phase transitions are found in a variety of systems and were shown to be deeply related with a thermodynamic description through scaling relations. Here, we investigate the entanglement entropy, which is a quantity that captures the central charge of a critical model and the thermodynamics of the non-reciprocal Su-Schrieffer-Heeger (SSH) model. Although this model has been widely studied, the thermodynamic properties reveal interesting physics not explored so far. In order to analyze the boundary effects of the model, we use Hill's thermodynamics to split the grand potential in two contributions: the extensive one, related to the bulk, and the subdivision one, related to the boundaries. Then, we derive the thermodynamic entropy for both, the edges and the bulk and the heat capacity for the bulk at the topological phase transitions. The latter is related to the central charge when the underlying theory is a conformal field theory, whereas the first reveals the resilience of the topological edge states to finite temperatures. The phase transition between phases that are adiabatically connected with the Hermitian SSH model display the wellknown behaviour of systems within the Dirac universality class, but the transition between phases with complex energies shows an unexpected critical behavior, which signals the emergence of an imaginary time crystal.

Zeb Osseweijer, Utrecht University
Poster

Title: *A Fractal Haldane model*

Abstract: We have studied the Haldane model on the fractal geometry of the Sierpinksi gasket. As a consequence of the fractal geometry, we observe a fractality driven gap opening mechanism, leading to the opening of multiple gaps. In addition, the introduction of a complex next-nearest neighbour hopping causes the opening of multiple flux-induced gaps. We will discuss a topological marker applicable to these fractal systems, to quantify the topology. Finally, we will present the phase diagram of this structure. Here, very intricate and complex patterns will emerge, in contrast with previous results. Therefore, we show that the fractality of the model greatly influences the phase space of these structures, and how the combination of topological phases of matter and fractal dimensions is an extremely compelling area of research.

David Santiago Quevedo, Utrecht University
Poster

Title: *From Sub-Diffusion to Time Crystals: Dynamics of the fractional Langevin equation with white and colored noise*

Abstract: Time crystals are exotic phases of matter where time-symmetry breaking occurs, analogous to the space-symmetry breaking that characterizes conventional crystals. This idea has sparked extensive research in recent years since it was first conjectured by Frank Wilczek in 2012. We investigate the emergence of periodic time-ordered phases revealing signatures of time crystallinity from the fractional Langevin equation with fractional-order friction that describes a system coupled to white and colored noise thermal baths. Anomalous sub-diffusive phases are observed in the long-term dynamics of the Mean Squared Displacement, dominated by the memory effects encoded in the fractional friction, while universal ballistic behavior dominates the short-term regime. Furthermore, the absence of linear friction in the system triggers the emergence of periodic time-ordered phases that manifest the properties of a time crystal, with a ground state satisfying the fluctuation-dissipation theorem and a periodicity proportional to¬†2œÄ, a time glass with periodicity proportional to¬†œÄ, and a mixed phase with contributions from both ground and out-of-equilibrium states when the system couples simultaneously to both baths. For all cases, we present analytical and numerical results and a microscopic description based on an extension of the Caldeira-Leggett model.

Fabio Salvati, Institute for Molecules and Materials, Radboud University
Poster

Title: *Emergence of non-ergodic multifractal quantum states in geometrical fractals*
[Salvati, F - Katnelson M.I. - Bagrov A]

Abstract: Eigenstate multifractality, a hallmark of non-interacting disordered metals and potentially present in the many-body localized phase, is important for their anomalous slow dynamics and holds significant promise for applications in quantum annealing, machine learning, and superconductivity. We propose a novel approach to achieve non-ergodic multifractal (NEM) states without disorder by iteratively introducing defects into a host lattice, reshaping it from a plain structure into fractal geometries. Our comprehensive analysis of the Sierpinski gasket provides robust evidence for the emergence of non-ergodic multifractal states, extending beyond conventional classification with thereby opening new pathways for quantum transport studies. Potential experimental applications are also discussed.

Cristoph Setescak, Universitat Regensburg
Poster

Title: *The Coarse Geometric Origin of Topological Phases*

Abstract: Topological phases of matter rely on the concept that the ensemble of occupied bulk energy bands of a translationally invariant Hamiltonian can be classified by topological invariants by making use of internal electronic symmetries. Non-trivial invariants give rise to remarkable electronic states at the boundary. This approach falls short when dealing with disorder induced by prevalent crystal defects. To overcome this, we employ combined experimental and theoretical studies of topological phases of matter. Combined Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM) provides an experimental platform for studying topological phases of disordered materials. On the theoretical side, we present a coarse geometric framework that extends the topological classification of matter to disordered materials in a mathematically precise way. This coarse geometric approach is physically motivated, provides a natural setting for the bulk-boundary correspondence and offers a numerical efficient way to calculate topological invariants. Concrete experiments are proposed to test predictions obtained by coarse geometric methods about the evolution of the topological phase diagram upon the introduction of disorder.

Robin Verstraten, Utrecht University
Poster

Title: *Dissipative systems fractionally coupled to a bath*

Abstract: Quantum diffusion is a major topic in condensed-matter physics, and the Caldeira-Leggett model has been one of the most successful approaches to study this phenomenon. Here, we generalize this model by coupling the bath to the system through a Liouville fractional derivative. The Liouville fractional Langevin equation is then derived in the classical regime, without imposing a non-Ohmic macroscopic spectral function for the bath. By investigating the short- and long-time behavior of the mean squared displacement, we show that this model is able to describe a large variety of anomalous diffusion. Indeed, we find ballistic, sub-ballistic, and super-ballistic behavior for short times, whereas for long times, we find saturation and sub- and super-diffusion.

Maria Zelenayova, Stockholm University and Max Planck Institute for the Science of Light
Poster

Title: *Bound States in the Continuum*

Abstract: I will present the results of our publication, "Non-Hermitian Extended Midgap States and Bound States in the Continuum" (Maria Zelenayova, Emil J. Bergholtz, Applied Physics Letters, vol. 124, no. 4). Our study explores various (de)localization phenomena in non-Hermitian systems by solving a class of generalized SSH/Rice-Mele models. In particular, I investigate bound and extended states in the continuum. One type of bound states is protected by a winding number, while the second type by quantized biorthogonal polarization. Additionally, we identify an extended state stemming from the boundary state that delocalizes while remaining in the gap at bulk critical points. This state may also delocalize within a continuum of localized (skin) states. These results clarify fundamental aspects of topology and symmetry in light of different approaches to the anomalous non-Hermitian bulk-boundary correspondence.

Sponsors

École de Physique des Houches

Université franco-allemande Deutsch-Französische Hochschule

QUANTERA

T-NiSQ Tensor Networks in Simulation of Quantum Matter

QuMat Materials for the Quantum Age

anr agence nationale de la recherche

Università degli Studi di Padova

Dipartimento di Fisica e Astronomia Galileo Galilei