Quasiperiodicity and Fractality in Quantum Statistical Mechanics
SISSA Trieste, 7–10 September 2026

TITLES AND ABSTRACTS OF THE TALKS

Speaker: Eva Andrei (Rutgers University)

Title: *Multifractality and heavy fermion behavior in quasiperiodic moiré crystals*

Abstract: TBA

Speaker: Simon Becker (Bocconi University)

Title: *Recent Developments for the Critical AMO*

Abstract: I will review some recent and new developments concerning the critical AMO, focusing on its intricate spectral structure. The talk will discuss questions related to fractal dimensions and gap labelling.

Speaker: David Damanik (Rice University)

Title: *The Deift Conjecture and Generalized Almost Periodicity*

Abstract: This talk will present joint work with Long Li and Nicolae Strungaru on a new perspective on the Deift conjecture. This conjecture states that the Korteweg-de Vries (KdV) equation with almost periodic initial data admits global solutions that are almost periodic in space and time. There has been exciting progress on this conjecture in the past couple of decades. The status quo is that it has been confirmed for suitable classes of almost periodic initial data, and it has also been realized that almost periodic initial data may develop discontinuities, which are incompatible with Bochner/Bohr almost periodicity. Our work is motivated by recent work of Daniel Lenz, Timo Spindeler, and Nicolae Strungaru on the characterization of structures with pure point diffraction - the central property in mathematical quasicrystal theory. It had been understood for a long time that Bochner/Bohr almost periodicity is not the right notion in the diffraction context, but Lenz-Spindeler-Strungaru have only recently realized precisely which almost periodicity notions are the correct ones when studying and even characterizing key properties in diffraction theory. Armed with these realizations, we give the Deift conjecture a fresh look.

Speaker: Bryn Davies (University of Warwick)

Title: *Quasiperiodic waveguides: periodic approximants, super band gaps and fractal rainbow trapping*

Abstract: Quasicrystalline geometries have generated significant excitement amongst engineers utilising their exotic spectra for wave control applications. The ability to support many large spectral gaps and spectra with exotic topologies has inspired the enlargement of the metamaterial design space beyond just periodic geometries, into the realm of quasicrystals.

In this talk, I will discuss two methods used to approximate the quasicrystalline geometries by periodic patterns: the supercell and superspace methods. In both cases, Floquet-Bloch theory can be applied to compute approximate spectra, which converge under a suitable limit. For the specific case of one-dimensional waveguides based on generalised Fibonacci tilings, I will present particular results demonstrating that supercell approximations give credible predictions of the main spectral gaps. We refer to these main gaps as "super band gaps" and have proved their existence for generalised Fibonacci tilings, based on characterising the growth of the underlying recursion relation.

Finally, I will present an example of using these methods to design a 'graded' waveguide that yields broadband wave energy harvesting. We have shown that the rainbow trapping phenomenon of graded metamaterials can be combined with the fractal spectra of quasiperiodic waveguides to give a metamaterial that performs 'fractal' rainbow trapping. This is achieved through a graded cut-and-project algorithm that yields a projected geometry for which the effective projection angle (and corresponding local band gap structure) is graded along its length, leading to broadband 'fractal' rainbow trapping. We demonstrated this principle experimentally by designing and building an acoustic waveguide.

Speaker: Felix Flicker (Bristol University)

Title: *A Quasicrystal-to-Crystal Phase Transition in The Hat Aperiodic Monotiling*

Abstract: The recent discovery of aperiodic monotiles such as 'The Hat' has challenged our understanding of quasicrystallography, much as the discovery of quasicrystals challenged our understanding of crystallography. The quantum properties of electrons on The Hat are predicted to show some similarities, and some differences, to those on graphene [1], while classical magnetism features a unique hierarchical structure and ground state degeneracy [2]. In this talk I will consider another remarkable property of The Hat: its ability to embed

perfectly onto a periodic lattice. By considering the classical statistical mechanics of such embeddings in the grand canonical ensemble (allowing Hats to be added and removed), we find phase transitions between the long-range aperiodic order of The Hat, periodic order, and disorder, tunable by temperature and alignment interactions. I will also present ongoing work on quantum localisation effects in these different regimes.

[1] J. Schirmann, S. Franca, FF, and A. G. Grushin, "Physical properties of an aperiodic monotile with graphene-like features, chirality, and zero modes", PRL 132, 086402 (2024)

[2] T. Wang, F. Museur, G. Macauley, Luca Berchialla, FF, P. Derlet, and L. J. Heyderman, "Monopole caging in an Artificial Spin Ice Aperiodic Monotiling", submitted

Speaker: Matteo Gallone (University of Milan)

Title: *Irrelevance of quasi-periodic disorder in the 2D Ising model*

Abstract: Universality is a fundamental concept in modern physics, referring to the independence of macroscopic properties near phase transitions from microscopic model details considered irrelevant. Understanding universality involves identifying perturbations that preserve this property and those that disrupt it. A significant type of perturbation is disorder, introduced through a random or quasi-periodic spatial potential. In the random Ising model, the Harris criterion predicts whether a perturbation is relevant or not based on the unperturbed model's critical exponents. A similar argument, adapted by Luck, applies to quasi-periodic disorder.

For instance, in the 2D Ising Model with weak quasi-periodic hopping disorder, the Harris-Luck criterion predicts irrelevance of the disorder. In the work I present, we rigorously confirm this prediction, proving that the energy correlation exponent's singularity is equal to the one of the pure system. The result holds for weak analytic 1D and 2D disorders with frequencies satisfying a Diophantine condition.

The proof combines a multiscale Renormalization Group analysis on the Grassmann representation of the Ising model. This approach provides a detailed framework for analyzing disorder effects and confirms the robustness of universality under specific quasi-periodic perturbations. This is joint work with V. Mastropietro.

Speaker: Miguel Gonçalves (Princeton)

Title: *Magnetism in quasiperiodic Hubbard models*

Abstract: In this talk, we will explore the ground states and excitations of quasiperiodic Hubbard models in two distinct regimes: (i) when the ground state is a fully polarized ferromagnet and (ii) when the ground state is spin unpolarized.

In (i), we will propose a new mechanism for ferromagnetism in narrow bands of Anderson-localized states, valid in any dimension. By exploiting single-particle localization, we will propose a controlled effective theory for the exchange interactions within the narrow band. We will then characterize, both analytically and numerically, the stability of the ferromagnetic ground state in terms of the bandwidth, interaction strength, and, most importantly, the geometry of the localized single-particle wave functions.

In (ii), we will explore the half-filled phase diagram of the one-dimensional quasiperiodic Hubbard model. We will uncover a previously overlooked gapped topological phase, separated from a more conventional Mott insulator either by an intermediate gapless phase or by a sharp topological transition in which the charge gap closes and reopens. We will characterize the full phase diagram as a function of interaction and quasiperiodic potential strength, revealing a pronounced quasiperiodic-induced spin and charge separation, manifested both in the ground-state and in the localization properties of low-lying excitations.

Speaker: Adolfo Grushin (Donostia International Physics Center and CNRS)

Title: *Fractons in the Fractional Quantum Hall Effect*

Abstract: The fractional Hall effect emerges only in extremely clean samples. Extending such fractionalised phase to severely disordered systems is an open question, especially if we are after properties which have no analogue in canonical crystalline systems. In this talk, I discuss an exactly-solvable model that realises such a phase. This is done by coupling together a patchwork of Laughlin fractional Hall phases, each with a different fractionalisation. We can exactly solve this model working with the coupled-wire construction, where we can tune the topology in real space by adjusting the spatial positioning of each wire. Its ground state is an emergent gapped phase, which we call the Fractonic Fractional Quantum Hall Effect, that displays an exotic interplay of fractional quantum Hall anyons together with fractonic quasiparticle constraints and exponential ground state degeneracy. Remarkably, this phase appears to realise a gapped fractonic order in 2D, seemingly violating a prominent

no-go result which prohibits such a phase emerging in fewer than three dimensions. Our method provides an analytically solvable pathway to a non-crystalline fractional quantum Hall effect and fractonic theories in two-dimensions, examples of which were lacking.

J. Schirmann*, P. D'Ornellas*, Charles Stahl, AGG, arxiv: 2503.18337

Speaker: Anuradha Jagannathan (Laboratoire de Physique des Solides, CNRS, Université Paris-Saclay)

Title: *Metallic mean 1D quasicrystals and their topological invariants*

Abstract: The metallic mean family of one-dimensional quasicrystals includes the well-known Fibonacci chain, which corresponds to the golden mean. The series of metallic mean chains tends towards the periodic crystal in a certain way that can be described simply using the cut-and-project scheme. In higher dimensions too, analogous metallic mean lattices have been proposed, such as in [1]. I will discuss electronic properties of the family of metallic mean chains as a function of k, the metallic mean index. One of the interesting properties studied are the values of topological invariants of the model, which lead to the quantization of certain transport properties, such as the Hall conductivity in a 2D system. In 1D systems, the same invariants can be measured in a topological pump experiment. The combined electronic spectra of the set of metallic mean quasicrystals form a subset of the Hofstadter butterfly [2]. For fixed k, the Hall conductivity has a distinctive non-monotonic behavior as a function of filling. I will discuss how, as k gets very large, one tends towards the standard Landau level physics expected for periodic crystals under a magnetic field.

[1] Koga, A. and T. Matsubara, Phys. Rev. B 111, 214422 (2025)

[2] A. Jagannathan, https:arxiv.org/abs/2602.09769

Speaker: Vansh Kaushik (SISSA)

Title: *Topological energy pumping in a quasiperiodically driven four-level system*

Abstract: We investigate a quasi-periodically driven four-level system that serves as a temporal analog of topological phenomena found in four-band models with intertwined spin and orbital degrees of freedom. Under a two-tone drive in the strong-driving regime, the system realizes a two-dimensional synthetic Floquet lattice, thus facilitating the realization of topological energy pumping. For a temporal quantum spin Hall insulator, we find that the rates of emission and absorption of energy between the two drives are not exactly op-

posite for a given band. However, when contributions from two chiral symmetric partner bands are added, they become exactly opposite. This quantized rate of energy exchange is a direct consequence of propagating edge modes in the real-space model, which we further characterize by computing the spin-Chern number. Interestingly, our analysis yields zero rate of exchange of energy between the drives for a temporal higher-order topological insulator, suggesting the presence of localized corner modes that we characterize by the mid-gap Wannier spectra. Our findings uncover the role of chiral, particle-hole and time reversal symmetries on the energy dynamics in temporal quantum spin Hall and higher-order topological insulators. Finally, we demonstrate that the perfect (imperfect) nature of the fidelity during the time-evolution of the system serves as a characteristic signature of a topological (trivial) phase.

References:

V. Kaushik, S. Choudhury, and T. Nag, Topological energy pumping in a quasiperiodically driven four-level system, Phys. Rev. B (accepted, 2026). DOI:https://doi.org/10.1103/prg5-3srn

Speaker: Johannes Kellendonk (Université Claude Bernard Lyon 1)

Title: *Spectral flow distinguishes 1-d quasicrystalline topological insulators*

Abstract: Aperiodic materials have a richer topological phase structure than periodic ones. These phases distinguish different classes of aperiodic materials. For 1-dimensional materials, this can be analysed by looking at a spectral flow of their edge eigenvalues. In this way we can distinguish, among quasicrystals, those which are entirely determined by their Bragg spectrum, like for instance the Fibonacci chain, from the others, like the period doubling chain, where there are phases which cannot be predicted by Bragg diffraction.

Speaker: Baptiste Lerat (Cambridge)

Title: *Probing the microscopic structure of an 8-fold quasicrystal lattice with a quantum gas magnifier.*

Abstract: Usual quantum gas microscopy techniques are typically difficult to implement for quasi-periodic lattices – however, by implementing instead a quantum gas magnification scheme, we observe the density distribution in an 8-fold rotationally symmetric optical quasicrystal with single site resolution. We measure how the site-resolved density distribution evolves across the superfluid to Bose-glass transition opening the door to further studying how this microscopic structure behaves in a wide range of scenarios.

Speaker: Mitchell Luskin (University of Minneapolis)

Title: *Math and Physics at the Moiré Scale*

Abstract: Placing a two-dimensional lattice on another with a small rotation gives rise to periodic "moiré" patterns on a superlattice scale much larger than the original lattice. The Bistritzer-MacDonald (BM) model attempts to capture the electronic properties of twisted bilayer graphene (TBG) by an effective periodic continuum model over the bilayer moiré pattern. We use the mathematical techniques developed to study waves in inhomogeneous media to identify a regime where the BM model emerges as the effective dynamics for electrons modeled as wave-packets spectrally concentrated at the monolayer Dirac points of linear dispersion, up to error that we rigorously estimate. Using measured values of relevant physical constants, we argue that this regime is realized in TBG at the first "magic" angle where the group velocity of the wave packet is zero and strongly correlated electronic phases (superconductivity, Mott insulators, etc.) are observed. We will also present models of TBG which account for the effects of mechanical relaxation, and we will couple our relaxed BM model with interacting TBG models. We find that our systematic relaxation model gives quantitative differences from earlier simplified models.

Speaker: Quentin Marsal (Uppsala)

Title: *Quantum geometry of a one-dimensional quasicrystal*

Abstract: The atomic structure of quasicrystals, long-range ordered but not translational invariant, results in specific electronic properties, especially regarding the electron localization. Electrons in quasicrystals are more delocalized than in disordered materials, but less than in translational invariant crystals. This in turn influences correlated states such as superconductivity or magnetic orders. The quantum metric is a quantum geometric indicator probing the spreading of the Wannier orbitals composing an electronic band. It plays a prominent role in flat-band correlated systems as, in the absence of dispersion, wave function delocalization is the only remaining mechanism that can account for long-range coherence and correlations. I will present a work [1] where we establish the quantum metric as an indispensable and natural tool to capture the deep relation between the structure of the

quasicrystal, its energy spectrum and the localization of the electrons, and position quasicrystals as a potential platform for intriguing correlated states. [1] Q. M., P. Holmvall, A. Black-Schaffer, ArXiv2506:15575 (2025)

Speaker: Vieri Mastropietro (University of Rome Sapienza)

Title: *Quasi-periodicity in condensed matter: Interacting Weyl semimetals and Twisted Bilayer Graphene*

Abstract: Small divisor problems appeared first in celestial mechanics at the end of XIX century but they play now a very important role in condensed matter. We present two results obtained generalizing methods introduced for the convergence of the Lindstedt series and based on rigorous Renormalization Group and number theoretical properties. The first is the stability of the semimetallic phase in interacting Weyl semimetals in presence of quasi-periodic disorder. The second of the persistence of Dirac cones in Twisted Bilayer Graphene provided the angles belong to a fractal set of large measure which decreases with the hopping strength.

Speaker: Cristiane Morais-Smith (Utrecht University)

Title: *TBA*

Abstract: TBA

Speaker: Tomaž Prosen (University of Ljubljana)

Title: *Ergodicity Breaking Transitions in East Circuits: From Dynamical Localization to Ruelle-Pollicott Resonances*

Abstract: I will present numerical evidence, perturbative arguments, and (partial) proofs for a dynamal localization transition in quantum East circuits on a semi-infinite qubit chain. In the ergodic phase, truncated Heisenberg-picture propagator reveals clear convergence of leading Ruelle-Pollicott-like resonances with clear fractal structure.

Speaker: Mikael Rechtsman (Pennsylvania State University)

Title: *Quantized Nonlinear Thouless Pumps*

Abstract: I will present my group's recent experimental work on the fractional pumping of solitons in nonlinear photonic Thouless pumps, using waveguide arrays. Specifically, I will show that the displacement (in unit cells) of solitons in Thouless pumps is strictly quantized to the Chern number of the band from which the soliton bifurcates in the low power regime; whereas in the intermediate power regime, nonlinear bifurcations lead to fractional quantization of soliton motion. This fractional quantization can be predicted from multi-band Wannier functions associated with the states of the pump. I will then present our experimental results on Thouless pumping under disorder; here, we find that nonlinearity acts to quantize transport where the linear system does not.

Speaker: Leanne Reeve (Cambridge)

Title: *Quench Dynamics of Ultracold Atoms in an Optical Quasicrystal*

Abstract: The combination of ultracold atoms and optical lattices provides a testing ground readily suited to studies of dynamics, thanks to these systems' inherent tunability. Here, we discuss the dynamics of ultracold bosons in an optical quasicrystal after quenches across the superfluid-Bose glass phase transition. After quenching to the superfluid regime we observe the spread of correlations as initially localized atoms hop between lattice sites, whereas after quenching into the Bose glass regime we observe a quantum walk in momentum space to ever higher diffraction orders whilst real space correlations display a complex pattern of decaying oscillations on all length scales. In the latter case, we go on to study these correlations in configuration space (effectively the perpendicular space of the quasicrystal), as a way to understand their intricate behaviour in terms of the quasiperiodic order of the underlying Hamiltonian.

Speaker: Ulrich Schneider (University of Cambridge)

Title: *Ultracold atoms in optical quasicrystals*

Abstract: Ultracold atoms in optical lattice have over the past two decades emerged as a workhorse for experimental many-body physics and quantum simulations. Optical lattices provide clean and versatile potentials that are typically periodic, akin to regular crystals. Here, in contrast, I will introduce a non-periodic optical lattice, namely an eightfold rotationally symmetric optical 2D quasicrystal. This potential is created by overlapping four independent 1D lattices in a plane and hence enables a simple description of the potential. I will highlight the connections between more abstract descriptions of this potential, including an octagon-shaped configuration space, and direct experimental observations including matter-wave diffraction to study the self-similar momentum structure in this structure and the realisation of the 2D Bose glass. I will also touch upon the topological structure of these optical quasicrystals.

References:

Matter-wave diffraction from a quasicrystalline optical lattice

Konrad Viebahn, Matteo Sbroscia, Edward Carter, Jr-Chiun Yu, Ulrich Schneider Phys. Rev. Lett. 122,110404 (2019)

Observing localisation in a 2D quasicrystalline optical lattice

Matteo Sbroscia, Konrad Viebahn, Edward Carter, Jr-Chiun Yu, Alexander Gaunt, Ulrich Schneider Phys. Rev. Lett. 125, 200604 (2020)

Hubbard Models for Quasicrystalline Potentials

Emmanuel Gottlob, Ulrich Schneider Phys. Rev. B 107, 144202 (2023)

Observing the two-dimensional Bose glass in an optical quasicrystal

Jr-Chiun Yu, Shaurya Bhave, Lee Reeve, Bo Song, Ulrich Schneider Nature 633, 338–343 (2024)

Quasiperiodicity protects quantized transport in disordered systems without gaps

Emmanuel Gottlob, Dan S. Borgnia, Robert-Jan Slager, Ulrich Schneider PRX Quantum 6, 020359 (2025)

Breakdown of bosonic Thouless pump due to interaction in a quasiperiodic lattice

Suman Mondal, Emmanuel Gottlob, Fabian Heidrich-Meisner, Ulrich Schneider Phys. Rev. B 113, 235131 (2026)

On the origin of energy gaps in quasicrystalline potentials

Emmanuel Gottlob, David Gröters, Ulrich Schneider Phys. Rev. B 113, 134202

Speaker: Nicolau Sobrosa (Porto)

Title: *Quantics purification mean-field approach to 2D Quasiperiodic Moiré Materials*

Abstract: The emergence of correlated phases, such as unconventional superconductivity, in two-dimensional moiré materials is one of the most fascinating developments in condensed matter physics. However, the interplay between the large-scale moiré patterns, the formation of flat bands, and the subsequent interaction-induced phases poses a significant challenge for numerical simulations. In realistic settings, twist-angle disorder or substrate interactions are sufficient to break translation symmetry or create super-moiré effects precluding the use of standard continuum models. To overcome this, we propose a mean-field approach enhanced by quantics tensor networks. By utilising a tensor-train representation of the mean-field Hamiltonian and the reduced density matrix, this method achieves logarithmic scaling with the system size. This scaling is a crucial advantage, enabling the simulation of exponentially large systems and capturing super-moiré physics. By comparison, exact diagonalization or even linear scaling methods such as the Fermi Oper-ator Expansion become prohibitive at these length scales. In this work, we study a two-dimensional model hosting both flat bands and quasiperiodicity-induced critical states. We introduce a zero-temperature purification scheme of the reduced density matrix that takes the tensor-network representation of the mean-field Hamiltonian and iteratively applies a low-order polynomial, converging to the density matrix. We analyze the real-space distribution of the charge density as well as its Fourier transform, to detect the presence of quasi-fractal order. Finally, we will discuss the physical implications of this quasi-fractal order for the broader understanding of strongly correlated phases in super-moiré systems.

Speaker: Yuki Tokumoto (University of Tokyo)

Title: *Superconductivity in van der Waals layered Ta–Te-based dodecagonal quasicrystals*

Abstract: Quasicrystals (QCs), characterized by long-range order without translational periodicity, provide a unique platform for exploring electronic states beyond those realized in periodic crystals. Nevertheless, superconductivity in QCs remains extremely rare, with bulk superconductivity established in only two systems to date. The recently discovered Ta–Te-based dodecagonal QC is the first known transition-metal chalcogenide van

der Waals layered QC and exhibits bulk superconductivity below approximately 1 K. Its thermodynamic stability and relatively high superconducting transition temperature make it a promising platform for investigating the interplay between quasiperiodicity and superconductivity. We have expanded this superconducting QC family through third-element substitution and found that the superconducting transition temperature can be systematically tuned by chemical composition. More recently, measurements on a large single grain of an Nb-substituted Ta–Te QC revealed strongly anisotropic upper critical fields. The in-plane upper critical field significantly exceeds the Pauli paramagnetic limit and deviates from conventional Werthamer–Helfand–Hohenberg behavior at low temperatures. These observations highlight unconventional aspects of superconductivity in a quasiperiodic van der Waals system.

Speaker: Munisa Tomayeva (National Research Nuclear University MEPhI, Moscow)
Title: *Temperature-driven structural crossover of vortex matter in a Penrose quasicrystal*
Abstract: TBA

Speaker: David Weld (University of California Santa Barbara)
Title: *Observing light-induced phase transitions and extended multifractality in a modulated 1D quasicrystal*
Abstract: Connections between systems of different dimensionality form a central motif in the study of quasicrystals, and of quantum matter in general. I will describe experiments that put such a cross-dimensional correspondence to work dynamically. Using ultracold atoms in a modulated bichromatic optical lattice, we realize a driven 1D quasicrystal that maps via the Harper-Hofstadter correspondence to a 2D integer quantum Hall system illuminated by intense polarized light. We observe an interlaced pattern of metal-insulator quantum phase transitions coherently controlled by the polarization of the driving light. Elliptically polarized driving can stabilize an extended critical phase featuring multifractal wavefunctions; we observe signatures of this multifractal phase in anomalous polarization-dependent subdiffusive transport. For carefully chosen drive parameters this phase of matter is predicted to feature spatially inhomogeneous effective tunneling, which may enable the future experimental study of synthetic curved spacetimes including event horizons. These experiments demonstrate a simple method for synthesizing exotic multifractal states and

exploring light-induced quantum phases across different dimensionalities.

Speaker: Marko Žnidarič (University of Ljubljana)

Title: *Many-body Kolmogorov cascade as a route to chaos*

Abstract: Complicated properties of classical chaotic system like relaxation can be understood as being due to fractal structures in phase space, causing evolution from initially smooth densities to exhibit increasingly finer structures. I will explain that analogous features can be also found in quantum many-body systems. The crucial object is the truncated propagator whose eigenvalues give the Ruelle-Pollicott resonances that determine the relaxation rate, while the eigenprojectors have a nontrivial fractal dimension that quantifies the operator time-flow from the local towards the non-local ones. The revealed structures explicitly explain how an effective relaxation of local observables is compatible with a purely unitary evolution. Results are verified in some simple solvable cases, for instance using orthogonal polynomials on a unit circle, as well as numerically in quantum chaotic toy models.