Israeli-German WE-Heraeus-Seminar:

Unifying Aspects of Topology in Quantum and Classical Systems

27 October – 1 November 2026

at the Physikzentrum Bad Honnef, Germany

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

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Introduction

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

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

In topology, properties of a geometric object are identified which remain unchanged under continuous deformations. Those properties are then referred to as topological invariants. This mathematical concept gains ever more importance in many branches of physics, comprising general relativity, quantum field theory, quantum chromodynamics, condensed matter, strongly correlated many-body system, magnetism, soft matter physics, and symmetry classification issues. Topological phases of matter have emerged as a far-reaching scientific breakthrough in the 21st century. The topological states were initially conceived as exotic states that are labeled by topological invariants interpreted as quantum numbers. Furthermore, the exotic transport properties exhibited by topological materials have been harnessed for applications in quantum technologies, making topology a very active research topic in quantum information theory and quantum computing. More recently, topological concepts have been studied in an increasingly diverse list of disciplines, also including applications in classical physics such as mechanics of elastic and deformable bodies, nonlinear dynamics, and biophysics. There are also considerable activites in mathematical physics.
This burst of interest, results, and applications originated in different communities, often without scientific contact or exchange. The resulting fragmentation of the topological physics community makes it hard for scientists to communicate their research and keep abreast of new developments.
In the proposed Israeli-German Binational Seminar many of the leading researchers in the field in Germany and in Israel will have the opportunity to overcome the standard disciplinary barriers, and communicate their ideas and form fruitful new collaborations. The purpose is to develop unifying viewpoints, terminologies and approaches.

Scientific Organizers:

Prof. Dr. Karin Everschor-Sitte	Faculty of Physics and Center for Nanointegration University of Duisburg-Essen Duisburg, Germany
Prof. Dr. Omri Gat	The Racah Institute of Physics The Hebrew University of Jerusalem Jerusalem, Israel
Prof. Dr. Thomas Guhr	Faculty of Physics University of Duisburg-Essen Duisburg, Germany

Introduction

Administrative Organization:

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Martina Albert

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Registration:

Martina Albert (WE Heraeus Foundation)
at the Physikzentrum, reception office
Tuesday (17:00 h – 21:00 h) and Wednesday morning

Program

Program

Tuesday, 27 October 2026

17:00 – 21:00 Registration

18:30 – 20:00 *BUFFET SUPPER*

Program

Wednesday, 28 October 2026

07:30 – 08:45	*BREAKFAST*	
08:45 – 08:50	Scientific Organizers	**Opening remarks**
08:50 – 09:00	Stefan Jorda	**About the Wilhelm and Else Heraeus Foundation**
09:00 – 09:45	Katharina Franke	**Wave-function engineering of Yu-Shiba-Rusinov states from magnetic atoms and molecules on superconductors**
09:45 – 10:30	Barbara Dietz-Pilatus	**Graphene Billiards Subject to the Haldane Model**
10:30 – 11:00	*COFFEE BREAK*	
11:00 – 11:45	Or Swartzberg	**Statistics of Zero-Energy Conical Intersections in Chiral Random-Matrix Fields**
11:45 – 12:30	Roser Valenti	**Correlations and topology in twisted bilayer graphene**
12:30 – 14:00	*LUNCH*	
14:00 – 14:45	Oded Agam	**Stochastic Morphodynamics in Hydra Regeneration**
14:45 – 15:30	Michael Wilkinson	**Dislocation Mediated Diffusion and the Endoplasmic Reticulum**
15:30 – 16:00	*COFFEE BREAK*	

Program

Wednesday, 28 October 2026

16:00 – 16:45	Netanel Lindner	**Probing Topological Order through the Phase Diagram**
16:45 – 17:30	Mikael C. Rechtsman	**Quantized Nonlinear Thouless Pumping**
17:30 – 18:15	Masahito Ueda	**Harnessing Nonequilibrium Open Quantum Systems**
18:30 – 20:00	*DINNER*	

Program

Thursday, 29 October 2026

08:00 – 09:00	*BREAKFAST*	
09:00 – 09:45	Martin Zirnbauer	**Comments on the "Tenfold Way"**
09:45 – 10:30	Ram Band	**Can one color the shape of a (Kohmoto) butterfly?**
10:30 – 11:00	*COFFEE BREAK*	
11:00 – 11:45	Anwesha Chakraborty	**Average Entanglement Entropy in Quantum Many -Body Systems with SU(2) Symmetry**
11:45 – 12:30	Karol Życzkowski	**Strongly entangled multipartite states: a topological approach**
12:30 – 12:35	*CONFERENCE PHOTO*	
12:35 – 14:00	*LUNCH*	
14:00 – 14:45	Roni Ilan	**Zeros as indicators of non-trivial topology, and where to find them**
14:45 – 15:30	Alexander Altland	**Anderson localization on expanding geometries**
15:30 – 16:00	*COFFEE BREAK*	
16:00 – 18:30	**Poster Session**	
18:30 – 20:00	*DINNER*	

Program

Friday, 30 October 2026

08:00 – 09:00	*BREAKFAST*	
09:00 – 09:45	Erez Zohar	**Gauging, Disentangling and Dualities**
09:45 – 10:30	Yonatan Anahory	**Evidence of competing orders in few-layer NbSe2**
10:30 – 11:00	*COFFEE BREAK*	
11:00 – 11:45	Budhaditya Bhattacharjee	**Beyond Gaussianity**
11:45 – 12:30	Gernot Akemann	**Various regimes of non-Hermiticity: Fluctuations and dissipative spectral form factor**
12:30 – 14:00	*LUNCH*	
14:00 – 14:45	Nir Davidson	**Complex bands and topology with coupled lasers**
14:45 – 15:30	Maciej Lewenstein	**Why photons? A psychoanalytic portrait of a scientist as a mature man**
15:30 – 16:00	*COFFEE BREAK*	
16:00 – 18:30	**Excursion**	
18:30 – 20:00	*HERAEUS CONFERENCE DINNER* *(social event with cold & warm buffet with complimentary drinks)*	

Program

Saturday, 31 October 2026

08:00 – 09:00	*BREAKFAST*	
09:00 – 09:45	Jacobus Verbaarschot	**Topology, Spontaneous Symmetry Breaking and Anti-Unitary Symmetries**
09:45 – 10:30	Hermann Schulz-Baldes	**News about the spectral localizer**
10:30 – 11:00	*COFFEE BREAK*	
11:00 – 11:45	Maria Azhar	**Beyond Integer Topology: Continuous Connections Between Skyrmions and Hopfions**
11:45 – 12:30	Dganit Meidan	**Topological entanglement transitions under partial post-selected monitoring**
12:30 – 14:00	*LUNCH*	
14:00 – 14:45	Harald Giessen	**Discovery of phonon-polaritonic skyrmions: Transition from bubble- to Néel-type**
14:45 – 15:30	Frank Meyer zu Heringdorf	**Linking extended vector wave fields with momentum space topology**
15:30 – 16:00	*COFFEE BREAK*	
16:00 – 16:45	Gregory Berkolaiko	**Topology of the Ritz energy landscape**
16:45 – 17:30	Eugene Kanzieper	**Local Level Spacings and the Inspection Paradox in Random Matrix Theory**
17:30 – 18:15	Mario Kieburg	**Winding Number Statistics for Non-Gaussian Random Fields**
18:30 – 20:00	*DINNER*	

Program

Sunday, 1 November 2026

08:00 – 09:00	*BREAKFAST*	
09:00 – 09:45	Joshua Feinberg	**Flowing to Normality and the Fate of the Single Ring Theorem**
09:45 – 10:30	Uzy Smilansky	**The Lyapunov exponent of a quantum Hamiltonian – graph and ergodic theoretical approach**
10:30 – 11:00	*COFFEE BREAK*	
11:00 – 11:45	Boris Gutkin	**Chern number in quantum graphs**
11:45 – 12:30	Ulrich Kuhl	**Bound states in the continuum induced via local symmetries in complex structures**
12:30 – 14:00	*LUNCH*	

End of the seminar and departure

Posters

Posters

Nadia Benlakhouy	**Engineering Topology with Light: Floquet Control of Chiral Flat Bands in Multilayer Graphene**
Philipp Gessler	**Topological Classification of Non-Normalizable Vector Fields**
Tim-Dominik Gómez	**Vectorial Mode Solver for Orbital Angular Momentum supporting fibers**
Qiannan Jia	**Optical broom for reconfigurable twistronics**
Oren Kereth	**Chiral disorder-robust frequency synchronization of coupled nonlinear oscillators**
Dragan Markovic	**Logarithmic transport at topological phase transitions of one-dimensional chiral quantum systems**
Arnab Mukherjee	**Quantum coherence measures in boosted entangled massive systems**
Shantonu Mukherjee	**Non-Abelian Order and Monopole Textures in Multi-Flavor Weyl Semimetals**
Alexander Neuhaus	**A Plasmonic Target Skyrmion: Local Topology Without a Global Skyrmion Number**
Gertian Roose	**T-duality and bosonization as examples of continuum gauging and disentangling**
Nilanjan Sasmal	**Jastrow Wavefunctions and Parent Hamiltonians for Ground State Solvable Quantum Many-body Systems**
Andreas Sinner	**Designing Moiré Patterns by Strain**
Jarod Tall	**Double-scaled bosonic and fermionic embedded ensembles, complex SYK, and the dual Hilbert space**

Posters

Pascal Toschka	**Statistical topology: Winding Number Statistics of Parametric Chiral Random Matrix Ensembles**
Nimrod Tsur	**Coloring the Kohmoto Butterfly using a Spectral Localizer**
Aishwarya Vishwakarma	**From Quantum Jumps to Classical Currents: Certified Point-Gap Topology under Coherence Elimination**
Yunjia Zhai	**Topological bound states in a lattice of rings with nearest-neighbor interactions**
Zihao Zhang	**Complex-structured beam produced by modulated phase mask**

Abstracts of Lectures

(in alphabetical order)

Stochastic Morphodynamics in *Hydra* Regeneration

O. Agam

The Hebrew University, Jerusalem, Israel

Hydra regeneration provides a minimal living system in which animal morphogenesis can be studied as the dynamics of an active, excitable, and mechanically deformable tissue. In this talk, I will present a physics-based view of whole-body regeneration from excised tissue fragments. The primary morphological transition, from a quasi-spherical shell to an elongated body form, behaves as an activation-like process in a slowly evolving morphological landscape, driven by stochastic Ca^{2+} activity coupled to tissue curvature [1]. Slowing the evolution of this landscape with an external electric field reveals stochastic transitions between spherical and elongated states. When the field is periodically modulated, the tissue also exhibits stochastic resonance, demonstrating that noise can play a functional role in morphogenesis [2]. I will then discuss how Ca^{2+} activity links shape dynamics to inherited tissue polarity, and how perturbation experiments involving arrest, reversal, and rescue reveal the importance of the spatiotemporal organization of this activity [1,3]. Finally, I will present evidence for hidden dynamical canalization: well before visible elongation begins, the effective dimensionality of shape fluctuations progressively decreases, indicating a gradual restriction of the landscape of accessible shapes [4]. Together, these findings suggest that *Hydra* regeneration is not the deterministic execution of a fixed developmental program, but a noisy yet canalized trajectory through an evolving morphogenetic landscape.

References

[1] O. Agam and E. Braun, EPL 143, 27001 (2023).
[2] O. Agam and E. Braun, Proceedings of the National Academy of Sciences 122, e2415736121 (2025).
[3] O. Agam and E. Braun, Biophysical Journal 125, 1 (2026).
[4] O. Agam and E. Braun, bioRxiv 2026.04.28.721438 (2026).

Various regimes of non-Hermiticity: Number variance and dissipative spectral form factor

G. Akemann[1]

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Non-Hermitian random matrices describe universal aspects of physical systems, with applications including open dissipative quantum systems that are chaotic, or quantum field theory with chemical potential. Of particular importance is the regime of weak non-Hermiticity introduced by Fyodorov, Khoruzhenko and Sommers on a microscopic scale. It describes the crossover to the Hermitian limit, e.g. in the presence of few open channels. This is realized in the simplest case by the elliptic or Ginibre-Girko ensemble of complex Gaussian random matrices, interpolating to the Gaussian unitary ensemble. On the mesoscopic scale a two-parameter family of scaling regimes has been found recently, both for the number variance and the dissipative spectral form factor. I will present mathematically rigorous results from joint work with M. Duits and L. Molag [1], and with S. Byun and S. Oh [2].

References

[1] G. Akemann, M. Duits, L. Molag, Ann. Henri Poincar\'e online (2026)
[2] Gernot Akemann, Sung-Soo Byun, Seungjoon Oh, arXiv:2605.28319 (2026)

Anderson localization on expanding geometries

A.Altland[1], B. Jobst[2], T.Micklitz[2], F. Pollmann[3], S. Warzel[3], C.Wille[4], M. Usoltcev[1]

[1]Institute for theoretical physics, University of Cologne
[2] Technical University, Munich
[3] CBPF, Rio de Janeiro
[4] University College, London
E-mail: alexal@thp.uni-koeln.de

The complexity of many-body localization (MBL) is tied to two structural features of the underlying Fock-space graphs: a proliferation of complex loops and non-Euclidean volume growth. In this talk, we will emphasize that the topology of Fock-space loops and the geometry of volume growth represent independent principles. In particular, microscopic MBL problems can exist on loopless graphs, motivating the question of what minimal extension of the one-parameter scaling paradigm of localization on hypercubic lattices is required to capture exponential volume growth. Using the hyperbolic plane as a simple and analytically tractable proxy, and building on a recent proposal, we develop a two-parameter scaling scheme that tracks the flow of conductivity alongside curvature as a measure of the system's scale-dependent effective dimensionality. To illustrate the relevance of such a "volume-growth-only" localization theory to many-body problems, we will finally discuss a constrained spin Hamiltonian realizing an MBL transition on a tree-like Fock-space graph.

References

1. A. Altland, T. Micklitz, M. Usoltcev, C. Wille, arXiv:2604.24917
2. A. Altland, F.Pollmann, S. Wartzel, B. Jost, unpublished.

Evidence of competing orders in few-layer $NbSe_2$

N. Fridman[1,2], T. D. Feld[1,2], A. Noah[1,2],A. Zalic[1,2], M. Markman[1,2],T.R Devidas[1,2], Y. Zur[1,2], E. Grynszpan[1,2], A. Gutfreund[1,2], I. Keren[1,2], A. Vakahi[2], S. Remennik[2], K. Watanabe[3], T. Taniguchi[3] , M. E. Huber[4], I. Aleiner[5], H. Steinberg[1,2], O. Agam[1], Y. Anahory[1,2]

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[2] Center for Nanoscience and Nanotechnology, Hebrew University of Jerusalem, Jerusalem, Israel
[3] Research Center for Electronic and Optical Materials, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan
[4] Departments of Physics and Electrical Engineering, University of Colorado Denver, Denver, CO , USA
[5] Google Quantum AI, Santa Barbara, CA, USA

The coexistence of multiple types of orders is a common thread in condensed matter physics and unconventional superconductors. The nature of superconducting orders may be unveiled by analyzing local perturbations such as vortices. For thin films, the vortex magnetic profile is characterized by the Pearl-length Λ, which is inversely proportional to the 2D superfluid density; hence, normally, also inversely proportional to the film thickness, d. Here we employ the scanning SQUID-on-tip microscopy to measure Λ in $NbSe_2$ flakes with thicknesses ranging from N=53 to 3 layers (Figure 1). For N>10, we find the expected dependence d^{-1}. However, six-layer films show a sharp increase of Λ deviating by a factor of three from the expected value[1]. This value remains fixed for N=3 to 6. This unexpected behavior suggests the competition between two orders; one residing only on the first and last layers of the film while the other prevails in all layers.

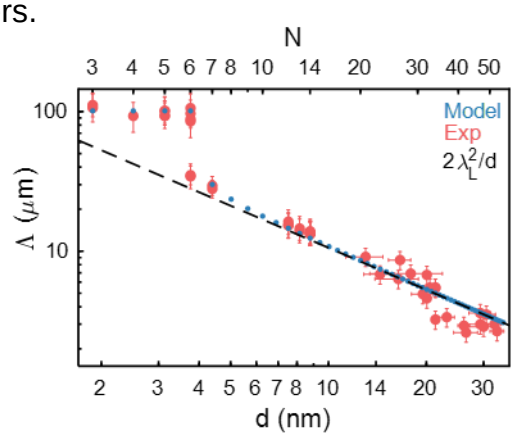


Figure 1: Thickness dependence of the Pearl length Measured Pearl length Λ (red dots) obtained from SOT images and the best fit to our phenomenological model (blue dots). The dashed line represents Pearl length thickness dependence according to the Pearl model considering λ_L=230 nm.

References

[1] N. Fridman et al. , Nature Communications **16**, 2696 (2025).

Beyond Integer Topology: Continuous Connections Between Skyrmions and Hopfions

Maria Azhar[1]

[1]*Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany*

Topology provides a common language for classifying physical structures by properties that remain unchanged under continuous deformation. Structured vector fields are a particularly rich example: Skyrmions characterize two-dimensional winding [1], while three-dimensional textures such as Hopfions involve linking and twisting.

These classifications usually assume a fixed and uniform background. When the background itself is structured, however, textures normally assigned to distinct topological classes can transform continuously into one another without singularities [2]. For example, a Hopfion can evolve into a Skyrmion tube through intermediate states such as Twistons [2,3].

This leads naturally to **mixed and fractional topology**. A flux-tube linking description provides a geometric way to characterize such states even for non-uniform backgrounds and open boundaries [2,4]. Skyrmions, Hopfions, Twistons, and related textures can therefore be viewed as part of a connected landscape rather than as isolated topological categories. Screw dislocations [5] and textures in vortex backgrounds [3] provide concrete magnetic realizations.

Although the examples are drawn mainly from magnetism, the same geometric ideas of winding, linking, background structure, and boundaries apply more broadly to structured fields in classical and quantum systems [6].

References

[1] S. Koraltan *et al.*, *The 2026 Skyrmionics Roadmap*, arXiv:2601.16575 (2026).
[2] M. Azhar *et al.*, SciPost Phys. **21**, 023 (2026).
[3] S. C. Shaju, M. Azhar, and K. Everschor-Sitte, APL Mater. **14**, 051111 (2026)
[4] R. Knapman *et al.*, Phys. Rev. B **111**, (2025).
[5] M. Azhar *et al.*, Phys. Rev. Lett. **128**, 157204 (2022).
[6] M. Azhar, Physik Journal **8/9** (2026).

Can one color the shape of a (Kohmoto) butterfly?

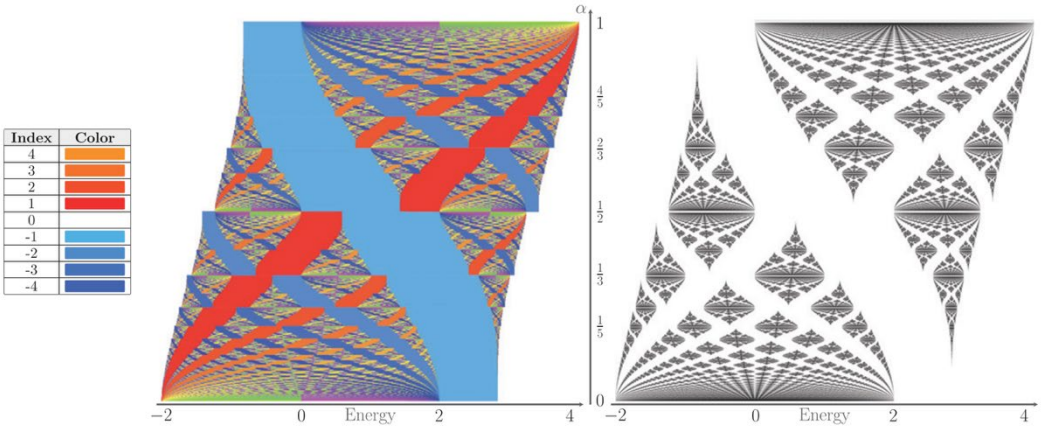
R. Band[1] and S. Beckus[2]

1Department of Mathematics, Technion-Israel Institute of Technology - Haifa, Israel
[2] Institute of Mathematics, University of Potsdam - Potsdam, Germany

The spectra of the Kohmoto model give rise to a fractal phase diagram, known as the Kohmoto butterfly. The butterfly encapsulates the spectra of all periodic Kohmoto Hamiltonians, whose index invariants are sought after. Topological methods are ill defined due to the discontinuous periodic potentials, and hence fail to provide index invariants.

We discuss how to overcome that obstacle and provide a complete classification of the Kohmoto model indices -- suggesting new physical invariants instead of Chern indices. Our approach encodes the Kohmoto butterfly as a spectral tree graph, reflecting the quasiperiodic nature via the periodic spectra. This yields a complete coloring of the phase diagram and a new perspective on other spectral butterflies.

The talk is based on a joint work with Siegfried Beckus.



Topology of the Ritz energy landscape

G. Berkolaiko[1] and M. Goresky[2]

[1]Texas A&M University, College Station, TX, USA

[2] Institute for Advanced Study, Princeton, NJ, USA

Motivated by questions from quantum chemistry and spectral optimization, this talk explores the topology of the Ritz energy landscape. Ritz values are the eigenvalues of a larger matrix (or operator) B compressed to a smaller trial subspace S. We can view the k-th Ritz value as a real-valued function ("Ritz energy landscape") on the manifold of all possible s-dimensional trial subspaces, the Grassmannian Gr(n,s).

We show that the k-th Ritz value (for any k) is a perfect Morse function, once the definition of "perfection" is suitably adjusted. A Morse function is called perfect if it describes the topology of its domain in the most efficient way possible, meaning the number of its critical points of each type exactly matches the corresponding Betti number of the space. While the k-th eigenvalue is Lipschitz rather than smooth and while its critical points are not isolated --- and not even Morse-Bott --- its critical point count is nevertheless well-defined and reflects the topology of the Grassmannian in a minimal, perfect way.

The proof proceeds by introducing a suitable perturbation which ensures that points of non-smoothness are not critical (by a theorem of Zelenko and the presenter) and that the critical points that remain are isolated. We also show that the notion of perfection we introduce ("homological perfection") is closed under such perturbations.

Beyond Gaussianity

Budhaditya Bhattacharjee[1], William E. Salazar[2], Alexei Andreanov[3] and Dario Rosa[4]

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Disordered many-body strongly correlated quantum systems serve as powerful analytically (statistically) tractable models capturing a wide range of physical phenomena ranging from quantum chaos to effective descriptions of quantum gravity. The construction of such models involves a choice of disorder distribution. It is known that these models demonstrate (approximate) universality in their properties if the disorder distribution obeys the central limit theorem (CLT). The usual practice of finding physics beyond such universality involves modifying the structure or ingredients of the model itself. In this talk, I will describe the outcome of changing the disorder distribution without structural changes. I will focus on distributions that do not obey central limit theorem. I shall demonstrate new and distinct physical properties that emerge by changing the distribution, without making any structural modifications. Using the Sachdev-Ye-Kitaev (Majorana) model as the platform, I will show effects such as non-maximal chaos, non-fermi liquid behavior and signatures of glassy physics; all of which are absent in the Sachdev-Ye-Kitaev model), emerging because of the disorder violating CLT. I will present a semi-analytical analysis of this model for finite system size, and a statistical analysis in the thermodynamic limit. Finally, I will conclude with thoughts on other classes of physical systems which may demonstrate new universality anchored on non-CLT distributions.

References

[1] B. Bhattacharjee, William E. Salazar, Alexei Andreanov and Dario Rosa, ArXiv:2604.01320 (2026)
[2] B. Bhattacharjee, William E. Salazar, Dario Rosa and Alexei Andreanov ArXiv: 2506.04343 (2025)

Average Entanglement Entropy in Quantum Many-Body Systems with SU(2) Symmetry

Anwesha Chakraborty[1] , Lucas Hackl[2] , Mario Kieburg[3]

[1,2,3] *University of Melbourne, Parkville, Victoria, Australia*

Understanding the entanglement structure of typical quantum states is central to quantum statistical mechanics, many-body physics, and quantum information. Page's celebrated result provides a universal prediction for the average entanglement of random pure states. However, its extension to systems with non-Abelian symmetries is considerably more subtle because the Hilbert space does not decompose into simple charge sectors: different angular-momentum representations are coupled through Clebsch–Gordan coefficients.

In this talk, I will present an analytical study of Haar-random pure states in spin 1/2 many-body systems with global SU(2) symmetry, restricted to a fixed total spin J and magnetization m=0. For subsystem fractions $f<1/2$, we derive the average bipartite entanglement entropy up to constant order in the total system volume V, for arbitrary spin density. Beyond the leading volume-law contribution, we identify a universal logarithmic correction originating from the asymptotic scaling of the Clebsch–Gordan coefficients. We also compute the constant volume independent contribution that captures the detailed angular-momentum coupling between magnetization blocks. Our approach combines representation theory with random-matrix methods, extending Page-type predictions to non-Abelian symmetry sectors and revealing how global symmetry leaves universal signatures in the entanglement of typical quantum states.

Reference

[1] Random matrix prediction of average entanglement entropy in non-Abelian symmetry sectors.
Anwesha Chakraborty, Lucas Hackl, Mario Kieburg, arXiv:2512.22942 [quant-ph].

Complex bands and topology with coupled lasers

Nir Davidson

Dept. of Physics of Complex Systems, Weizmann Institute of Science, Rehovot, Israel

Complex coupling in periodic laser arrays leads to complex bands, where the real part corresponds to the dispersion relation of the band w(k) and the imaginary part corresponds to k-dependent loss. By precisely tuning the complex coupling and the array geometry we engineer the complex bands to generate unique topological lasing states. We demonstrate how lasing at Dirac points in a hexagonal laser lattice can lead to Klein tunneling of coherence through a barrier, how complex Hermitian coupling can generate artificial gauge fields and edge states. Finally, we characterize the effects of quenches disorder and hints to KT Physic in coupled laser arrays.

Graphene Billiards Subject to the Haldane Model

Barbara Dietz[1,2], Dung Xuan Nguyen[3]

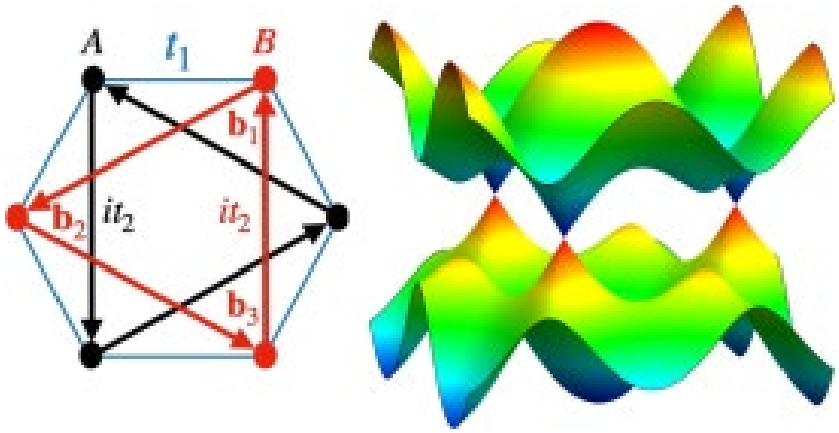
[1]Max-Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden, Germany
[2]TU Dresden, Institute of Theoretical Physics, 01062 Dresden, Germany
[3]International Centre for Interdisciplinary Science and Education, 55131 Quy Nhon, Vietnam

It is well known by now that the spectral properties of graphene billiards (GB) in the region of low-energy excitations around the Dirac points K and K' at zero energy generically coincide with those of the corresponding nonrelativistic quantum billiard (NRQB), even though there the spectrum is described by the same Dirac equation for massless spin-1/2 particles as relativistic quantum ('neutrino') billiards (RQB). Deviations from the expected behavior originate from differing boundary conditions and backscattering at the boundary leading to a mixing of valley states at the two Dirac points K and K', which are mapped into each other through time reversal. This backscattering is prevented in GBs subject to the Haldane-model, which was introduced by Duncan Haldane to realize a quantum Hall phase without applying an external magnetic field, that is, to 'make graphene topological'. Specifically, by appropriately tuning the Semenoff mass, generated by opposite onsite potentials on the two triangular sublattices that form the honeycomb lattice, and thus breaking inversion symmetry, and the Haldane mass arising from purely imaginary next-nearest-neighbor hopping, the resulting band structure exhibits a single Dirac cone at either the K or the K′ point, while the other valley remains gaped [1]. In my talk I will show for a few examples, that the spectral properties of such 'Haldane' graphene billiards (HGB) agree with those of RQBs. Then I will briefly review the application of the semiclassical approach for the spectral density and wave functions to NRQBs, RQBs, GBs and HGBs with the shape of the stadium billiard. We employed it to show that in contrast to HGBs the quantum scarred eigenstates of GBs do not exhibit chirality and, generally, the characteristics of relativistic ones [2].

References

[1] Dung Xuan Nguyen and Barbara Dietz, *Haldane graphene billiards versus relativistic neutrino billiards,* Phys. Rev. B **110**, 094305 (2024)

[2] Barbara Dietz, Dung Xuan Nguyen and Tilen Čadež, *Nonrelativistic versus relativistic quantum scars in billiard systems,* Discover Quantum Science **2**, 15 (2026)



Flowing to Normality and the Fate of the Single Ring Theorem

Joshua Feinberg

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Random non-hermitian matrix ensembles with double-sided rotation invariance obey, in the limit of large matrix size, the Single Ring Theorem, which states that the support of the mean eigenvalue distribution in the complex plane is either a disk or an annulus. In contrast, rotational-invariant random normal matrix ensembles can have mean eigenvalue densities supported over any number of concentric annuli in the complex plane. In this paper we introduce and investigate, both analytically and numerically, a non-hermitian matrix model which flows from a generic matrix distribution obeying the Single Ring Theorem to a distribution of normal matrices by tuning a parameter which penalizes non-normality.

We observe numerically breakdown of the Single Ring Theorem as the model flows towards normality, and determine the critical value of the parameter at which the transition occurs. We also study in detail the behavior of the singular values of these matrices under the flow. These singular values form a Fermi gas confined to the positive half-line. In particular, we find that at small values of the flow parameter, the interparticle spacings in the gas exhibit Wigner-Dyson repulsion, whereas for asymptotically large values of the flow parameter, at the normal matrix endpoint of the flow, the spacing statistics is Poissonian. The flow interpolates continuously between these two types of statistics. However, this change in statistics is not related directly to breaking of the Single Ring Theorem, which occurs very early-on along the flow, in the regime of Wigner-Dyson statistics. Finally, we introduce a certain ensemble of random permutations associated with the gas, and make a conjecture on how to use it in order to reconstruct approximately the average density of complex eigenvalues from that of the singular values in the large-N limit.

Wave-function engineering of Yu-Shiba-Rusinov states from magnetic atoms and molecules on superconductors

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Exchange-coupled magnetic adatoms on superconductors induce Yu-Shiba-Rusinov (YSR) states within the superconducting gap. Their spatial extent and symmetry are governed by the substrate's electronic structure and the adatom adsorption site, while their confinement within the superconducting gap protects them from hybridization with continuum states. This makes YSR states an ideal platform for engineering wave functions with tailored symmetries.

Using scanning tunneling microscopy (STM), we investigate magnetic atoms and molecules on superconducting surfaces, combining atomic manipulation and self-assembly to control YSR states and their hybridization. First, we assemble Fe atoms on the quasi-two-dimensional superconductor 2H-$NbSe_2$ into designed structures, from dimers to chains [1-3]. By deliberately breaking mirror symmetry, we realize chiral YSR wave functions in triangular adatom assemblies [4]. Second, we exploit temperature-controlled self-assembly of Fe-porphin-chloride molecules on Pb(111) to form kagome precursors and extended kagome lattices. We observe hybridized YSR states in the precursors that evolve into long-range YSR bands in the kagome lattice [5].

Our results demonstrate how YSR-state engineering enables the controlled design of superconducting interfacial quantum states.

References

[1] E. Liebhaber, L. M. Rütten, G. Reecht, J. F. Steiner, S. Rohlf, K. Rossnagel, F. von Oppen, K. J. Franke, Nat. Commun. **13**, 2160 (2022).
[2] L. M. Rütten, H. Schmid, W. M. J. van Weerdenburg, E. Liebhaber, K. Rossnagel, K. J. Franke, Phys. Rev. B **111**, 205424 (2025).
[3] L. M. Rütten, E. Liebhaber, G. Reecht, K. Rossnagel, K. J. Franke, Nanoscale **17**, 26811 (2025).
[4] L. M. Rütten, H. Schmid, E. Liebhaber, G. Franceschi, A. Yazdani, G. Reecht, K. Rossnagel, F. von Oppen, K. J. Franke, ACS Nano **18**, 30798 (2024).
[5] L. Farinacci, G. Reecht, F. von Oppen, K. J. Franke, Nat. Commun. **15**, 6474 (2024).

Discovery of phonon-polaritonic skyrmions: Transition from bubble- to Néel-type

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Abstract:
We observe for the first time phonon-polariton skyrmions in ultrathin silicon carbide membranes, demonstrating a tunable transition from bubble- to Néel-type skyrmions via wavelength control across the Reststrahlen band. Using scanning near-field microscopy, we reveal highly confined skyrmion lattices, enabling topological tuning [1].

Optical skyrmions constitute an emerging and rapidly developing field in the domains of solid-state physics and photonics, allowing for control over topological light textures through light-matter interactions. However, until now, their practical application has been severely limited by high inherent optical losses in plasmonic materials, resulting in the lack of tunability between different topological properties. Here, we leverage the strong dispersion of silicon carbide (SiC) thin films to realize highly confined surface phonon polariton (SPhP) skyrmion lattices, which we image for the first time via near-field microscopy. We experimentally demonstrate topological tuning between bubble- and Néel-type skyrmions, a unique advantage that polar dielectrics offer over most existing approaches. The ability to control and manipulate these skyrmion lattices through small changes (<10%) in excitation wavelength allows for tailoring the size of individual skyrmions by a factor of 4. We investigate the transition from bubble- to Néel-type skyrmions by analyzing the domain wall size, which depends on the relationship between the in-plane and out-of-plane electric field components of the phononic skyrmion lattice.

Our results expand the tunability of skyrmions in evanescent waves and are a starting point to investigate other topological features in phononic systems such as merons, skyrmion bags, and other complex structured light fields. Furthermore, strong light-matter hybridization and nonlinear effects owed to anharmonicity of the phonons may be observed in the future, possibly leading towards the discovery of polaritonic skyrmion-skyrmion interactions.

References:
[1] F. Mangold, E. Baù, L. Nan, J. Schwab, T. Gölz, A. Mancini, B. Frank, A. Tittl and H. Giessen, Phonon-polaritonic skyrmions: Transition from bubble- to Néel-type, Light Sci. Appl. (2026), https://doi.org/10.1038/s41377-026-02332-3. Preprint: arXiv:2603.22176.

Chern number in quantum graphs

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The Chern number is a prominent example of a topological invariant that is robust against perturbations to a quantum system and enables the differentiation between distinct topological phases. It takes on integer values, which can only change when a spectral gap closes. In this work, we investigate the Chern number of energy bands in quantum graphs subjected to two magnetic fluxes. For a single-vertex quantum graph with two loops of equal length, we establish the conditions for gap closure between energy bands and identify two distinct topological phases: a trivial phase, where the Chern number is 0 for all energy bands, and a non-trivial phase, where the Chern number alternates between +1 and -1. We analytically derive phase diagrams for the Chern number as a function of the vertex scattering matrix parameters.

References

[1] O Swartzberg, O Gat, B **Gutkin,** preprint arXiv:2605.25899, (2026)

Zeros as indicators of non-trivial topology, and where to find them

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Band topology is usually encoded in the Berry connection and curvature of individual bands. A recently proposed alternative approach that uses a geometric object called the singular connection, can characterize band topology via the zeros of a chosen complex function. The curvature derived from such a connection is concentrated at those zeros, and the topological invariants are recovered from the windings around them, reducing the problem to analyzing a complex function which can often be physically motivated. This shifts the focus from finding the curvature of a band, which may provide information not required to determine the topological properties, to searching for the right quantity and its zeros, and the freedom in choosing this quantity is what makes the construction powerful and broadly useful. I will illustrate how this approach can provide new insight into two problems. The first concerns the relative topology of two gapped band structures, where the overlap between their occupied states defines a natural quantity whose zeros indicate the obstruction to deforming one into the other. The singular connection unifies the treatment of Chern and time-reversal-invariant Z2 insulators, and gives the zeros a direct meaning as gap closings. The second concerns bound two-particle states, with excitons serving as a prototype. Here, the zeros of the two-body wavefunction in momentum space can isolate the contribution of the binding interaction, showing that a pair can carry topology beyond that of its constituent bands.

Local Level Spacings and the Inspection Paradox in Random Matrix Theory

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We introduce a notion of *local level spacings* and study their statistics within a random-matrix-theory approach. In the limit of infinite-dimensional random matrices, we determine *universal sequences* of mean local spacings and of their ratios which uniquely identify the global symmetries of a quantum system and its internal—chaotic or regular—dynamics. These findings, which offer a new framework to monitor single- and many-body quantum systems, are corroborated by numerical experiments performed for zeros of the Riemann zeta function, spectra of irrational rectangular billiards, and many-body spectra of the Sachdev-Ye-Kitaev Hamiltonians.

References

[1] P. Tian, R. Riser, and E. Kanzieper, Phys. Rev. Lett. **132**, 220401 (2024)

Winding Number Statistics for Non-Gaussian Random Fields

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In a series of recent works, Gaussian random matrices have been employed to model Bloch Hamiltonians. Especially when the spectrum exhibits a gap, such as for chiral Hamiltonians of real (class BDI), complex (class AIII) and quaternion (class CII) matrices, nontrivial topological properties may arise of which one can ask the statistics of topological indices such as the winding number for the determinant of the off-diagonal block of the chiral Hamiltonian. The question is how universal those results are and which of the observations are actually based on the choice of a Gaussian probability distribution of the random matrices. Mathieu Yahiaoui and I generalised the calculations at finite matrix dimension to the broad class of multiplicative Polya ensembles which cover most of the classical random matrices in the class AIII. They have algebraic advantageous properties which make analytic calculations feasible. A specific subclass are Muttalib-Borodin ensembles for which we have performed the limit of large matrix dimensions to understand how the tail of the distribution may affect the winding number. I will report on this progress in my talk.

References

[1] M. Yahiaoui and M. Kieburg, J. Stat. Phys. **193**, 115 (2026), arXiv:2511.06669

Bound states in the continuum induced via local symmetries in complex structures

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Bound states in the continuum (BICs) defy the conventional wisdom that assumes a spectral separation between propagating waves, that carry energy away, and spatially localized waves corresponding to discrete frequencies. They can be described as resonance states with infinite lifetime, i.e., leaky modes with zero leakage. The advent of metamaterials and nanophotonics allowed the creation of BICs in a variety of systems. Mainly, BICs have been realized by destructive interference between outgoing resonant modes or by exploiting engineered global symmetries that enforce the decoupling of a symmetry-incompatible bound mode from the surrounding radiation modes. Here, we study BICs relying on a different mechanism, namely local symmetries that enforce a field concentration on a part of a complex system without implying any global symmetry. We experimentally implement these BICs using microwaves in a compact one-dimensional photonic network. We demonstrate that such BICs form an infinite ladder in k-space and emerge from the annihilation of two topological singularities, a zero and a pole, of the measured scattering matrix.

Why photons? A psychoanalytic portrait of a scientist as a mature man

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I will start with the origins: Maxwell theory, present five reasons to quantize, or maybe four? I will then discuss quantum theory of optical coherence, answering the question: How to reconcile Maxwell with photons? I will describe shortly coherent states and squeezed states. I will then turn to strong field physics, starting with a historical introduction and description of the present times, where semi-classical theory is sufficient. I will then mention the generation of Schrödinger cat states within atto-physics, answering the question: yes, we do need photons. At the end, I will discuss three mechanisms to exhibit quantumness of EM fields: i) Conditioning/post-selection with applications [1]; ii) Nonlinear effects induced by depletion/interband transitions, or dipole correlations [2]; iii) Use quantum fields [3].

References

[1] **M. Lewenstein, M.F. Ciappina, E. Pisanty, J. Rivera-Dean, Ph. Stammer, Th. Lamprou and P. Tzallas**, Generation of optical Schrodinger cat states in intense laser–matter interactions, **Nature Phys., 17**(10), 1104–1108 (2021)
[2] **D. Theidel, V. Cotte, R. Sondenheimer, V. Shiriaeva, M. Froidevaux, V. Severin, V., P. Mosel, H. Merdji, A. Larue, S. Frohlich,** S. et al. Evidence of the quantum-optical nature of high-harmonic generation, **Phys. Rev. X Quantum 5**, 040319 (2024).
[3] **A. Rasputnyi, Z. Chen, M. Birk, O. Cohen, I. Kaminer, I., M. Kruger, D. Seletskiy, M. Chekhova, M. and F. Tani**, High-harmonic generation by a bright squeezed vacuum. **Nature Phys. 20**, 1960–1965 (2024).

Probing Topological Order through the Phase Diagram

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Topologically ordered phases are characterized by global properties that can be difficult to access directly. In this talk, I will discuss how the phase diagram surrounding a topologically ordered state can provide a powerful probe of its underlying topological order.

I will focus on fractional quantum Hall states near even-denominator filling factors. Candidate states at even-denominator fillings can be distinguished by an integer C characterizing their chiral Majorana edge modes. We show that this topological invariant leaves a characteristic imprint on the surrounding phase diagram: it determines sequences of Abelian fractional quantum Hall daughter states that emerge upon moving away from the even-denominator filling. While the sequence on either side alone does not uniquely identify the parent state, the two sequences together provide a unique fingerprint of C.

I will then discuss the phase transitions between these daughter states and more conventional fractional quantum Hall states belonging to the Jain series. We show that these transitions occur in a neutral topological sector and can be related to a transition between an invertible (E_8) bosonic topological phase and a topologically trivial state. Instead of a single direct transition, the system generically undergoes a cascade of topological phase transitions, with intermediate phases supporting neutral anyonic excitations.

Together, these results illustrate how the phase diagram surrounding a topologically ordered state, including both the nearby phases and the transitions between them, can encode detailed information about its underlying topological order.

References

[1] Evgenii Zheltonozhskii, Ady Stern, Netanel H. Lindner, arXiv: 2508.17457

[2] Evgenii Zheltonozhskii, Ady Stern, Netanel H. Lindner, Physical Review B **110**, 245140 (2024)

Topological entanglement transitions under partial post-selected monitoring

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Frequent monitoring of a many-body quantum system can drive a measurement-induced phase transition, steering the system into a non-equilibrium steady state in which different regions become disentangled. Remarkably, the system can retain extensive entanglement as long as the monitoring rate stays below a critical threshold, demonstrating a surprising robustness despite the fragility typically associated with quantum coherence. Entanglement can even be enhanced by simultaneously measuring physical operators that do not commute. The same approach can also be used to dynamically engineer topological quantum states, with potential applications in quantum error correction.

Studying these measurement-induced phase transitions is challenging because it requires accounting for the full range of possible random measurement outcomes. Most existing theoretical tools, however, are better suited to following individual deterministic trajectories. To address this challenge, we introduce a new partially post-selected theoretical framework that focuses on a subset of measurement histories. This approach reveals an abrupt change in the character of the phase transition. In particular, when the ensemble of measurement histories is sufficiently small, the system's dynamics closely resemble those of a single post-selected trajectory. Our approach establishes a way to study MiPTs for arbitrary subsets of quantum trajectories and provides a potential route to tackle the experimental post-selected problem.

Linking extended vector wave fields with momentum space topology

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The success of topology in physics is based on its ability to describe complicated, intractable physical systems by simple quantities, the topological invariants. These topological invariants are integer-valued and will not change under continuous deformations, making them highly interesting candidates for robust technological applications. Topology, however, relies on a compact base manifold. For infinitely extending wave fields that naturally occur in optics and hydrodynamics, a global real-space topological classification is generally well-defined only if the real-space can be compactified. This can either be achieved by utilizing a spatial periodicity or by requiring the field to approach a uniform background at infinity. Here, we show how one can use a momentum-space linking number to classify infinitely extending two-dimensional wave fields without requiring a compact base in real-space. Spin-momentum locked surface wave fields, such as capillary-gravity water waves (CGW) and surface plasmon polaritons (SPP), offer an ideal testbed, spanning multiple orders of magnitude in temporal and spatial scales. While time-resolved polarimetric photoemission electron microscopy and near-field scanning optical microscopy give direct access to the electric field vectors of SPPs, a 3D-printed water wave experiment allows for the reconstruction of CGWs by fast checkerboard decomposition. These experiments directly reveal the discrete transition between distinct topological sectors in modes carrying fractional orbital angular momentum, and their robustness against spatial deformations.

References

[1] P. Dreher et al., Advanced Photonics, 6, 066007 (2024)
[2] A. Neuhaus et al., Ultramicroscopy, 276, 114248 (2026)
[3] A. Neuhaus et al., ArXiv, https://arxiv.org/abs/2604.26610 (2026).

Quantized Nonlinear Thouless Pumps

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I will present my group's experimental work on the fractional pumping of solitons in nonlinear photonic Thouless pumps, using waveguide arrays[1,2]. 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.

References

[1] M. Jürgensen, S. Mukherjee, and M. C. Rechtsman, Nature **596**, 63 (2021)
[2] M. Jürgensen, S. Mukherjee, C. Jörg, and M. C. Rechtsman, Nature Physics **19**, 420 (2023)

News from the spectral localizer

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The spectral localizer is a numerically very efficient tool to compute topological invariants such as Chern numbers and winding number. It also has interesting index-theoretic interpretations. The talk gives an overview over existing variants and describes some recent developments.

The Lyapunov exponent of a quantum Hamiltonian – graph and ergodic theoretical approach.

Sven Gnutzmann, Arkady Kurnosov, Uzy Smilansky

In the first part of the lecture I shall provide a brief review of the method:
Given a quantum Hamiltonian H as a Hermitian matrix of an arbitrary large but finite dimension N.
A graph on N vertices is associated with the matrix. Graph theory guarantees that an initial quantum state expressed as a vector in the space of the graph directed edges, evolves in time by a unitary matrix U – the quantum analogue of a discrete classical Poincare' map. U is written in terms of H and it is a function of the energy. The intimate connection between H and U is evident from the known theorem that the spectrum of H is the set of E values where U has 1 as an eigenvalue (if and only if).
The semi classical evolution is written in terms of a Markovian matrix with elements which are the absolute square of the corresponding elements of U.
Ergodic theory provides an expression for the Lyapunov exponent per trajectory on the graph.
The mean Lyapunov exponent (with respect to the distribution of all graph trajectories) and its variance follow.

In the second part I shall describe the application of the formalism to four random matrix ensembles:
The adjacency matrices of random d regular graphs, GOE, GUE and the tri diagonal Dumitriu-Edelman ensembles.
We computed the mean values of the Lyapunov exponents, variances, and thermal averages both numerically
and by deriving approximate expressions. The results of the two methods agree very well in most circumstances.
We also computed the spectral distributions of the stochastic evolution matrices, and in particular their gap distributions.

I shall conclude with a summary and a list of open problems.

Chiral Conical Intersections: Statistics and Topological Charge

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Topological invariants are stable under smooth perturbations and can change only when a spectral gap closes. In systems with chiral symmetry, generic zero-energy gap closings appear as isolated conical intersections. Each intersection carries a signed topological charge, which determines the change in the chiral winding number when the intersection is crossed. Understanding the statistics of these intersections is therefore essential for describing topology in complex and disordered systems.

We model these intersections using a chiral Gaussian random-matrix field that depends on two parameters. The ensemble is fully specified by the two-point correlations of its matrix elements, which can be chosen quite generally.

For the unsigned density of zero-energy conical intersections, we obtain an exact expression for the mean density and identify its universal local form. For the signed topological-charge density, we calculate its first two moments, namely its mean and two-point correlation function. We also derive the corresponding moments of the associated winding field, which describes the phase winding around the intersections. The topological-charge density is the curl of this field, directly relating the statistics of the conical intersections to the spatial correlations of the winding field.

Harnessing Nonequilibrium Open Quantum Systems

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Isolated quantum systems are described by Hermitian Hamiltonians. However, when they are open to surrounding environments or subject to quantum measurements, one should go beyond the Hermitian framework. Beyond-Hermitian physics has recently attracted a great deal of attention due to remarkable advances in experimental techniques and theoretical methods in AMO, condensed matter and nonequilibrium statistical physics. Complete knowledge about quantum jumps allows a description of quantum dynamics at the single-trajectory level. A subclass thereof without quantum jumps can be described by a non-Hermitian Hamiltonian. Here, symmetry, topology and many-body effects are fundamentally altered from Hermitian physics. In this talk, I will discuss what new potentials can be liberated once we go beyond the Hermitian framework. I will illustrate them in the context of the quantum speed limit, intermediate-state engineering, continuous quantum phase transitions and non-Hermitian topological phases. I will also discuss applications of beyond-Hermitian quantum physics to statistical physics and condensed matter physics, such as Yang-Lee zeros, nonunitary critical phenomena and non-Hermitian BCS superconductivity.

References

[1] H. Li, et al., Phys. Rev. Lett. 135, 166001 (2025)
[2] H. Li, et al., Phys. Rev. Lett. 131, 216001 (2023)
[3] Y. Ashida, et al., Adv. Phys. **69**, 249 (2020)

Correlations and topology in twisted bilayer graphene

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The controlled stacking, twisting, and straining of two-dimensional van der Waals materials has opened new avenues for realizing correlated and topological quantum phases. In such systems, interactions between layers can give rise to emergent behavior not present in the individual constituents, including correlated metals, unconventional superconductivity, and topological phases. In this talk, I will outline the rich phase diagram of twisted bilayer graphene and theoretical approaches for modeling these systems [1-4] with connections to recent experimental findings.

References

[1] Kim *et al.* Nature 623, 942 (2026) [arXiv:2505.17200]
[2] Crippa *et al.* arXiv: 2509.19436
[3] Rai *et al.* PRX, **14** (3), 031045 (2024)
[4] Hu *et al.* PRL **131**, 166501 (2023)

Topology, Spontaneous Symmetry Breaking and Anti-Unitary Symmetries

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Topology and spontaneous symmetry breaking have been essential for understanding strongly interacting systems. It was realized, in particular in the framework of random matrix theory, that anti-unitary symmetries impose constraints on both properties. In this presentation, we will examine examples from quantum field theory and non-Hermitian many-body theory, demonstrating how they can be described in a unified framework.

References

[1] Antonio García-García, Lucas Sá, Jacobus Verbaarschot, Can Yin, Emergent topology in many-body dissipative quantum matter, *Physical Review B* 111 (2025) 3, 035157.

[2] Mario Kieburg, Jacobus Verbaarschot, Savvas Zafeiropoulos, Eigenvalue Density of the non-Hermitian Wilson Dirac Operator, *Physical Review Letters* 108 (2012) 022001.

Dislocation Mediated Diffusion and the Endoplasmic Reticulum

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I discuss a model for diffusion in a lamellar medium which is permeated by randomly positioned dislocations. There is two-dimensional diffusion on each layer, and paths which wind around dislocations make transitions between layers. Contrary to some earlier suggestions, the dispersion of trajectories across layers is found to be diffusive, rather than superdiffusive. Obtaining the correct result depends upon understanding the role of 'screening' in the distribution of dislocations.

I also argue that this apparently arcane problem has relevance to biology. The sheet-like endoplasmic reticulum (ER) of eukaryotic cells has been found to be riddled with spiral dislocations, known as ‘Terasaki ramps’. The sheets of the ER are formed by lipid bilayers, which are a barrier to diffusion of water-soluble molecules. These dislocations provide an efficient mechanism for the diffusion of molecules within cells.

The talk reports collaborations with John Hannay, University of Bristol, and Greg Huber, Chan-Zuckerberg Biohub, San Francisco.

References

1. M. Wilkinson and J. H. Hannay, in preparation
2. G. Huber and M. Wilkinson, *Terasaki Spiral Ramps and Intracellular Diffusion*, *Phys. Biol*., **16**, 065002, (2019).

Comments on the “Tenfold Way”

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Building on Dyson´s "Threefold Way" of random-matrix ensembles, the "Tenfold Way" classifies free-fermion Hamiltonians with symmetries. Originally conceived for disordered systems, the scheme was later found to have a bearing on the classification of topological phases of matter. In this talk, I will review the history of the Tenfold Way, with an emphasis on the distinction between "symmetry" and "structure". Along the way, I will clarify the difference between charge conjugation and particle-hole symmetries. Time permitting, I will touch on (i) the celebrated Haldane phase as a topological phase protected by a particle-hole symmetry, and (ii) the striking phenomenon that fermion-vortex duality in 2+1 dimensions exchanges particle-hole conjugation with time-reversal symmetry.

Gauging, Disentangling and Dualities

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Duality transformations are well known in many-body physics, both in the condensed matter and particle physics contexts, as powerful tools for studying challenging physics (e.g. mapping strongly interacting theories to weakly interacting ones). In the recent years, it was noted that they could be derived through a well defined recipe involving the gauging of a global symmetry and a disentangling procedure, or in other words – through a quantum circuit. This allows one to (1) implement them physically in the lab, e.g. in a quantum simulation experiment; (2) derive new duality transformations; (3) replace fermionic degrees of freedom by bosonic ones locally, and many more. In my talk I will review the idea and provide examples, for both lattice and continuum physics.

References

[1] Zohar, E. and Cirac, J.I., Eliminating fermionic matter fields in lattice gauge theories, Phys. Rev. B **98**, 075119 (2018)

[2] Zohar, E. and Cirac, J.I.., Removing Staggered Fermionic Matter in U(N) and SU(N) Lattice Gauge Theories, Phys. Rev. D **99**, 114511 (2019)

[3] Ashkenazi, S. and Zohar, E., Duality as a feasible physical transformation, Phys. Rev. A **105**, 022431 (2022)

[4] Roose, G. and Zohar, E., T-duality and bosonization as examples of continuum gauging and disentangling, arXiv:2509.24630 [hep-th] (2026)

Strongly entangled multipartite states: a topological approach

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The orbit of maximally entangled states for N times N system has topology of the projective space U(N)/U(1), which for N=2 reduces to real projective space RP^3. This manifold is known to be indisplaceable in complex projective space CP^3: this implies that for any two partition of a ququart into two qubits there exists a pure state maximally entangled with respect to both splittings. We show that the same property holds also for any power of prime, N=p^k, which implies existence of such mutually maximally entangled states for these dimensions.

As this statement holds for N=4, there are 4-qubit states maximally entangled with respect to both partitions, say AB|CD and AC|BD. However, as showed in [1] there are not such states which are simultaneously maximally entangled for the third partition AD|BC. We show that such *absolutely maximally entangled* state exists for four subsystems with six levels each [2]. If four dice were prepared in such a distinguished quantum state, then looking at the outcome of any two dice would allow one to predict the outcome of the remaining two. Our analytic results provide a solution to the quantum version of the famous problem of the 36 officers of Euler, in which all officers appear in an entangled state, so that each square of the grid of size six contains more than a single symbol. In the original parlance of Euler, a captain of artillery has to be entangled with, say, a major of cavalry. This state enables us to construct a pure nonadditive quhex quantum error detection code, which allows one to encode a 6-level state into a triplet of such states.

References

[1] A. Higuchi, A. Sudbery, Phys. Lett. **A 273**, 213 (2000)
[2] S. Rather et al. Phys. Rev. Lett. **128**, 080507 (2022)

Abstracts of Posters

(in alphabetical order)

Engineering Topology with Light: Floquet Control of Chiral Flat Bands in Multilayer Graphene

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Twisted bilayer graphene (TBG) hosts a magnetic-field-induced Hofstadter butterfly spectrum whose fractal structure is deeply tied to the chiral symmetries of the underlying lattice model. We show that TBG admits two distinct chiral limits, realized by selectively switching off either the AA-type or the AB/BA-type interlayer hopping processes. Counter-intuitively, it is the AA-type hopping — not the AB/BA-type hopping responsible for magic-angle flat bands — that drives the splitting of the central Landau level and the emergence of the butterfly pattern at low energies. Building on this observation, we use an effective Floquet Hamiltonian, valid beyond the conventional high-frequency expansion, to investigate how periodic light driving reshapes this chiral structure and its associated fractal spectrum.

Circularly polarized light is found to open a gap term that explicitly breaks both chiral symmetries, producing a Hofstadter butterfly that is visibly and measurably asymmetric about zero energy, with the degree of asymmetry controlled by the driving strength and handedness. In contrast, longitudinal light emanating from a waveguide renormalizes the interlayer couplings through Bessel-function factors without introducing any symmetry-breaking terms, leaving the spectrum's mirror symmetry intact. Strikingly, tuning the waveguide driving strength allows either chiral limit to be reached on demand, at specific zeros of the relevant Bessel function, offering a fully optical, non-invasive route to switching between chiral regimes of a moiré flat-band system.

These results identify light polarization as a practical control knob for chiral symmetry and topology in twisted van der Waals heterostructures, complementary to twist-angle engineering, and point toward experimentally accessible driving regimes for probing and manipulating flat-band physics in graphene-based moiré systems.

References

[1] N. Benlakhouy, A. Jellal, H. Bahlouli, and M. Vogl, Phys. Rev. B 105, 125423 (2022).

Topological Classification of Non-Normalizable Vector Fields

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Topology provides a unifying classification framework for structures across diverse physical systems. Topological classifications based on homotopy theory typically require normalized fields and thus break down at amplitude zeros, where normalization becomes singular. Points of vanishing amplitudes naturally arise in a number of physical systems, for example, in optical and wave fields [1,2].
We introduce a new approach for the topological classification of non-normalizable n-dimensional vector fields with compactifiable base spaces by mapping them onto normalized n+1-dimensional vector fields [3]. This construction incorporates amplitude zeros into the topological description rather than excluding them, thereby extending homotopy-based classification to a broader class of physical fields.
We illustrate the framework using representative non-normalizable vector fields in two and three dimensions and derive the corresponding topological invariants. The resulting topological charges are robust under continuous deformations and can change only under discontinous transformations. Our framework thus provides a common topological description applicable to magnetic textures, ferroelectrics, and electromagnetic fields and more general wave fields.

References

[1] A. Neuhaus, P. Dreher, P. Gessler, B. Frank, T. Davis, H. Giessen, K. Everschor-Sitte, F. J. Meyer zu Heringdorf, “Analysis of the Topology of a Plasmonic Target-Skyrmion Texture”, *arXiv:2607.15046* (2026).

[2] A. Neuhaus, P. Gessler, P. Dreher, D. Janoschka, A. Rödl, M. Manten, Th. Bauer, M. Azhar, B. Frank, T. J. Davis, H. Giessen, K. Everschor-Sitte, F. J. Meyer zu Heringdorf, “Linking extended vector wave fields with momentum space topology”, *arXiv:2604.26610* (2026).

[3] P. Gessler, A. Pignedoli, A. Neuhaus, F.-J. Meyer zu Heringdorf, M. Azhar, and K. Everschor-Sitte, “Topological Classification of Non-Normalizable Vector Fields”, arXiv:2607.25848 (2026).

Vectorial Mode Solver for Orbital Angular Momentum supporting fibers

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Scaling the number of spatial modes supported by optical fibers offers a route toward higher capacity classical and quantum communication networks, lower energy consumption per transmitted bit, and fiber-integrated devices controlled through the orbital angular momentum (OAM) of light. Designing such systems requires reliable knowledge of the highest OAM order that a fiber can support. Conventionally, modal cutoff is often inferred from the behavior of the calculated attenuation under variations of a perfectly matched layer (PML), with a sharp increase or divergence interpreted as the loss of guidance. Because the intrinsic attenuation of practical fibers can be extremely small, however, such behavior may reflect the numerical termination rather than a physical cutoff. Here, we introduce a full-vectorial mode solver for rotationally symmetric fibers. The refractive-index profile is represented by concentric layers, and the boundary conditions of the corresponding analytical vector-field solutions are solved numerically. This approach avoids imposing vanishing fields at an artificial outer boundary and permits otherwise identical calculations both with and without a PML termination. We use the solver to examine the robustness of cutoff-order predictions and to track interactions between ring-core and cladding modes. The resulting modal spectra reveal hybridization regimes in which nominal OAM modes acquire substantial cladding-mode character, making selective coupling into the ring-core infeasible. Accurately distinguishing physical cutoff from termination-dependent loss and mode mixing is essential for designing high-capacity OAM fibers and fiber-integrated micromachines that require predictable excitation of specific angular momentum states.

[1] Z. Ma, Science **380**, 278-282 (2023)
[2] J. Liu, Optica **13**, 602-620 (2026)

Optical Broom for Reconfigurable Twistronics

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The physical properties of twistronic systems are highly sensitive to the twist angle. On top of it, the center of rotation is another degree of freedom constituting the topological feature of the moiré superlattices. Hence, a technique that allows for reconfigurable adjustment of both the twist angle and center of rotation, preferably in an *in situ* manner, carries great significance in facilitating the advancement of the burgeoning field of twistronics. Recent studies have reported the use of micro-electromechanical systems[1] and atomic force microscopy[2] for this very purpose, both featuring a mechanical moving part that prescribes motion of the target layer in the dual-layer systems through mechanical contacts. Counterintuitively, such prescribed motions can also be induced in a contact-free manner, using only a focused beam of pulsed laser. The corresponding technique, termed as “optical broom”, is capable of actuating target materials anchored to solid surfaces by the adhesive van der Waals force. Herein, we propose to bridge the optical broom technique with twistronics for contact-free and reconfigurable engineering of the topology of twistronic systems. The optical broom features sub-milliradian rotational precision[3] and angstrom-scale linear resolution[4]. Micro-objects, including both bulk and layered materials, can be manipulated by a focused laser spot to move incrementally, pulse by pulse, across extended solid substrates over unlimited angular or linear ranges, while maintaining high spatial resolution at the single-pulse level[3][4]. We are currently working on applying the optical broom to dual-layer systems based on both photonic crystal slabs and few-layer 2D materials. The setup can be made ultra-compact through lensed-fiber integration, making it compatible with cryostats and electron microscopes.

References

[1] Tang H, et al. Nature 632, 1038-1044, (2024)

[2] A. Inbar, et al., Nature 614, 682–687 (2023)

[3] Q. Jia, et al., Laser & Photonics Reviews 19, 2401370 (2025)

[4] Q. Jia, et al., Advanced Science 11, 2401418 (2024)

Chiral disorder-robust frequency synchronization of coupled nonlinear oscillators

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Synchronization is a basic collective phenomenon of coupled interacting systems — from living systems to clocks. When the coupling overcomes the frequency detuning between not-exactly-identical oscillators, they tune their oscillation frequencies $\mathrm{d}\varphi_n/\mathrm{d}t$ to the same value (frequency synchronization) and also adjust the oscillation phases φ_n (phase synchronization). Here, we show that the minimal coupling required to maintain the frequency synchronization can be drastically suppressed in the chiral synchronization regime, when the oscillator array has a nonzero phase gradient $\nabla_n\varphi$. We put forward several schemes for a chiral synchronization either globally or in sign-alternating domains by engineering the local couplings between the oscillators. Our results are supported by an analytical theory based on the Kardar–Parisi–Zhang (KPZ) equation with the chiral terms, as well as the rigorous numerical simulations in the framework of the Kuramoto model with complex coupling. Our predictions can be tested in the state-of-the-art coupled laser arrays, where laser phase (and frequency) synchronization is a way to enhance the total emission power.

Logarithmic transport at topological phase transitions of one-dimensional chiral quantum systems

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Disorder-driven topological phase transitions in one-dimensional chiral Hamiltonians such as the disordered Su-Schrieffer-Heeger model can be characterized by a vanishing Lyapunov exponent and a Dyson peak in the density of states. In this this work it is shown for a random hopping model (RHM), how the quantum dynamics leads to a logarithmic growth of the moments of the position operator, similar as in classical Sinai diffusion. Using probability theory techniques one is able to see that the eigenfunction corresponding to the smallest eigenvalue is well-approximated by the random walk induced by the RHM. Additionally, one is able to provide bounds on the smallest positive energy of the Hamiltonian as well as the bounds on the energy gap to the first positive excited state.

1. **D. Bagrets, A. Altland, A. Kamenev, Sinai Diffusion at Quasi-1D Topological Phase Transitions**, Phys. Rev. Lett. 117, 196801 (2016)

2. **J. De Moor, C. Sadel, H. Schulz-Baldes, Footprint of a topological phase transition on the density of states**, Lett. Math. Phys. 113, 96 (2023)

Quantum coherence measures in boosted entangled massive systems

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arXiv: 2511.20371v1 [quant-ph]

Abstract:

In this study, we investigate the effect of the Lorentz transformation on the measures of quantum coherence in an entangled atomic system. Here, we consider the effect of this relativistic boosts on two-particle entangled generalized Gaussian wave packets in two scenarios. In the first scenario, we consider that the relativistic boost affects the one particle and other remains unaffected while in the second scenario, we consider that both the particles are affected by the effect of the relativistic boost. The coherence of the wave function as measured by the boosted observer is studied as a function of the boost parameter and the width of the Gaussian wave packets. Using different measures of coherence, it is shown that in general the coherence decays with the increase in the width of the Gaussian wave packet, higher values of boost parameter, and the number of particles on which boost is applied. Comparing these results with our previous work [*Phys. Rev. A 110 (2024) 5 052413*], it is observed that for the Frobenius-norm measure, in the bipartite setting, maximal entanglement reduces the Lorentz-induced coherence loss even for relatively broad wave packets. This offers valuable insights from the quantum information processing viewpoint.

Non-Abelian Order and Monopole Textures in Multi-Flavor Weyl Semimetals

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In ordinary Weyl semimetals, interaction-driven charge-density-wave (CDW) order is described by a complex scalar field whose phase supports axion-string defects. We show that an additional flavor degree of freedom qualitatively changes this picture. In a two-flavor Weyl system, we consider an SU(2)-adjoint CDW, described by a common CDW phase and an orientation in flavor space, with vacuum manifold $(S^2 \times S^1)/Z_2$. The ordered phase consequently supports hedgehog, or global-monopole, defects that have no analogue in the conventional single-flavor CDW. Unlike familiar textures of magnetic order, these defects reside directly in the interaction-generated matrix mass that gaps the Weyl fermions. We obtain an exact normalizable zero-energy state bound to an elementary hedgehog and show that its existence is guaranteed by the winding of the mass texture. Thus, flavor transforms the topology of the ordered phase and produces a robust fermionic state localized at the defect. Our results establish multi-flavor Weyl systems as a setting for interaction-driven topological defects and bound states unavailable in conventional Weyl semimetals.

A Plasmonic Target Skyrmion: Local Topology Without a Global Skyrmion Number

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Structured optical fields, such as plasmonic nearfields, are often described in terms of their topology, exhibiting local skyrmionics textures. A topological description in terms of skyrmion numbers implicitly assumes compactness of the underlying manifold, a condition that is generally not fulfilled in extended optical fields. Here, we investigate a plasmonic nano-focus that exhibits a sequence of radially extending alternating skyrmion and antiskyrmion textures (c.f. Fig. 1) [1]. Experimentally, we access the topology of the plasmonic nano-focus by time-resolved polarimetric photoemission electron microscopy (PEEM). Polarimetric PEEM reconstructs the full instantaneous electric field vectors of the nano-focus, allowing for a topological analysis directly from the retrieved vectorial data. At a fixed point in time, the skyrmion number reveals a non-decaying oscillatory behavior with increasing integration radius, arising from alternating skyrmion and antiskyrmion textures, which prevents convergence to a well-defined global skyrmion number. As a function of time, the skyrmion density inverts every half oscillation period, rendering the time average of the skyrmion density to zero. Our results demonstrate that a global skyrmion number cannot be assigned in such non-compact fields, despite the presence of local skyrmion-like texture.

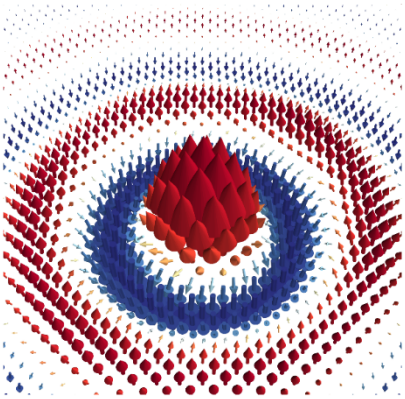


Figure 1: Plasmonic nanofocus: the electric field vectors reconstructed by polarimetric PEEM display skyrmion-like textures.

References

[1] A. Neuhaus, P. Dreher, P. Gessler, B. Frank, T. Davis, H. Giessen, K. Everschor-Sitte, F. Meyer zu Heringdorf, “Analysis of the Topology of a Plasmonic Target-Skyrmion Texture”, arXiv:2607.15046

T-duality and bosonization as examples of continuum gauging and disentangling

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Dualities and duality transformations form a well established methodology in various aspects of quantum many body physics and quantum field theories, allowing one to exploit equivalence between models which may naively seem completely different in order to gain access to further physical regimes, either analytically, numerically or experimentally. Recently, in the context of condensed matter physics and quantum information, it was shown that dualities can be understood very well through a gauging and disentangling procedure that can be represented by a finite depth quantum circuit. In this letter we expand these concepts to the continuum, suggesting them as a way to derive duality transformations in continuum field theories and particle physics, and benchmark the presented ideas through the re-derivation of T-duality and bosonization.

Jastrow Wavefunctions and Parent Hamiltonians for Ground State Solvable Quantum Many-body Systems

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Jastrow-type wavefunctions provide a versatile and physically transparent framework for describing quantum many-body systems with analytically tractable ground states, ranging from quantum fluids to fractional quantum Hall states and cold-atom systems. Historically, Jastrow wavefunctions have appeared prominently in models known to be *integrable* [1–4]. Here, we consider the construction of Jastrow ansatz wavefunctions of the form [4, 5]

$$\Psi_o(\mathbf{r}_1, \cdots, \mathbf{r}_N) = \prod_{i<j} f(r_{ij}), \quad r_{ij} = ||\mathbf{r}_i - \mathbf{r}_j||, \tag{1}$$

in one and D dimensions [6]. We discuss an algorithmic procedure for reverse engineering the parent Hamiltonian corresponding to a prescribed Jastrow ansatz. The resulting parent Hamiltonian generally contains, in addition to the conventional two-body interaction, a three-body interaction. The presence of irreducible three-body terms generally leads to non-integrability, irrespective of whether the two-body Hamiltonian is integrable.

This construction can be further extended to systems in which interactions are encoded by different graphs [7], for which it has been shown that the corresponding Jastrow states are ground states. In one-dimensional systems, the ground state is unique provided that the Jastrow wavefunction is nodeless.

Furthermore, following [8], this framework can be extended to systems with internal degrees of freedom by incorporating generalized permutation operators acting on the internal states. These degrees of freedom can be interpreted as spin for SU(2) or as color for SU(N), thereby providing a systematic route to spin- and color-generalized parent Hamiltonians.

References

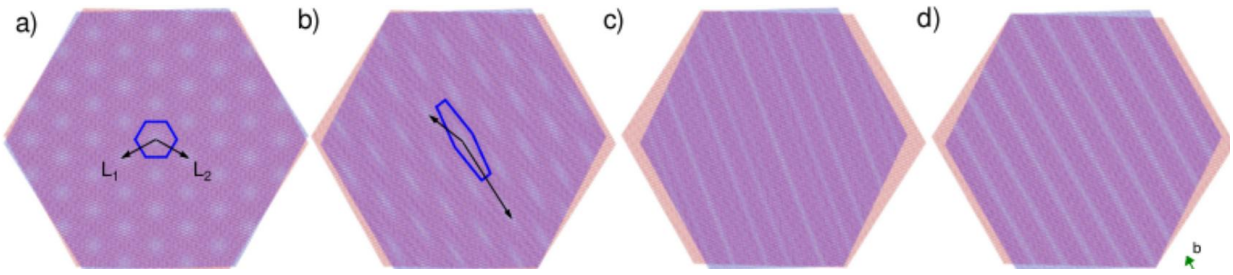
[1] F. Calogero, J. Math. Phys. **10**, 2191 (1969).
[2] B. Sutherland, J. Math. Phys. **12**, 246 (1971).
[3] F. D. M. Haldane, Phys. Rev. Lett. **60**, 635 (1988).
[4] B. Sutherland, *Beautiful Models* (World Scientific, Singapore, 2004).
[5] A. del Campo, Phys. Rev. Research **2**, 043114 (2020).
[6] M. Beau and A. del Campo, SciPost Phys. Core **4**, 030 (2021).
[7] N. Sasmal and A. del Campo, Phys. Rev. B **113**, 235151 (2026).
[8] A. P. Polychronakos, Phys. Rev. Lett. **70**, 2329 (1993).

Designing Moiré Patterns by Strain

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Experiments conducted on two-dimensional twisted materials, involving both twist angle and strain, have consistently shown the presence of a diverse array of moiré patterns with distinct forms and shapes. Especially striking is the appearance of 1D structures under some certain but opaque conditions. In our studies we undertake a systematic investigation of the lattice structure in these systems, taking into account the combined effects of twist and strain. Particularly for moiré systems composed of honeycomb lattices we identified the conditions governing the emergence of such 1D channels and formulate the required criteria for lattice periodicity restoration. By carefully manipulating the strain direction, we have identified a family of engineered moiré systems. These results provide deeper insights into the interplay between twist angle, strain, and lattice structure in two-dimensional layered materials.



Strain induced geometrical effects in a moire superlattice as function of the strain and elastic moduli (Poisson ratio) of graphene. Blue hexagon denotes the moire unit cell in real space. a) A moire sublattice without strain; b) The deformation of the moire supperlattice under moderate strain; c) The emergence of an apperiodic 1d moire superlattice at a critical strain. The system is quasicrystallic; d) The restoration of the exact periodicity by fine-tuning the Poisson ratio to a certain critical value.

* In collaboration with F. Escudero, Z. Zang, P. A. Pantaleon, and F. Guinea
IMDEA Madrid, Spain.

References:

[1] Physical Review Letters 131, 166402 (2023)
[2] Physical Review Research 6, 023203 (2024)

Double-scaled bosonic and fermionic embedded ensembles, complex SYK, and the dual Hilbert space

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Embedded ensembles are p-body random ensembles defined in fixed particle spaces, with applications to a wide class of many particle and mesoscopic systems. We derive the density of states, two- and four- point functions for bosonic and fermionic degrees of freedom in a double-scaled limit. We demonstrate these models are of the same universality class as double-scaled SYK, expanding this class to both fermionic and bosonic systems. Moreover, new techniques are developed to derive the density of states and n-point functions of double-scaled models, sidestepping the need for chords diagrams. The techniques rely on introducing the Wick product of q-commuting Gaussian random variables, which we show is equivalent to normal ordering of q-oscillators. The latter property leads to the duality between double-scaled random ensembles and the Hilbert space of q-oscillators.

References

[1] J. Tall and S. Tomsovic, arXiv:2604.14522 [hep-th] (2026)

Statistical topology: Winding Number Statistics of Parametric Chiral Random Matrix Ensembles

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Statistical topology is a powerful theory with minimal requirements that unravels universal properties in quantum systems with a gapped Hamiltonian, from e.g. quantum chromodynamics, condensed matter or quantum optics. The winding number is a simple topological invariant that originates from complex analysis. In the case of chiral symmetry the winding number emerges as a topological index that characterises gapped phases of Fermions. In Ref. [1], this topological index' statistics were analysed for the chiral class AIII by mapping the problem onto random matrix ensembles.

[1] P. Braun, N. Hahn, D. Waltner, O. Gat, and T. Guhr, J. Phys. A: Math.

Theor. 55, 10.1088/1751-8121/ac66a9 (2022).

Coloring the Kohmoto Butterfly using a Spectral Localizer

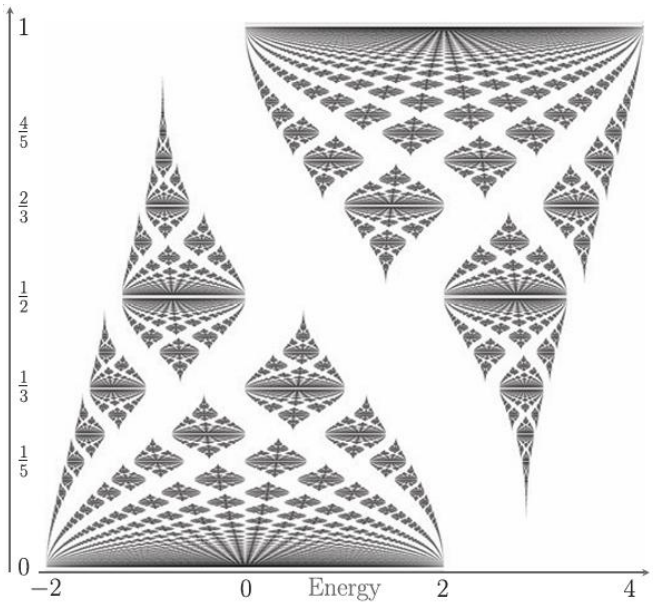
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The Kohmoto Hamiltonian is a discrete operator on $\mathbb{Z}$ with an aperiodic potential governed by a frequency parameter. The union of its spectra over all frequencies forms a fractal known as the Kohmoto butterfly. This fractal's spectral gaps carry topological indices that we seek to determine. By finding these indices and assigning each index a color, we get a coloring of the butterfly. Unfortunately, the discontinuity of the potential makes standard topological methods for computing indices unsuitable.

We present a coloring of the butterfly using the spectral localizer, a method developed by Loring and Schulz-Baldes. We then compare our results with a previous coloring proposed by Band and Beckus, offering an independent computation of the indices.

The talk is based on joint work with Ram Band, Siegfried Beckus and Hermann Schulz-Baldes.



From Quantum Jumps to Classical Currents: Certified Point-Gap Topology under Coherence Elimination

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Open quantum systems and classical stochastic processes obey distinct dynamical equations, yet both can be represented by non-Hermitian generators supporting point-gap topology. We investigate a time-independent Liouvillian Hatano-Nelson chain with reciprocal coherent hopping, directionally biased quantum jumps, and local dephasing, and determine conditions under which coherence elimination preserves the point-gap topology of the full Lindblad generator. The nonreciprocal Bloch dependence responsible for the winding is generated by recycling terms, while the corresponding no-jump Hamiltonian remains reciprocal and point-gap trivial.

For periodic boundaries, the momentum-resolved Liouvillian admits an exact finite-size characteristic determinant. Under an explicit invertibility condition, the coherence-sector eigenvalues contribute zero winding, so the complete Liouvillian winding reduces exactly to a scalar Schur complement. We derive a controlled reduction to an effective biased Markov generator and bound its deviation from the exact scalar loop. If this elimination error remains smaller than the local point-gap distance throughout the Brillouin zone, a homotopy argument guarantees identical Liouvillian and Markov windings. For $J = 1$, $\Gamma_R = 1$, $\Gamma_L = 0.35$, and $\lambda_0 = -0.4$, a conservative system-size-uniform bound certifies the common winding for $\gamma_\phi \geq 8.01$. A dimensionless formulation identifies a finite certified region in parameter space.

The boundary analysis yields a second structural result. At zero coherent hopping, populations and coherences decouple exactly, and all N eigenmodes of the biased population block acquire the same directional skin envelope within an N^2-dimensional Liouville space. The wound slow sector is therefore extensive in system length but subextensive in Liouville space, with spectral fraction $1/N$. At finite hopping and strong dephasing, numerical continuation retains N localized population-associated slow modes, whereas the coherence sector remains extended. Hence the point-gap winding can govern a localized classical slow sector while the localized fraction of the complete Liouvillian spectrum vanishes as N^{-1}. Reported Ti spin systems on bilayer MgO/Ag(100) provide relevant coherent-control and decoherence scales; realization of the model additionally requires an engineered direction-selective dissipative channel.

References

[1] N. Hatano and D. R. Nelson, Phys. Rev. Lett. **77**, 570 (1996); [2] K. Kawabata et al., Phys. Rev. X **9**, 041015 (2019).

[3] T. Haga et al., Phys. Rev. Lett. **127**, 070402 (2021); [4] A. Chaduteau et al., Phys. Rev. Lett. **136**, 016603 (2026).

Topological bound states in a lattice of rings with nearest-neighbor interactions

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Topological systems are one of the most fascinating areas in condensed matter physics [1]. While the properties of single particle topological systems are now well understood, the many body regime remains far less explored. Two body systems, where tightly bound pairs of interacting particles known as doublons can emerge, are particularly intriguing and offer a promising route to uncovering many new body topological phenomena.

In this work, we study a system of ultracold bosons loaded into the states with orbital angular momentum (OAM) in a one-dimensional staggered lattice of ring potentials. We consider the hard-core limit and large nearest-neighbor interactions such that two particles in next neighbouring sites are bound. In the case with OAM l=1 in all sites, the system can be mapped to a Creutz ladder chain, using the circulation as a synthetic dimension. Moreover, focusing on the manifold of the bound states, we derive an effective model consisting of two Bose-Hubbard chains and two Su-Schrieffer-Heeger (SSH) chains exhibiting opposite topological phases and thus, two-particle edge states for some parameter values. By considering the case of OAM l=0 and l=1 in alternating sites, the system can be mapped into a diamond chain formed by the real dimension and the synthetic dimension spanned by the two circulations and the effective model consists of an extended Creutz ladder [2]. This extended Creutz model for doublons features staggered interleg couplings, generating four flat bands and hosting edge states embedded in the flat band. This model can also be mapped into two SSH chains if all the couplings in the original system are equal. Tuning spatially the amplitude of the couplings destroys the inversion symmetry of these SSH chains, but enables the appearance of multiple flat bands.

References

[1] M. Z. Hasan and C. L. Kane, Colloquium: Topological insulators, Rev. Mod. Phys. **82**, 3045 (2010).
[2] Y. Kuno, Extended flat band, entanglement, and topological properties in a Creutz ladder, Phys. Rev. B **101**, 184112 (2020).

Complex-structured beam produced by modulated phase mask

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Super-resolution technologies for both imaging and measurement have become major research frontiers over the past decade, driven by advances such as Stimulated Emission Depletion (STED) microscopy and Structured Illumination Microscopy (SIM). STED routinely achieves resolutions down to 30 nm with strong depletion, while SIM offers enhanced resolution with compatibility for live-cell imaging. However, both methods rely on complex-structured beams, typically donut-shaped or otherwise spatially engineered, whose generation often requires bulky and intricate optical assemblies. Many practical applications, therefore, demand compact, easily integrated solutions for producing such illumination fields. In this work, we exploit state-of-the-art Two-Photon Grayscale Lithography (2GL) to fabricate customizable, continuous, and freeform microscale phase masks capable of generating advanced beam profiles. We demonstrate multiple design strategies, including aspect-ratio tuning, controlled phase-rotation gradients, and phase extraction from superposed fields. These approaches enable the realization of complex-structured beams in a highly compact form factor, suitable for straightforward implantation into existing optical systems. Our results establish 2GL-fabricated phase masks as a versatile platform for next-generation super-resolution illumination engineering.