December 14–18, 2025
Ambrož, Krvavec, Slovenia

BOOK OF ABSTRACTS

NQW

Nonequilibrium Quantum Workshop

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NQW Nonequilibrium Quantum Workshop

December 14 – 18, 2025
Krvavec, Slovenia

Webpage: https://nqw.ijs.si/
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Abstracts

Boundary-driven magnetization transport in the spin-1/2 XXZ chain and the role of the system-bath coupling

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Understanding transport in quantum many-body systems is a central challenge in condensed matter and statistical physics. Theoretical studies typically rely on two main approaches: Dynamics of linear-response functions in closed systems and Lindblad dynamics in open systems with boundary driving. While the equivalence of their dynamical behavior has been explored in recent studies [1,2], a systematic comparison of the transport coefficients obtained from these two classes of approaches is a less explored question. Here [3], we address this question by comparing and contrasting the diffusion constants from the two approaches. We find a clear mismatch and in particular a strong dependence on the system-bath coupling for the open spin-1/2 XXZ chain with boundary driving. We trace the origin of this mismatch to an incorrect order of limits of time $t \to \infty$ and system size $L \to \infty$, which we argue to be intrinsic to the open system. As a practical resolution, we advocate to study the whole time dependence of transport coefficients, which convincingly agree for the two approaches, up to a time scale set by the system size.

[1] T. Heitmann, J. Richter, F. Jin, S. Nandy, Z. Lenarčič, J. Herbrych, K. Michielsen, H. De Raedt, J. Gemmer, R. Steinigeweg, Physical Review B 108, L201119 (2023).
[2] M. Kraft, J. Richter, F. Jin, S. Nandy, J. Herbrych, K. Michielsen, H. De Raedt, J. Gemmer, R. Steinigeweg, Physical Review Research 6, 023251 (2024).
[3] M. Kempa, M. Kraft, S. Nandy, J. Herbrych, J. Wang, J. Gemmer, R. Steinigeweg, arXiv:2507.16528.

The race of energy and spin: who is faster?

F. Heidrich-Meisner[1]

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For most spin-1/2 spin models in one dimension, energy transport is faster than spin transport and carried by collective excitations or heavy quasiparticles that do not carry magnetization. Theses class of models include the spin-1/2 XXZ chain, Heisenberg ladders and also the more general Fermi-Hubbard model. Some of these models are integrable, and in those cases, energy transport can even be qualitatively faster that spin transport. This relationship apparently survives upon perturbing away from integrable models as usually, spin diffusion is slower than energy diffusion. As a consequence the slowest physical time scale that is seen as the onset of random matrix behavior in the spectral form factor is usually associated with spin transport (or particle transport).

In our work [1], we identify a model in which the opposite behavior is observed at infinite temperature, namely a spin-1/2 XX ladder whose transport properties have recently also been studied in an optical-lattice experiment [2]. Notable, in this model, there are no diagonal contributions to the local energy density in the computational basis due to the absence of S^zS^z terms. As a consequence, magnetization can propagate without changing the local energy density and hence spin diffusion is the faster process. Alternatively, one may view this behavior as being inherited from the case of two decoupled chains of free fermions, where energy can only be transported by moving a particle. We conjecture, though, that in a broader class of models that do not have diagonal contributions to the local energy density, a similar behavior of energy versus spin diffusion may emerge may emerge.

We study two perturbations of the XX ladder: diagonal disorder and additional S^zS^z terms. In the case of disorder, energy diffusion remains slower than spin diffusion but both diffusion constants become identical as disorder increases. Adding interactions leads to a reversal, i.e., at some finite strength of the interaction, spin transport becomes the slowest channel. We discuss implications of our results for other models.

[1] K. Ceven, , L. Peinemann, F. Heidrich-Meisner, Hierarchy of timescales in a disordered spin-1/2 XX ladder. arXiv:2509.20078

[2] S. Karch, et al. Probing quantum many-body dynamics using subsystem Loschmidt echos, preprint arXiv:2501.16995

Transport and thermalization in modulated spin chains: classical vs. quantum processor study

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Quantum spin models in quasiperiodic external fields reveal phenomena very similar to the case of random fields. In particular the transport and thermalization are exponentially suppressed with the increasing field strength, revealing an effective glassy crossover to the regime of many-body localization [1]. In contrast, random systems manifest in addition a very broad distribution of transport values, which might indicate even subdiffusive behavior [2]. The similarity and differences will be presented within the study of spin and energy diffusion in anisotropic Heisenberg chains [1], [2]. Qualitatively similar results are obtained also for the energy diffusion within the transverse-field Ising model subject to quasiperiodic diagonal field. Such system has been recently also simulated by the RIKEN group as one dimensional as well two dimensional kicked Ising model on the quantum processor IBM-Kobe with 144 qubits, with results revealing an effective breakdown of thermalization.

[1] P. Prelovšek. J. Herbrych, and M. Mierzejewski, Phys. Rev. B **108,** 035106 (2023).

[2] J. Herbrych, and P. Prelovšek, Phys. Rev. B **112,** 045108 (2025).

Structural contribution to light-induced gap suppression in Ta_2NiSe_5

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An excitonic insulator is a material that hosts an exotic ground state, where an energy gap is opened due to spontaneous condensation of bound electron-hole pairs. Ta_2NiSe_5 is a promising candidate for this type of materials. Nevertheless, the coexistence of a structural phase transition with the gap opening has led to a long-standing debate regarding the origin of the insulating gap. Here, we employ MeV ultrafast electron diffraction to obtain quantitative insights into the atomic displacements in Ta_2NiSe_5 following photoexcitation. In conjunction with first-principles calculations using the measured atomic displacements, we find that the structural change can largely account for the reduction in the energy gap following photoexcitation. Our work illustrates the importance of a quantitative reconstruction of individual atomic pathways during nonequilibrium phase transitions, paving the way for a mechanistic understanding of a diverse array of electronic and magnetic transitions in correlated materials where the lattice dynamics can potentially play a pivotal role.

Equilibrium and electrically driven charge density wave states in $EuTe_4$

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Controlling charge density wave (CDW) states is of fundamental and technological importance, yet the ability to control charge-ordered states is limited to a handful of systems. In this presentation, we will focus on a recently discovered van der Waals semiconductor $EuTe_4$, which hosts several CDW states. [1] The complex physics of CDW states gives rise to an exceptionally wide (>400 K) hysteresis loop, the origin of which remains elusive. [2] The recent demonstration of optical non-volatile switching between CDW states underscores the compound's unique properties and potential. [3]

Here, we present that electrical pulses can be used for non-volatile manipulation of CDW states, which can be performed from cryogenic temperatures up to room temperature and beyond. [4] As switching of electronic order is accompanied by a change in material resistance, such devices act as memristors. We establish that the switching mechanism is non-thermal, which enables fast and energy-efficient non-volatile CDW switching even at high temperatures.

Due to the complexity of charge ordering physics of $EuTe_4$, equilibrium states need to be explored before moving towards understanding the metastability. Recent work has shown that the stacking and interaction between CDWs in different layers could be responsible for the unusual material response. [5] Our preliminary diffraction experiments indicate the existence of competition between distinct CDW orders already in equilibrium. The evolution of this competition with temperature likely gives rise to an anomalous hysteretic behaviour.

[1] D. Wu et al., Phys. Rev. Materials 3, 024002 (2019).
[2] B. Q. Lv et al., Phys. Rev. Lett. 128, 036401 (2022).
[3] Q. Liu et al., Nat. Commun. 15, 8937 (2024).
[4] R. Venturini et al., arXiv:2412.13094 (2024).
[5] B. Q. Lv et al., Nat. Mater. (2025).

Ultrafast order by non-thermal disorder

Nikolaj Klinkby[1], Francesco Grandi[2], Khalid Siddiqui, Lara Bremer[3], Dante M. Kennes[4], Tim Wehling[3], Martin Eckstein[3,5], Simon E. Wall[1]

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Harnessing nonequilibrium dynamics to manipulate the structure of condensed matter opens the door to new and exciting phases. With ultrafast light pulses, we can drive systems far from equilibrium, revealing these new "hidden phases". The process through which these phases emerge is still not fully understood, and controlling them is essential for studying them. One method to achieve control over phase transitions is by coherently manipulating the crystal structure to induce a new state with long-range order in the material.[1] Alternatively, optical excitations can cause the unit cells within the material to respond differently, leading to disordered non-thermal vibrational distributions.[2] While it may seem counterproductive to introduce disorder into the system, recent theory[3] suggest that the non-thermal fluctuations can stabilize new long-lived ordered phases far from equilibrium instead of rapidly thermalizing to a thermally accessible phase. This opens up a new path to access and controlling emerging nonequilibrium phases.

We present experimental evidence for the observation a long-lived disorder stabalized phase in the material $Pr_{0.5}Sr_{1.5}MnO_4$ which remains meta-stable at room temperature. The material exhibits a mirror symmetry-breaking phase below ~330 K, where it exhibits orbital ordering. The light-induced emerging order is probed by the changes in optical anisotropy.

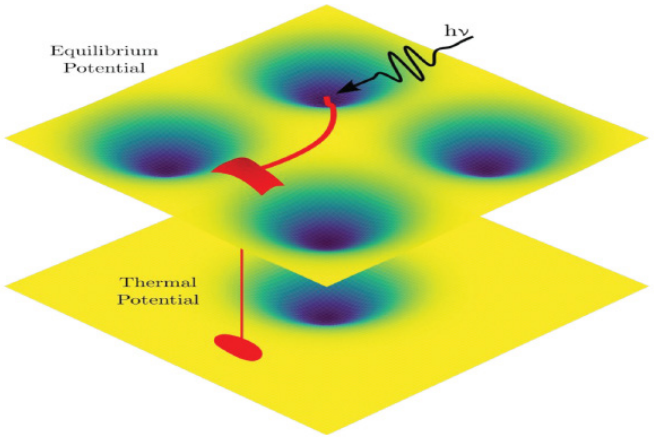

Figure 1: Illustration of a C4 symmetry broken potential, where the system is driven out of equilibrium to a non-thermal state, which is disordered (broad distribution)

[1] D. Fausti et al. Science 331 6014 (2011)
[2] S. Wall et al. Science 362 6414 (2018)
[3] F. Grandi et al. Newton 1 6 (2011)

Phantom quasiparticles and zero modes in 1T-TaS_2

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The imposition of topologically nontrivial space by non-equilibrium self-assembly in an inhomogeneous CDW superlattice leads to the formation of exotic excitations with unusual properties. Here I will present an analysis of the collective excitations at a vertex formed by the intersection of 3 domains with translation- and mirror- symmetry breaking domain walls.

The observation of gapped low-frequency modes and phantom quasiparticles is discussed for the case where a direct correspondence to the above-mentioned excitations is experimentally measured. In addition, phantom quasiparticles - mesoscopic electronic excitations - are observed that can be interpreted as weakly bound topologically protected electronic states - qubits - with well-defined and measurable two-level system spectra.

The combination of hybridised Goldstone-Higgs mode excitations and electronic bound states with ultraslow dynamics observed in a well-known prototype material opens the way to a search for similar phenomena in other systems. A particular important technologically important example is AlOx, where the same symmetries are broken in the quasi-amorphous junction layer of transmon qubits which can lead to the generation of TLS noise recently observed on a very similar timescale.

Ultrafast local charge-order dynamics and THz-induced metastability in 1T-TaS_2

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The integration of broadband THz pulses with low-temperature scanning tunneling microscopy (THz-STM) [1,2] has opened up new possibilities for probing and controlling quantum materials on the angstrom scale. In this talk, I will present THz-STM measurements on the dynamical evolution of the commensurate charge density wave (CDW) phase in the layered material 1T-TaS_2 [3]. We demonstrate the ability of lightwave-driven THz-STM to track the ultrafast dynamics of coherent collective modes in real space and time, and to locally map the CDW amplitude mode with a precision of individual CDW superlattice sites. Furthermore, I will discuss the potential role of interlayer stacking for the observed dynamics. First, our pump-probe THz-STM measurements reveal a pronounced low-frequency mode at 1.3 THz that appears in the vicinity of a local CDW irregularity, and whose frequency matches that predicted for interlayer phonon modes. Second, beyond ultrafast dynamics probed by lightwave-driven THz-STM, we find that the tip-enhanced THz pulses can induce long-lived changes of the local CDW pattern and the local density of states of the insulating gap, with lifetimes ranging from milliseconds to effectively quasi-stationary on experimental scales. The observed metastable changes are predominantly observed near CDW irregularities and are consistent with THz-induced modifications of the local stacking configuration. Our work opens new opportunities for the ultrafast manipulation and control of nonequilibrium and metastable phases at the angstrom scale.

[1] T. Cocker et al., Nanoscale terahertz scanning probe microscopy. Nature Phot. 15, 558–569 (2021)

[2] M. Müller, M. Imaging surfaces at the space–time limit: New perspectives of time-resolved scanning tunneling microscopy for ultrafast surface science. Prog. Surf. Sci. 99, 1 (2024)

[3] L. E. Parra López et al., arXiv:2505.20541 (2025)

The Timescale for the Electron Dynamics in 1T-TaS_2

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1T-TaS_2 is known for its variety of non-equilibrium states, which differ significantly from the commensurate charge density wave (CDW) observed at equilibrium [1]. From the hidden domain state and electronic amorphous state [2] to the chiral CDWs interfering within the single layer [3], when the material is studied on the nanometre scale, we are typically limited to either static scanning tunnelling microscopy (STM) experiments or time resolution on the order of minutes between the consecutive STM images.

Using a novel Fast STM technique, which allows us to reach millisecond resolution, we demonstrate how this presumably `slow` method reveals single-electron and collective charge motion on the surface of 1T-TaS_2, influenced by local CDW configurations as well as microscopic crystal strains. Conducting measurements down to 4.2 K, where CDW dynamics is typically considered quasi-static or slow [4], and up to 77 K, where the metastable states relax fast [1], we uncover dynamics on time scales previously inaccessible – either too fast for conventional STM or too slow to be associated with typical electron dynamics.

[1] J. Ravnik et al. Nat. Commun. 12, 2323 (2021)
[2] Y.A. Gerasimenko et al. Nat. Mater. 18, 1078 (2019)
[3] J. Ravnik et al. Sci. Rep. 13, 19622 (2023)
[4] J. Vodeb et al. Nat. Commun. 15, 4836 (2024)

Amplitude modes in 2D coherent spectroscpy

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Two-dimensional coherent spectroscopy (2DCS) is an experimental technique which employs a sequence of laser pulses to reveal the nonlinear response of target systems. Widely used in chemistry to study excitation pathways in molecules, this method has been recently adopted in the condensed matter community to study nonlinear optical properties of quantum materials. We simulate the multi-pulse protocols of 2DCS using nonequilibrium dynamical mean field theory and show that in symmetry broken phases, certain 2DCS signals are dominated by the amplitude mode of the order parameter [1,2]. 2DCS measurements can thus reveal the transition of a system into an ordered state and provide insights into the physics of materials such as Ta_2NiSe_5, where Coulomb-driven and phonon-driven ordering mechanisms cooperate.

[1] J. Chen, N. Tsuji, P. Werner, Higgs mode in two-dimensional coherent spectroscopy of weak-coupling antiferromagnets, arXiv:2504.21351 (2025).
[2] J. Chen, J. Mravlje, D. Golez, P. Werner, 2D coherent spectroscopy signatures of exciton condensation in Ta2NiSe5, to be published

Mechanism of Eigenstate Thermalization Breakdown

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The random matrix theory (RMT) has been a hallmark in the study of quantum thermalization as it sets a link between properties of random matrix eigenstates and observable matrix elements. Nevertheless, this description is incomplete for lattice models. A more relevant picture is given by the eigenstate thermalization hypothesis (ETH), which takes into account the local structure of the Hamiltonian and introduces an energy scale, dubbed Thouless energy, separating universal RMT dynamics from local Hamiltonian dynamics. Recently, this picture has been extended to systems in the vicinity of an ergodicity breaking phase transition, where the Thouless energy becomes vanishingly small. This phenomenon, denoted fading ergodicity [Phys. Rev. B 110, 134206], shows how fluctuations of matrix elements soften whence an eigenstate transition is approached. Here, following the approach in the seminal work by Deutsch we show that within RMT one can derive the softening of matrix elements fluctuations from the properties of eigenstate coefficients. Remarkably, there exist a direct relation to the fractal nature of its eigenstates in the unperturbed basis. For new abstract: our theory provides a common background of RMT models and integrability breaking models. It also shows that common theoretical framework can be applied to systems with a nonzero EBT point and to systems in which non-ergodicity (integrability) is limited to a singular point.

[1] M. Heckschen et al., PRX ENERGY **2**, 043009 (2023).
[2] L. Kämmerer et al., arXiv:2312.01438 (2023).

Quantum Devices with Rydberg Atoms

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Rydberg atoms are neutral atoms excited to high principal quantum numbers, exhibiting extremely large polarizabilities, strong dipole–dipole interactions, and long intrinsic lifetimes. These exaggerated atomic properties make Rydberg states highly sensitive to external electromagnetic fields and give rise to the Rydberg blockade mechanism, which suppresses multiple excitations within a blockade radius and enables fast, high-fidelity quantum gates and collective many-body operations. Because of their tunable interactions, compatibility with both cold-atom arrays and compact hot-vapor platforms, and their demonstrated scalability, Rydberg systems represent one of the most versatile architectures for quantum simulation and quantum computation [1,2], as well as for advanced quantum sensing [3].

In this contribution we present several quantum devices and measurement schemes that exploit the unique properties of Rydberg atoms. We first describe a Rydberg-atom antenna for broadband detection of microwave and radio-frequency electric fields, where Rydberg-state electrometry enables absolute, calibration-free measurements together with spatially resolved mapping of local microwave field distributions. We then discuss the realization of a dissipative time crystal in driven Rydberg ensembles, where simultaneous excitation of several Zeeman-split Rydberg states produces robust subharmonic temporal responses detectable through modulations of electromagnetically induced transparency (EIT). Finally, we outline approaches to quantum computation using individually trapped atoms as qubits in optical tweezers, as well as collectively encoded qubits in cold cesium ensembles [2,4], where the Rydberg blockade enforces a single shared excitation and enables collective state readout via EIT.

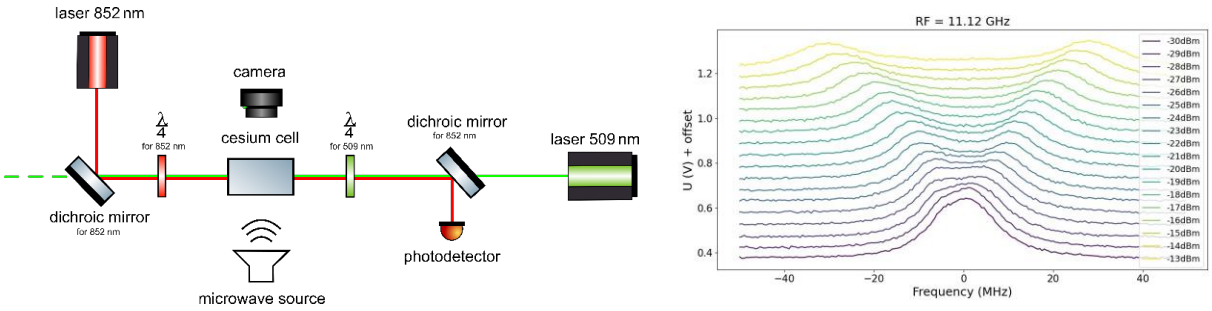

Figure 1: Schematic of the Rydberg-atom antenna and splitting of the $70S_{1/2}$ EIT signal in the presence of rf fields.

[1] A. Browaeys, T. Lahaye, *Nat. Phys*. **16**, 132 (2020).

[2] M. Morgado, S. Whitlock, *AVS Quantum Sci.* **3**, 023501 (2021).

[3] J. Yuan *et al.*, *Rep. Prog. Phys.* **86**, 106001 (2023).

[4] K. Gosar *et al.*, *Phys. Rev. A* **106**, 022604 (2022).

From Critical Dynamics to Coarsening: Bias-Tuned Quantum Phase Transitions on a 2400 Qubit Coherent Annealer

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Understanding the real-time dynamics of symmetry-breaking quantum phase transitions is a central challenge in quantum physics. While the Kibble–Zurek mechanism (KZM) successfully describes universal scaling in many systems, post-critical dynamics — particularly in two dimensions — can modify or even dominate the evolution. In this work, we explore this crossover using a next-generation 2400-qubit coherent D-Wave quantum annealer, studying longitudinal-field-driven quantum Ising models across 1D chains and 2D square lattices. We demonstrate how external symmetry-breaking fields allow continuous tuning between KZM and adiabatic dynamics, with system dimensionality controlling the nature of post-critical evolution. In 1D, we recover textbook Kibble–Zurek physics. In 2D, we witness a breakdown of freeze-out scaling and the emergence of quantum coarsening — accessible in real time and under tunable control. The next obvious question is on the role of bias h in the overall dynamics which has not been addressed so far using a quantum simulation of this scale. A well-known postcritical dynamics model — Model A —predicts a volume force due to a finite bias in addition to the surface tension, present at h=0. However, it is possible that the state of the system after the quantum phase transition is completely determined by adiabatic dynamics governed by Landau-Zener transitions during the crossing of the quantum critical point and that post-critical dynamics play a negligible role. This is the key question addressed by this work. Our study demonstrates the value of quantum annealing platforms for answering fundamental physics questions, such as what happens during a quantum phase transition, that are difficult to address using classical numerical methods.

High Harmonic Spectroscopy of Multifractality, Mobility Edges and Topology in Quasiperiodic Chains

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The interaction between a strong laser field and matter results in a nonlinear optical process that gives rise to the generation of high harmonics of the incident frequency, which has emerged as a transformative technique for studying dynamics of electronic systems.

Recently, there has been a growing interest in the use of high harmonic generation (HHG) to probe various properties of solid state systems. Spectroscopy based on HHG can serve as a tool of ultrafast imaging to detect signatures of quantum phase transitions in high-temperature superconductors, distinguish between trivial and non-trivial topology, and probe dynamical and structural properties of electrons.

Here, we present theoretical results for high-harmonic spectroscopy for a one-dimensional lattice system with on-site modulation. In contrast to the Anderson model, the presence of incommensurate modulation – quasiperiodicity – allows for the localization-delocalization transition even in one dimension. We show that HHG provides information about localization, delocalization and phenomena resulting from the interplay between them [1]. Moreover, we demonstrate that high harmonic spectroscopy can capture features of non-trivial topology of such systems, both in the non-interacting and interacting scenarios. [2]

[1] M. Dziurawiec, et al., Phys. Rev. B **110**, 014209 (2024)

[2] M. Dziurawiec, et al., in preparation

Josephson effect in strongly disordered metallic wires

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We study localization effects in Josephson junctions with two superconductors connected by a strongly disordered metallic wire of length L. The conventional description of the Josephson effect in such systems, based on the quasiclassical Usadel equation, neglects electron interference and is only applicable when L is shorter than the localization length ξ in the wire. We develop a more general theory for the Josephson effect using the non-linear sigma model that fully accounts for electron interference, and hence localization. We show that for L ≫ ξ, three qualitatively different regimes of the Josephson current arise depending on the ratio of the superconducting order parameter Δ and the mean level spacing in the localization volume Δ ξ. We derive the average supercurrent as a function of the phase difference for all three regimes. Quite unexpectedly, we observe that the Ambegaokar-Baratoff relation between the average critical current and the normal-state conductance still holds in the strongly localized state when Δ ξ ≫ Δ and ξ ≪ L ≪ (ξ / π^2) ln^2(Δ ξ / Δ).

Evidence for a Two-Dimensional Quantum Glass State at High Temperatures

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Nanocenter CENN and Jozef Stefan Institute, Ljubljana, Slovenia

Google Quantum AI collaboration, Santa Barbara, USA

Disorder in quantum many-body systems can drive transitions between ergodic and non-ergodicphases, yet the nature of these transitions remains intensely debated. Using a two-dimensional array of superconducting qubits (their number n was up to 70), we study an interacting spin-1/2 model with XY coupling at high temperature in a strong random field along Z direction. Crucially, we were tracking dynamics both in real space and in Hilbert space. Over a broad disorder range, 10 < W < 35, we observe an intermediate non-ergodic regime with glass-like characteristics: physical observables become broadly distributed and some - but not all - degrees of freedom are effectively frozen. The Hilbert-space return probability shows slow power-law decay, R(t) ~ t-η consistent with finite-temperature quantum glassiness. Exponent η is found to show unusual dependence on the system size, η (W) ~ κ(W) n2. In the same regime, we detect the onset of a finite Edwards-Anderson order parameter and the disappearance of spin diffusion. By contrast, at lower disorder, spin transport persists with a nonzero diffusion coefficient. Our experimental results are supplemented by semi-quantitative theory and by numerical simulations on smaller systems. In particular, we demonstrate the existence of an intermediate quantum state - with de-phasing but without relaxation - within a model of spins-1/2 residing at the Cayley tree. Thus we demonstrate the presence of non-ergodic glass-like state in two-dimensional quantum spin-1/2 system - that is not, however, fully localized in the sense of many-body-localization (MBL). The glassy phase we found is characterized by intrinsic spin de-phasing rate that is much larger than typical spin relaxation rate. At very strong disorder W > 30, the exponent η (W) drops sharply towards zero for all studied system sizes, indicating plausible second transition into fully MBL state.

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University of Ljubljana

Eigenstate transitions in exactly self-dual 1D and 3D Aubry-André models

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We study localization-delocalization wave-function properties of finite-size exactly self-dual approximations [1] of the Aubry-André model in 1D and 3D lattices. For each lattice, we first numerically demonstrate the self-dual property of the approximations. To characterize the eigen spectrum and eigen functions of the model, we employ spectral measures, such as the gap ratio and the spectral form factor, as well as wave function measures, such as the inverse participation ratio and the participation entropy. With these measures, we show that the model exhibits eigenstate transitions of different types depending on the dimensionality. In 1D, the transition point is the same as the self-dual point $W_c^{1D} = W_{SD} = 1$, similar to the one in the original 1D Aubry-André model. In 3D, two transition points were conjectured away from the self-dual point at W_c^{3D} and $1/W_c^{3D}$. We provide an estimate of W_c^{3D} and show that the estimated transition point belongs to the class of critical points between phasis with Gaussian Unitary Ensemble (GUE) and Poisson statistics [2].

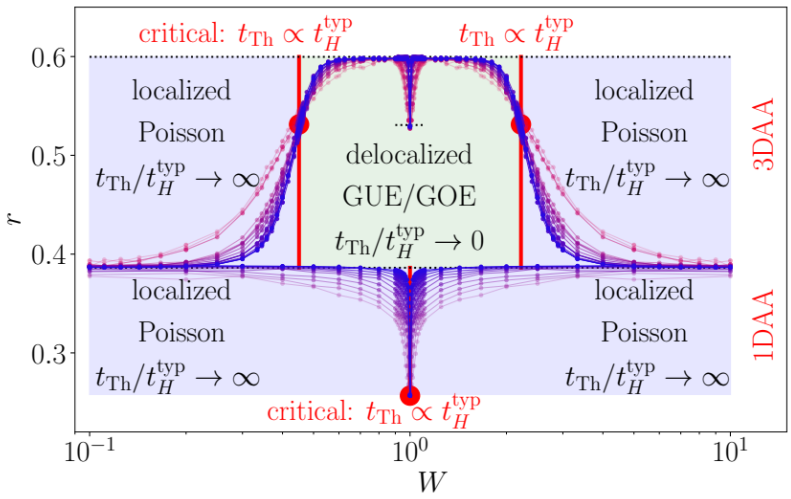

Figure 1: The phases of the exactly self-dual 1D and 3D Aubry-André models measured by the gap ratio r of neighboring energy levels

[1] T. Devakul and D. A. Huse, PRB **96**, 214201 (2017)

[2] P. Das, L. Vidmar and M. Hopjan , in preparation.

Neural Networks and GGEs for simulation of light-matter coupled systems

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2 University of Ljubljana, Faculty for mathematics and physics, Ljubljana, Slovenia

Recent advances in quantum simulation are focused on combining matter and light to engineer new types of interactions, typically characterized by long-range effects, requiring the development of advanced numerical simulation techniques. For instance, ordered arrays of atoms placed at distances smaller than the wavelength of light display photo-mediated long-range interactions and a peculiar correlated emission. The main features observed when starting from a highly excited initial state are a superradiant burst at short times, followed by a non-trivial subradiant critical regime with a slow power-law relaxation. By integrating out the photonic degrees of freedom, the dynamics are effectively described by a Lindblad equation with long-range interactions and dissipation. To simulate these dynamics, we employ a recently proposed numerical approach that combines a positive operator-valued measure (POVM) description of the density matrix—approximated by a neural network—with a time-dependent variational principle (TDVP) to project the evolution of the state onto the neural network manifold. We explore upscaling to larger system sizes as a complementary tool to standard tensor network techniques, especially for long-range interactions and two-dimensional setups. From a more physical perspective, by applying a time-dependent Generalized Gibbs ensemble Ansatz, we uncover the role of (approximate) integrability at long times, which leads to the observed polynomial decay.

Interlayer stacking controls the electronic properties of the van der Waals material 1T-TaS_2

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Given the small binding between layers, stacking of van der Waals materials is a powerful tool for exploring the physics of quantum condensed matter. However, exploitation for engineering will require taking advantage of thicker defective stacks, or an ability to control the stacking order via external stimuli, such as electrical or optical pulses.

I will present X-ray diffraction data of the equilibrium [1] and non-equilibrium [2] charge-density wave phases of the model material 1*T*-TaS_2, promising application as a highly efficient cryogenic phase-change memory platform. Comparison to a computational framework based on recursive Hendricks-Teller calculations and Monte Carlo simulations [3] reveals that layer stacking order and faults underly the rich electronic phase diagram of 1*T*-TaS_2. The experiments also identify charge rearrangement and concomitant lattice strain as the drivers of the metastable hidden phase transition. More generally, the results underscore the importance of domain sizes and layer stacking in defining electronic behaviors of van der Waals materials.

[1] C. Burri, H. G. Bell, F. Dizdarević, W. Hu, J. Ravnik, J. Vonka, Y. Ekinci, S.-W. Huang, S. Gerber & N. Hua. *Three-dimensional electronic domain correlations in 1T-TaS_2*. arXiv:2508.17839.

[2] C. Burri, N. Hua, D. Ferreira Sanchez, W. Hu, H. G. Bell, R. Venturini, S.-W. Huang, A. G. McConnell, F. Dizdarević, A. Mraz, D. Svetin, B. Lipovšek, M. Topič, D. Kazazis, G. Aeppli, D. Grolimund, Y. Ekinci, D. Mihailović & S. Gerber. *Imaging of electrically controlled van der Waals layer stacking in 1T-TaS_2*. arXiv:2411.04830 (Nat. Commun., accepted).

[3] N. Hua, F. Petocchi, H. G. Bell, G. Aeppli, P. Werner & S. Gerber. *Interlayer stacking controls the electronic properties of the van der Waals material 1T-TaS_2*. arXiv:2503.24124 (Phys. Rev. Research, accepted).

Phase locking and comb synthesis at free electron lasers

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ETHZ, EPFL, PSI, Switzerland

The ability to arbitrarily dial in amplitudes and phases enables the fundamental quantum state operations and measurements pioneered for microwaves and then infrared and visible wavelengths during the second half of the last century. Self-seeded X-ray free-electron lasers (FELs) routinely generate coherent, high-brightness, and ultrafast pulses for a wide range of experiments, but have so far not achieved a comparable level of amplitude and phase control. Here we report on the exploitation of seeding by external lasers as well as seeding by the FEL itself to generate coherent optical combs in the soft x-ray regime and phase locked pulses for hard x-rays, respectively. These phenomena are themselves manifestations of interesting non-linear dynamics, and should enable new examinations of dynamical condensed matter.

1. Demonstration of mode-locked frequency comb for an X-ray free-electron laser. Wenxiang Hu, Gabriel Aeppli, Christopher Arrell, Marco Calvi, Sergio Carbajo, Andreas Dax, Yunpei Deng, Philipp Dijkstal, David Dunning, Simon Gerber, Martin Huppert, Stefan Neppl, Sven Reiche, Thomas Schietinger, Neil Thompson, Alexandre Trisorio, Carlo Vicario, Alexander Zholents, and Eduard Prat, Phy. Rev. Lett. (editor's choice), accepted 30 September 2025.
2. A perfect X-ray beam splitter and its applications to time-domain interferometry and quantum optics exploiting free-electron lasers Sven Reiche, Gregor Knopp, Bill Pedrini, Eduard Prat, Gabriel Aeppli and Simon Gerber PNAS 119 (7) e2117906119 (2023).

What can we learn from high-harmonic generation in strongly correlated electronic systems?

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2 RIKEN, CEMS, Wako, Japan

High-harmonic generation (HHG) is a fundamental nonlinear optical phenomenon arising from strong light–matter interactions. Initially discovered in gases, the concept of HHG has recently been extended to condensed matter systems. While most studies have focused on weakly correlated band insulators, increasing attention is now directed toward strongly correlated electron systems (SCESs). SCESs provide a new frontier for HHG research owing to their nontrivial excitation structures, rich phases, and their dynamical tunability [1].

In this talk, we discuss the physics of HHG in SCESs and its potential spectroscopic applications, with a particular focus on Mott insulators—prototypical SCESs governed by strong Coulomb interactions.

First, based on a series of theoretical analyses of the Hubbard model with different dimensionalities, we establish the fundamental picture of HHG in Mott insulators and clarify the crucial role of spin–charge coupling [2–4]. HHG in these systems can be understood within a three-step framework describing the nonlinear dynamics of charged elementary excitations emerging from strong correlations. The nature of these elementary excitations depends sensitively on dimensionality due to the spin–charge coupling. We illustrate this using the two-leg ladder system [4], where the coupling gives rise to characteristic dephasing processes and fractionalization of the HHG signal. We also reveal a peculiar temperature dependence of HHG originating from spin–charge coupling and relate it to recent experimental observations in the Mott insulator Ca_2RuO_4 [3].

Second, we demonstrate that HHG in SCESs can serve as a probe of ultrafast evolution of electronic states during photoinduced phase transitions [5]. Because SCESs are sensitive to laser excitation, the strong fields driving HHG can simultaneously trigger phase transitions. In Sr_2CuO_3, we observe redshifts of high-harmonic peaks associated with a photoinduced insulator–metal transition. Using nonequilibrium dynamical mean-field theory, we show that these redshifts originate from ultrafast modifications of the electronic structure, which alter charge dynamics cycle-by-cycle.

Our results underpin the intriguing features of HHG in SCESs and pave the way for its potential applications in ultrafast spectroscopy.

[1] Y. Murakami*, D. Golež*, M. Eckstein* and P. Werner*, RMP, 97, 035001 (2025).
[2] Y. Murakami, M. Eckstein and P. Werner, PRL, 121, 057405 (2018).
[3] Y. Murakami, K. Uchida, A. Koga, K. Tanaka and P. Werner, PRL 129, 157401 (2022).
[4] Y. Murakami, T. Hansen, S. Takayoshi, L. Madsen and P. Werner, PRL 134, 096504 (2025).
[5] R. Ikeda, Y. Murakami, D. Sakai, T. Miyamoto, T. Ito, H. Okamoto, arXiv:2508.00296.

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Jožef Stefan Institute

Conserved quantities enable the quantum Mpemba effect in weakly open systems

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In the classical Mpemba effect, a system that is initially hotter cools faster than one that starts out colder. This counterintuitive behavior was first observed in water: under certain conditions, hotter water can freeze more quickly than cooler water.
The quantum Mpemba effect has recently spurred much interest in its enabling conditions and its relation to the classical counterpart. To draw an analogy to the classical phenomenon, we consider a quantum system weakly coupled to the environment and initialized in different thermal states. We claim that the number of conserved quantities of the unitary part of the evolution plays a crucial role: The Mpemba effect is possible only when the Hamiltonian commutes with other local conserved quantities, whereas it is not possible in strictly ergodic systems. The key distinction lies in the fact that the time evolution of states unfolds within parameter spaces of different dimensions. When energy is the only conserved quantity, the evolution happens through a one-dimension manifold of thermal states. In contrast, for Hamiltonians with several conserved quantities, the trajectories lie within a higher-dimensional space of generalized Gibbs ensembles [1]. In the latter case, as a result, a thermal state that is initially farther from the stationary state can approach it more rapidly by following faster trajectories. We provide thermodynamically stable numerical results using tensor network and free fermion techniques, supporting our claim. [2]

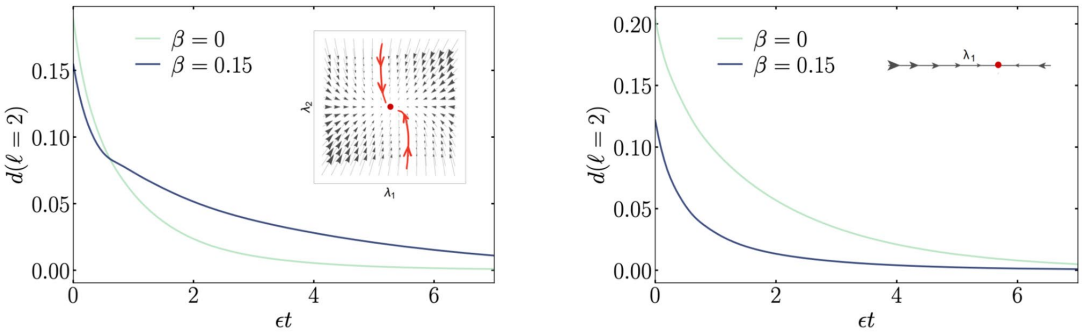

Figure: (left) Presence of the Mpemba effect in an integrable transverse field Ising model weakly coupled to a bath and initialized in two different thermal states. On the x-axis the rescaled time is plotted and on the y-axis the distance between the reduced density matrix at time t and the reduced density matrix of the steady state. (right) See left figure, except that the system is a chaotic Ising model with longitudinal and transverse fields. We do not observe the Mpemba effect in this case.

[1] I. Ulčakar and Z. Lenarčič, Generalized Gibbs ensembles in weakly interacting dissipative systems and digital quantum computers, SciPost Phys. 19, 068, 2025.
[2] I. Ulčakar, R. Sharipov, G. Lagnese and Z. Lenarčič, Conserved quantities enable the quantum Mpemba effect in weakly open systems, in preparation, 2025.

Stochastic resonance in disordered charge-density-wave systems

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Photoexcitation in charge density wave (CDW) systems can potentially lead to inhomogeneously disordered phases [1], where ions are displaced locally but do not achieve global ordering. In these phases, each ion moves within a local double-well potential and settles in one of the two equilibrium positions with equal probability. Similar behaviours have also been observed experimentally in VO2 through scattering experiments [2]. A fundamental question in understanding these disordered states is identifying their signatures beyond X-ray scattering. In this talk I will address the issue by discussing the results of simulations performed on a simple model of coupled electrons and ions. Exploiting the semiclassical stochastic approach [3] to quantum dynamics, the linear response to an external probe is computed. At low frequencies and as a function of temperature, we observe a peak in the response amplitude of the system, which we attribute to stochastic resonance, a phenomenon typically observed in bistable systems when they experience both periodic driving and noise [4]. The position of such peak can provide insights into the features of the potential and of the fluctuations to which the ions are subject, thus constituting a possible probe into the disordered state of the system.

[1] Antonio Picano et al., Phys. Rev. B 107, 245112 (2023)
[2] Simon Wall et al., Science 362, 572-576 (2018)
[3] Antonio Picano et al., Phys. Rev. B 108, 035115 (2023)
[4] Gammaitoni et al., Rev. Mod. Phys. 70, 223 (1998)

Signature of preformed pairs in angle-resolved photoemission spectroscopy

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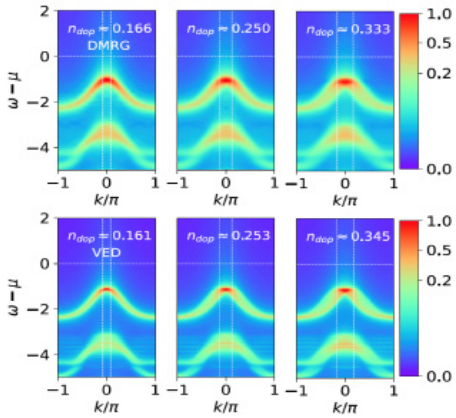
2 *Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, Canada, V6T 1Z1 and Stewart Blusson Quantum Matter Institute, University of British Columbia, Vancouver, BC, Canada, V6T 1Z4*

We use density matrix renormalization group (DMRG) and variational exact diagonalization (VED) to calculate the single-electron removal spectral weight for the Hubbard- Holstein model at low electron densities. Tuning the strength of the electron-phonon coupling and of the Hubbard repulsion allows us to contrast the results for a liquid of polarons versus a liquid of bipolarons. The former shows spectral weight up to the Fermi energy, as expected for a (uncorrelated) metal. The latter has a gap in its spectral weight, set by the bipolaron binding energy, although this is also a (strongly correlated) metal. This difference suggests that angle-resolved photoemission spectroscopy could be used to identify liquids of pre-formed pairs. Furthermore, we show that the liquid of bipolarons is well approximated by an ensemble of bosons that are hard-core in momentum space, filling the states inside the Fermi sea but otherwise non-interacting [1].

In the second part I will discuss the two-electron removal spectral weight for the Hubbard-Holstein model, starting from the ground-state with two electrons on a one-dimensional chain. We argue that this spectral weight provides a valuable proxy for the intensity of 2e-ARPES processes. Our results show that when contrasted to the (large) signal due to two electrons ejected from two different pairs, the (much weaker) signal due to two electrons ejected from the same pair (i) is segregated in energy, appearing at a lower binding energy, and (ii) has a very characteristic momentum dependence, with different symmetry than that corresponding to two electrons emitted from two different pairs [2].



Comparison between ARPES spectra calculated with DMRG for different dopings ndop with those generated from single-pair VED calculations for a liquid of hard-core bosons at the closest attainable doping levels [1].

[1] K. Kovač, A. Nocera, A. Damascelli, J. Bonča, and M. Berciu, Phys. Rev. Lett. 134, 096502 (2025).
[2] J. Bonča, A. Damascelli, and M. Berciu, in preparation.

Simulation of a pinning in the vortex glass model

Kabanov Viktor

Jožef Stefan Institute

Disorder-Driven Phase Transitions from Phonon and Photoexcitation

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Modifying the structure of a material, on the ultrafast timescale is believed to be responsible for many light induced states. For example, light-induced changes in the tolarence factor been proposed to drive the insulator-metal phase transions in the manganites [1], while changes light-induced changes in the apical-oxygen position have been proposed to enhance superconductivity [2]. The mechanism for such changes is belived to be non-linear phononics, where non-linear coupling between phonon modes results in coherent (long wavelength) changes in the structure [3].

Recently, it has been shown that optically-induced phase transitions generate significant short-range structural fluctuations which are ultimately responsible for the phase transition, rather than coherence [4,5]. Therefore, this could point to a difference between phonon-driven phase transitions and photon driven ones. However, the presence, or lack of, short-range fluctuations resulting from phonon pumping have not been investigated experimentally before.

In this talk, I will present our latest unpublished results on phonon pumping in the manganites. We measure the melting of orbtial order using time-resolved diffuse X-ray scattering to look for the presence of short range fluctuations. We find that orbital order is quickly supressed by phonon pumping, but at the same time, significant diffuse scattering is generated, indicating the presence of phonon-induced short range fluctuations. Our results suggest that orbital order melting under phonon pump follows the same pathway as optical excitation.

[1] M. Rini et al. *Nature* **449**, 72 (2007)
[2] R. Mankowsky et al. *Nature* **516**, 71 (2014)
[3] M. Först et al. *Nature Physics* **7**, 854 (2011)
[4] S. Wall et al. *Science* **362**, 572 (2018)
[5] M. Monti et al. *Nature Materials* (in press)

Optical detection of out-of-equilibrium spin accumulations in multilayers

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Magneto-optical techniques are powerful and widely used tools that enable the investigation of ultrafast spin dynamics in various magnetic materials [1,2]. Currently, these techniques are becoming one of the emerging tools for studying the accumulation of spin and/or orbital angular momentum in magnetic/non-magnetic materials [3]. In time-resolved magneto-optical experiments, it has long been believed that the signal due to these accumulations was orders of magnitude smaller than the signals due to the magnetization dynamics. Recently, we showed that under certain conditions the accumulation signals can be comparable to or even exceed the signal coming from the magnetization itself during the ultrafast demagnetization [4]. Furthermore, we experimentally demonstrated how to isolate these accumulation signals.

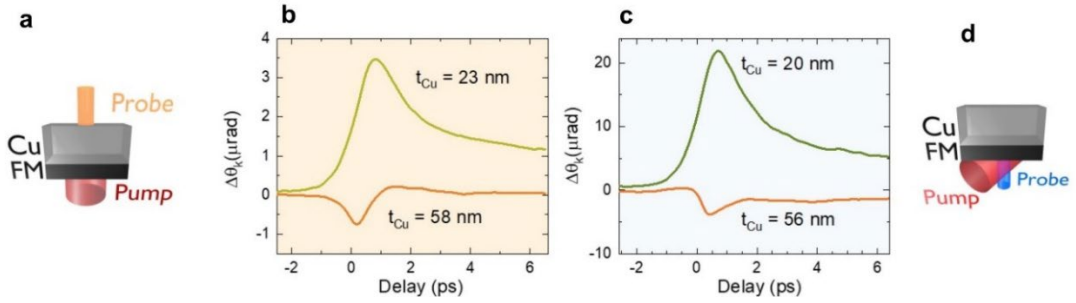

Figure 1. Typical pump-probe magneto-optical experiment (a,d) Two experimental configuration: pump is incident on the *ferromagnet (FM)* side, while probe is incident either on the (a) Cu side or (d) the FM side. (b,c) Time-resolved magneto-optical measurements for two different *Cu* thicknesses, with probe on the (b) Cu side and (c) FM side.

In this talk I will describe a number of our recent experiments, where we disentangle magnetization dynamics and spin accumulation signals. Accessing the ultrafast spin accumulations can, for example, help us identify magnetization reversal mechanisms induced by femtosecond optical excitations in certain multilayer stacks [5], and opens up new ways to probe magnetization dynamics, exchanges of angular momentum as well as their transport properties. An example experiment is shown in Fig.1(a,d), where we either probe a ferromagnet (FM) or a neighboring Cu layer. Fig.1 (b,c) show the time-resolved magneto-optical measurements. For thin Cu layers, we observe a typical demagnetization curve. For the larger thickness a somewhat unexpected sign and shape change of the singal is observed, which we associate with spin accumulation, even when the probe is directly impinging on the FM layer.

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Stabilization of Antiferromagnetic Grains in Co/CoO Ultrathin Films by Gaq_3 Adsorption

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Exchange bias of hysteresis loops in a ferromagnet (FM) that is in contact with an antiferromagnet (AFM) is a well-known phenomenon [1]. The magnetic ordering of the AFM at the interface, through exchange interaction, induces an interfacial effective magnetic field in the thin FM film. As a result, the magnetic loops of the FM become asymmetric and shifted in the magnetic field. The change in magnetic loops strongly depends on the thicknesses of the FM and AFM layers as well as on the microscopic details of the heterostructure and the interface.

In a recent study [2], measurements of magnetic loops in layered heterostructures with an interface between FM cobalt (Co) and AFM cobalt oxide (CoO) have shown that adsorption of organic molecules on AFM CoO increases the temperature at which exchange bias appears in the FM Co film.

We present the results of a study in which we investigated the effect of Gaq_3 molecule adsorption on the dynamic magnetic properties of Co/CoO/Gaq_3 heterostructures. We compared heterostructures with different Co/CoO thicknesses, both with and without adsorbed Gaq_3 molecules. Through systematic measurements of the temperature and field dependence of the time-resolved magneto-optical Kerr effect, we demonstrated that adsorption of Gaq_3 on sufficiently thin CoO films leads to an increased precession frequency (a larger interfacial effective field) in the ferromagnet and raises the temperature below which exchange bias appears in FM Co. The results indicate that the adsorbed molecules stabilize the AFM ordering in CoO, which directly affects the interfacial effective field in FM Co.

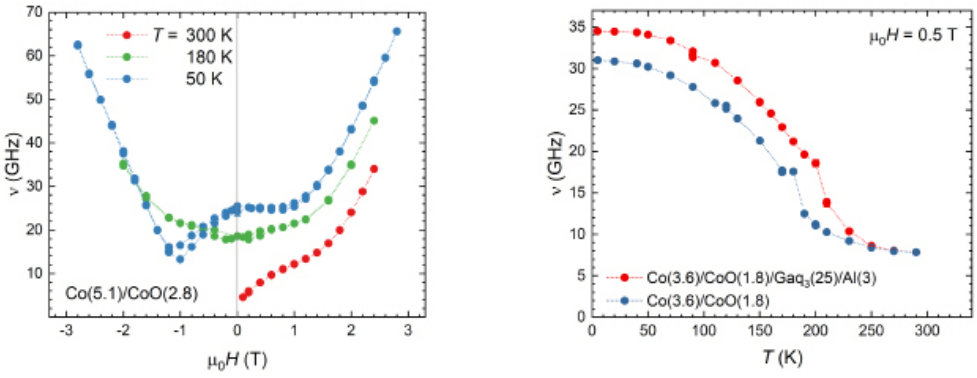

Fig. 1: Dependence of precession frequency on magnetic field at a few representative temperatures in Co(5.1)/CoO(2.8) heterostructure (left). Comparison of temperature dependence of precession frequency dependence at same magnetic field in heterostructures with and without Gaq3 (right).

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Finding local integrals of motion in quantum lattice models in the thermodynamic limit

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Accurate numerical studies typically involve a diagonalization procedure that can only be applied to small quantum systems. Consequently, thermodynamic limit results for generic quantum systems are very rare. Here, we demonstrate that identifying local integrals of motion (LIOMs) belongs to this rare class of problems [1]. LIOMs are essential for the long-time dynamics and thermalization of closed quantum systems. We derive a method that provides exact LIOMs for Hamiltonian systems and also for arbitrarily large quantum circuits. When applied to (more realistic) nearly integrable models, it provides slow modes and approximate relaxation times. Our approach can be applied to problems that are very demanding for other numerical methods, and the codes [2] demonstrate its technical simplicity.

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Entanglement Entropies of Eigenstates of Many-Body Systems and Random Matrices

Masudul Haque

I will consider eigenstates of chaotic many-body quantum systems and of a class of random matrices designed to mimic some behaviors of many-body systems (power-law-banded random matrices). I will focus on the entropy of entanglement between two halves of the system, and describe the properties of eigenstate entanglement entropies in different parts of the spectrum.

Beyond the Off-Diagonal Eigenstate Thermalization Hypothesis

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The Eigenstate Thermalization Hypothesis (ETH) offers an insightful theoretical framework for explaining thermalization phenomena in quantum many-body systems. The diagonal ETH states that in large systems local observables evaluated in individual eigenstates do not depend on microscopic details but only on the charge averages. While the standard ETH additionally stipulates a specific form for the suppression of the off-diagonal matrix elements, it is oblivious to the fact that statistical properties may in general depend not only on the macrostate parameter but also on the specific properties of the averaging procedure. To elucidate this aspect, we perform a systematic study of statistical distributions of the off-diagonal matrix elements by incorporating an additional scaling parameter to control the magnitude of charge fluctuations, granting access to matrix elements outside of a finite microcanonical shell. In this work, we implement our program in a minimal, exactly solvable model which permits an efficient numerical computation of matrix elements and allows for explicit analytic results. We find that statistical distributions of off-diagonal matrix elements depend quite intricately on the fluctuation scale. Most prominently, the mean value, corresponding to the suppression rate, undergoes a sharp transition from a regular regime of exponential suppression akin to ETH, to a regime exhibiting a parametrically enhanced suppression.

Controlling the functionality of quantum materials by light

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Department of Physics, University of Trieste

The properties of complex quantum materials (QM), such as transition metal oxides, arise from the interplay of electrons, phonons, and magnons, making them highly sensitive to external parameters like pressure, doping, fields, and temperature. This susceptibility makes QM ideal for experiments where tailored electromagnetic fields can be used to induce novel properties on ultrafast timescales [1].

I will present our efforts to manipulate material properties through light, both in free space and optical cavities. After reviewing our work on cuprates, which demonstrates the feasibility of light-driven phase control [2–4], I will introduce new spectroscopic methods that merge quantum optics with time-domain techniques to probe fluctuations in non-equilibrium phases [5–11].

Building on our recent demonstration that a metal–insulator transition in 1T-TaS_2 can be controlled by resonant cavity coupling [12, 13], I will outline future directions aimed at controlling by cavity electrodynamics metal-insulator transitions in Calcium Rutanate and explore new light–matter coupling regimes to bypass thermodynamic limits and dynamically sustain quantum coherence in high temperature superconductors.

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Interplay Between Ferromagnetism and Charge Density Waves in $SmNiC_2$ Probed by Femtosecond Optical Spectroscopy

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$SmNiC_2$ belongs to the rare-earth transition metal carbide family $RNiC_2$ (R = La, Ce, Pr, Nd, Sm, Gd, Tb,..), a unique class of intermetallic compounds, which crystallize in the non-centrosymmetric orthorhombic $CeNiC_2$-type structure, displaying pronounced quasi-1D characteristics. With the exception of $LaNiC_2$ and $CeNiC_2$, where exotic superconductivity has been reported, most of these compounds are characterized by the appearance of Charge Density Wave (CDW) order [1], while at low temperatures, competing magnetic orders, related to the magnetic moments of the lanthanides sublattice, appear [2].
In $SmNiC_2$ diffraction studies reveal an incommensurate CDW modulation with wavevector $(0.5,0.5+\delta,0)$ below $T_{cdw} \approx 148$ K [2]. Upon lowering the temperature, a first order phase transition into the ferromagnetic (FM) state takes place at $T_M \approx 18$K, with a complete suppression of the CDW order [2].
Here, we apply optical pump-probe and quench-pump-probe spectroscopy to investigate the interplay between FM and CDW, and the dynamics of the photoinduced FM-CDW phase transition, respectively. In the FM phase, a slow build-up on the 10 ps timescale is observed, whose temperature and excitation density dependence suggest to be a result of slow photoinduced demagnetization attributed to the RKKY-mediated coupling between the f-moments [3]. In the CDW phase, the response is characterized by an oscillatory component of the CDW amplitude mode [4,5], and presents a fingerprint of the CDW order [6].
To study photoinduced FM-CDW transition we apply quench-pump-probe approach [7], using collective modes of CDW as proxy for studying buildup of CDW phase. The rate of buildup of CDW order is found to increase as a function of absorbed energy density in excess to energy density required to thermally quench the FM order, reaching 0.1 ps^{-1} (governed by the demagnetization timescale).

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Van der Waals devices for surface-sensitive experiments

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In-operando characterization of van der Waals (vdW) devices using surface-sensitive probes provides critical insight into phase transitions and correlated electronic states. However, integrating vdW materials into functional device geometries while preserving pristine surfaces remains a central challenge, as conventional lithographic steps typically introduce contamination that limits advanced spectroscopies. We present a stencil-lithography-based fabrication scheme (see Figure 1) enabling resist-free patterning of micron-scale electrical contacts and ultra-high-vacuum exfoliation of thin flakes down to the monolayer limit [1]. Using 1*T*-TaS_2 as a model system, we demonstrate devices that combine reliable electrical pulsing and transport measurements with clean surfaces suitable for angle-resolved photoemission spectroscopy and X-ray photoelectron spectroscopy (XPS).
In particular, spatially resolved microbeam XPS of the Ta 4*f* core level reveals pronounced differences between bulk-like and monolayer flakes. Bulk-like samples show the expected multi-component CDW lineshape, whereas monolayers exhibit a reduced overall splitting and shifted relative intensities, consistent with the absence of out-of-plane stacking in a single 1*T*-TaS_2 layer.

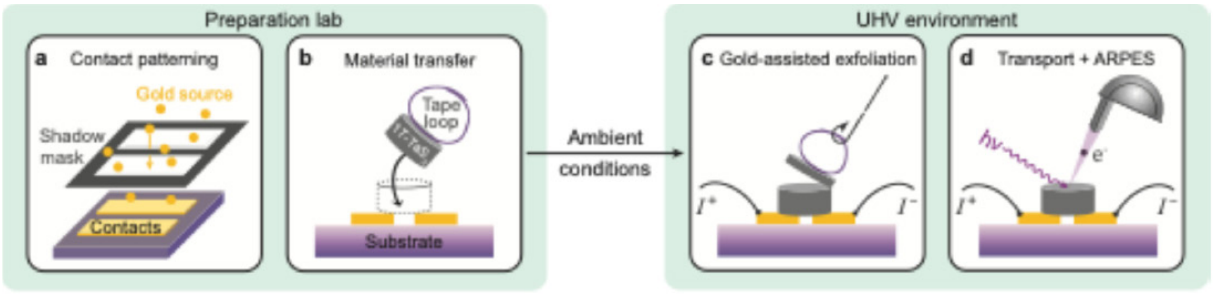

Figure 1: Schematic of the device fabrication workflow. Contact evaporation and direct patterning through a stencil mask and transfer of bulk vdW material under standard laboratory conditions. The devices are then transported under ambient conditions to the experimental site, where gold-assisted exfoliation in UHV yields flakes with pristine surfaces, enabling integration with surface-sensitive probes.

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To Be Announced

Yursa Viktoriia

Nanocenter

Tensor-Network Compression for Fast Real-Time Evaluation of Multidimensional Spectroscopy

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2. *The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany*

Time-resolved inelastic X-ray scattering (tr-RIXS) is a powerful experimental tool for exploring nonequilibrium dynamics in light-driven solids. However, computing time-resolved scattering signals is challenging because it requires evaluating higher-order correlation functions. Similar difficulties arise in other nonlinear spectroscopies, including time-resolved electronic Raman scattering and multidimensional ultrafast spectroscopy. Within DMFT, for example, the X-ray spectrum is typically obtained from an extended impurity problem that includes the core hole, but real-time simulations of the resulting four-point correlation function have so far only been performed by neglecting vertex corrections. In Floquet-driven systems, these vertex corrections can be essential for capturing the correct weights of Floquet sidebands.
In this work, I present an approach that decomposes the multidimensional spectroscopic integrand (or kernel") on the fly into a tensor-network representation using the tensor cross-interpolation algorithm. This strategy can substantially accelerate the evaluation of four-point correlators in benchmark cases. Potential future applications include the simulation of multiplet dynamics in laser-driven solids and the identification of current-induced features in time-resolved spectroscopies. More broadly, tensor-network decompositions of multidimensional spectroscopic integrands may offer a general route to efficient real-time simulations across a wide range of ultrafast scattering techniques.

Quantum Thermalization via Travelling Waves in Isolated and Open Quantum Systems

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Isolated quantum many-body systems which thermalize under their own dynamics are expected to act as their own thermal baths [1], thereby losing memory of initial conditions and bringing their local subsystems to thermal equilibrium. Here [2], we show that the infinitedimensional limit of a quantum lattice model, as described by dynamical mean-field theory (DMFT), provides a natural framework to understand this self-consistent thermalization process. Using the Fermi-Hubbard model as a working example, we demonstrate that the emergence of a self-consistent bath occurs via a sharp thermalization front, moving ballistically and separating the initial condition from the long time thermal fixed point (Fig. 1). We characterize the full DMFT dynamics through an effective temperature for which we derive a traveling wave equation of the Fisher-Kolmogorov-Petrovsky-Piskunov type [3]. We extend our results in order to study the shape of the front and its velocity in open dissipative fermionic systems by integrating DMFT into the Lindblad Master Equation formalism. We show that thermalization under open quantum system dynamics is qualitatively different from the closed-system case. In particular, the thermalization front is strongly modified, a signature of the irreversibility of open-system dynamics [4].

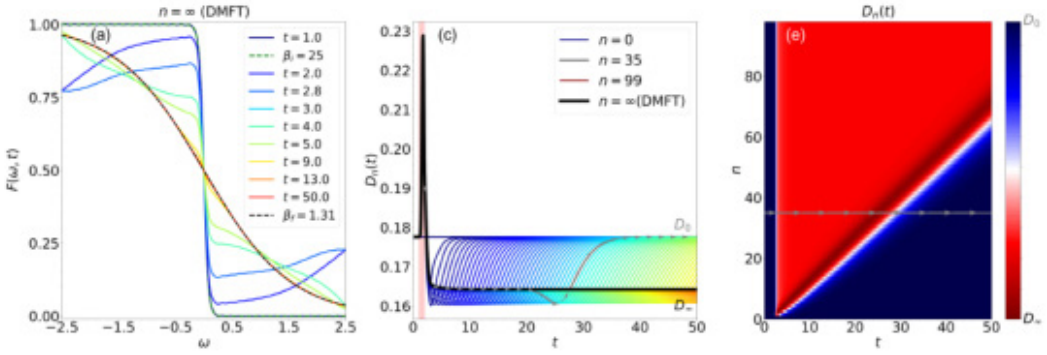

Figure 1: Thermalization in infinite dimensions with DMFT. Time evolution of the distribution function (a) after an energy excitation, for U = 2 (initial inverse temperature β_i = 25). Full self-consistent DMFT solution [n = ∞ in the notation of panels (c)]. Thermalization front: time evolution of the double occupation (c) after an energy excitation, for different DMFT iteration numbers (colored lines from blue to red as a function of the DMFT iteration number n ∈ [0, 99] and compared to the full self-consistent DMFT solution (black line)). Emergence of a thermalization front in double occupation, panels (e).

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Exploring relaxation dynamics of electron-phonon systems with tensor-train Green's function methods

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Compression-based nonequilibrium Green's function (NEGF) solvers are emerging as a new generation of methods capable of addressing long-time and large-system dynamics in correlated lattice systems. Among these, the quantics tensor train (QTT) representation provides an exceptionally compact and accurate encoding of high-dimensional two-time and momentum-dependent quantities, enabling simulations far beyond the reach of conventional matrix-based approaches. While recent benchmarks have established the numerical efficiency and stability of QTT-based NEGF implementations [1-3], their application to study concrete physical phenomena is only beginning to unfold. In this talk, I present first QTT-compressed NEGF simulations of electron-phonon coupled systems, contrasting relaxation dynamics mediated by optical and acoustic phonons. Such calculations are particularly demanding when accounting for the electron-phonon feedback, which necessitates storing momentum-resolved two-time phonon correlation functions and self-energies. The QTT framework makes such calculations tractable, paving the way for systematic studies of energy flow between electrons and phonons in realistic correlated materials.

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Critical Photoinduced Reflectivity Relaxation Dynamics in Single-Layer Bi-Based Cuprates Near the Pseudogap End Point

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Quantum criticality in overdoped superconducting cuprates has remained an unresolved issue despite intensive and systematic research of equilibrium properties. Here we report on nonequilibrium photoinduced transient reflectivity dynamics in heavily overdoped single-layer cuprate $(Bi,Pb)_2Sr_2CuO_{6+\delta}$ (Pb-Bi2201), across the pseudogap and superconducting endpoint dopings. We find that just below the pseudogap endpoint doping the normal-state the transient reflectivity dynamics resemble the pseudogap response observed in optimally doped La-Bi2201. Differently from the optimal doping, however, the relaxation time exhibits a power-law divergence, $\tau \sim 10\hbar/k_BT$, signaling a possible quantum critical behavior at the pseudogap end point doping. A similar, but less pronounced, power-law increase in relaxation time is also observed in Pb-Bi2201 just beyond the pseudogap doping end point.

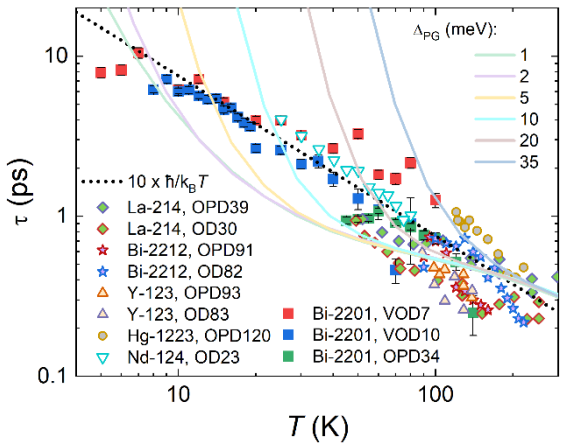

FIG. 4. Temperature dependence of the normal-state transient-reflectivity relaxation time in various optimally doped (OPDx) and overdoped (ODx) cuprates, where x corresponds to Tc in K. The dotted line is a scaled Planckian timescale expected in the quantum critical region. The full lines correspond to anharmonic-bottleneck relaxation time scaled to the experimental timescales. The data for La-124, Bi-2212, Y-123, Hg-1223 and Nd-124 were taken from Kusar et al. [1], Toda et al. [2,3], Demsar et al. [4], Demsar et al. [5] and Hinton et al. [6], respectively.

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Coherent transfer of optically induced THz magnons to charges in an antiferromagnet

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Cloud-based data services play an increasing central role in the modern digital economy and society, driving the demand for data centers together with new technologies such as artificial intelligence [1]. These developments intensify the pursuit of data manipulation and storage concepts that operate on ultrafast timescales with minimal energy dissipation. The use of coherent spin excitations, so called magnons, are promising candidates for low-energy information carriers [2]. In particular, antiferromagnets with the lack of net magnetization and magnon frequencies in the terahertz (THz) regime [3]. One, still unsolved key challenge is the conversion of the THz spin- into charge-signals.

Recent studies have shown that coherent magnons can be excited within a single magnetic domain of nickel oxide (NiO) single crystals via optical pumping of an exciton-magnon transition [4]. However, the transient electronic properties on ultrashort timescales remain are mainly unexplored [5] and it is still an open question, whether the photo-driven coherent magnons can be converted into a charge signal in conventional antiferromagnets.

To address this, we developed an experimental setup for cryogenic optical and magneto-optical pump-probe spectroscopy in the visible to near-infrared (VIS–NIR) range. With this we demonstrate the transfer of optically driven coherent magnons to the charge system, resulting in a THz-frequency modulation of the optical response in the prototypical antiferromagnet NiO. By identifying the key conditions for this effect, we develop a microscopic theoretical model that reproduces the experimental findings without parameter fine-tuning.

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Ballistic false vacuum decay in the 2D Ising model

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False vacuum decay, describing the quantum transition from a metastable to a true vacuum configuration, represents a key non-perturbative phenomenon in field theory and non-equilibrium statistical mechanics However, its intrinsically non-perturbative character and limited experimental accessibility make it challenging to study, leaving key questions about the nucleation, propagation, and interactions of true vacuum bubbles [1-3]. Building on our previous study of false vacuum decay dynamics in one-dimensional tilted Ising chains [4], we investigate the extension to the two-dimensional Ising model. In this case we identify a specific regime where the decay of the false vacuum exhibits novel behaviour. In this regime, starting from a metastable false vacuum state, a seeded bubble of true vacuum can spread resonantly as the energy cost of creating new domain walls is offset by the energy gain from the created lower-energy true vacuum state. This resonance mechanism leads to a fractal-like expansion of the true vacuum domain. To analyse this process, we combine classical cellular automata simulations, quantum tensor-network simulations, and experimental simulations performed on a programmable quantum annealer. Across all approaches, we observe a ballistic propagation of the true-vacuum bubble wavefront, revealing robust dynamics that persists in the presence of dissipation and disorder.

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Universal Relation between Spectral and Wavefunction Properties at Criticality

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Quantum-chaotic systems exhibit several universal properties, ranging from level repulsion in the energy spectrum to wavefunction delocalization. On the other hand, if wavefunctions are localized, the levels exhibit no level repulsion and their statistics is Poisson. At the boundary between quantum chaos and localization, however, one observes critical behavior, not complying with any of those characteristics. An outstanding open question is whether there exist yet another type of universality, which is genuine for the critical point. Previous work suggested that there may exist a relation between the global characteristics of energy spectrum, such as spectral compressibility χ, and the degree of wavefunction delocalization, expressed via the fractal dimension D_1 of the Shannon–von Neumann entropy in a preferred (e.g., real-space) basis. Here we study physical systems subject to local and non-local hopping, both with and without time-reversal symmetry, with the Anderson models in dimensions three to five being representatives of the first class, and the banded random matrices as representatives of the second class. Our thorough numerical analysis supports validity of the simple relation $\chi + D_1 = 1$ in all systems under investigation. Hence we conjecture that it represents a universal property of a broad class of critical models. Moreover, we test and confirm the accuracy of our surmise for a closed-form expression of the spectral compressibility in the one-parameter critical manifold of random banded matrices. Based on these findings we derive a universal function $D_1(r)$, where r is the averaged level spacing ratio, which is valid for a broad class of critical systems.

Fidelity susceptibility in closed quantum systems

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Understanding how non-ergodic systems behave when perturbed toward ergodicity is of broad interest. Many measures have been proposed to detect and characterize such transitions, including spectral statistics and entanglement entropies. Recently, the fidelity susceptibility, which quantifies the sensitivity of energy eigenstates to perturbations, has attracted particular attention. Its key feature is that it exhibits a pronounced peak at the transition point, indicating the absence of thermalization accompanied by maximally chaotic behavior [1].

We first focus on the t-J_z model. It exhibits the Hilbert space fragmentation, in which the Hamiltonian shatters into exponentially many blocks (in system size) when written in some local basis (such as the computational basis). We show that a carefully chosen perturbation can gradually eliminate conservation laws, merging the fragmented subspaces one by one. Remarkably, the fidelity susceptibility exhibits multiple peaks, demonstrating its sensitivity to the breaking of just a few integrals of motion, in stark contrast to other common measures of quantum chaos [2].

Finally, we introduce a minimal (phenomenological) model that explains the emergence of the peaks in the fidelity susceptibility. The model focuses on integrals of motion and how they acquire finite relaxation times. It captures two limiting cases. In the first, the relaxation times are narrowly distributed, leading to fading ergodicity and maximal divergence of fidelity susceptibilities. In the second, the relaxation times are broadly distributed, which is encoded in the long-time asymptotic behavior of the autocorrelation function, resulting in sub-maximal scaling of fidelity susceptibilities. We test it in the 3D Anderson model [3] and the Heisenberg XXZ model [4].

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Exact solution to a Bhatnagar-Gross-Krook-type equation for quantum lattice gases with dephasing noise

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The mean-state dynamics of free fermions subject to random projective measurements of local occupation number operators is governed by a Lindblad equation with dephasing noise. In the continuum limit, the equation of motion for the correlation matrix is mapped to a kinetic equation for the Wigner function, which corresponds to a special case of the Bhatnagar-Gross-Krook (BGK) equation without energy conservation. Our main result is the solution to the kinetic equation, showing that the Wigner dynamics emerges from stochastic sampling of classical run-and-tumble processes. As an application, we recover the crossover between ballistic and diffusive transport regimes. [1]

[1] PHYSICAL REVIEW B 112, 024315 (2025)

New type of ETH breakdown

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The eigenstate thermalization hypothesis (ETH) successfully explains thermalization in isolated quantum systems. Nevertheless, how the ETH breaks down as the boundary of ergodicity breaking is approached remains an open question. Recently, the fading ergodicity has been proposed as an example of the ETH breakdown [1]. Here we consider another type of the ETH breakdown.

We introduce the stiffness as an indicator of the ETH breakdown. The stiffness corresponds to the converged value of the autocorrelation function in the long time limit as in Fig. (a). The stiffness indicates the ETH breakdown when it becomes $\mathcal{O}(1)$ whereas the ETH holds when it is $\mathcal{O}(e^{-L})$. The stiffness is given by $R = e^{-S} |f(\omega = 0)|^2$, where the thermal entropy S, and the dynamical function $|f(\omega = 0)|^2$ in the ETH. The thermal entropy scales with the system size. As in Fig. (b), $|f(0)|^2$ grows as the ETH breakdown is approached until it reaches $\mathcal{O}(e^{L})$ [2]. The increasing trend of $|f(0)|^2$ is distinct from that of the fading ergodicity. Figure (c) shows $|f(0)|^2$ as a function of disorder strength. For small disorder, $|f(0)|^2$ grows as a function depending only on disorder strength (black curve). At threshold disorder strength w^*, $|f(0)|^2$ starts to saturate to $\mathcal{O}(e^{L})$. The threshold w^* clearly shifts to larger together with the saturation value of $|f(0)|^2$ as the system size increases. This implies that the ETH breakdown is a finite-size effect that vanishes in the thermodynamic limit.

We demonstrate the ETH breakdown that we introduced above by numerical calculation of the stiffness in the J_1 - J_2 model under position-dependent external fields.

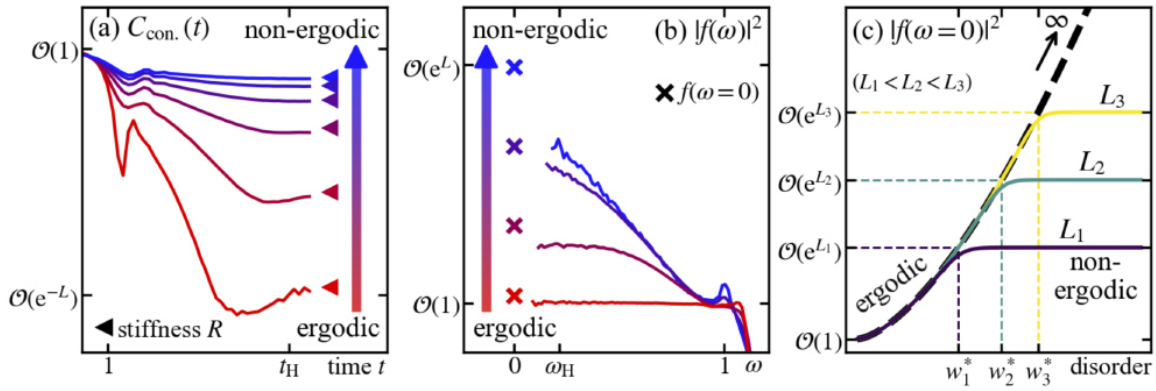

Figure: (a) Autocorrelation function converges to stiffness in the long time limit. (b) Dynamical function at diagonal elements in the ETH grows until it reaches to $\mathcal{O}(e^{L})$. (c) Dynamical function at diagonal elements increases as disorder strength increases.

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Poster session

Universal distributions of overlaps from generic dynamics in quantum many-body systems

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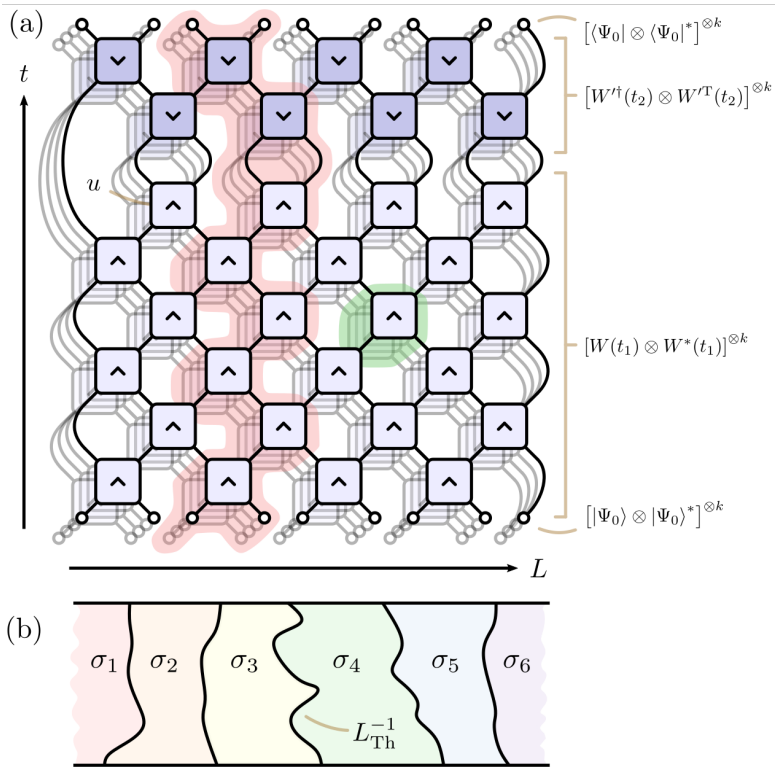
We study the distribution of overlaps with the computational basis of a quantum state generated under generic quantum many-body chaotic dynamics, without conserved quantities, for a finite time t. We argue that, scaling time logarithmically with the system size $t_\infty \log L$, the overlap distribution converges to a universal form in the thermodynamic limit, forming a one-parameter family that generalizes the celebrated Porter-Thomas distribution. The form of the overlap distribution only depends on the spatial dimensionality and, remarkably, on the boundary conditions. This picture is justified in general by a mapping to Ginibre ensemble of random matrices and corroborated by the exact solution of a random quantum circuit. Our results derive from an analysis of arbitrary overlap moments, enabling the reconstruction of the distribution. Our predictions also apply to Floquet circuits, i.e., in the presence of mild quenched disorder. Finally, numerical simulations of two distinct random circuits show excellent agreement, thereby demonstrating universality.



Diagrammatic representation of the coarse grained picture of the k-replicas along with the domain walls.

Additional Term in the Entanglement Entropy of Many-body Quantum Systems

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It is believed that a quantum system is ergodic when the spectral statistics of the Hamiltonian follows random matrix theory (RMT), which can been seen in the scaling of the average entanglement entropy [1–3]. Resolving all symmetries of the Hamiltonian gives us separate eigenpairs for each symmetry sector. Adding disorder destroys the space symmetries, but gives multiple realizations of the Hamiltonian and thus multiple realizations of the eigenpairs.

Also the presence or absence of particle number conservation has been studied [4–6], but the same analysis has been conjectured for energy conservation via a non-exact U(1) symmetry that gives rise to an additional term in the average entanglement entropy [7–9]. We examine the deviation of the mid-spectrum entanglement entropy of the disordered Bose-Hubbard (dBH) model with or without particle number conservation from the Bianchi-Dona or Page curve, respectively. We find that with system size the deviation appears to agree with the prediction for the biggest particle number sector when a maximum occupancy number is introduced to each site, but gets smaller as you go to a smaller particle number sector.

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Non-Drude transport in anisotropic metals

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We reveal a mechanism that may explain the non-metallic out-of-plane resistivity in layered metals. By examining how the Drude-Boltzmann expression for the c-axis conductivity emerges out of the Kubo formula, we find, besides the standard metallic term proportional to the carrier lifetime τ , a non-Drude contribution proportional to $1/\tau$. The Drude behavior breaks down when $1/\tau > 2\eta$, the crossover value η being small (and hence observable) when the c-axis velocities vary rapidly with the distance from the Fermi surface. We consider the Hund metal Sr_2RuO_4 as a test case, which we study within a realistic dynamical mean-field theory approach. The non-Drude behavior observed experimentally in c-axis transport is reproduced and explained by our considerations, showing that earlier invoked extrinsic mechanisms that involve either impurities or phonons are unnecessary. We point out that the small value of η is due to a peculiar accidental cancellation due to destructive interference characteristic of body-centered tetragonal lattices.

Optical transient grating investigation of different states in 1T-TaS_2

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The transition metal dichalcogenide 1T-TaS2 attracts a lot of attention due to its rich phase diagram with multiple long-lived states. The material has already been extensively studied using numerous types of pump-probe experiments, including optical reflectivity, ARPES, and, lately, extreme ultraviolet (EUV) transient grating. In EUV, it is possible to study sub-nm deformations of the material, caused by the grating, using non-resonant probe.

Here we present the results of EUV transient grating experiments, focusing on the comparison between resonant excitation from atomic levels and off-resonant excitation conditions. Under resonant excitation, we observe two different types of dynamics: nearly-instantaneous switching to a so-called textured hidden state [1] and slow switching behavior to a different configuration, which might involve an amorphous state, previously observed in STM experiments [2].

The optical transient grating technique enables the investigation of electronic dynamics caused by the grating formation in the material, in addition to the lattice response observed in non-resonant EUV experiments. Therefore, it is a complementary technique, which allows the study of various states in 1T-TaS2, including thermal and photo-induced hidden states. We will show the first data, revealing the potential of the method to observe the amorphous state, which has not been accessible using conventional optical methods.

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Slow dynamics from a nested hierarchy of frozen states

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We identify the mechanism of slow heterogeneous relaxation in quantum kinetically constrained models (KCMs) in which the potential energy strength is controlled by a coupling parameter. The regime of slow relaxation includes the large-coupling limit. By expanding around that limit, we reveal a nested hierarchy of states that remain frozen on time scales determined by powers of the coupling. The classification of such states, together with the evolution of their Krylov complexity, reveal that these time scales are related to the distance between the sites where facilitated dynamics is allowed by the kinetic constraint. While correlations within frozen states relax slowly and exhibit metastable plateaus that persist on time scales set by powers of the coupling parameter, the correlations in the rest of the states decay rapidly. We compute the plateau heights of correlations across all frozen states up to second-order corrections in the inverse coupling. Our results explain slow relaxation in quantum KCMs and elucidate dynamical heterogeneity by relating the relaxation times to the spatial separations between the active regions.

[1] V. Marić, L. Paljk, L. Zadnik, arXiv:2510.03159

Polynomial filtered exact diagonalization in quantum many body systems

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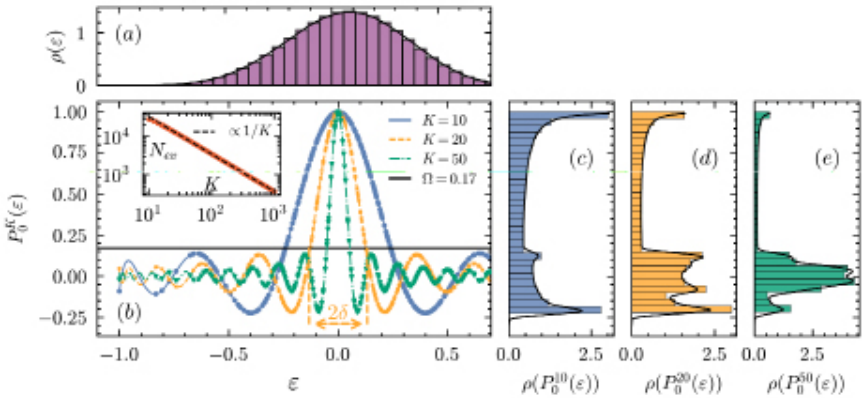
Exact diagonalization is a powerful tool for studying quantum many-body systems, but its applicability is severely limited by the exponential growth of Hilbert-space dimension, making system sizes beyond L \approx 18 difficult to access. Polynomially Filtered Exact Diagonalization (POLFED) offers an efficient alternative for extracting eigenvalues and eigenvectors in targeted energy windows, particularly in the middle of the spectrum where chaotic properties are typically probed. POLFED improves upon the shift-and-invert method by preserving the sparsity of the Hamiltonian, reducing memory consumption, and enabling straightforward implementation. The method relies on a Chebyshev-polynomial approximation of a Dirac delta peak centered at a chosen energy, with the expansion order determined adaptively from the local density of states. Because the spectral transformation is analytic, eigenvectors remain unchanged, and only matrix–vector operations with the original sparse Hamiltonian are required. With POLFED we can reach system sizes up to L = 24 on HPC clusters and L = 20 even on a standard laptop. We benchmark the method on modified SYK models and demonstrate accurate extraction of spectral and chaos indicators such as the level-spacing ratio. POLFED therefore enables the study of thermalization and many-body localization phenomena in significantly larger systems than accessible with standard exact diagonalization.



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Superconductors with delicate topology

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We consider superconductivity in two-dimensional delicate topological bands, where the total Chern number vanishes but the Brillouin zone can be divided into subregions with a quantized nontrivial Chern number. We formulate a lower bound on the geometric contribution to the superfluid weight in terms of the sum of the absolute values of these sub-Brillouin zone Chern numbers. We verify this bound in Chern dartboard insulators, where the delicate topology is protected by mirror symmetry. In iso-orbital models, where the mirror representation is the same along all high-symmetry lines, the lower bound increases linearly with the number of mirror planes. This work points to delicate bands as promising candidates for particularly stable superconductivity, especially in narrow bands where the kinetic energy is suppressed due to lattice effects.

Keywords: Superconductors, strongly correlated electrons, topological condensed matter, quantum geometry

Thermoelectric effect in excitonic insulators

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At sufficiently low temperatures, materials can enter various exotic states due to many-body interactions. One such state is the excitonic insulator, which hosts a condensate of electron-hole pairs known as excitons. Candidates for excitonic insulators have been proposed (e.g. Ta_2NiSe_5 [1] and $Ta_2Pd_3Te_5$ [2]), but a decisive measurement that can confirm the excitonic phase in bulk materials is still lacking.

We investigate the thermoelectric effect in excitonic insulators, which relates to the voltage induced by a temperature gradient and is quantified by the Seebeck coefficient. We hypothesize that, since excitons are neutral particles, their condensation manifests as an unusual thermoelectric effect. To test this hypothesis, we calculate transport coefficients using both Boltzmann's theory and Kubo's linear response theory, identifying the limitations of the former. Our study of a simple one-dimensional model within the mean-field approximation suggests that the Seebeck coefficient as a function of temperature does not exhibit a universal behaviour but depends strongly on microscopic parameters of the model. To describe realistic materials, we derive the Seebeck coefficient within Kubo's formalism for a tight-binding Hamiltonian. We apply this method to Ta_2NiSe_5, in which an anomalous thermoelectric effect has been observed [3].

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Solution for the Navier-Stokes equation with boundary conditions using tensor networks

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Computational fluid dynamics (CFD) is not only a dynamic area of research, but also an essential instrument in cutting-edge industrial applications. Its main difficulty lies in modeling turbulent flows within complex geometries — a process that demands significant computational resources because of the highdimensional vector spaces generated by mesh discretization.

In this work, we used quantum-inspired approach to achieve solid speed up in CFD problems. The main object that we exploited is matrix product state (MPS), that first appear in statistical physics, particularly in Density Matrix Renormalization problem [1]. It allowed us to keep all functions and operators in compressed form without loosing crucial information about the whole system.

Matrix product state formalism preserved most of the basic linear algebra operations, like addition, multiplication, matrix-vector multiplication, etc. [2] Vectors represented as MPS, while operators represented as matrix product operators (MPO) 1. It's shown that function, which were discretized on finite lattice, might also be represented as MPS. Same approach work with differential operators, which might be represented as MPO.

After transformation, any difference method might be used to solve a given CFD problem (like flow in a square lid-driven cavity on figure 1, 2). This way lead us to runtime scaling poly-logarithmically in the mesh size. In table 1 one's might see maximum TT rank in different grid size. According to this table, grid size reduced up to 4 times compare to classical approach. Based on this, we believe that this method might open new approaches to more effective solvers to real-life fluid problems

$$|\psi\rangle = M^{\sigma_1}_{k_0,k_1} M^{\sigma_2}_{k_1,k_2} \dots M^{\sigma_1}_{k_{L-1},k_L}$$

$$\hat{O} = W^{\sigma_1,\sigma_1'}_{k_0,k_1} W^{\sigma_2,\sigma_2'}_{k_1,k_2} \dots W^{\sigma_L,\sigma_L'}_{k_{L-1},k_L}$$

2^N	6	8	10	11
χ_{max}	54	87	110	183

Table 1: Maximum bond dimension value during in different grid size

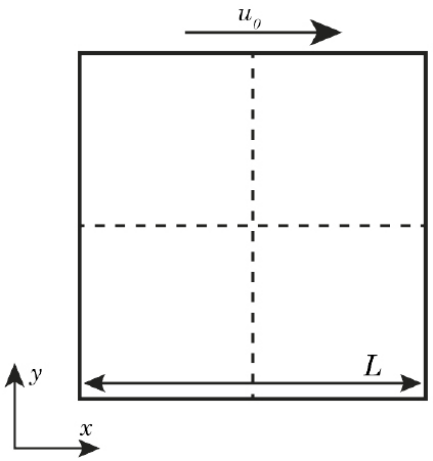

Figure 1: Computational formulation of the problem of numerical modelling of the incompressible flow in square lid-driven cavity

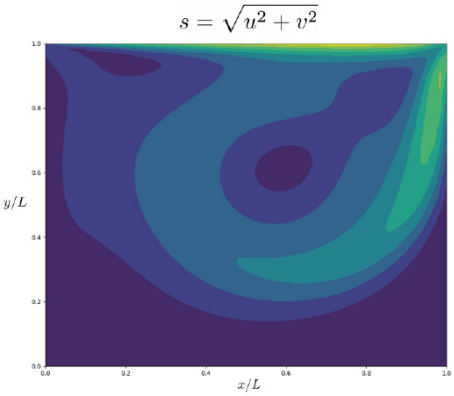

Figure 2: Profile of the flow speed magnitude during the iteration process

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Mraz Anže	Jožef Stefan Institute
Muller Melanie	Fritz Haber Institute
Murakami Yuta	Tohoku University
Nigmatulin Artem	Jožef Stefan Institute
Ogane Kohei	Jozef Stefan Institute
Paljk Luka	Univesity of Ljubljana, Faculty of Mathematics and Physics
Pezer Mario	Jožef Stefan Institute
Picano Antonio	College de France
Pintar Rok	Jožef Stefan Institute
Prelovsek Peter	Jožef Stefan Institute
Prijon Tijan	Jožef Stefan Institute
Prosen Tomaž	University of Ljubljana
Sharipov Rustem	Univesity of Ljubljana FMF
Sroda Maksymilian	University of Fribourg
Steinigeweg Robin	University of Osnabrück
Strohsach Jaka	Jožef Stefan Institute
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Świętek Rafał	Georg-August-University in Goettingen
Tatarkin Oleg	Jožef Stefan Institute
Taufertshofer Nicolai	Paul Scherrer Institute / ETH Zurich
Ulčakar Iris	Jožef Stefan Institute
Valiera Francesco	University of Hamburg
Vaskivskyi Igor	Jožef Stefan Institute
Vaskivskyi Yevhenii	Jožef Stefan Institute
Venturini Rok	Paul Scherrer Institute
Vidmar Lev	Jožef Stefan Institute
Vodeb Jaka	Jožef Stefan Institute
Wall Simon	Aarhus University
Werner Philipp	University of Fribourg
Yursa Viktoriia	Nanocenter
Zong Alfred	Stanford University