School on Quantum Dynamics of Matter, Light and Information | (SMR 4095)

18 Aug 2025 - 05 Sep 2025
ICTP, Trieste, Italy

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We study the quantum Newman-Moore model, or quantum triangular plaquette model (qTPM), in the presence of a longitudinal field (qTPMz). We present evidence that indicates that the ground state phase diagram of the qTPMz includes various frustrated phases breaking translational symmetries, dependent on the specific sequence of system sizes used

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Decoherence and Quantum Discord based on linear entropy in qubit-qutrit Systems under the Non-Markovian Colored Noise Dephasing

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Abstract: This work investigates the dynamics of decoherence and quantum discord in qubit-qutrit systems subjected to non-Markovian colored noise dephasing. Using linear entropy as a measure of mixedness and quantum correlations, we explore the evolution of quantum discord and the impact of non-Markovian memory effects on the system's coherence. The colored noise model introduces a frequency-dependent dephasing mechanism, providing a more realistic framework for understanding open quantum systems. Our results reveal that non-Markovianity significantly influences the preservation and revival of quantum correlations, while Markovian dynamics lead to a monotonic decay of coherence and discord. This contrast highlights the interplay between system-environment interactions and the robustness of quantum discord, emphasizing the role of memory effects in non-Markovian regimes. These findings offer insights into the resilience of qubit-qutrit systems in practical quantum information processing tasks under realistic noise conditions.

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P02

Chaos-Driven and Disorder-Induced Phase Transitions via Permutation Symmetry Breaking

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The influence of disorder and chaos in quantum many-body systems often exhibits similar characteristics, yet their combined effects remain largely unexplored. In this work, we uncover a continuous phase transition triggered by the breaking of permutation symmetry due to disorder. The nature of this transition is dictated by the degree of chaos present in the clean, disorder-free system. Specifically, we show that beyond a critical disorder strength, the system shifts from an area-law entangled phase—where collective variables are well-defined in the permutation-symmetric subspace—to a volume-law entangled phase that spans the entire Hilbert space. Remarkably, this critical disorder strength approaches zero when the original system is fully chaotic. Our analysis primarily relies on studying the scaling behavior of the collective spin in non-equilibrium states, which transition to exhibit characteristics of the so-called "deep Hilbert space." These findings have potential implications for understanding the interplay between chaos, disorder, and quantum entanglement in many-body systems.

P03

Counter-intuitive yet Efficient Regimes for Measurement-Based Quantum Computation in Symmetry Protected Spin Chains

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Resource states for measurement-based quantum computation (MBQC) are known to be exponentially rare in Hilbert space. However, symmetry significantly alters this landscape. In the thermodynamic limit, short-range entangled quantum states organize into what are known as computational phases of quantum matter, driven by symmetry. From a condensed matter perspective, these phases exhibit *symmetry-protected topological (SPT) order*. In the context of quantum computation, these phases serve as reservoirs of MBQC resource states, where any state within a given SPT phase can perform the same quantum computations. Thus, MBQC power is uniform across all states in an SPT phase.

Quantum states drawn from an SPT phase exhibit two types of entanglement. The first is *symmetry-protected entanglement*, which remains constant across the entire phase and defines the common characteristics of all states within that phase. The second is *residual "junk" entanglement*, which varies throughout the phase and accounts for differences between individual ground states. In the context of MBQC, symmetry-protected entanglement is the primary asset, while residual entanglement poses a significant challenge. The key difficulty in leveraging SPT ground states as MBQC resources lies in mitigating the adverse effects of this residual entanglement.

Regarding the measurements that drive MBQC, a curious dichotomy arises: while *symmetry characterizes and classifies computational power, symmetry breaking is required to achieve it.* Specifically, MBQC resource states remain invariant under the given symmetry, but measurements can enact non-trivial logical gates only if they break that symmetry. This work focuses on the question of how densely algorithmically powerful measurements can be packed into a given resource state.

A priori, there are two regimes: the *dilute, uncorrelated regime* and the *dense, correlated regime.*

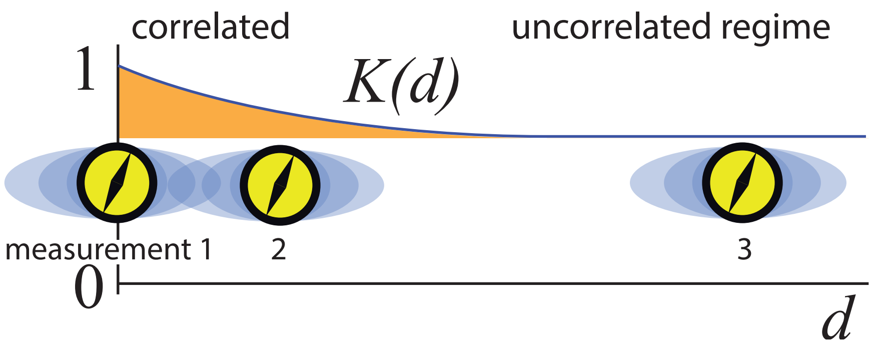

Figure 1: Regimes of SPT-MBQC.

- In the *former*, symmetry-breaking local measurements are spaced far apart. (e.g. 1 and 3 in Fig. 1)

- In the *latter*, they are close (e.g. 1 and 2 in Fig. 1), relative to a characteristic length scale set by the residual entanglement.

Historically and somewhat understandably, the natural inclination has been to avoid the correlated regime. Indeed, all known MBQC methods operate in the uncorrelated regime, minimizing the effects of residual entanglement.

Until now, it has been unclear whether MBQC is even possible in the correlated regime. In this work, we answer this question with an emphatic *yes*. Moreover, under a general condition on the decay of correlations, we establish that the ***strongly correlated regime is actually the most computationally efficient***. In summary, we present a counterintuitive measurement strategy designed to extract the maximum computational potential from a quantum state drawn from an SPT phase.

P04

Single-qubit quantum gate at an arbitrary speed

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Quantum information processing comprises physical processes, which obey the quantum speed limit (QSL): high speed requires strong driving. Single-qubit gates using Rabi oscillation, which is based on the rotating wave approximation (RWA), satisfy this bound in the form that the gate time T is inversely proportional to the Rabi frequency Ω, characterizing the driving strength. However, if the gate time is comparable or shorter than the qubit period $T_0 \equiv 2\pi/\omega_0$, the RWA actually breaks down since the Rabi frequency has to be large compared to the qubit frequency ω_0 due to the QSL, which is given as $T \gtrsim \pi/\Omega$. We show that it is possible to construct a universal set of single-qubit gates at this strong-coupling and ultrafast regime, by adjusting the central frequency ω and the Rabi frequency Ω of the driving pulse. We observe a transition in the scaling behavior of the central frequency from the long-gate time regime ($T \gg T_0$) to the short-gate time ($T \ll T_0$) regime. In the former, the central frequency is nearly resonant to the qubit, i.e., $\omega \simeq \omega_0$, whereas in the latter, the central frequency is inversely proportional to the gate time, i.e., $\omega \sim \pi/T$. We identify the transition gate time at which the scaling exponent n of the optimal central frequency $\omega \sim T^n$ changes from $n = 0$ to $n = -1$. In the frequency domain, we find that the Fourier component of the driving pulse at the qubit frequency is nearly constant of T and converges to the half of the gate angle in both long- and short-gate time limits.

P05

Quantum Mpemba effect in dissipative cavity spin systems

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In the Mpemba effect a system prepared at a higher temperature cools down faster to a target equilibrium state than the same system prepared at a lower temperature. Lately the search for quantum analogoues of this effect has attracted great attention, especially in the context of Markovian open quantum systems. We investigate the occurence of such a Markovian quantum Mpemba effect in spin systems coupled to lossy optical cavities. In this setting the coupling to photon modes enables high energy states to cool down resonantly to the ground state, while states lower in energy can remain trapped in local minima of the systems energy landscape, leading to intriguing anomalous relaxation behaviours.

P06

Novel probes of universality via shallow critical quenches

Universal behaviour emerges near continuous phase transitions, such as a quantum critical point. Quantum simulation experiments, such as Rydberg atom arrays and trapped ion chains, have successfully extracted critical exponents by preparing the critical ground state or by performing a Kibble-Zurek sweep through the phase transition. Calabrese and Cardy (CC) introduced another possible route for probing criticality via global quenches to 1+1-dimensional conformal field theories, where critical exponents are encoded in the relaxation rates of local observables.

We study the CC quench protocol on the lattice, where we examine the non-equilibrium dynamics of local observables after a shallow global quench. Using a combination of conformal field theory, fermion methods, and large-scale tensor network simulations, we extend the CC quench protocol to more experimentally feasible initial finite-temperature ensembles in free, integrable, and non-integrable spin chains.

P07

Abstract for School on Quantum Dynamics of Matter, Light and Information

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

P08

Electronic and magnetic properties of S-graphene compound

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Graphene has recently emerged as a key material in condensed matter physics due to its unique electronic properties. For instance, its two Dirac cones lead to massless charge carriers protected by inversion and time-reversal symmetries. Initially, it was believed that Dirac cones only appeared in materials like graphene under strict conditions, including a 2D crystalline structure, hexagonal symmetry, and sp^2 hybridized carbon atoms. However, recent studies have shown that some carbon allotropes exhibit Dirac cones even when these conditions are not met [1]. New 2D carbon allotropes like S-graphene [1] exhibit Dirac cones despite their non-hexagonal symmetries. However, their properties have primarily been explored using the tight-binding model [2,3]. Although S-graphene exhibits promising characteristics, its properties remain largely unexplored. In order to fill this gap, here we investigate the electronic and magnetic properties of the S-graphene by using an effective lattice Hamiltonian. In particular, we examine the Hubbard model, whose Hamiltonian reads

$$\hat{\mathcal{H}} = -\sum_{\langle i,j\rangle,\sigma} t_{i,j}\left(a^{\dagger}_{i,\sigma}a_{j,\sigma} + a^{\dagger}_{j,\sigma}a_{i,\sigma}\right) + U\sum_{i} a^{\dagger}_{i,\uparrow}a_{i,\uparrow}a^{\dagger}_{i,\downarrow}a_{i,\downarrow}, \tag{1}$$

in which $a^{\dagger}_{i,\sigma}$ and $a_{i,\sigma}$ correspond to creation and annihilation operators of electrons with spin σ in a given sites i. The first term on the right-hand side denotes the hopping between nearest neighbors sites, while the second term describes the on-site repulsive Hubbard interaction between electrons on the same lattice site. By varying the hopping terms in the tight-binding model ($U = 0$), we identified features compatible with the presence of (i) Dirac cones, (ii) band insulator, (iii) or even flat bands. For cases where ($U \neq 0$), as extensively covered in the literature, the quartic interaction term in 2D systems cannot be analytically solved with complete accuracy due to the inherent complexity of interacting many-body problems at the thermodynamic limit. Consequently, this study adopts two distinct methodologies to address this challenge. The first approach is the Hartree-Fock approximation applied to the quartic term, which transforms the system into a quadratic Hamiltonian with an effective field that is determined self-consistently. By varying the hopping parameters respecting the lattice symmetry, the phase diagram of the model was calculated and presents semi-metal, band insulator and antiferromagnetic insulator. We simulated stress on the S-graphene lattice and performed first-principles calculations using Density Functional Theory to confirm the presence of a magnetic phase.

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P09

Electromagnetically-induced transparency in optomechanical system with an optical parametric amplifier

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In this paper, we investigate the phenomenon of optomechanically induced transparency (OMIT) in a cavity that has a moving end mirror and is subjected to an external force. Furthermore, we place an optical parametric amplifier (OPA) inside the cavity. We show that the transmission intensity of the probe field and the group delay is enhanced by the parametric gain and phase of the OPA. We also show that this enhancement is influenced by external forces. We believe that these findings could be valuable in the area of quantum information processing.

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P10

Quantum metrology using quantum recurrences

P11

Theory of fractional Quantum Hall liquids coupled to quantum light and emergent graviton polaritons

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Recent breakthrough experiments have demonstrated how it is now possible to explore the dynamics of quantum Hall states interacting with quantum electromagnetic cavity fields [1-3]. While the impact of strongly coupled non-local cavity modes on integer quantum Hall physics has been recently addressed, the effects on fractional quantum Hall (FQH) liquids– and, more generally, fractionalized states of matter– remain largely unexplored.
In our recent work [4], we develop a theoretical framework for the understanding of FQH states coupled to quantum light. In particular, combining analytical arguments with tensor network simulations, we study the dynamics of a $\nu = 1/3$ Laughlin state in a single-mode cavity with finite electric field gradients. We find that the topological signatures of the FQH state remain robust against the non-local cavity vacuum fluctuations. By exploring the low-energy excited spectrum inside the FQH phase, we identify a new neutral quasiparticle, the graviton-polariton, arising from the hybridization between quadrupolar FQH collective excitations (known as gravitons) and light.

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P12

onreciprocal electrical transport in linear systems with balanced gain and loss in the bulk

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We investigate electrical transport in a quantum wire of N sites connected to an equal number $N_i\ 2)$ of sources and drains of charges in bulk. Each source and drain injects and extracts charges at the same rate, respectively. We show that the linear-response electrical current is nonreciprocal in such a system when the arrangement of sources and drains breaks the system's parity. We prove that inelastic scattering is essential for nonreciprocity in this system. For this, we invoke a master equation description of classical charge transport in a similar system. The nonreciprocal current in quantum wire matches that in the classical model for $N_i\ N \quad 1$, generating a finite scattering length much smaller than the length of the wire. The nonreciprocity in the quantum wire oscillates with wire length when $N_i\ N \ll 1$, and it can vanish at specific lengths.

P13

Quantum refrigeration system employing a two-spin-1/2 Heisenberg model with DM and KSEA interactions as the working medium

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The connection between quantum entanglement and quantum refrigerators is an active area in quantum thermodynamics. Ongoing investigations are exploring how entanglement in the working medium of a quantum refrigerator can impact its performance. This investigation focuses on a two-qubit Heisenberg XXZ spin-1/2 system featuring Kaplan-Shekhtman-Entin- Wohlman-Aharony (KSEA) and Dzyaloshinsky-Moriya (DM) spin-orbit exchange interactions as the operational physical matter medium for a quantum refrigerator. We provide explicit formulations for relevant thermodynamic quantities of the quantum refrigerator, dependent on the magnetic field (B) and the strengths parameters of spin-orbit interactions. In addition, the relationship between entanglement and thermodynamic properties is explored using concurrence as a quantitative metric of thermal entanglement. The results emphasize the significant impact of fine-tuning the amplitudes of both DM and KSEA strengths on improving the quantum refrigerator's performance. Finally, the findings suggest that entanglement between the qubits is superfluous for enhancing the quantum refrigerator's efficiency.

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P14

Non-Stabilizerness of Sachdev-Ye-Kitaev Model

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March 21, 2025

Abstract

We study the non-stabilizerness or quantum magic of the Sachdev-Ye-Kitaev (SYK) model, a prototype example of maximally chaotic quantum matter. We show that the Majorana spectrum of its ground state, encoding the spreading of the state in the Majorana basis, displays a Gaussian distribution as expected for chaotic quantum many-body systems. We compare our results with the case of the SYK_2 model, describing non-chaotic random free fermions, and show that the Majorana spectrum is qualitatively different in the two cases, featuring an exponential Laplace distribution for the SYK_2 model rather than a Gaussian. From the spectrum we extract the Stabilizer Renyi Entropy (SRE) and show that for both models it displays a linear scaling with system size, with a prefactor that is larger for the SYK model, which has therefore higher magic. Finally, we discuss the spreading of quantun magic under unitary dynamics, as described by the evolution of the Majorana spectrum and the Stabilizer Renyi Entropy starting from a stabilizer state. We show that the SRE for the SYK_2 model equilibrates rapidly, but that in the steady-state the interacting chaotic SYK model has more magic than the simple SYK_2. Our results therefore suggest that non-stabilizerness allows to sharply detect many-body quantum chaos.

[1]. Surajit Bera, and Marco Schiro. **Non-Stabilizerness of Sachdev-Ye-Kitaev Model(arXiv:2502.01582)**

P15

A local quantized marker for topological magnon bands from circular dichroism

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- Materials can exhibit magnonic excitations described by topological Bloch bands (non-zero Chern number). A direct manifestation of these topological properties is provided by the chiral edge excitations, which can be probed spectroscopically. In this context, a relevant question concerns whether one could access a quantized topological response, deep in the bulk of the system, which would directly reflect the topological nature of the magnonic Bloch bands. Besides, edge magnonic excitations have been shown to be affected by losses/dissipation. It would therefore be appealing to develop a realistic scheme to access topological responses of magnonic excitations that would remain immune to losses.

More generally, the identification of local markers of topology has been an important quest in the realm of topological quantum matter. Prime instances are provided by the so-called Bianco-Resta marker, and also by the local Streda response, which allow for the local determination of the (many-body) Chern number deep in the bulk of a Chern-insulating system. Here, we introduce a local topological marker that can be experimentally accessed in a broad range of systems, including bosonic settings. In contrast to previous approaches, our construction consists in three steps: (i) the preparation of a local (single-site) excitation, deep in the bulk, which entirely projects onto a single topological band; (ii) the application of a circular drive, which acts globally on the system; (iii) the monitoring of excitation rates (or power absorbed) upon the action of the circular drive, for the two opposite orientations of the drive. This local circular-dichroic measurement eventually provides the desired topological marker, as we illustrate for the concrete case of magnonic excitations in a 2D Heisenberg-type spin system. Importantly, the preparation step can be achieved through a driven-dissipative approach, which potentially guarantees the robustness of this approach to inevitable losses.

P16

Quantum Mpemba effect without global symmetries

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The Mpemba effect, where a system initially farther from equilibrium relaxes faster than one closer to equilibrium, has been extensively studied in classical systems and recently explored in quantum settings. While previous studies of the quantum Mpemba effect (QME) have largely focused on isolated systems with global symmetries, we argue that QME is ubiquitous in generic, non-integrable many-body systems lacking such symmetries, including U(1) charge conservation, spatial symmetries, and even energy conservation. Using paradigmatic models such as the quantum Ising model with transverse and longitudinal fields, we show that QME can be understood through the energy density of initial states and their inverse participation ratio in the energy eigenbasis. Our findings provide a unified framework for QME, linking it with classical thermal relaxation and phenomena such as prethermalization and weak ergodicity breaking.

P17

Dynamical Heterogeneity in an extended Spin Ice Model

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We study the dynamics of a spin ice model on the pyrochlore lattice with the inclusion of third-nearest-neighbour interactions. This extension to the conventional nearest-neighbour model gives rise to a first-order phase transition into a nematically ordered state, while retaining extensive ground state degeneracy [1]. We focus on the real-time dynamics across this transition and explore the role of topological defects in driving the system's relaxation. The nucleation into the ordered phase proceeds via the motion of defects, whose dynamics at low temperatures is severely constrained by both their low density and limited mobility. As a result, the system exhibits extremely slow relaxation characteristic of glassy dynamics. We analyze this slow dynamics in terms of temporal and spatial heterogeneities, identifying patterns similar to those observed in structural glass formers.

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P18

Transmigration of Edge States with Interaction in Su-Schrieffer-Heeger Chain

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The effect of Hubbard and Kondo interactions on the edge states in the half-filled Su-Schrieffer-Heeger chain of electrons is investigated by studying the behavior of charge quasiparticles using Kumar representation and the density matrix renormalization group method. For any finite dimerization of hopping, by increasing the Hubbard interaction, the edge states are found to transmigrate from the physical charge gap to a high energy gap through an intermediate phase without the edge states. The extent of this phase with no edge states shrinks smoothly upon increasing the dimerization. The transmigration of edge states from the charge gap to the high energy gap is also found to occur with Kondo interaction, but through an intermediate phase which itself changes from having no edge states for weak dimerization to having the edge states in the physical as well as the high energy gaps coexisting from moderate to strong dimerization.

[1] Jyoti Bisht, Somenath Jalal and Brijesh Kumar, Physical Review B 110, 245110 (2024).

P19

Stark Many-Body Probes with Long-Range Interactions and Super-Heisenberg Precision

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Abstract: Unlike interferometry-based quantum detection, where particle interactions are generally considered detrimental, many-body quantum probes exploit these interactions to improve measurement sensitivity. Most studies to date have focused on short-range interactions.

This work explores the influence of long-range interactions on the performance of Stark quantum probes for different filling factors, in the context of weak gradient field detection. These probes rely on the Stark localization phase transition in the ground state, which manifests itself as soon as an infinitesimal gradient field is applied, as the size of the system increases.

The results show that super-Heisenberg accuracy can be achieved independently of interaction range, but that Stark probes with long-range interactions exhibit two distinct regimes. Firstly, as the interaction range increases algebraically, localization is enhanced, reducing the sensitivity of the probe. Secondly, when the interaction becomes almost uniform over the whole system (close to a fully connected graph), the localization effect disappears and sensitivity improves again.

Super-Heisenberg accuracy remains accessible in the extended phase up to the transition point, and remains valid even when taking into account the state preparation time in the resource analysis. On the other hand, as the system enters the localized phase, sensitivity decreases and becomes independent of system size, following a universal law. Finally, the study reveals that lower filling factors improve accuracy for the detection of weak gradient fields.

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P20

Bridging Quantum Nonlocality and Ergotropy: A Thermodynamic Perspective

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Understanding the interplay between quantum nonlocality and thermodynamic resources is a central challenge in quantum information science. While distance-based and information-theoretic measures have been widely used to characterize nonlocality, the relationship between quantum correlations and ergotropy—the maximum work extractable via unitary operations—remains nontrivial, as nonlocality does not inherently imply thermodynamic advantage. We introduce an ergotropy-based measure of Measurement Induced Nonlocality (EMIN), recasting nonlocality through a thermodynamic lens. EMIN is defined as the difference in ergotropy of states after and before measurement. EMIN offers physically meaningful insights by quantifying quantum correlations as a resource for energy extraction. This measure satisfies properties such as vanishing for uncorrelated states and invariance under local unitaries that preserve the energy structure of the system. We benchmark EMIN against existing MIN measures for various quantum states: pure entangled states, Werner states, and Isotropic states under various Hamiltonians. Our results reveal that EMIN captures similar qualitative trends while providing deeper insights into how Hamiltonian structure governs extractable work. Additionally, random matrix analysis shows that measurements can either enhance or diminish ergotropy, suggesting a novel mechanism for "charging" quantum systems through measurement-induced dynamics. Our work establishes a conceptual bridge between quantum thermodynamics and information theory, highlighting the dual role of measurement as both an informational and energetic process, opening pathways for future research on using measurement as a resource in quantum batteries and energy management protocols in quantum technologies.

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P21

Tensor Network simulation of a waveguide QED architecture with multiple emitters

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Waveguide Quantum Electrodynamics (Waveguide QED) is a promising and versatile platform for studying fundamental *light-matter interactions* and *quantum technology* implementations [1]. Notably, interesting effects emerge when two or more quantum emitters are coupled to the waveguide, including *collective phenomena*, e.g., superradiance and formation of bound states in the continuum (BICs) [2, 3].
An effective approach to address the behaviour of such systems is via Tensor Network quantum-inspired simulation techniques, enabling to efficiently simulate the real-time dynamics of many-body quantum systems, i.e, a waveguide QED platform.
In particular, I will present a method based on **Matrix Product States (MPS)** to model a waveguide QED architecture featuring multiple emitter pairs and simulate its dynamics in the *non-Markovian* regime. Then, I will discuss the obtained results, focusing on the emergence of BICs and other collective effects in the long-time limit.

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P22

Superradiant lasing in one-dimensional reservoirs

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Collective decay of emitters can be harnessed to realize novel light sources. A notable example is the superradiant laser, where incoherently pumped atoms inside a single-mode cavity are driven to a steady state from which they emit coherent light with an ultranarrow spectrum- a feature that holds promise for enhancing the precision of atomic clocks. Whether superradiant lasing emerges in electromagnetic environments with multiple competing modes and light propagation effects, as well as how these factors influence the statistics of the emitted light, remain open questions. In this poster I present our results on superradiant lasing in one-dimensional baths, such as ring cavities and waveguides. In these systems, atoms synchronize to collectively emit to either the left or the right propagating mode. The competition of these two emerging orders gives rise to a bimodal Wigner distribution and modifies the lasing thresholds. I further discuss how this competition impacts the coherence and spectral properties of the emitted light. Our findings indicate that cold atoms coupled to ring cavities or single-mode nanofibers are promising candidates for realizing superradiant lasers.

P23

Abstract template for Tricriticality in 4D U(1) Lattice Gauge Theory

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The 4D compact U(1) gauge theory has a well-established phase transition between a confining and a Coulomb phase. In this paper, we revisit this model using state-of-the-art Monte Carlo simulations on anisotropic lattices. We map out the coupling-temperature phase diagram, and determine the location of the tricritical point, $T/K_0 \simeq 0.19$, below which the first-order transition is observed. We find the critical exponents of the high-temperature second-order transition to be compatible with those of the 3-dimensional $O(2)$ model. Our results at higher temperatures can be compared with literature results and are consistent with them. Surprisingly, below $T/K_0 \simeq 0.05$ we find strong indications of a second tricritical point where the first-order transition becomes continuous. These results suggest an unexpected second-order phase transition extending down to zero temperature, contrary to the prevailing consensus. If confirmed, these findings reopen the question of the detailed characterization of the transition including a suitable field theory description.

[1] R. C. Torres, N. Cardoso, P. Bicudo, P. Ribeiro, P. McClarty, Phys. Rev. D **110**, 034518 (2024).

P24

I. ABSTRACT

In this study, we propose a scheme to improve quantum correlations (QCs) between two magnons in a tripartite magnonical system. We use Gaussian interferometric power (GIP) to quantify QCs beyond entanglement. Additionally, Gaussian quantum steering is discussed. We investigate the enhancement of QCs via a squeezing parameter and an optical parametric amplifier (OPA). The Mancini criterion is considered to confirm the presence of shared entanglement between the two magnons. We observed a squeezing of about 7 dB for the first magnon. Additionally, the squeezed vacuum field and the OPA improve the generation of genuine tripartite entanglement. We hope that current experimental technology will allow the proposed scheme to be implemented.

P25

Entanglement phases, localization and ergodicity of monitored free fermions in 2D

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Monitored quantum systems, characterized by the interplay between unitary evolution and mid-circuit measurements, have recently emerged as a novel expression of quantum dynamics. Despite their inherently out-of-equilibrium nature, these systems can host robust quantum phases and display measurement-induced phase transitions (MIPT) in the entanglement entropy. Remarkably, they are also unique in providing a link between quantum dynamics in D dimensions and quantum statistical mechanics in $D+1$ dimensions. Here, I will present our recent work on a new arena with a rich phenomenology: continuously monitored, $U(1)$-symmetric free fermions in $2D$ [1]. I will address the emerging MIPT and its similarities and differences with Anderson-type localization transitions. I will also present a new, powerful approach based on random matrix theory concepts. This provides a link between monitored dynamics and quantum chaos, as well as a precise quantitative description of the physical contents of the system.

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P26

We theoretically investigate the stochastic dynamics of two qubits subject to one-site and two-site correlated continuous weak measurements. When measurements dominate over the local unitary evolution, the system's dynamics is constrained and part of the physical Hilbert space becomes inaccessible: a typical signature of the Quantum Zeno (QZ) effect. In this work, we show how the competition between these two measurement processes gives rise to two distinct QZ regimes, which we call *standard* and *correlated*, characterised by a different topology of the allowed region of the physical Hilbert space—being a simply connected and non-simply connected domain, respectively. We develop a theory based on a stochastic Gutzwiller ansatz for the wavefunction that is able to capture the structure of the phase diagram. Finally, we show how the two QZ regimes are intimately connected to the topology of the flow of the underlying non-Hermitian Hamiltonian governing the no-click evolution.

P27

Fractional diffusion without disorder in two dimensions

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We analyse how simple local constraints in two dimensions lead a defect to exhibit robust, non-transient, and tunable, subdiffusion. We uncover a rich dynamical phenomenology realised in ice- and dimer-type models [1]. On the microscopic scale the path of a single defect exhibits anomalously long retractions, amounting to dynamical caging in a continuous-time random-walk framework, culminating in an effective fractional diffusion equation. Mapping to a height field yields an effective random walk subject to an emergent (entropic) logarithmic potential, whose strength is tunable, related to the exponent of algebraic ground-state correlations. The defect's path, viewed as non-equilibrium growth process, yields a frontier of fractal dimension of 5/4, the value for a loop-erased random walk, rather than 4/3 for simple and self-avoiding random walks. Such frustration/constraint-induced subdiffusion is expected to be relevant to platforms such as artificial spin ice and quantum simulators aiming to realize discrete link models and emergent gauge theories.

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Generalized Peierls substitution for Wannier obstructions: response to disorder and interactions

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We study the interplay between quantum geometry, interactions, and external fields in complex band systems. When Wannier obstructions preclude a description based solely on atomic-like orbitals, this complicates the prediction of electromagnetic responses particularly in the presence of disorder and interactions. In this work, we introduce a generalized Peierls substitution framework based on Lagrange multipliers to enforce the constraints of the Wannier obstruction in the band of interest. Thus we obtain effective descriptions of interactions and disorder in the presence of non-trivial quantum geometry of that band. We apply our approach to examples including the diamagnetic response in flat-band superconductors and delocalization effects in flat-band metals caused by interactions and disorder.

[1] Shuai A. Chen, Roderich Moessner, Tai Kai Ng. arXiv: 2503.09709

P29

Simulating the dynamics of observables on quantum computers

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In the Heisenberg picture, time evolution leads to the evolution of an initial operator O to the Heisenberg operator $O(t) = U^{\dagger}OU$. The spectral properties of $O(t)$ – when expanded in an appropriate basis such as the Pauli basis. i.e. $O(t) = \sum_k c_k(t)P_k$ where $c_k(t) = \text{tr}(O(t)P_k)/2^n$ and $P_k \in \mathcal{P}_n$ – contains a wealth of information on the dynamics due to U, characterizing the propagation of quantum information, entanglement, magic, and more [1, 2].

Our approach consists of preparing, evolving, and extracting information from a representation of $O(t)$ as a quantum state on a quantum computer. It naturally allows the advantages (and difficulties) of quantum simulation in the usual Schrodinger picture to be carried over to the Heisenberg picture, in the sense that the resources of magic and entanglement required is inherited. Our framework further enables access to a highly useful subroutine: drawing samples from the Pauli distribution of a Heisenberg operator – the probability distribution formed by c_k^2. This subroutine forms the core of our other algorithms, enabling us to compute and study the dynamics of various information-theoretically relevant quantities such as stabilizer and entanglement entropies, out-of-time-ordered correlators, and other hydrodynamical quantities.

To demonstrate the practical utility of our framework, we describe a proposal to probe the spreading of quantum information due to a 2D lattice Hamiltonian H, and estimate the resources required to implement this proposal on a quantum computer featuring a square grid topology, such as existing ones based on superconducting qubits. We show that Heisenberg dynamics due H can be implemented efficiently, incurring only a small multiplicative overhead (in both time and space) compared to conventional Schrodinger-picture simulation.

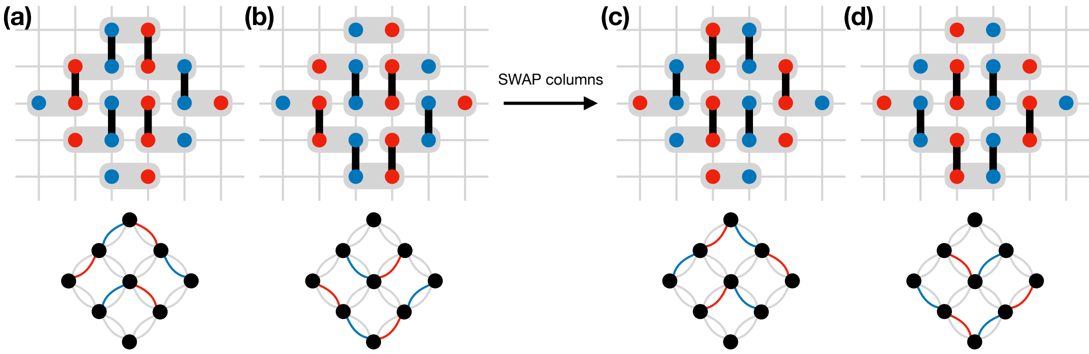

Figure 1: Embedding of qubits onto a square-grid quantum computer that implements a single Trotter-step of time-evolution in the Heisenberg picture ((a)-(d); black lines indicate entangling gates to be performed), due to a Hamiltonian with square grid connectivity (bottom graphs).

Our framework enables quantum computers to be used to study of dynamics in the Heisenberg picture, and provides motivation for certain architectural design choices of quantum computers.

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P30

Unbiased Analysis via Correlation Matrix Methods and Quantum Monte Carlo

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We present a Quantum Monte Carlo-based approach to detect dominant and relevant connected correlations in any interacting spin system amenable to SSE. The approach facilitates the identification of the unknown or exotic order parameters in unexplored phases. It allows for probing connected correlations post-simulation in an unbiased manner through reduced density matrix-based tools. We utilize recent developments in SSE methods [1] and correlation density matrix-based methods [2] to formulate this novel approach.

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P31

Exploring Quantum Effects in Perylene-Based Dimers

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Organic molecules such as Perylene-Bisimide dimers present promising platforms for quantum technologies due to their strong dipole–dipole interactions. This study investigates the influence of thermal noise on quantum resources within dimeric perylene-based arrays. We assess Bures entanglement, Hellinger coherence, EPR steering, and Bell inequality violation across a range of temperatures and molecular parameters. Our findings indicate that Hellinger coherence exhibits greater resilience to thermal noise compared to entanglement, and that EPR steering surpasses Bell nonlocality at elevated temperatures. By modulating dipole interaction strength and molecular transition frequencies, it is possible to control the persistence of quantum features. These insights enhance the understanding of quantum effects in noisy organic systems, with significant implications for light-harvesting and quantum information applications.

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P32

Environment assisted Discrete Time Crystal

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Time crystals, a new non-equilibrium phase of matter, show spontaneous time-translation symmetry breaking. This innovative proposal came from Wilczek [1], though early discussion of time crystals concluded with no-go theorems forbidding the existence of such phase in equilibrium [2, 3]. Consequently, periodically driven models were proposed as a test bed for new generation of time crystals, namely Discrete Time Crystal (DTC) [4, 5, 6, 7, 8], and properly defined [9]. In the literature, there are two types of DTC phases, depending on the convergence of Magnus expansion [10] or initial state dependence of lifetime [11], namely Floquet DTC and prethermal DTC, both having Hamiltonian descriptions. In this work, we are pointing out a novel DTC phase where a carefully chosen environment stabilizes the DTC, notably this phase does not have Hamitonian description all the time, rather has a Liouvillian. The lifetime of this DTC phase is also independent of the initial conditions. We experimentally validate the existence of such a phase.

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P33

Modelling and dispersion engineering of a topological photonic crystal waveguide

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In this work, we present the modelling and dispersion engineering of a topological photonic crystal waveguide inspired by the Su–Schrieffer–Heeger (SSH) model. The structure consists of a one-dimensional periodic dielectric system designed to support topologically protected edge states. The transfer matrix method is employed to compute the dispersion relations and identify edge modes, while the topological nature of the system is further characterised through independent calculations of the Chern numbers. Our study takes into account both TE and TM polarisations, which lead to distinct dispersion characteristics. From the dispersion curves, the group velocity and the real dispersion parameter are extracted, providing a comprehensive description of the waveguide's dispersive properties. By varying design parameters, we demonstrate the ability to shift the zero-dispersion wavelength, thereby controlling the transition between normal and anomalous dispersion regimes. This tunability is particularly relevant for applications in ultrashort pulse propagation. Our findings highlight the potential of SSH-inspired topological photonic crystal waveguides as versatile platforms for dispersion control and the exploration of topologically enhanced photonic functionalities.

P34

Dynamical cluster-based optimization of tensor network algorithms for quantum circuit simulations

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We optimize Matrix-Product State (MPS)-based algorithms for simulating quantum circuits with finite fidelity, specifically the Time-Evolving Block Decimation (TEBD) [1] and the Density-Matrix Renormalization Group (DMRG) [2] algorithms, by exploiting the irregular arrangement of entangling operations in circuits. We introduce a variation of the standard TEBD algorithm, we termed "cluster-TEBD", which dynamically arranges qubits into entanglement clusters, enabling the exact contraction of multiple circuit layers in a single time step. Moreover, we enhance the DMRG algorithm by introducing an adaptive protocol which analyzes the entanglement distribution within each circuit section to be contracted, dynamically adjusting the qubit grouping at each iteration. We analyze the performances of these enhanced algorithms in simulating both stabilizer and non-stabilizer random-structured quantum circuits [3], with up to 1000 qubits and 100 layers of Clifford and non-Clifford gates, and in simulating Shor's quantum algorithm [4] with up to hundreds of thousands of layers. Our findings show that, even with reasonable computational resources per task, cluster-based approaches can significantly speed up simulations of large-sized quantum circuits and improve the fidelity of the final states.

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P35

Applying Coherent Two-Dimensional Spectroscopy to a Pulsed Magnetophononic System

Coherent two-dimensional spectroscopy is a powerful tool to distinguish non-linear contributions to the non-equilibrium physics of quantum systems. The technique has no frequency-range limitation and thus has recently been used in the terahertz regime to observe the high-order response of magnon excitations [1]. In linear magnetophononics, the modulation of magnetic interactions by laser-driven phonons, the coupled phononic and magnetic excitations both have frequencies similar to that of the driving pulse. In this work we use the new frequency axis offered by coherent two-dimensional spectroscopy to isolate the non-linear response of such a system by applying the methodology to a straightforward model of a gapped quantum spin chain with strong magnetophononic coupling [2]. Pulsed driving in this model reveals non-linear contributions of hybrid phononic and magnetic nature, including the sum and difference frequencies of composite phonon-bitriplon excitations [3]. We demonstrate that coherent two-dimensional spectroscopy offers both qualitative and quantitative separation of the different non-linear contributions emerging at strong coupling in pulsed magnetophononics.

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P36

Meron Cluster Algorithm for Spin-1/2 U(1) Quantum Links Coupled with Fermionic matter

P37

Gauging away the ground-state photon content of the quantum Rabi model

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The quantum Rabi model (QRM) features the simplest type of coupling between a single cavity light mode and an atomic electron. It is integrable if the electronic degree of freedom is truncated to just two states [1]. The derivation of the effective Hamiltonian leads to different forms depending on the chosen gauge [2]. In the dipole gauge, the ground state of the QRM exhibits non-zero photon number in contrast to its weak coupling approximation, the Jaynes-Cummings model. We compute the exact photon content for all eigenstates in an arbitrary gauge and obtain a gauge for which the ground state contains no photons. Thus only this gauge fits the intuitive understanding that the cavity should be empty in the lowest energy state even for strong light-matter interaction.

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P38

Controlling discrete time crystals via single-site operations in zero-field diamond quantum simulators

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The control of artificial quantum systems plays a central role in exploring non-equilibrium quantum dynamics and has promising applications in quantum information technologies. In particular, discrete time crystals (DTCs), observed as novel non-equilibrium steady states in periodically driven quantum many-body systems using individually controllable quantum simulators, have attracted attention for spontaneously breaking discrete time-translation symmetry [1]. So far, DTCs are typically implemented using global operations within the time-evolution sequence, but a major challenge is how we can realize and control different DTC phases by incorporating only a single-site operation, which leads to an extension of the conventional framework of DTCs.

In this study, we focus on the single nitrogen-vacancy (NV) center in diamond. This system can be regarded as a quantum spin register consisting of a single electron spin at the center and surrounding nuclear spins. By applying microwave and radiofrequency driving to this system, we can manipulate individual spins, functioning as a quantum simulator. Recently, diamond quantum simulators constructed under a bias magnetic field have experimentally demonstrated the observation of many-body localized discrete time crystals induced by periodic external fields [2]. However, conventional methods face the challenge of restricted electron spin manipulation due to the electron spin level structure influenced by the applied magnetic field. In contrast, under zero-field conditions, we can eliminate constraints on electron spin manipulation [3], which creates variety in DTCs by exploiting the single electron spin control.

From this perspective, we theoretically propose the realization of discrete time crystals through the design of single electron-spin control in a diamond quantum simulator operating without a bias magnetic field [4] (Fig. 1). Our findings show that these single-site operations enable the emergence of DTCs with distinct periodicities and significantly extended lifetimes.

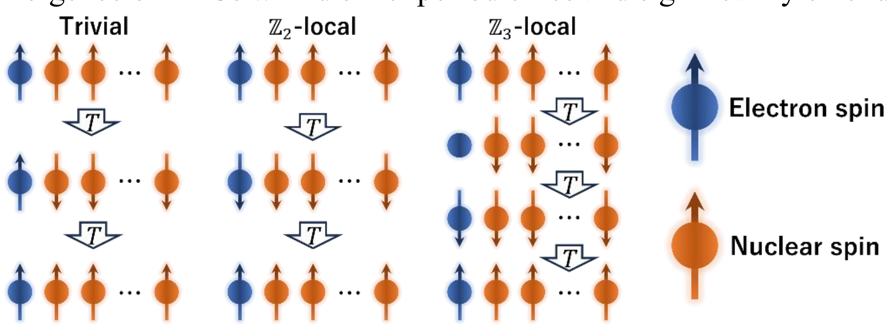

Figure 1: Stroboscopic spin dynamics under three different periodic-driving protocols.

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P39

Entanglement-assisted variational algorithm for discrete optimization problems

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Quadratic unconstrained binary optimization (QUBO) is a paradigmatic class of optimization problems ubiquitous across all fields, ranging from fundamental sciences to industrial productions, finance, and health services. Despite their popularity, most of these problems belong to the NP-Hard complexity class, meaning they become computationally intractable to solve exactly as their size grows [1]. This inherent difficulty makes the development of efficient algorithms to find approximate solutions not just a theoretical pursuit, but a practical necessity with far-reaching implications. Among these, heuristics inspired by classical physics like *simulated annealing* (SA) [2] have long played a central role due to their effectiveness and low computational cost.

Quantum technologies offer promising alternatives to classical optimization heuristics, with potential gains in runtime and resource efficiency. Quantum annealing, in particular, has garnered considerable attention by reformulating optimization problems as ground-state preparation of a quantum Hamiltonian via adiabatic evolution. Numerous studies have been conducted to understand the underlying physical process of quantum annealing, usually relying either on Path Integral Monte Carlo (PIMC), or on Variational Monte Carlo (VMC) dynamics. Despite their value for understanding the mechanisms of quantum annealing, these methods are not viable as efficient optimization heuristics due to their high computational cost and unfavorable scaling with problem size. Additionally, many of these methods rely on Monte Carlo sampling, which further increases computational overhead.

In this work, we propose a quantum-inspired heuristic for solving QUBO problems [3]. Inspired by quantum annealing, we design an efficient variational procedure that emulates its dynamics analytically. The variational Ansatz we employ is based on Generalized Group-Theoretic Coherent States (GCS) [4], which enable efficient evaluation of both the energy and its gradient. At the same time, it captures some of the entanglement structures that emerges during the quantum annealing process, thus leveraging the advantage it provides. Without the need for Monte Carlo sampling, our algorithm is highly scalable and allows for the efficient optimization of problems with thousands of variables.

We benchmark our algorithm on random instances of the three-dimensional Edwards-Anderson model [1], comparing its performance to that of standard heuristics such as SA, Local Quantum Annealing (LQA) [5], and Parallel Tempering with Iso-energetic Cluster Moves (PT-ICM) [6]. We identify parameter regimes in which our algorithm achieves performance comparable to the best methods tested, and present evidence suggesting its potential advantages in the large-system-size limit.

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P40

Quantum Turbulence and Quantum Metrology with Ultracold Atoms

P41

Stabilizer disentangling of conformal field theories

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Understanding how entanglement can be reduced through simple operations is crucial for both classical and quantum algorithms. We investigate the entanglement properties of lattice models hosting conformal field theories cooled via local Clifford operations, a procedure we refer to as stabilizer disentangling. We uncover two distinct regimes: a constant gain regime, where disentangling is volume-independent, and a log-gain regime, where disentanglement increases with volume, characterized by a reduced effective central charge. In both cases, disentangling efficiency correlates with the target state magic, with larger magic leading to more effective cooling. The dichotomy between the two cases stems from mutual stabilizer Renyi entropy, which influences the entanglement cooling process. We provide an analytical understanding of such effect in the context of cluster Ising models, that feature disentangling global Clifford operations. Our findings indicate that matrix product states possess subclasses based on the relationship between entanglement and magic, and clarifying the potential of new classes of variational states embedding Clifford dynamics within matrix product states.

P42

Coherent Dynamics and Decoherence in XYZ-Heisenberg Qubits: Entanglement under DM and KSEA Interactions

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Abstract

We analyze the coherent dynamics of a two-qubit XYZ-Heisenberg system under the influence of Dzyaloshinsky–Moriya (DM) and (KSEA) interactions, external magnetic fields, and thermal effects. Using entanglement negativity, local quantum uncertainty (LQU), and local quantum Fisher information (LQFI), we characterize the behavior of thermal entanglement and its response to external perturbations. Our investigation reveals that increasing the DM interaction parameter D_z enhances thermal entanglement in the antiferromagnetic regime, while the ferromagnetic case exhibits a contrasting behavior.

To study the impact of decoherence, we employ the Kraus operator formalism to simulate dephasing channels. Our results show that LQFI remains more robust under dephasing effects compared to negativity and LQU, even demonstrating a frozen behavior under specific conditions. This comprehensive analysis provides insights into the interplay between coherent dynamics, external interactions, and thermal noise in many-body quantum systems.

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Abstract for School on Quantum Dynamics of Matter, Light and Information — (smr 4095)

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Title: Transport in open quantum systems in presence of lossy channels

Abstract: Transport in low-dimensional open quantum systems with boundary drives has been an active area of research both theoretically [1] and experimentally [2, 3]. Such quantum systems can potentially have additional dissipative effects which arise due to inevitable imperfections in experimental platforms.
In this work [4], we have studied the nonequilibrium steady-state transport in a boundary-driven one-dimensional fermionic lattice setup subjected to particle loss dissipative channels. By analyzing the system size scaling of conductance at zero temperature for different values of the chemical potential of the boundary reservoirs, we show that these dissipative channels are not necessarily always detrimental. We consider a variety of loss channel configurations: (i) single loss at the middle site of the lattice, (ii) multiple but nonextensive lossy channels, and (iii) extensive lossy channels. For the cases (i) and (ii), the conductance scaling with system size remains robust (i.e., same as the case with no loss) for chemical potential within and outside the lattice band, while at the band edge rich anomalous conductance scaling emerges including the enhancement of conductance. For case (iii), we find the conductance scaling becomes ballistic in the thermodynamic limit for any value of chemical potential. We explain the emergence of these different system size scalings of conductance by analyzing the spectral properties of the associated non-Hermitian transfer matrices of the underlying lattice. We demonstrate that the emergence of anomalous scaling is deeply connected to the existence of exceptional points of transfer matrices. Our study unravels that by carefully optimizing the loss mechanism configurations, one can in principle realize systems with rich transport properties in low-dimensional open quantum systems.

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P44

Generating constraints and Hilbert space fragmentation by periodic driving

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Hilbert space fragmentation has long been proposed as a route to evade thermalization in isolated quantum systems by restricting its dynamics through the imposition of constraints. However, in equilibrium, such constraints are usually inserted *a priori* in the Hamiltonian of the system. In one of our earlier works [1, 2], we had considered one such system and showed that such constraints can be realized through periodic driving. In this work, we generalize this idea and propose a general framework to generate such emergent constraints for a given system. We show that special drive frequencies exist where destructive interference suppresses processes which violate the constraints and thereby reinforces these constraints as emergent phenomena. Led by this insight, we suggest what kind of drive protocol might be suitable to generate a particular constraint for a given system. This result, in fact, goes beyond the purview of Hilbert space fragmentation and applies to the more general context of emergent symmetries in driven systems. As an application, we use this protocol to spatially localize quantum information in a spin-$1/2$ chain through Hilbert space fragmentation [3].

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[3] Manuscript under preparation

P45

Translation symmetry restoration in integrable systems: the noninteracting case

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The study of symmetry restoration has recently emerged as a fruitful means to extract high-level information on the relaxation of quantum many-body systems. For instance, this revealed the surprising `quantum Mpemba effect' that occurs when a symmetry is restored more rapidly when the initial configuration is less symmetric [1,2]. However, while the restoration of internal symmetries has been investigated intensively, the restoration of spatial symmetries has only been considered recently in the context of random unitary circuits [3]. Here we present a complementary study of translation symmetry restoration in integrable systems. Specifically, we consider non-interacting spinless fermions on the lattice prepared in non-equilibrium states invariant only under $\nu > 1$ lattice shifts and follow the restoration of one-site shift invariance. We do so by measuring the Frobenius distance between the state on a subsystem, and its symmetrised counterpart. We compute the latter exactly, using standard Gaussian methods, and conjecture a quasiparticle picture describing analytically its asymptotic behaviour. Since the initial states that we study are invariant only under ν lattice shifts, they produce multiplets of ν correlated quasiparticles. We show that in this setting the relaxation is slower for the initial states that receive larger contributions from multiplets where two quasiparticles have approximately the same velocity. We use this to argue that the quantum Mpemba effect goes beyond the hydrodynamic regime. Our results can directly be extended in higher dimensions.

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P46

because I am still working on the Project of dimer-dimer correlations in different two-dimensional RVB states with Professor Kirill Shtengel, I do not have ready poster yet. I will upload it as soon as I have one.

P47

Low-Rank Readout of Transmon Qubits

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Superconducting quantum computing stands as a leading platform in the race toward scalable quantum technologies [1]. At its heart lies the *transmon qubit* – a weakly anharmonic oscillator resilient to charge noise while maintaining compatibility with fast microwave control [2]. One of the major sources of error in this architecture is the readout: how to quickly and accurately measure the qubit state without inducing unwanted decoherence or backaction. Add to this the need to model dissipation via the Lindblad master equation and the large number of modes required by the circuit components, and a high-fidelity simulation of the readout quickly becomes intractable.

In this work, we attempt to remedy these ills by employing a low-rank approximation [3]. This admits a very simple idea: since many quantum systems of interest – in particular, those initialized in near-pure states and evolved under local drives and dissipation – remain close to low-entropy states, the density matrix $\rho(t)$ can be well-approximated as a low-rank object of fixed rank M which is chosen to be much smaller than the Hilbert space size. Doing so greatly reduces the computational complexity all without sacrificing essential dynamics. Crucially, this approximation is controlled: increasing the rank systematically improves the accuracy, in contrast to the uncontrolled and widely used Rotating Wave Approximation (RWA), which is dichotomic and often fails in fast, strongly-driven regimes such as those relevant for readout.

We apply this method to simulate the transmon readout process with a Purcell filter at realistic circuit QED parameters without invoking the RWA. Despite the inherent high-dimensionality of the system, we achieve high-fidelity results using only modest computational resources, avoiding the need for specialized hardware like tensor processing units (TPUs) [4]. We further analyze how the fidelity scales with the rank and show that our method captures key features missed by RWA-based approaches.

This low-rank framework opens several exciting directions for future work, such as optimizing readout parameters for speed and fidelity, incorporating adaptive-rank evolution to capture entropic bursts during measurement [5], or integrating Floquet-inspired techniques to address strongly driven regimes, all of which move towards an efficient modeling of quantum hardware beyond standard approximations.

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Stabilizer Rokhsar-Kivelson scars

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We investigate quantum many-body scars in Abelian lattice gauge theories [1] and identify a class of scarred eigenstates-specifically singlet scars associated with gauge-invariant zero modes—that are exact stabilizer states. We also demonstrate that certain high-energy eigenstates exhibit a stabilizer structure. These states possess vanishing stabilizer Renyi entropy [2], indicating limited entanglement and enabling efficient classical simulation. Building on this structure, we construct an explicit quantum circuit that prepares the stabilizer scar states in a two-dimensional lattice gauge theory. Our findings reveal a previously unexplored link between quantum many-body scars and stabilizer states, with implications for quantum information, classical simulability, and nonthermal dynamics in constrained quantum systems.

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P49

Universal Approach to Dynamics of Finite and Extended Atomistic ystems in the Phase pace

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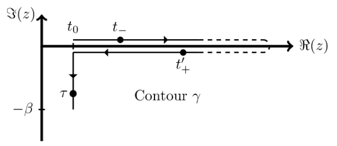
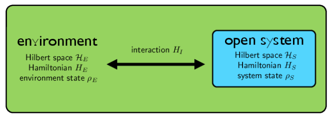
Konstantinov-Perel's Contour and Open Quantum ystem

Non-adiabatic effects play the fundamental role in many areas of condensed matter physics, such as the quantum engineering, lattice dynamics in the correlated electronic systems and motions of ions in the cold atom experiments. Although a quality of theoretical tools have been developed over the years, rigorous quantum dynamics for finite and extended atomistic systems remains a long-standing challenge under nonequilibrium electronic environments.





To conquer this, the real-time evolution is naturally coupled to the thermalization of an atomistic system. The Liouville equation for ionic reduced density matrix is derived by constructing partial path integrals over nuclei and representing electrons explicitly via an effective functional,[3, 5]

Driven ingle-Mode Holstein Model at the Finite Temperature

The Holstein model is widely applied to describing the electron-phonon interaction process in the condensed phase. Without the loss of generality, the nonequilibrium non-adiabatic dynamics approach is applied to this model in order to elucidate motions of quantum dot.[1]

Phononic System: $\mathscr{V}(x) = \frac{1}{2}p^2 + \frac{1}{2}\omega x^2.$

Electronic System: $(x) = \sum_{k,l=1}^{N} V_{kl}(x)\,\hat{c}_k^\dagger \hat{c}_l + \sum_{k=1} \gamma_k^{(1)}\, x(\tau)]\, x\, \hat{c}_k^\dagger \hat{c}_k + \frac{1}{2}\sum_{k=1} \gamma_k^{(2)}\, x(\tau)]\, x^2\, \hat{c}_k^\dagger \hat{c}_k\,.$

Electronic Environment: $_{\mathrm{L}}(x) = \sum_{p=1}\sum_{k=1}\sum_{l=1} \left(\gamma_{k,l}^{p}(x)\,\hat{c}_l^\dagger \hat{d}_k + \gamma_{k,l}^{p}(x)\right]^* \hat{c}_l\, \hat{d}_k^\dagger\Big).$

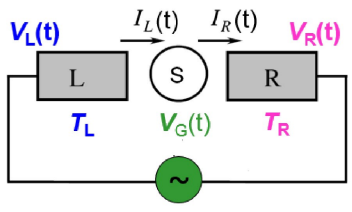


Figure 1. Lead-Device-Lead

Here, the motions of quantum dot are restrained in the harmonic oscillator potential, which is driven by the leads at the finite temperature.

The Equations of Motions in the Phase pace

The thermalization of moments, $\mathscr{A}_{\mathrm{W}}^{n,m}(\tau)$, is realized at the finite temperature,

$$\partial_\tau \mathscr{A}_{\mathrm{W}}^{n,m}(\tau) = \frac{1}{\hbar}\; i\,\bar{Y}^<(\tau) + \bar{\mu}(\tau)]\,\mathscr{A}_{\mathrm{W}}^{n\,m}\,\langle x\rangle_\tau$$
$$\frac{1}{\hbar}\; i\,\bar{Y}^<(\tau) + \bar{\mu}(\tau)] \sum_{r=0}^{\min(n+1,\,m)} \sum_{j=0}^{\min(n,\,r)} \sigma_r^e\;{}_{j,\,j}\,\bar{\Gamma}_{j,\,r\;\;j}^{n,\,m,\,1,\,0}\,\mathscr{A}_{\mathrm{W}}^{n+1\;\;r,\,m\;\;r}$$
$$+\frac{1}{2m}\sum_{r=0}^{\min(n,\,m+2)} \sum_{j=0}^{\min(m,\,r)} \sigma_{j,\,r\;\;j}^{e}\,\bar{\Gamma}_{j,\,r\;\;j}^{n,\,m,\,0,\,2}\,\mathscr{A}_{\mathrm{W}}^{n\;\;r,\,m+2\;\;r}$$
$$+\sum_{k=1}\sum_{r=0}^{\min(n+1,m)}\sum_{j=0}^{\min(n,r)} \omega_k\,\sigma_r^e\;{}_{j,j}\,\bar{\Gamma}_{j,\,r\;\;j}^{n,\,m,\,k,\,0}\,\mathscr{A}_{\mathrm{W}}^{n+k\;\;r,\,m\;\;r}. \tag{1}$$

where the Canonical variables, $\hat{x}$ and $\hat{p}$, are arranged to the Weyl order and $\{\bar{\mu}(\tau)\}$ are the effective environmental fluctuations.

The Matsubara Green's Function and Complex Colour Noise

The equations of motion are driven by the complex colour noise, $\bar{\mu}(\tau)$, *i.e.* environmental fluctuations around are determined by the time correlation function,

$$\bar{\Pi}(\tau+\Delta\tau,\tau) = \langle \bar{u}(\tau+\Delta\tau)\,\bar{u}(\tau)\rangle = \quad i\delta(\tau \quad \tau')\,\bar{Y}^<(\tau,\tau') \quad \theta(\tau \quad \tau')\,\bar{Y}^{<>}(\tau,\tau') \quad \theta(\tau' \quad \tau)\,\bar{Y}^{><}(\tau,\tau').$$

The fluctuation of electronic environment contributes $\bar{Y}\;(\tau,\tau^+)$ and $\bar{Y}\;{}^{,\beta}(\tau,\tau')$,

$$\bar{Y}\;(\tau,\tau^+) = \mathrm{Tr}_C\;\mathbb{G}_{\mathrm{M}}(\tau,\tau^+)\,\mathrm{V}_0]$$
$$\bar{Y}\;{}^{,\beta}(\tau,\tau') = \mathrm{Tr}_C\;\mathbb{G}_{\mathrm{M}}(\tau,\tau')\,\mathrm{V}_0\,\mathbb{G}_{\mathrm{MM}}^{\beta}(\tau',\tau)\,\mathrm{V}_0].$$

$G\;(\tau,\tau')$ are the different components of the Matsubara Green's function, *i.e.* greater and less ones,

$$\mathbb{G}_{\mathrm{M}}^<(\tau,\tau') = \frac{1}{2\pi}\int_{\infty}^{+\infty} d\omega\, f(\omega)\, e^{\;\;\omega\delta}\;\;\mathbb{G}_{\mathrm{M}}^a(\omega)\quad \mathbb{G}_{\mathrm{M}}^r(\omega)\,] = \frac{1}{2\pi}\int_{\infty}^{+\infty} d\omega\, f(\omega \quad \mu)\, e^{\;(\omega\;\;\mu)\delta}\,\mathbb{A}_{\mathrm{M}}(\omega)$$
$$\mathbb{G}_{\mathrm{M}}^>(\tau,\tau') = \frac{1}{2\pi}\int_{\infty}^{+\infty} d\omega\, f(\omega)\, e^{\;\omega(\delta\;\;\beta)}\;\;\mathbb{G}_{\mathrm{M}}^r(\omega)\quad \mathbb{G}_{\mathrm{M}}^a(\omega)\,] = \frac{1}{2\pi}\int_{\infty}^{+\infty} d\omega\, f(\omega \quad \mu)\, e^{\;(\omega\;\;\mu)(\delta\;\;\beta)}\,\mathbb{A}_{\mathrm{M}}(\omega).$$

The retard and advanced components are computed,

$$\mathbb{G}_{\mathrm{M}}^r(i\omega_n) = \frac{1}{(i\omega_n+\mu)\mathbb{1}_{cc} \quad {}_{\mathrm{el}}(x) + \frac{i}{2}\;\; {}_m}, \qquad (\omega_n > 0)$$
$$\mathbb{G}_{\mathrm{M}}^a(i\omega_n) = \frac{1}{(i\omega_n+\mu)\mathbb{1}_{cc} \quad {}_{\mathrm{el}}(x) \quad \frac{i}{2}\;\; {}_m}, \qquad (\omega_n < 0)$$

where $\{\omega_n = \frac{n\pi}{\beta}\}$ are the Matsubara's frequencies.

The Generation of Complex Noise

The $\bar{\mu}(\tau) = \Re\bar{\mu}(\tau) + i\Im\bar{\mu}(\tau)$ is composed of the real and imaginary parts, which is considered as an two-components real noise, $\bar{\boldsymbol{\mu}}(\tau) = \;\;\Re\bar{\mu}(\tau), \Im\bar{\mu}(\tau)\,] \;\;=\;\; \bar{\mu}_0(\tau), \bar{\mu}_1(\tau)\,]$. They satisfy the correlation function,

$$\bar{\Pi}_{00}(\tau,\tau') = \langle\bar{\mu}_0(\tau)\,\bar{\mu}_0(\tau')\rangle = \frac{1}{2}\{\Re\;\bar{\Pi}_1(\tau,\tau')] + \Re\;\bar{\Pi}_2(\tau,\tau')]\}$$
$$\bar{\Pi}_{11}(\tau,\tau') = \langle\bar{\mu}_1(\tau)\,\bar{\mu}_1(\tau')\rangle = \frac{1}{2}\{\Re\;\bar{\Pi}_1(\tau,\tau')] \quad \Re\;\bar{\Pi}_2(\tau,\tau')]\}$$
$$\bar{\Pi}_{01}(\tau,\tau') = \langle\bar{\mu}_0(\tau)\,\bar{\mu}_1(\tau')\rangle = \frac{1}{2}\{\Im\;\bar{\Pi}_1(\tau,\tau')] \quad \Im\;\bar{\Pi}_2(\tau,\tau')]\}$$
$$\bar{\Pi}_{10}(\tau,\tau') = \langle\bar{\mu}_1(\tau)\,\bar{\mu}_0(\tau')\rangle = \frac{1}{2}\{\Im\;\bar{\Pi}_1(\tau,\tau')] + \Im\;\bar{\Pi}_2(\tau,\tau')]\}.$$

$\bar{\mu}_0(\tau), \bar{\mu}_1(\tau)\,]$ is realized according to the circulant embedding matrix,

$$\bar{\Lambda}_{00} \leftarrow \mathsf{FFT}(\bar{\Pi}_{00}^c);\; \bar{\Lambda}_{11} \leftarrow \mathsf{FFT}(\bar{\Pi}_{11}^c);\; \bar{\Lambda}_{01} \leftarrow \mathsf{FFT}(\bar{\Pi}_{01}^c).$$

The noise is generated after the Fourier transformation,

$$\tilde{\mu}_0 \leftarrow \mathsf{FFT}\;\;\bar{\Lambda}_{00}^{\frac{1}{2}}\;\;{}_1] \in \mathbb{C}^{2N};\; \tilde{\mu}_1 \leftarrow \mathsf{FFT}\;\;\bar{\Lambda}_{11}^{\frac{1}{2}}\;\;{}_2] \in \mathbb{C}^{2N},$$

with $\bar{\boldsymbol{\mu}}_0 = \Re\tilde{\boldsymbol{\mu}}_0$ and $\bar{\boldsymbol{\mu}}_1 = \Re\tilde{\boldsymbol{\mu}}_1$.

tochastic Hierarchical Equations and Cumulant Truncatiuon

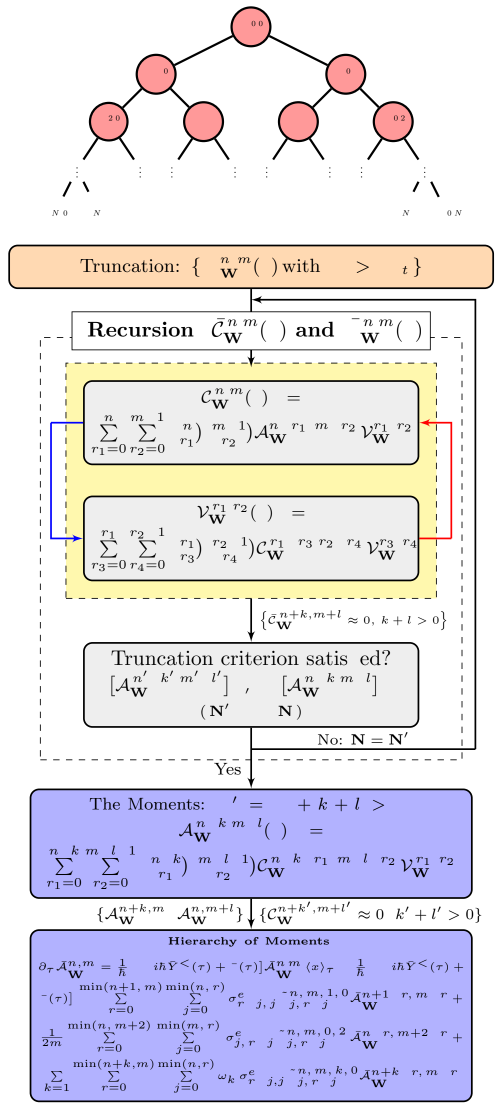


Figure 2. Open Quantum Systems

Conclusions and Exceptations

Our theory enables one to construct equation of motion for the observable atomic positions with full account of the non-adiabatic interaction with the electrons and at a finite temperature and general non-equilibrium conditions (e.g., a time-dependent bias)

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P50

Effect of off-diagonal disorder in the vicinity of the multi-critical point of graphene-nanoribbons

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Typically, 1D systems depict Anderson Localization upon the addition of disorder, where the transport is exponentially suppressed with system size. However, there are certain systems which depict ”anomalous localization”, in which the transport is suppressed with system size, however the suppression is much weaker. One such example is the 1D chain with hopping disorder, tuned to its critical point. The anomalous localization properties of this system [1] are connected to a singularity in the density of states [2] near zero energy. In general, in the vicinity of its critical point, the 1D chain with hopping disorder develops a power-law singularity in the density of states at zero energy, with a non-universal exponent [3]. At the critical point, the exponent takes a universal value of 1 with logarithmic corrections to obtain a specific form called the “Dyson Singularity” [3]. Zig-Zag graphene nanoribbons, which are essentially generalizations of the 1D chain, can be shown to host a multi-critical point [4]. We add hopping disorder to graphene-nanoribbons in the vicinity of this multi-critical point, and study if the disordered multi-critical point depicts the same behaviour as the usual disordered critical point.

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P51

Exploring the effects of higher Josephson harmonics on superconducting circuits.

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Limitations of the sinφ current phase relation in explaining the observed higher-level spectroscopy of transmon artificial atoms has led to the proposal of a more accurate description of the Josephson element, with non-negligible higher-harmonic corrections to the sinusoidal current phase relation [1]. We investigate the Fraunhofer effect in thin film Al-AlOx-Al junctions as a tool to discriminate stray-inductances effects from intrinsic higher harmonics of the junctions. The presence of a strong in-plane magnetic field directly affects the Josephson coupling at the junction by laterally penetrating the JJ's oxide barrier, which causes Fraunhofer-like pattern [2, 3]. The magnetic field affects each harmonic contribution of the junction with a different characteristic field, resulting in a magnetic field dependence strikingly different from the one due to stray-inductance effects alone. We also examine how the presence of a few percent higher-harmonics affects the various qubit designs like the 0-Pi qubit, cos2phi, and fluxonium[4,5,6] qubit and comment on how it changes the useful qubit parameter regimes which are crucial for accurately targeting the implementation of desired Hamiltonians on superconducting hardware.

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P52

Deep thermalization in Gaussian continuous-variable quantum systems

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We uncover emergent universality arising in the equilibration dynamics of multimode continuous-variable systems. Specifically, we study the ensemble of pure states supported on a small subsystem of a few modes, generated by Gaussian measurements on the remaining modes of a globally pure bosonic Gaussian state. We find that beginning from highly entangled, complex global states, such as random Gaussian states and product squeezed states coupled via a deep array of linear optical elements, the induced ensemble attains a universal form, independent of the choice of measurement basis: it is composed of unsqueezed coherent states whose displacements are distributed normally and isotropically, with variance depending on only the particle-number density of the system. We further show that the emergence of such a universal form is consistent with a generalized maximum entropy principle, which endows the limiting ensemble, which we call the "Gaussian Scrooge distribution", with a special quantum information-theoretic property of having minimal accessible information. Our results represent a conceptual generalization of the recently introduced notion of "deep thermalization" in discrete-variable quantum many-body systems—a novel form of equilibration going beyond thermalization of local observables—to the realm of continuous-variable quantum systems. Moreover, it demonstrates how quantum information-theoretic perspectives can unveil new physical phenomena and principles in quantum dynamics and statistical mechanics. [1]

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Intrinsic Heralding for Decoding Non-Abelian Topological Codes

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Topological orders (TOs) are long-ranged entangled topological phases that are characterized by ground state degeneracy and anyon excitations. [1-8] They have been exploited to encode and manipulate quantum information thanks to their robustness against local noise. [9] For Abelian TOs, such as the toric code, the error correction problem has been well studied. [10] In contrast, the error correction problem of non-Abelian TOs is more difficult due to non-Abelian braiding statistics and non-deterministic fusion of anyon excitations. [11] In this work, we explore the challenges and opportunities when applying the toric code decoders to the non-Abelian D4 TO, which has been experimentally realized using measurement-based protocols. [12-14] Specifically, we demonstrate that non-Abelian anyon strings have intrinsic heralding without the requirement of additional flag qubits or feedback. [15] Such intrinsic heralding could be harnessed to drastically enhance the error correction threshold of the decoder, as confirmed by numerical simulations. Furthermore, we generalize this intrinsically heralded decoding approach to effectively correct general Pauli errors, especially in the presence of noise bias.

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P54

Pair localization across the BCS-BEC crossover in the attractive Hubbard model

P55

Exploring Quantum Machine Learning for Qauntum Phase Identification in Many-Body Systems

P56

Quantum control of subradiant states in transmon pair arrays

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Here we study the dissipative dynamics of an array of transmons. Transmons are a type of superconductive qubit that facilitates a system suitable for storing quantum information. Specifically, we study two pairs of transmons coupled to a common waveguide. The pairs, consisting of two capacitively coupled transmons, are separated by a distance corresponding to half of the wavelength. In this work, we model transmon arrays with parameters that can be realised in experiments. The device offers an intriguing structure of eigenstates, particularly so-called dark states (c) which are protected from decay. We provide a detailed analysis of the eigenspectra examining the symmetry and decay of the states, as well as driving the system from the ground state to the states of interest.

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P57

Tensor Cross Interpolation of Purities in Quantum Many-Body Systems

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The defining feature of quantum many-body systems is an exponential scaling of the Hilbert space with the number of degrees of freedom. This exponential complexity naïvely renders the complete characterization of state, for instance via the complete set of bipartite Renyi entropies, a challenging task. Recently, the compact way of storing subregions' purities by encoding them as amplitudes of a fictitious quantum wave function, known as the entanglement feature (EF), was proposed. Matrix product state (MPS) encoding of such EF was obtained for Haar random states, however, the general applicability and practical usage of such encoding remained unclear. In this work, we demonstrate that EF can be efficiently learned using only polynomial amount of samples in the number of degrees of freedom through an active (machine) learning algorithm, called tensor cross interpolation, assuming EF is expressible as a finite bond dimension MPS. We benchmark this learning process on Haar and random MPS states, utilizing analytic insights. Additionally, we devise novel applications for the learned EF, such as quantifying the distance between different entanglement patterns and finding the optimal one-dimensional ordering of physical indices in a given state, highlighting the potential utility of proposed learning method in characterizing quantum many-body systems.

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P58

Operator space fragmentation in perturbed Floquet-Clifford circuits

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Floquet quantum circuits are able to realise a wide range of non-equilibrium quantum states, exhibiting quantum chaos, topological order and localisation. The circuit based perspective has led to new regimes of many-body quantum dynamics with potential applications to quantum technologies. In this work, we investigate the stability of operator localisation and the emergence of chaos in random Floquet-Clifford circuits subjected to unitary perturbations which drive them away from the Clifford limit. We construct a nearest-neighbour Clifford circuit with a brickwork pattern and study the effect of including disordered non-Clifford gates. The perturbations are uniformly sampled from single-qubit unitaries with probability p on each qubit. We show that the interacting model exhibits strong localisation of operators for $0 \leq p < 1$ that is characterised by the fragmentation of operator space into disjoint sectors due to the appearance of *wall* configurations. Such walls give rise to emergent local integrals of motion for the circuit that we construct exactly. We analytically establish the stability of localisation against generic perturbations and calculate the average length of operator spreading tunable by p. Although our circuit is not separable across any bi-partition, we further show that the operator localisation leads to an entanglement bottleneck, where initially unentangled states remain weakly entangled across typical fragment boundaries. Finally, we study the spectral form factor (SFF) to characterise the chaotic properties of the operator fragments and spectral fluctuations as a probe of non-ergodicity. In the $p = 1$ model, the emergence of a fragmentation time scale is found before random matrix theory sets in after which the SFF can be approximated by that of the circular unitary ensemble. Our work provides an explicit description of quantum phases in operator dynamics and circuit ergodicity which can be realised on current NISQ devices.

P59

SU(2) symmetric Hamiltonian for the four-color states on the pyrochlore lattice

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Frustrated Heisenberg models are known to host numerous competing phases, making precise numerical identification of their ground states particularly challenging. Exactly solvable models play a crucial role in this context, providing reference points for exploring complex phase diagrams. Prominent examples include the Majumdar-Ghosh [1] and Affleck-Kennedy-Lieb-Tasaki (AKLT) [2] Hamiltonians, which can be expressed as sums of noncommuting projectors whose eigenstates naturally yield the ground state wavefunctions. Recently, a macroscopically degenerate XXZ model was identified for the spin-1/2 kagome quantum antiferromagnet, featuring a three-coloring product state as its exact ground state [3].

In this work, we introduce a chiral, SU(2)-symmetric spin-1 Hamiltonian defined on the pyrochlore lattice, expanding the class of known exactly solvable models. Its ground states form a product state over tetrahedra, with each tetrahedron hosting four spin-coherent states

$$|\psi\rangle = \prod_{\text{tetrahedra}} \otimes|\mathbf{n}_1\rangle \otimes |\mathbf{n}_2\rangle \otimes |\mathbf{n}_3\rangle \otimes |\mathbf{n}_4\rangle, \tag{1}$$

where $|\mathbf{n}_i\rangle$, $i = 1, 2, 3, 4$, are the spin coherent state pointing in four directions $\mathbf{n}$ on the Bloch-sphere and obey the four color rule on each tetrahedron (termed tetrahedratic states). A representative configuration, defined up to a global O(3) rotation, is given by:

$$\mathbf{n}_1 = (111),\ \mathbf{n}_2 = (\bar{1}\bar{1}1),\ \mathbf{n}_3 = (1\bar{1}\bar{1}),\ \mathbf{n}_4 = (\bar{1}1\bar{1}), \tag{2}$$

Twelve distinct configurations arise from even permutations of Eq. (2) [4], and these configurations with the global O(3) rotation span exactly 65 linearly independent states within the 81-dimensional Hilbert space (3^4) of each tetrahedron. We construct the Hamiltonian $\mathcal{H}_\alpha$ on each tetrahedron explicitly:

$$\mathcal{H}_\alpha = \sqrt{3}J \sum_{ijk} \mathbf{S}_i(\mathbf{S}_j \times \mathbf{S}_k) - J \sum_{i<j} \mathbf{S}_i\mathbf{S}_j + J \sum_{(ij)(kl)} (\mathbf{S}_i\mathbf{S}_j)(\mathbf{S}_k\mathbf{S}_l), \tag{3}$$

where in the first sum $ijk = 123, 142, 134, 243$ and the last sum is over $(ij)(kl) = (12)(34), (13)(24)$, and $(14)(23)$. Summing $\mathcal{H}_\alpha$ over all tetrahedra gives the full Hamiltonian $\mathcal{H} = \sum_\alpha \mathcal{H}_\alpha$, whose ground-state manifold is precisely spanned by these four-color product states, Eq. (1).

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Tabletop squeezed light optomechanics with phononic crystals

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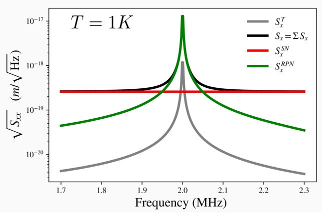
P60

Measuring mechanical displacements

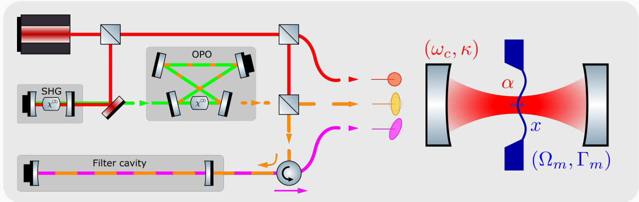
Interferometry of small displacements

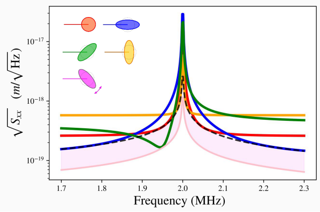
- optomechanical coupling induced by radiation pressure
- phase fluctuations spectrum : $S_q^{\text{out}}(\Omega) = S_q^{\text{in}}(\Omega) + \dfrac{256 I_{in}\mathcal{F}^2}{\lambda^2(1+(\Omega/\Omega_c)^2)^2} S_x(\Omega)$
- thermal bath filtered by resonator : $S_x^T(\Omega) = 2m\Gamma_m k_B T |\chi(\Omega)|^2$



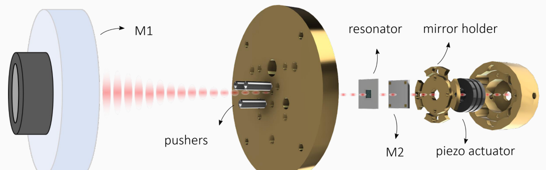
Squeezed light interferometry

- used to minimize SN or RPN (phase or amplitude squeezing)
- need frequency dependent angle matching resonator's response
- overall noise reduction of e^{-2r}

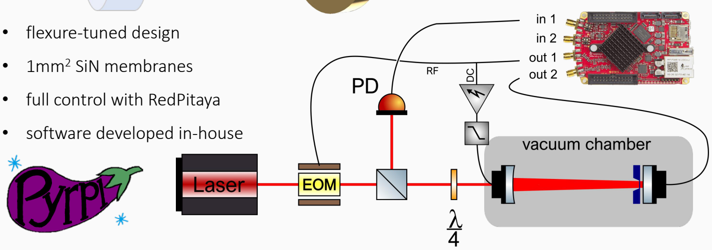




Quantum limited optomechanical system



- flexure-tuned design
- 1mm² SiN membranes
- full control with RedPitaya
- software developed in-house

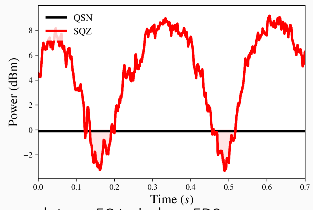


Frequency dependent squeezing

OPO pump from SHG (η~60%)

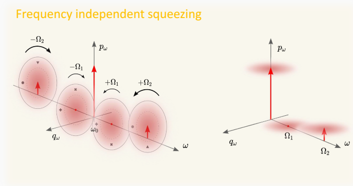
two-mode squeezed state from OPO

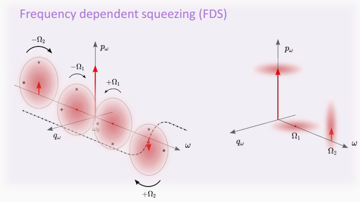
mCLF to lock ellipse angle (PLL)



detune FC to induce FDS

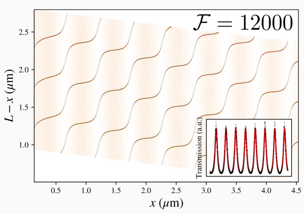
FC t_{in} and Δ tuned to resonator

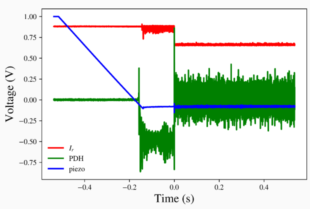




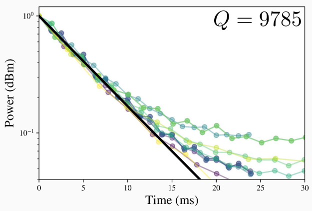
Experimental results

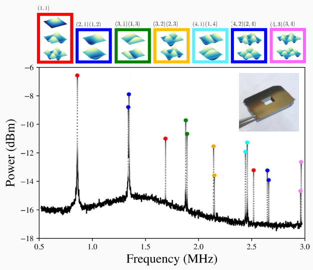
Automated with PyRPL API : calibration, scans, locks, ringdowns



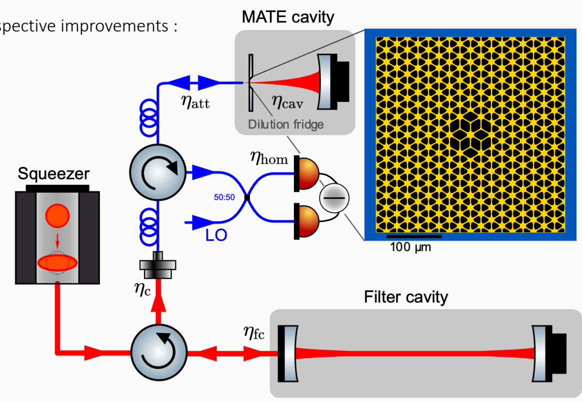


- can lock cavity on any working point
- optical + mechanical characterisation

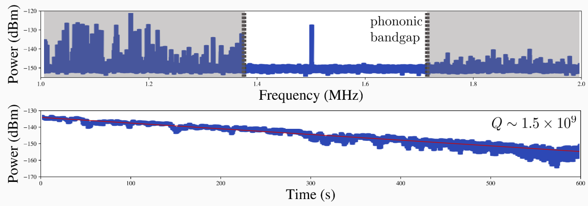




Prospective improvements :



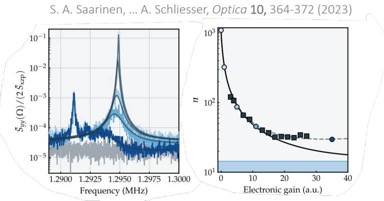
from Y. Seis, ..., A. Schliesser, *Nature Com.* **13**, 1507 (2022)



Perspectives

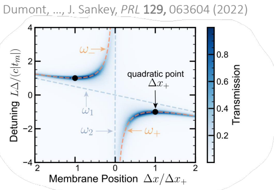
Cooling experiments

S. A. Saarinen, ... A. Schliesser, *Optica* **10**, 364-372 (2023)



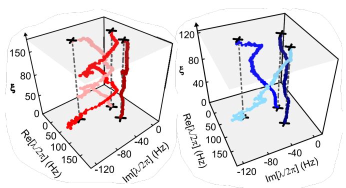
Quadratic optomechanics

V. Dumont, ..., J. Sankey, *PRL* **129**, 063604 (2022)



Non-Hermitian optomechanics

Y.S.S. Patil, ..., J.Harris, *Nature* **607**, 271-275 (2022)



P61

Calculating New Entanglement Measures in Matrix Product States

P62

Multipartite entanglement structure of monitored random quantum circuits

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We characterize the multipartite entanglement structure of monitored random quantum circuits using the quantum Fisher information [1]. We show that, despite the known phase transition in bipartite correlations, the multipartiteness is bounded. On the other hand, we generate a phase with extensive multipartite entanglement under symmetry preserving random operations by introducing two-qubit measurements. We focus on the limit where no unitary operations are applied, but there is a competition between two noncommuting projective measurements. We exploit a map to bond percolation to precisely calculate the universal scaling of multipartite entanglement.

[1] Arnau Lira-Solanilla, Xhek Turkeshi, Silvia Pappalardi, (2024), arXiv:2412.16062.

P63

Paired Parton Trial States for the Superfluid-Fractional Chern Insulator Transition

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We consider a model of hard-core bosons on a lattice, half-filling a Chern band such that the system has a continuous transition between a fractional Chern insulator (FCI) and a superfluid state (SF) depending on the bandwidth to bandspacing ratio. We construct a parton-inspired trial wavefunction ansatz for the ground states that has remarkably high overlap with exact diagonalization in both phases and throughout the phase transition. Our ansatz is stable to adding some bosonic interactions beyond the on-site hard core constraint. We confirm that the transition is well described by a projective translation symmetry-protected multiple parton band gap closure, as has been previously predicted. However, unlike prior work, we find that our wavefunctions require anomalous (BCS-like) parton correlations to describe the phase transition and SF phase accurately.

[1] T. Lotrič and S.H. Simon, arXiv:2504.20139 (2025).

P64

Work Statistics and Quantum Trajectories: No-Click Limit and Non-Hermitian Hamiltonians

Abstract

We present a generalized framework for quantum work statistics in continuously monitored quantum systems that extends the conventional two-point measurement scheme to include the effects of multiple generalized measurements and post-selection of no-click trajectories. By deriving a modified generating function for work, our approach naturally incorporates non-Hermitian dynamics arising from quantum jump processes and reveals deviations from the standard Jarzynski equality due to measurement-induced asymmetries. We illustrate our theoretical framework by analyzing a one-dimensional transverse-field Ising model under local spin monitoring. In this model, increased measurement strength projects the system onto the no-click state, leading to a suppression of energy fluctuations and measurement-induced energy saturation, reminiscent of the quantum Zeno effect.

P65

Partial projected ensemble and spatio-temporal structure of information scrambling in quantum dynamics

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Understanding how quantum information spreads in many-body systems is crucial for characterizing different dynamical phases of matter like ergodic phase or many body localised(MBL) phase. In this work, we introduce the partial projected ensemble(PPE), a generalization of the projected ensemble introduced in the context of deep thermalisation in quantum many body systems [1, 2]. In this partial projected ensemble(PPE) we perform projective measurements on only one part of the bath and look at distribution of states in the subsystem of our interest and the fluctuations in it. We show how the fluctuations of the PPE captures the spatiotemporal profile of information spreading. We explicitly establish the results in a floquet circuit model both in the ergodic regime and many body localised regime, highlighting different scrambling profile in different dynamical phases. Moreover, we relate the PPE fluctuations to experimentally realisable quantities like local bit-string probabilities [3]. We also establish the late time fate of such PPE fluctuations exactly.

[1] Jordan S. Cotler, Daniel K. Mark et al., PRX QUANTUM **4**, 010311 (2023)
[2] Daniel K. Mark, Soonwon Choi et al., Phys. Rev. X **14**, 041051 (2024)
[3] Joonhee Choi, Adam L. Shaw et al., Nature **613**, 468–473 (2023)

Full distribution and large deviations of local observables in an exactly solvable current carrying steady state of a strongly driven XXZ chain

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Indian Institute of Science Education and Research, Pune 411008, India

Current carrying steady states of interacting spin chains exhibit rich structures generated through an interplay of constraints from the Hamiltonian dynamics and those induced by the current. The XXZ spin chain when coupled to maximally polarizing Lindblad terms (with opposite signs on either ends) admits an exact solution for the steady state in a matrix product state (MPS) form. We use this exact solution to study the correlations and distributions of local spin observables in the non-equilibrium steady state (NESS). We present exact expressions for spin correlators, entropy per site and scaled cumulant generating functions(SCGF) for distributions of local observables in the XX limit (Ising anisotropy $\Delta = 0$). Further, we use the exact MPS solution in $\Delta > 0$ regime, to calculate numerically exact entropy, correlations, as well as full distributions of spin observables in large systems. In systems where Δ is a cosine of rational multiple of π, we can numerically exactly estimate the large system limit of the SCGF and the large deviation/rate functions of local-z magnetization. For these, we show that the deviations of the SCGF, calculated in finite systems, from the asymptotic large system size limit decay exponentially with system size, however the decay rate is a discontinuous function of Δ. The x magnetization density shows a double peak structure at $\Delta \lesssim 1$ suggesting short-range ferromagnetic ordering in the x-direction similar to what was reported for the ground state of XXZ chain.

[1] Sandipan Manna and G. J. Sreejith. "Full distribution of local observables in an exactly solvable current carrying steady state of a driven XXZ chain." arXiv preprint arXiv:2409.10458 (2024). (To appear in PRE)

P67

SU(3) Fermi-Hubbard gas with three-body losses: symmetries and dark states

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Two and three-body losses are one of the most investigated mechanisms that can induce a many-body correlated open quantum dynamics in a fermionic degenerate gas. Particular attention in experimental and theoretical analyses has been devoted to the steady properties of the setup. In the case of two-body losses, the dissipative dynamics is known to generate many-body entangled steady-states due to total spin conservation [1, 2].

In this work, we focus on a SU(3) invariant fermionic gas trapped in a lattice and subject to one-site three-body losses. We show that steady-state properties, such as the total number of fermions remaining on the lattice, are ruled by the conservation of the two independent Casimir operators of SU(3). A basis of the Hilbert space which takes care of the symmetries of the system can be written in terms of semi-standard Young tableaux [3, 4]. We demonstrate what is the effect of a loss process on a state belonging to this relevant basis, unveiling the presence of a rich zoology of stationary states. We also derive a mean-field equation for the dynamics of the density of fermions, using the formalism of time-dependent generalized Gibbs ensemble [5, 6].

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P68

Entanglement dynamics and geometric phase in a dissipative two-atom non-linear Jaynes-Cummings model

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The Jaynes-Cummings model is a paradigmatic model for the study of interaction between light and matter. Its usefulness stems from its simplicity, and it has experimental applications. Recently, this model has seen renewed interest in quantum technologies because of the introduction of transmons as the leading architecture for quantum computing. Given the fact that the dynamics of both systems, transmons in superconducting circuits and a trapped atom described by the Jaynes-Cummings model, are essentially the same. This makes the study of such optical semiconducting cavities have interest and direct applications in quantum computing.

The main advantage of superconducting circuits over the other proposed architectures are their scalability and the range of coupling that can be reached. The second point is the main reason why these systems can mitigate some of the destructive effects induced by the environment. This last point is the focus of this work.

It is interesting to find an object or a quantity that is not sensible to the effects of the environment; a "quantum sensor" that given information on the system. A possible candidate is the geometric phase, related to the path made by the system in state space.

In this work we extend the Jaynes-Cummings model to two interacting qubits in a non-linear cavity. We study dynamics, entanglement between qubits and geometric phase in the presence of a zero-temperature environment.

We conclude that there are certain relations between the parameters of the problem that predict interesting behavior, where the geometric phase seems to be less affected by the environment. This is very useful for implementations on quantum circuits and information.

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P69

Abstract of poster: Quantum-geometric bounds in non-Hermitian systems

M. P. Matraszek[1,2], **W. Jankoswki**[1,2], **and J. Behrends**[1]

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Quantum geometry is closely linked to the topology of condensed matter systems. It was first introduced by Provost and Vallee[4], and helps relating different phenomena, such as polarization fluctuations and susceptibility fluctuations(!) in extended systems [6, 2]. The geometric properties lead to appearance of bounds in Hermitian systems [3, 2], in particular on the energy gap.

While our current understanding of the quantum geometry is mostly limited to closed quantum systems, recent works have extended the geometry to open systems effectively described by a non-Hermitian Hamiltonian [5]. In this work, motivated by geometry-induced bounds in Hermitian systems, we study bounds in various non-Hermitian generalizations of the quantum geometric tensor. We applied our findings to establish relationship of right-right, left-left and mixed quantum geometric tensors (QGTs) as well as to the response functions of wave-packets in non-Hermitian systems [1] and response functions of open quantum systems described by quadratic Lindbladians [7].

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P70

Topological SU(N) Physics and Geometric Quantum Noise

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Wess-Zumino (WZ) terms are topological contributions to the Lagrangian of quantum systems, arising from the geometry of the phase space and encoding important topological features in systems with non-trivial internal symmetries, such as SU(N). Geometric quantum noise, on the other hand, refers to the stochastic noise terms that appear in the equations of motion due to the quantum fluctuations in dissipative environments, which are influenced by the presence of geometric phases in the form of WZ terms. In particular, the geometric contribution to stochastic processes can modify the behavior of quantum systems at low temperatures, such as the diffusion of magnetization on the Bloch sphere in the case of SU(2). This way, in a first part, we'd like to present a detailed formalization of the topological features of WZ-terms in the light of the topological index, expressed as either the Chern number or winding number, as well as a complete derivation of Geometric Quantum Noise through an introduction to the Keldysh model and the field theory of out-of-equilibrium systems.

In the second part of this work, and within the context of SU(N) physics, we first consider the role of higher SU(N) groups in magnetism, particularly in the large-N limit of antiferromagnetic models, which exhibit unique phase transitions and topological effects, including spin-Peierls and valence-bond-solid orders. As we will see, these models offer insights into alkaline earth metals and the study of Mott insulators with enhanced SU(N) symmetry, where topological order and chiral spin liquids emerge. Finally, we investigate entanglemons—quantum bits derived from entangling internal degrees of freedom in SU(4) systems—and briefly touch on the experimental realization of artificial SU(3) non-Abelian gauge fields via coupling resonant lasers to ultracold atoms.

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P71

Universal Counterdiabatic Driving

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[1] Boston University

Local counterdiabatic (CD) driving provides a systematic way of constructing a control protocol to approximately suppress the excitations resulting from changing some parameter(s) of a quantum system at a finite rate. However, designing CD protocols typically requires knowledge of the original Hamiltonian a priori. In this work, we design local CD driving protocols in Krylov space using only the characteristic local time scales of the system set by e.g. phonon frequencies in materials or Rabi frequencies in superconducting qubit arrays. Surprisingly, we find that convergence of these universal protocols is controlled by the asymptotic high frequency tails of the response functions. This finding hints at a deep connection between the long-time, low frequency response of the system controlling non-adiabatic effects, and the high-frequency response determined by the short-time operator growth and the Krylov complexity. [1]

[1] S. Morawetz, A. Polkovnikov, *arXiv:2503.01952* (2025).

P72

Electroluminescence Driven by Electron Transport in Molecular Junctions

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In this work, we investigate the electroluminescence effect in a molecular junction driven by a tunneling current as in a scanning tunneling microscope setup. Recent studies [1,2] have shown promising results in this line. Here, we model a molecular junction using a time-linear nonequilibrium Green's function (NEGF) formalism [3] to study the electroluminescence on the benzenedithiol molecule connected to two copper electrodes and coupled to a cavity. Our current approach treats electron-electron interactions within the molecule at the Hartree-Fock level, while electron-photon coupling is explored via the Ehrenfest approximation. We focus on the photonic and electric responses in order to describe the electroluminescence in the system under weak and intermediate effective couplings. Our calculations are performed with CHEERS code [4], which implements quantum transport simulations based on NEGF. By clarifying the conditions under which electroluminescence can be detected, we aim to provide a fundamental understanding of electron dynamics in out-of-equilibrium molecular junctions.

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P73

Exceptional stationary state in a dephasing many-body open quantum system

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The eigenstate thermalization hypothesis (ETH) [1] is a cornerstone of condensed matter physics, offering a simple and physical framework to explain the emergence of thermal features in the late-time dynamics of closed quantum systems. Nevertheless, the presence of rare eigenstates, known as quantum many-body scar states, that escape thermalization and violate ETH have been recently pointed out in relevant physical systems. While for closed systems these exceptional eigenstates have been thoroughly studied, their counterparts in open dynamics have been less explored.

In this work [2], we study a dephasing many-body open quantum system that hosts, together with the infinite-temperature state, another additional stationary state, that is associated with a non-extensive strong symmetry. This state, that is a pure dark state, is exceptional in that it retains memory of the initial condition, whereas any orthogonal state evolves towards the infinite-temperature state erasing any information on the initial state.

We discuss the approach to stationarity of the model focusing in particular on the fate of interfaces between the two states. A simple model based on a membrane picture helps developing an effective large-scale theory, which is different from the usual hydrodynamics since no extensive conserved quantities are present. The fact that the model reaches stationary properties on timescales that diverge with the system size, while the Lindbladian gap is finite, is duly highlighted. We point out the reasons for considering these exceptional stationary states as quantum many-body scars in the open system framework.

[1] M. Srednicki, Journal of Physics A: Mathematical and General, **32**, 1163 (1999).
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ymTFT out of equilibrium: 1d Floquet systems as boundaries of 2d topological order

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Introduction

- SymTFT is a framework to capture universal features of quantum many-body systems by viewing them as a boundary of topological order in one higher dimension.
- We use SymTFT to study systems *out-of-equilibrium*, focusing on one-dimensional (1D) periodically driven i.e. Floquet systems and their 2D SymTFTs.
- Floquet systems are characterized by the Floquet unitary, which is the time evolution operator over a period:

$$U_F = \exp(\ i \int_0^T dt H(t)), \quad H(t+T) = H(t) \tag{1}$$

Abelian anyon model

Anyons

flux-charge composite anyons $(g, \ )$ with flux $g \in G$ and charge $\ \in$ Rep G [the set of irreducible representations $\chi \ : G \to U(1)$ of G]

Fusion

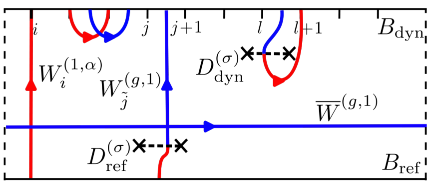
Fusing $a = (g, \ )$ with $b = (g', \ ')$ yields $ab = (gg', \ \ ')$ where $\chi \ \ ' = \chi \ \chi \ '$.
The antianyon of a is thus $\bar{a} = (g^{\ 1}, \ \ ^{1})$,

Braiding & exchange phases

Encircling a with b yields braiding phase $e^{i2\theta_{ab}} = \chi \ (g')\chi \ '(g)$, while exchanging two a gives $e^{i\theta_{aa}} = \chi \ (g)$.

Framework

- Our 1D system is embedded on the top gapped boundary B_{dyn} of a 2D topological order on a cyliner.
- The anyon strings $W_i^{(1,\ )}$ serve as local order parameters in 1D. The non-contractible loops winding around the cylinder $\overline{W}^{(g,1)}$ are global symmetry operators.



1D algebra & phases

- The operators for the 1D system consist of string operators W_{ij}^a with both endpoints i, j at B_{dyn}.
- For every B_{dyn}, there exists a subset of anyons $\mathcal{A}$, such that every $a \in \mathcal{A}$ condenses there and $b \notin \mathcal{A}$ creates an excitation. Choices of $\mathcal{A}$ then correspond to phases in the 1D system.
- Example $G = \ _2$: the symmetric algebra is generated by $W_{i,i+1}^e = Z_i Z_{i+1}$ and $W_{i\ 1,i}^m = X_i$. The order paramter is $W_i^e = Z_i$ and global symmetry, $\overline{W}^{(m)} = \Pi_k X_k$.

Twisted boundary conditions

- Inserting a string $W_{\tilde{j}}^{(g,1)}$ into B_{dyn} g-twists the boundary conditions.
For $G = \ _2$, this can be seen via: $W_{\tilde{j}}^{(m)} W_{k,k+1}^{(e)} W_{\tilde{j}}^{(m)\dagger} = (\ 1)^{\delta_{jk}} W_{k,k+1}^{(e)}$; thus $W_{\tilde{j}}^{(m)}$ takes $Z_k Z_{k+1} \to \ Z_k Z_{k+1}$ for $k = j$.

1D Floquet drives

- 1D Floquet unitaries can be expressed as:

$$U_{\mathsf{F}}^{(b,\mathcal{A})} = \overline{W}^{(b)} e^{\ iH} e^{\ iH_0^{(\mathcal{A})}}. \tag{2}$$

$H_0^{(\mathcal{A})}$ is a local G-symmetric Hamiltonian with mutually commuting terms, built from anyons a in a Lagrangian subgroup $\mathcal{A}$ of the topological order. $\mathcal{A}$ sets the eigenstate order. H_1 adds local G-symmetric perturbations.

Need for disorder

The perturbations in H_1 along with disorder in $H_0^{(\mathcal{A})}$ leads to many-body localization (MBL) which is a prerequisite for the existence of non-trivial phase structure and helps them avoid the fate of generic Floquet systems, i.e. heating up to infinite temperature.

Time Crsytal (TC) ymTFT

Consider $G = \ _2$ and the fixed-point time crystal unitary $U_{\mathsf{F}}^{(m,\langle e \rangle)} = \overline{W}^{(m)} e^{\ iH_0^{(e)}}$.

Spatiotemporal order

Using the evolution of the local order parameter for $t \in \ $ cycles :

$$W_i^{(e)}(t) = \ U_{\mathsf{F}}^{(m,\langle e \rangle)\dagger}]^t W_i^{(e)} \ U_{\mathsf{F}}^{(m,\langle e \rangle)}]^t = e^{\ 2it\theta_{em}} W_i^{(e)} \tag{3}$$

one can show that the correlator $C_{ij} = \langle n | W_{ij}^{(e)} | n \rangle$ evolves under time as:

$$C_{ij}(t) = \langle n | W_i^{(e)}(t) W_j^{(e)} | n \rangle = (\ 1)^t C_{ij}(0). \tag{4}$$

and hence shows period-doubled long range a.k.a. spatiotemporal order.

Spectral multiplets

For an eigenstate $|n\rangle$ with quasienergy ε_n, there is another eigenstate $W_i^{(e)} |n\rangle$ at quasienergy $\pi \ \ \varepsilon_n$ (mod 2π). This arises due to

$$U_{\mathsf{F}}^{(m,\langle e \rangle)} |n\rangle = e^{\ i\varepsilon_n} |n\rangle \tag{5}$$

$$U_{\mathsf{F}}^{(m,\langle e \rangle)} W_i^{(e)} |n\rangle = e^{2i\theta_{em}} e^{\ i\varepsilon_n} W_i^{(e)} |n\rangle \tag{6}$$

where the braiding phase $e^{2i\theta_{em}} = e^{i\pi}$. Hence we see π spectral pairing.

Dual TC order

- Consider the 0πPM phase with unitary $U_{\mathsf{F}}^{(e,\langle m \rangle)} = \overline{W}^{(e)} e^{\ iH_0^{(m)}}$. Since this is the electric-magnetic dual of the TC, one can study the correlator

$$C'_{ij}(t) = \langle n | W_i^{(m)}(t) W_j^{(m)} | n \rangle , \tag{7}$$

which can be evaluated via:

$$W_i^{(m)}(t) W_{\tilde{j}}^{(m)} = \ U_{\mathsf{F}}^{(e,\langle m \rangle)\dagger}]^t W_{ij}^{(m)} \ U_{\mathsf{F}}^{(e,\langle m \rangle)\prime}]^t, \tag{8}$$

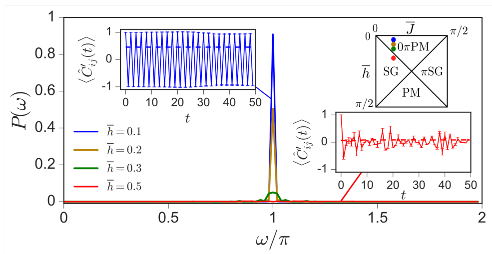
where $U_{\mathsf{F}}^{(e,\langle m \rangle)\prime}]$ has boundary conditions twisted (APBC) w.r.t $U_{\mathsf{F}}^{(e,\langle m \rangle)}$.

- Therefore, the PM eigenstates show period doubled long range order in

$$C'_{ij}(t) = (\ 1)^t C'_{ij}, \quad \text{with } C'_{ij} = \langle n | W_{ij}^{(m)} | n \rangle \tag{9}$$

when considering the PBC and APBC evolution simultaneously.

- Below we see the dual TC correlations for different points in the phase diagram. $P(\omega)$ is the power spectrum of $\langle \hat{C}'_{ij}(t) \rangle$ showing a sub-harmonic peak corresponding to the period doubling.



Absolute stability of π spectral pairing

- As a consequence of the electric-magnetic duality the dual TC also inherits the π pairing seen in the TC but now between different boundary conditions (PBC & APBC), instead of symmetry sectors.
- This pairing is absolutely stable i.e. robust against both $\ _2$ and $\tilde{\ }_2$ symmetry breaking perturbations. See further discussion in Ref.[5].

Conclusions

- We demonstrate how to study 1D Floquet systems via SymTFT.
- We interpret the period-doubling in the $\ _2$-time-crystal as arising from the braiding phase of e and m anyons of the toric code.
- By considering the full (PBC + APBC) Hilbert space of the boundary, we show that the 0πPM phase shows *dual* time-crystalline order.

Acknowledgements

This work was supported by a Winton and an EPSRC Studentship and by EPSRC grant EP/V062654/1.

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P75

High fidelity control of a many-body Tonks-Girardeau gas with an effective mean-field approach

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Shortcuts to adiabaticity (STA) are powerful tools that can be used to control quantum systems with high fidelity. They work particularly well for single particle and noninteracting systems which can be described exactly and which possess invariant or self-similar dynamics. However, finding an exact STA for strongly correlated many-body systems can be difficult,as their complex dynamics may not be easily described, especially for larger systems that do not possess self-similar solutions. Here, we design STAs for one-dimensional bosonic gas in the Tonks-Girardeau limit by using a mean-field approach that succinctly captures the strong interaction effects through a quintic nonlinear term in the Schrödinger equation. We show that for the case of the harmonic oscillator with a time-dependent trap frequency, the mean-field approach works exactly and recovers the well-known STA from literature. To highlight the robustness of our approach, we also show that it works effectively for anharmonic potentials, achieving higher fidelities than other typical control techniques

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P76

Emergence of Quantum Spin Liquids from Atom-Cavity Interactions

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Neutral atoms individually trapped in arrays of optical tweezers and featuring strong, controllable Rydberg interactions have emerged as a leading platform for quantum information processing and the exploration of synthetic quantum matter. More recently, there have been efforts to integrate optical tweezer arrays with high-finesse optical cavities (see *Figure 1*). The long- or even infinite-range flip-flop interactions between atoms mediated naturally by cavity photons are quite distinct from the short-range Ising interactions mediated by direct Rydberg interactions. From a quantum information processing perspective, the addition of cavities to the tweezer array toolbox brings new opportunities in terms of increased connectivity or the potential to connect distant quantum processors over long distances. However, the question of what novel paradigms might emerge for synthetic quantum matter (and/or light) has hardly been explored.

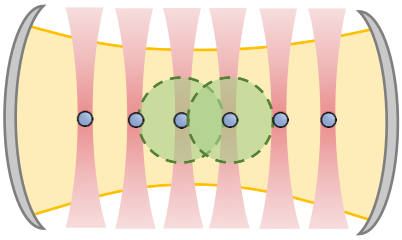

Figure 1 – Illustration of Rydberg atoms in an optical tweezer array inside of a cavity.

In Reference [1], we propose that tweezer-cavity systems can serve as a novel paradigm to prepare and investigate topological quantum spin liquids (QSLs). Notably, the cavity-mediated interactions are chosen to be antiferromagnetic and therefore, the ground state is a global singlet with no magnetic ordering. Topological QSLs, which for example are predicted to emerge as the ground states of certain frustrated spin models, have a host of interesting properties. For example, two QSLs might be in distinct phases but still not break any symmetry (rotational, spatial) of the system, and thus require a new concept (topological order) beyond Landau's concept of symmetries to characterize phases and phase transitions. Furthermore, QSLs contain excitations that carry fractional spin and non-trivial statistics, and at low energies are characterized by an emergent lattice gauge theory.

All of these low-energy properties of QSLs hold true for short-range interacting models, as typically encountered in condensed matter physics. However, in our proposed setup spatial locality is not guaranteed as the cavity can mediate the exchange atomic excitations regardless of the distance. Despite the all-to-all coupling, in the strong cavity regime locality (in the low-energy sector emerges) as the full model is projected into a short-range Heisenberg model. Because of this correspondence, the tweezer-cavity platform hosts a QSL provided that the Heisenberg model does. Crucially, although the ground state is a QSL described by a short-range Hamiltonian, its spin-1 excitations remain elusive due to the complexity of the full long-range frustrated model.

Beyond the realization of a QSL as the ground state of our cavity system, we also discuss several other intriguing aspects of our model. These include a novel transition out of the "QSL" phase into the "squeezed Néel" phase and the apparent presence of "partial" Lieb-Robinson bounds due to the emergent locality within individual decoupled global spin sectors.

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P77

Sequential quantum circuits as maps between quantum many-body scars in Rokhsar-Kivelson models.

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In this work, we investigate a phase transition between scar subspaces in a particular Z_2 symmetric Hamiltonian, analogous to the transition between the ordered/disordered phases of the transverse-field Ising model (TFIM). This transition is dictated by self-duality, enforced by the Kramers-Wannier (KW) duality operator. We focus on a class of models that admit a stochastic matrix form decomposition, where scar states correspond to so-called square root states, providing useful analytical tools for their study; in particular, we employed computations using Matrix Product States (MPS) representations. Moreover, the presence of sequential quantum circuits (SQCs) connecting these states indicates a non-invertible symmetry at a self-dual point, which signal the presence of the quantum critical point.

P78

Recoil-free control of optical qubit beyond the Lamb-Dicke regime

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When we drive an atom by laser, the atom can absorb or emit a photon, which imparts momentum to a motional mode of the atom. The corresponding phenomenon is called photon recoil and can be described by the Hamiltonian below under the rotating wave approximation (RWA):

$$\frac{H_{\mathrm{RWA}}(t)}{\hbar} = \omega a^\dagger a + \Omega(t)[e^{i\varphi(t)+i\eta(a+a^\dagger)}\sigma_+ + \mathrm{H.c.}].$$

Here, $a, a^\dagger$ are annihilation/creation operators of the motional mode and σ_-, σ_+ play the same role for an internal two-level system. In a neutral-atom qubit with microwave clock states, the wavenumber k_L of the driving is much smaller than the inverse of the zero-point fluctuation amplitude of the motional state ($x_0 = \sqrt{\hbar/2m\omega}$) so that we can assume the Lamb-Dicke parameter $\eta = k_L x_0$ to be negligibly small. Then, the internal degree of freedom and the motional mode of the atom are decoupled, hence the problem reduces to controlling the two-level system. However, for atomic qubits with transition frequencies in the optical range, the problem becomes much more complex since the wavenumber corresponding to the transition frequency is not sufficiently small compared to $1/x_0$. Then, the photon recoil plays an important role in the dynamics. This is attributed to the decoherence of the qubit state [1].

The elementary method to mitigate this problem is by using an effective motional sideband cooling so that the atom barely moves in the trap. However, in practice, one cannot perfectly suppress the motional sideband by cooling. Alternatively, we may mitigate this error by pulse shaping. In the Lamb-Dicke regime, where $e^{i\eta(a+a^\dagger)} \simeq 1 + i\eta(a + a^\dagger)$, such a pulse shaping method has been proposed recently [1]. However, when the motion of the atom is not small enough or the trap depth is too shallow to use the Lamb-Dicke approximation, new methods are required.

We propose a new pulse protocol to implement an arbitrary $R_x(\theta), R_y(\theta)$ gate beyond the Lamb-Dicke regime. The gate time is $T_\omega = 2\pi/\omega$. This protocol only changes the internal state while preserving the motional state of the atom. We can perfectly suppress the decoherence due to the photon recoil under the model Hamiltonian. Our method was motivated by the spin-motion entangling operation [2] and the two-qubit gate protocol for the ion-trap qubit platform [3]. Potentially, our gate protocol can be also applied to the optical transition in quantum state shelving for mid-circuit measurement operations [4]. As a future direction, we envisage exploring pulse shaping beyond the RWA to enable gate times even shorter than T_ω.

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P79

Localization and Tunability of ^{4}He Inside Pre-plated Nanopores

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Low dimensional quantum fluids, where one can probe the effects of enhanced thermal and quantum fluctuations on macroscopic quantum wavefunctions, can be experimentally realized through transverse confinement of superfluid helium.[1, 2] However to observe truly 1D behaviour numerical simulations [4] indicate the need for confinement to be engineered on scales smaller than the coherence length. Reaching this scale is difficult, requiring physical confinement in single or multiple pores with nanometer radii. Porous silicates such as MCM-41[3] have a pore radius larger than the coherence length of 4 He, and in this work we systematically explore the possibility of pre-plating pores with other elements to reduce the pore size without localizing the confined superfluid. Through direct solution of the few-body Schrodinger equation combined with quantum Monte Carlo, we explore a wide range of preplating elements, including rare gases and alkali metals. Our intuition is guided by previous studies of helium wetting on two dimensional solid surfaces and the experimental result that helium fails to wet the surface of cesium, instead forming a phase separated state of discrete ^{4}He droplets at the boundary.[5][6] For rare gases, we find that the density of a helium core inside the pore is nearly constant, but a Cs coating prevents localization near the walls and presents a platform to realize a tunable one-dimensional quantum liquid.

This work was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Award Number DE-SC0024333

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P80

Super-Heisenberg scaling of the Quantum Fisher information using spin-motion states

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We propose a spin-motion state for high-precision quantum metrology with super-Heisenberg scaling of the parameter estimation uncertainty using a trapped ion system. Such a highly entangled state can be created using the Tavis-Cummings Hamiltonian which describes the interaction between a collective spin system and a single vibrational mode. Our method relies on an adiabatic evolution in which the initial motional squeezing is adiabatically transferred into collective spin squeezing. In the weak squeezing regime, we show that the adiabatic evolution creates a spin-squeezed state, which reduces the quantum projective noise to a sub shot noise limit. For strong bosonic squeezing we find that the quantum Fisher information follows a super-Heisenberg scaling law $\propto N^{5/2}$ in terms of the number of ions N. Furthermore, we discuss the spin squeezing parameter which quantifies the phase sensitivity enhancement in Ramsey spectroscopic measurements and show that it also exhibits a super-Heisenberg scaling with N. Our work enables the development of high-precision quantum metrology based on entangled spin-boson states that lead to faster scaling of the parameter estimation uncertainty with the number of spins.

P81

Random Transverse Field Effects on Magnetic Noise in Spin Systems

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Motivated by experimental developments in non-Kramers spin ice materials and the unclear role of disorder therein, we study the impact of random transverse fields on the dynamics of correlated magnetic systems. We model the effect of dilute, randomly placed transverse fields on quantities such as magnetic noise/susceptibility and the diffusivity of topological excitations. We consider a random ferromagnetic Ising chain (RTFIC) as well as three-dimensional spin ice. At low temperatures, both exhibit (sub-)diffusive defect dynamics, i.e., of domain walls and magnetic monopoles, respectively. Introducing sparse transverse fields leads to the emergence of an additional timescale on the order of the single-spin flip time. We develop a Lindbladian framework that combines Monte Carlo simulations and exact diagonalization which allows us to characterize the dynamics and develop an analytical understanding of the phenomenon. This framework can be benchmarked in detail for the RTFIC. Our findings provide insights into the magnetization dynamics of disordered non-Kramers oxides, such as oxygen-diluted Ho2Ti2O7, and offer a framework for interpreting experimental observations in these systems.

P82

Kinetic magnetism in the crossover between the square and triangular lattice Fermi-Hubbard models

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We calculate the spin correlations that result from the motion of a single dopant in the hard-core Fermi-Hubbard model, as the geometry evolves from a square to a triangular lattice. In particular, we consider the square lattice with an additional hopping along one diagonal, whose strength is continuously varied. We use a high-temperature expansion which expresses the partition function as a sum over closed paths taken by the dopant. We sample thousands of diagrams in the space of closed paths using the quantum Monte Carlo approach of Raghavan and Elser [1], which is free of finite-size effects and allows us to simulate temperatures as low as $T \sim 0.3|t|$ even in cases where there is a sign problem. For the case of a hole dopant, we find a crossover from kinetic ferromagnetism to kinetic antiferromagnetism as the geometry is tuned from square to triangular, which can be observed in current quantum gas microscopes. We propose other correlation functions that can elucidate the nature of this kinetic magnetism and are also readily observable.

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P83

1 Abstract

We investigate the emergence of the topological dipole at the interface between distinct fractional quantum Hall (FQH) phases within the composite fermion framework. Employing the Chern-Simons Hartree-Bogoliubov approximation, we construct composite fermion wavefunctions and analytically demonstrate the presence of a topological dipole at the interface of equal filling-factor states in a class of multilayer Jain sequence states. This result holds in the absence of spectral transfer — that is, when each momentum mode is occupied by the same number of composite fermions, though band occupancy is not fixed. We argue that spectral transfer is expected under realistic conditions, and thus disrupts the formation of the topological dipole. Extending our analysis, we consider boundaries between $(p+ip)^{l_1}$ and $(p+ip)^{l_2}$ paired composite fermion states at filling $\nu = \frac{1}{2}$, and find that the composite fermion picture predicts the breakdown of the topological dipole at the interface between Pfaffian and anti-Pfaffian states. Furthermore, we show that the edge confining potential modifies the edge current and thereby alters the dipole moment. To support our analytical findings, we propose a numerical study using the density matrix renormalization group (DMRG) method.

P84

Measurement-induced phase transitions in quantum inference problems and quantum hidden Markov models

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Recently, there is interest in coincident 'observable-sharpening' and 'learnability' transitions in monitored quantum systems. In the latter, an outside observer's ability to infer properties of a quantum system from measurements undergoes a phase transition. Such transitions appear to be related to the decodability transition in quantum error correction, but the precise connection is not clear. In this work, we study these problems under one framework we call the general quantum inference problem. In cases such as above where the system has a Markov structure, we say that the inference is on a quantum hidden Markov model. We show a formal connection to classical hidden Markov models and that the two coincide for certain setups. For example, we prove this for those involving Haar-random unitaries and measurements. We introduce the notion of Bayes non-optimality, where parameters used for inference differs from true ones. This allows us to expand the phase diagrams of the above models. At Bayes optimality, we obtain an explicit relation between 'observable-sharpening' and 'learnability' order parameters, explicitly showing that the two transitions coincide. Next, we study concrete examples. We review quantum error correction on the toric and repetition code and their mapping to 2D random-bond Ising model (RBIM) through our framework. We study the Haar-random $\mathrm{U}(1)$-symmetric monitored quantum circuit and tree, mapping each to inference models that we call the planted SSEP and planted XOR, respectively, and expanding the phase diagram to Bayes non-optimality. For the circuit, we deduce the phase boundary numerically and analytically argue that it is of a single universality class. For the tree, we present an exact solution of the entire phase boundary, which displays re-entrance as does the 2D RBIM. We discuss these phase diagrams, with their interpretations for quantum inference problems and rigorous arguments on their shapes.

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P85

Energy dynamics in a class of local random matrix Hamiltonians

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Random matrix theory yields valuable insights into the universal features of quantum many-body chaotic systems. Although all-to-all interactions are traditionally studied, many interesting dynamical questions, such as transport of a conserved density, require a notion of spatially local interactions. We study the transport of the energy, the most basic conserved density, in few-body and 1D chains of nearest-neighbor random matrix terms that square to one, which we dub the "Haar-Ising" local random matrix model. In the few-body but large local Hilbert space dimension case, we develop a mapping for the energy dynamics to a single-particle hopping picture. This allows for the computation of the energy density autocorrelators and an out-of-time-ordered correlator of the energy density. In the 1D chain, we numerically study the energy transport for a small local Hilbert space dimension. Throughout, we discuss the density of states and touch upon the relation to free probability theory. We identify a succinct conjecture that will play a crucial role in generalizing analytical results to the full 1D Haar-Ising chain in future work.

P86

Two dimensional coherent spectroscopy as a probe of fractionalisation

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Two-dimensional coherent spectroscopy (2DCS) promises to provide clear signatures of fractionalised continua, otherwise obfuscated in linear response, a vital tool in the hunt for quantum spin liquids (QSLs). We investigate how this technique may be applied to promising material candidates for quantum spin liquid ground states: the dipolar-octupolar rear earth pyrochlore magnets.

We demonstrate how control of probe field polarisation can be used to explore the properties of fractionalised spinons and conventional magnon excitations within dimension-reduced chain phases of these magnets when they are placed in an external magnetic fields.

We also investigate how the emergent gauge fields of quantum spin ice can be probed through their influence on spinon dynamics through non-linear spectroscopy. Spinon behaviour is found to be markedly different between a low temperature regime where the gauge field behaves coherently, and an intermediate regime where it behaves as a static classical background. We demonstrate that 2DCS can distinguish this classical from the quantum behaviour, and also distinguish different QSL phases at low temperature.

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Joint observables induced by indirect measurements in cavity QED

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A fundamental feature of quantum mechanics is that there are observable pairs that cannot be measured jointly, such as observables corresponding to position and momentum or spin direction measurements [1]. However, unsharp versions of non-jointly measurable observables may become jointly measurable [2]. In this work, we investigate the joint measurability of time-continuous observables emerging from indirect time-continuous measurements. In particular, we study a paradigmatic situation where a qubit is interacting with a mode of light in a cavity and the light escaping the cavity is continuously monitored. We find that the properties of the observables can be tuned by changing the type of the monitoring scheme or by tuning the initial state of the cavity. In partic- ular, we demonstrate that heterodyne measurements is a joint measurement of a noisy homodyne measurement of pair of canonical quadratures. Moreover, we investigate the purity of the induced qubit observables as a function of the noise.

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P88

Abstract: Robustness of superradiance to decoherence

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When an ensemble of N identical emitters is confined in a volume smaller than λ³, where λ is the wavelength of the emitted light, the light cannot distinguish the emitters, and therefore leads to a collective coupling with the light mode. The emitters synchronize their dipoles, developing large correlations, and begin to coherently emit their excitation in the light mode. This leads to N times faster emission and an equivalent increase in emission intensity, known as superradiance, i.e. coherent spontaneous emission [1].

Solid-state emitters collectively coupled to light — such as nano-spheres or nano platelets — are inevitably immersed in a finite-temperature environment introducing dephasing. This destroys correlations between the dipoles of the emitters, and therefore it is detrimental for collective emission phenomena such as superradiance. **This raises the question whether superradiance can survive the presence of individual dephasing**.

By exploiting the existence of an efficient numerical solution for systems with permutational invariance [2], in this work we study the collective emission property of large ensembles of emitters, both in the case of an excitation pulse, as well as under continuous incoherent pumping. In both situations, we observe that superradiance survives up to a sizeable critical dephasing rate, comparable with the collective emission rate. The critical dephasing marks a sharp dynamical transition in the pulsed case; and a steady-state dissipative phase transition under continuous pumping. In both cases the critical point is characterized by a well defined scaling of the emission intensity, respectively $I \sim N^{4/3}$ and $I \sim N^{3/2}$, intermediate between the normal one $I \sim N$ and the superradiant one $I \sim N^2$.

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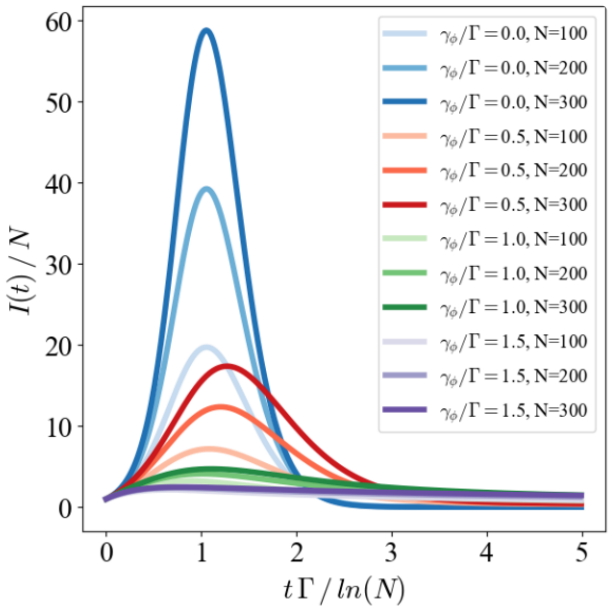

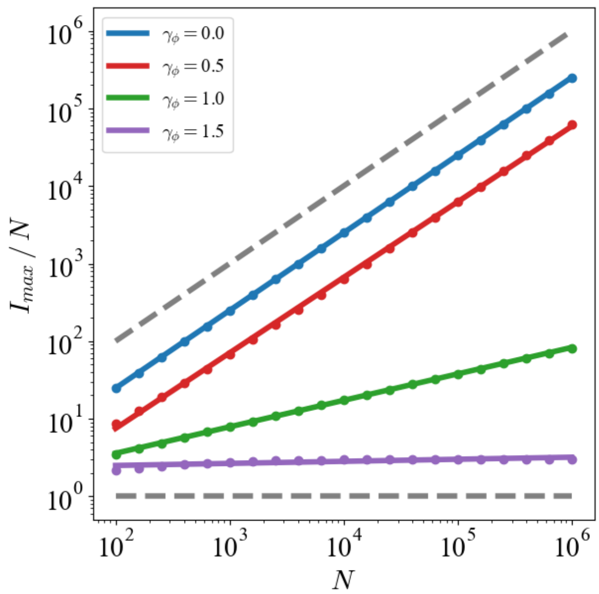

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Page curve-like dynamics in Interacting Quantum Systems

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We study the dynamics of entanglement in a one-dimensional XXZ spin-$1/2$ chain, with and without integrability breaking interactions, connected to a bath. We start from a state where the system and bath are completely unentangled, and the bath is empty. We consider two different initial states for the system - (i) a filled state, and (ii) an infinite temperature state. In the spin representation, the filled state corresponds to the polarized spin-up state, whereas, an empty state corresponds to a polarized spin-down state. Starting from these inhomogeneous quenched states, in all the above-mentioned cases we obtain the Page curve-like behavior in the entanglement. We report different power-law behavior in the growth of entanglement for different initial states and different kinds of baths (interacting and non-interacting). In an attempt to explore plausible deep connections between entanglement and Boltzmann entropy, we investigate the latter in both the filled and the infinite temperature case, for the system and the bath. For the filled case, the Boltzmann entropy of the system interestingly has the form of a Page curve but quantitatively deviates from the entanglement. On the other hand, the entropy of the bath keeps on increasing. Remarkably, for the infinite temperature case, we find that the system and bath Boltzmann entropies agree with the entanglement entropy, after and before the Page time respectively. Our findings are expected to hold for generic interacting quantum systems and could be of relevance to black hole physics.

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Superconductivity in two-dimensional heterostructures with spin-orbit coupling

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A magnetic field parallel to the plane of a 2DEG with Rashba Spin-orbit-coupling in proximity to a superconductor may lead to a topological phase with antichiral edge-states of copropagating Majorana fermions localized at the edges perpendicular to the magnetic field. We study the Josephson phase-current relation in junctions made of such topological superconductors, in order to look for signatures of this topological phase.

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P91

Exploring Phases in Copper Oxides: Numerical Data Fitting in Superconductivity Investigation

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Materials with strong electronic interaction, such as copper oxides, exhibit phenomena that emerge from this interaction, such as superconductivity. In addition to the superconducting phase, there are other phases of these systems that are not well understood, such as the pseudogap, where there is a suppression of spectral weight in certain directions in momentum space. A model that describes correlated systems is the Hubbard model, which does not have an exact solution in two dimensions. In previous work by the group, the Hubbard model was numerically solved using Dynamical Mean Field Theory, and two distinct metallic phases were found: the conventional phase and the pseudogap phase, by varying the system's doping. The current project investigates whether the two mentioned metallic phases give rise to distinct superconducting phases. For this purpose, we performed a fit of the numerical data using an analytical expression of a phenomenological model and analyzed how the model parameters differ between one superconducting solution and another.

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P92

Destabilisation of local magnetic anisotropy in heavy-fermion compounds and application to UTe2

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The magnetic anisotropy of a typical crystalline compound is often attributed to the combined effect of crystal electric fields and spin-orbit coupling [1]. We show that this simple picture is transformed in heavy-fermion compounds by the development of coherent electron scattering from local spin degrees of freedom. As the latter fractionalise and delocalise, they frustrate the magnetic anisotropy of the crystal by generating competing anisotropies in the effective moments and Curie-Weiss constants [1]. Collective and local forces oppose each other in determining the direction of dominant magnetic fluctuations. This frustration manifests itself through the reorientation of the crystal's magnetic easy axis as it transitions from the high-temperature paramagnetic regime to the low-temperature magnetically correlated regime. In agreement with our theory (an extension of Read-Newns theory to the underscreened Kondo lattice), we confirm that the temperature at which the reorientation takes place tracks the coherence energy scale across a wide range of actinide and lanthanide compounds [3,4]. In some compounds the frustration can be the beginning of a cascade of decreasing energy scales. Once the easy-axis changes, further growth of magnetic correlations with cooling can lead to a rapid quenching of the hard-axis susceptibility, which we capture theoretically. At even lower temperatures, the high-temperature easy axis is revealed via a metamagnetic jump when a high magnetic field is applied along it, and in some cases the jump leads to the destruction of superconductivity. This theory is applied to UTe_2 using a self-consistent classical Monte Carlo simulation with magnetic couplings determined by the large-N theory. Using this method, we are able to capture the metamagnetic jump in the magnetisation when a large magnetic field is applied along the hard axis and accurately reproduce the functional form of the magnetic susceptibilities, including the maximum in the low-temperature hard axis [5].

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The quantum triangular plaquette model in a longitudinal field

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We study the quantum Newman-Moore model, or quantum triangular plaquette model (qTPM), in the presence of a longitudinal field (qTPMz). We present evidence that indicates that the ground state phase diagram of the qTPMz includes various frustrated phases breaking translational symmetries, dependent on the specific sequence of system sizes used to take the large-size limit. This phase diagram includes the known first-order phase transition of the qTPM, but also additional first-order transitions due to the frustrated phases. Using the average longitudinal magnetization as an order parameter, we analyze the magnetization plateaus that characterize the ground state phases, describe their degeneracies, and obtain the qTPMz phase diagram using classical transfer matrix and quantum matrix product state techniques. We identify a region of parameter space which can be effectively described by a Rydberg blockade model on the triangular lattice and also find indications of topological order connecting the quantum paramagnetic and classical frustrated phases.

This poster is based on the following articles [1, 2].

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Study of Quantum Dimer Model using Group Convolutional Neural Network

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Quantum Dimer Models (QDM) were proposed in studies of high-temperature superconductors, specifically in the study of SU(2) singlet dominated phases in various spin models. QDM, originally introduced by Rokhsar and Kivelson, are among the simplest systems which exhibit ground-states with topological order and fractionalization. We study the QDM on square lattices of sizes upto 48×48 sites, with periodic boundary conditions, using state-of-the-art Neural Quantum States, particularly Group Convolutional Neural Network (GCNN), as the variational wavefunction. We first benchmark the GCNN results against Exact Diagonalisation calculations for small system sizes to validate its accuracy in computing the ground state properties. We then investigate various properties of the square-lattice QDM, viz. Ground state energy density, nematic order parameter, columnar order parameter, flip operator, dimer-dimer correlations. We also study the properties of the QDM ground state for various topological sectors, characterized by their winding numbers.

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Spin-charge-entangled Kondo effect induced by a side-coupled Majorana zero mode

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Numerical evaluation of the real-time photon-instanton cross-section in a superconducting circuit

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Instantons, semi-classical trajectories of quantum tunneling in imaginary time, have long been used to study thermodynamic and transport properties in a myriad of condensed matter and high energy systems. A recent experiment in superconducting circuits [1] provided first evidence for direct dynamical signatures of instantons (phase slips), manifested by order-unity inelastic decay probabilities for photons with which they interact, motivating the development of a scattering theory of instantons [2]. While this framework successfully predicted the measured inelastic decay rates of the photons for several experimental devices, it is valid only if the tunneling time of the instantons is much shorter than the relaxation time of the environment in which they are embedded, and requires a closed analytical expression for the instanton trajectory. In this work which will be presented [3], we amended these issues by incorporating numerical methods that lifted some of the previously applied approximations. Our results agreed with the experimental measurements, also for devices with shorter relaxation times, without fitting parameters. This framework should be useful in many other quantum field theoretical contexts.

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*Equal contribution

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Gapless Edge Gravitons and Quasiparticles in Fractional Quantum Hall Systems with Non-Local Confinement

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One of the central tenets of the theory of fractional quantum Hall systems is that the bulk quantized Hall response requires the existence of a gapless chiral edge mode. The field theoretical arguments for this rely on locality. While locality is typically met in standard experimental settings, it need not always apply. Motivated by experimental capabilities of photonic platforms[1], we study confining potentials that are step-like in angular momentum, and thus non-local in position. We show that this non-local potential does not host conventional chiral edge modes. These are replaced by gapless spin-2 edge states, which we show are connected to the collective 'graviton' excitations that are gapped in the bulk [2]. Furthermore, we show that FQH states host gapless (charged) quasiparticles on their edges, even in the absence of conventional edge modes.

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P98

U(2) Goldstone modes far from equilibrium

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We study the behaviour of Goldstone modes out of equilibrium, which arise due to the spontaneous symmetry breaking of U(2) polarization symmetry of exciton-polariton condensates [1]. Using the semi-classical limit of Keldysh field theory (the Martin-Siggia-Rose-Janssen-DeDominicis functional integral), we derive the minimal action for the Goldstone modes which parameterise the 3-sphere. We compare our results in the limit of thermal equilibrium to the known results for the U(2) non-linear sigma model.

Out of equilibrium, we observe that one of the Goldstone modes displays universal Kardar-Parisi-Zhang behaviour, unique to non-equilibrium physics. Using renormalization group methods we are able to find the equilibrium and non-equilibrium fixed points and derive associated scaling exponents. Additionally, we also investigate the emergence of vortices and other topological defects [2].

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P99

Real-Time Electron Dynamics for Electroluminescence: Bias-Driven Emission in Molecular Wires

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Modeling electrically driven luminescent devices at the atomic scale remains a fundamental challenge, as conventional electronic structure methods fail to describe electroluminescence—the radiative emission induced by bias and current flow. While semiclassical approaches (e.g., Maxwell–Bloch equations) cannot fully capture spontaneous emission [1] and rate equations rely on empirical transition probabilities [2], quantum electrodynamics (QED) methods, though rigorous, remain computationally intractable for realistic systems [3].

In this work, we apply a real-time electron dynamics framework that combines the Redfield formalism for a quantum photon bath with the driven Liouville–von Neumann scheme for biased open quantum systems, recently developed in our group [4]. We investigate the internal quantum yield of electroluminescence in poly(p-phenylene vinylene) (PPV) molecular wires—a cornerstone material for organic light-emitting diodes (OLEDs). Despite their technological ubiquity, the fundamental relationships governing electroluminescence efficiency in these systems—including the roles of applied bias, current density, molecular length, and lead coupling—have remained elusive.

Our mean-field tight-binding simulations reproduce key experimental observations such as band bending, while revealing new mechanistic insights: quantum efficiency is primarily governed by the circulating current, with longer wires outperforming shorter ones due to their increased density of emitting states at a given current. Notably, bias-induced charge redistribution and lead hybridization can create localized states with large transition dipole moments, demonstrating that the electroluminescence quantum yield is a complex, multi-factorial property. This work provides atomic-scale insights into the tunability of electroluminescence in molecular wires and establishes a foundation for designing efficient OLED materials.

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P100

Simulating Free Conformal Scalar on the Fuzzy Sphere via Tricriticality

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The quantum Hall ferromagnetic phase transition on the sphere, the so-called fuzzy sphere regularization, provides a powerful tool to tackle the (2+1)-dimensional conformal field theory. In this work, we consider the setup of a bilayer system and examine the tricritical point. On the one hand, our result provides a non-perturbative proof on the Gaussianity of the (2+1)-dimensional tricritical point. On the other hand, it provides a proof-of-principle that the fuzzy sphere regularization, being able to realize the free scalar, can be applied to simulate all renormalizable quantum field theories.

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Paraconductivity in Ultra-Thin NbN Films

Ultra-thin niobium nitride (NbN) films are key to superconducting technologies due to high kinetic inductance. This study examines how film thickness affects paraconductivity and superconducting properties.

NbN films (5 nm, 12 nm, 90 nm) were deposited via DC magnetron sputtering. Resistance versus temperature measurements characterized transition temperature (Tc), normal-state resistance (R_n), and dimensionality, assessed by comparing film thickness (d) to coherence length (ξ ≈ 7.6 nm). Excess conductance was analyzed using Aslamazov-Larkin (AL) theory. The 90 nm film showed the highest T_c (16.50 K), lowest R_n (24.40 Ω), and three-dimensional (3D) behavior (d > ξ) with sharp transitions. The 12 nm film indicated a transitional regime (T_c=14.3 K, R_n= 171 Ω, α = 0.86). The 5 nm film exhibited two-dimensional (2D) behavior (d < ξ), lowest Tc (5.60 K), highest R_n (436 Ω), and broadened transitions due to strong 2D fluctuations.

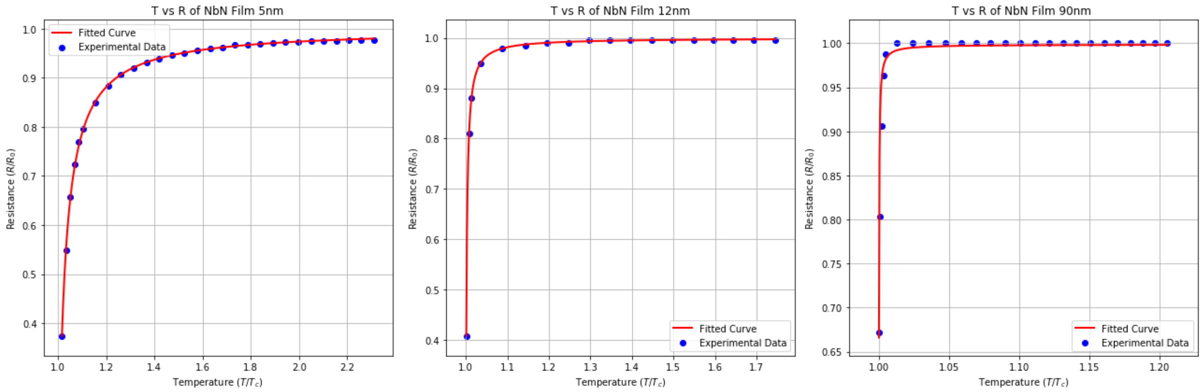

Figure 1 Normalized resistance (R/R0) vs. temperature (T/Tc) for NbN films (5 nm, 12 nm, 90 nm) with AL theory fits

These results align with paraconductivity theory. Ultra-thin films (5 nm) show strong 2D fluctuations, potentially increasing SNSPD noise, while thicker films (90 nm) exhibit stable 3D behavior. The 12 nm film suggests a crossover regime. Understanding paraconductivity aids in optimizing NbN-based devices for quantum technologies.

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The measurement-only toric code with fermions

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The non-unitary dynamics generated by stochastically measuring operators drawn from a set of local observables which do not all commute can give rise to interesting dynamical phases of matter, including topologically ordered, critical, and volume-law entangled phases. Here, we study such measurement-only dynamics of the toric code with short fermion strings. The stochastic dynamics can be described entirely in terms of the *frustration graph*, which captures the failure of operators to commute [1]. The frustration graph reveals a connection between the steady-state properties of this problem and that of the measurement-only Kitaev honeycomb model, which can be understood in terms of a Majorana parton description [2]. In the toric code, this description has an interpretation in terms of fermionic correlation strings. As the Kitaev model, the toric code model has a topologically ordered phase and a critical phase. In the critical phase, numerical evidence suggests fermionic correlations become long-ranged. We suggest an understanding of these correlations in terms of quasi-1D chains of fermion correlation strings, which wind around the torus.

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P103

Critical Behavior in One-Dimensional Spin Systems Through Robustness of Magic

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Robustness of Magic (RoM) characterizes the usefulness of a given quantum state for non-Clifford operations. RoM quantifies the classical simulation overhead and serves as a well-defined measure of nonstabilizernass (magic) for generic quantum states. It is computed by convex optimization over the set of all pure stabilizer states. In this contribution, we will present the application of RoM in many-body systems, focusing on the one-dimensional Ising model.

We will examine a tri-partitioned system of different sizes, where some degree of freedom will be traced out via quantum Monte Carlo (QMC), leaving two disconnected subregions. The density matrix of the full as well as reduced system is calculated by exact diagonalization and QMC method. Results on RoM and mutual-RoM as functions of the transverse field strength for the ground state and their finite-temperature behavior will be presented. Additionally, we will investigate the critical behavior through finite-size scaling governed by the power-law decay of the RoM.

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The advent of periodically driven systems has revolutionized modern condensed matter physics by offering two transformative opportunities. First, they allow the realization of nonequilibrium analogs of well-established equilibrium phases under highly tunable conditions. Second, they facilitate the emergence of novel phases with no equilibrium counterparts. In this work, we focus on the former, leveraging the tunable parameters of periodically driven systems to enhance the quantum metric in flat-band systems. The quantum metric, a fundamental geometric property of the band structure, plays a critical role in the formation of superconductivity in flat-band systems with attaractive density interactions. Here, we present preliminary results demonstrating how the interplay between periodic driving and electron correlations can amplify the quantum metric, leading to enhanced physical properties compared to the equilibrium case. These findings pave the way for designing quantum states and exploring the interplay of nonequilibrium dynamics and strong correlations in flat-band systems.

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Periodically and aperiodically Thue-Morse driven long-range systems: From dynamical localization to slow dynamics

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Driven quantum systems are a rich playground for interesting non-equilibrium quantum sta- tistical phenomena. Electric field-driven systems are a particular subclass that exhibit a wide range of novel features from the perspective of Floquet engineering [1]. In this poster, I will present our investigation on the electric-field driven power-law random banded matrix(PLRBM) model where a variation in the power-law exponent α yields a delocalization-to-localization phase transition [2]. We examine the periodically driven PLRBM model with the help of the Floquet operator. The level spacing ratio and the generalized participation ratio of the Floquet Hamiltonian reveal a drive-induced weak multifractal (fractal) phase accompanied by diffusive (subdiffusive) transport on the delocalized side of the undriven PLRBM model. On the localized side, the time-periodic model remains localized - the average level-spacing ratio corresponds to Poisson statistics and logarithmic transport is observed in the dynamics. Extending our analysis to the aperiodic Thue-Morse (TM) driven system, we find that the aperiodically driven clean long-range hopping model (clean counterpart of the PLRBM model) exhibits the phenomenon of *exact dynamical localization* (EDL) on tuning the drive-parameters at special points. The disordered time-aperiodic system shows diffusive transport followed by relaxation to the infinite-temperature state on the delocalized side, and a prethermal plateau with subdiffusion on the localized side. Additionally, we compare this with a quasi-periodically driven AAH model that also undergoes a localization-delocalization transition. Unlike the disordered long-range model, it features a prolonged prethermal plateau followed by subdiffusion to the infinite temperature state, even on the delocalized side.

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P106

Open quantum system modeling of an optically trapped nanoparticle

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We study an open quantum system model for a levitating nanoparticle trapped in an optical cavity by external optical tweezers. The model consists of two interacting quantum harmonic oscillators, one representing the particle's center of mass mode and the other the optical field inside the cavity, which interact with each other and an external environment. By studying the quantum properties of a relatively large particle in a highly controlled environment we aim to bridge the gap between quantum and classical physics.

We solve the dynamics of this system in a new way that works even for non-Gaussian states. Starting with the Gorini-Kossakowski-Sudarshan-Lindblad (GKSL) master equation for the density matrix of this system [1], we unravel it into the corresponding quantum state diffusion (QSD) equation for pure states. Using an ansatz for the pure states, we reduce the complicated QSD equation to a system of six partial differential equations for the state parameters.

Using this method we are able to solve many properties of interest for the system, including the expectation values of the system operators as functions of the state parameters, the steady state values for the squeezing parameters of the state, and the entanglement between the optical field and the mechanical mode of the nanoparticle.

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Signatures of chaos in the Yukawa-SYK model

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The Sachdev-Ye-Kitaev (SYK) model describes a strongly-correlated quantum many-body system consisting of N Majorana fermions with random all-to-all q-body interactions, exhibiting several intriguing properties. Notably, the SYK model displays maximal scrambling of mutual information and maximal quantum chaos. Additionally, the model is of significant interest in the context of the AdS/CFT correspondence, being holographically dual to Jackiw-Teitelboim gravity and sharing much of its interesting features with two-dimensional black holes.

Recently, a proposal has been put forward for the analog quantum simulation of the SYK model in a cavity QED experiment consisting of a cloud of fermionic atoms interacting with the eigenmodes of an optical cavity [1]. The cavity realizes long-range all-to-all fermion-fermion interactions, mediated by the exchange of virtual cavity photons. Furthermore, the interactions are randomized using an optical speckle pattern, approaching the SYK physics. This shows that the SYK model is within the reach of cQED-based experiments and a significant step forward in the search of holographic quantum matter. With this experimental proposal in mind, we investigate a generalization of the SYK model called the Yukawa-SYK (YSYK) model [2], incorporating a boson represented by the cavity photons in the experimental setup.

We analyze the chaotic nature of the model by numerically computing both static spectral properties, like the spectral form factor, and dynamic time evolution as given by the out-of-time-ordered correlations. We show through detailed numerics that as the role of the interactions is enhanced by increasing the mass of the bosonic modes, the YSYK model smoothly crosses over between single-particle chaos given by SYK_2 to many-body chaos of SYK_4.

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Multilicative Kitaev Chains

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Topological qubits composed of unpaired Majorana zero modes are under intense experimental and theoretical scrutiny in efforts to realize practical quantum computation schemes. In this work, we show that the minimum four *unpaired* Majorana zero modes required for a topological qubit according to braiding schemes and control of entanglement for gate operations are inherent to multiplicative topological phases, which realize symmetry-protected tensor products—and maximally entangled Bell states—of unpaired Majorana zero modes. We construct and characterize both one-dimensional and two-dimensional multiplicative topological phases with two parent Kitaev chain Hamiltonians. We furthermore characterize topology in the bulk and on the boundary with established methods while also introducing techniques to overcome challenges in characterizing multiplicative topology. In the process, we explore the potential of these multiplicative topological phases for an alternative to braiding-based topological quantum computation schemes, in which gate operations are performed through topological phase transitions.

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Magic spreading in doped Clifford circuits

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We study the spreading of magic, or nonstabilizerness, by evolving a stabilizer state with locally injected magic under Clifford circuits. We characterize the spatial extent of magic in classes of Clifford circuits where the growth behavior of entanglement entropy and operator strings are known. The dynamics of magic spreading in such circuits are numerically computed using both the Clifford-Augmented-MPS (CAMPS) method and stabilizer-based simulation, where various measures including the stabilizer Renyi entropy (SRE) and linear code distance are employed to quantify the amount of magic. We observe ballistic spreading of magic and compare the velocity of magic spreading to other velocity scales in the system, such as the entanglement velocity and the butterfly velocity. We also provide analytical explanation to the numerically observed dynamics.

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Halting the quantum Mpemba effect with long-range interactions

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Symmetry and spontaneous symmetry breaking (SSB) are foundational concepts in many-body physics, particularly in the Landau paradigm of equilibrium phase transitions. Recent work has extended these ideas to non-equilibrium quantum systems, where the interplay between symmetry and thermalization gives rise to novel phenomena such as the quantum Mpemba effect (QME)—the counterintuitive observation that more symmetry-broken initial states can exhibit faster symmetry restoration under unitary dynamics [1]. While the QME has been studied primarily in systems with unbroken continuous symmetries, its behavior in systems exhibiting SSB remains largely unexplored. In this work, we investigate the QME in the long-range spin-$\frac{1}{2}$ XXZ chain, a one-dimensional model known to undergo a $U(1)$ SSB transition as the interaction range increases [2]. By comparing the timescales of symmetry restoration across different interaction regimes, we characterize the robustness of the QME in proximity to the SSB transition, thereby elucidating the connection between non-equilibrium relaxation dynamics and equilibrium symmetry-breaking phases. Our results highlight the potential of long-range interacting systems—both as theoretical tools to circumvent the Mermin-Wagner theorem and as experimentally relevant platforms—for exploring rich non-equilibrium quantum behavior.

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Long-range correlations in a locally constrained exclusion process

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BandKAN: Leveraging Learnable Activation Functions for Accurate Bandgap Prediction