Measurement-invisible quantum correlations in scrambling dynamics

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If two parties have access to entangled parts of a quantum state, the common lore suggests that when measurements are made by one of the parties and its outcomes are classically communicated to the other party, it changes the state of the part accessible to the other party. Here we show that this lore is not necessarily true – in generic scrambling dynamics within a tripartite setting (with the R, S and E labelling the three parts), a new kind of dynamical phase emerges, wherein local measurements on S are invisible to one of the remaining two parts, say R, despite there existing non-trivial quantum correlations and entanglement between R and S. At the heart of this lies the fact that information scrambling transmutes local quantum information into a complex non-local web of spatio-temporal quantum correlations. This non-locality in the information then means that ignorance of the state of part E can leave R and S with sufficient information for them to be quantum correlated or entangled but not enough for measurements on S to have a non-trivial back-action on the state of R. This new dynamical phase is sandwiched between two conventionally expected phases where the R and S are either disentangled from each other or are entangled along with non-trivial measurement back-action. This provides a new characterisation of entanglement phases in terms of their response to measurements instead of the more ubiquitous measurement-induced entanglement transitions. Our results have implications for the kind of tasks that can be performed using measurement feedback within the framework of quantum interactive dynamics.

Title	**Spin injection route to the magnon Berry curvature dipole**
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Abstract of the Poster Presentation

Berry curvature of Bloch bands arising in lattice systems can induce a Hall response even in the absence of topology due to the so-called Berry-curvature dipole (BCD). Such a response is universal and, in principle, should occur as a thermal-Hall effect in magnon systems under the application of a temperature gradient. However, this effect intrinsically appears as a nonlinear (second-order) response to the temperature gradient making experimental detection difficult. Here we propose an alternate route to access BCD in magnons [1]. By utilizing the process of spin-injection in conjunction with a temperature gradient, we uncover two previously unreported contributions to the BCD-induced Hall response for magnons—one that is linear in temperature gradient and the other is nonlinear in the magnon chemical potential gradient arising from spin injection. As an added benefit of our approach, both these responses extract distinct moments of the genuine BCD distribution over the magnon bands, as opposed to the recently reported extended BCD in magnons. We use Boltzmann transport theory to derive the expression for the magnon-Hall response in the presence of a thermal gradient and spin injection. Furthermore, using this expression, we offer predictions for the BCD-induced magnon-Hall effect to be observed in experiments for ferro-, antiferro-, and ferrimagnetically ordered models on various lattices, including the honeycomb lattice, the kagome lattice, and the dice lattice.

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[1] Atul Rathor, Saurav Kantha, and Arijit Haldar, *Spin injection route to the magnon Berry curvature dipole*, Phy. Rev. B 110, 214441 (2024).

Noise-Induced Relaxation and Coherence Dynamics in a Bosonic Josephson Junction

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(Dated: April 18, 2025)

We investigate the dynamics of atomic and molecular bosons weakly coupled via Feshbach detuning in a standard Bosonic Josephson Junction (BJJ). The population imbalance between the two species is analyzed as a component of the Bloch vector. When the coupling strength and detuning are subjected to white Gaussian noise, the system exhibits relaxation of the Bloch vector toward a stable equilibrium. Under these conditions, the relaxation rates in the mean field (MF) approximation are found to be greater than those predicted by the Bogoliubov Born Green Kirkwood Yvon (BBGKY) hierarchy. Additionally, within the BBGKY framework, the fringe visibility quantified by the transverse length of the Bloch vector increases, while the Von Neumann entropy decreases, indicating enhanced coherence.

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[1] **Relaxation dynamics in a stochastic bosonic Josephson junction**
D. Stefanatos, and E. Paspalakis, Phys. Lett. A **383**, 2370-2375 (2019)

[2] **Decoherence and entanglement in a bosonic Josephson junction : Bose-enhanced quantum zeno control of phase diffusion**
Y. Khodorkovsky, G. Kurizki, and A. Vardi, Phys. Rev. A **80**, 023609 (2009)

[3] **Noise-Induced Relaxation and Coherence Dynamics in a Bosonic Josephson Junction**
A. Mukherjee, R.Dasgupta, Manuscript under preparation.

Stabilising Time Crystals through Non-Markovian Dynamics

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We study stabilizing discrete and continuous time crystals through non-Markovian dynamics. While time crystals in earlier works have primarily been explored in the Markovian regime, we demonstrate that non-Markovian dynamics can significantly enhance their stability in the presence of strong dissipation, over a wide range of parameter values. We present dynamical phase diagrams showing significant differences between the Markovian and non-Markovian regimes. In addition, the effects of non-Markovianity are also apparent in the associated quantum Fisher information. Our study highlights the crucial role of information backflow for making robust time crystals, and suggests the potential use of time crystals as probes for non-Markovianity in open quantum systems at long times.

Anderson localisation in spatially structured random regular graphs

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We study the localisation phase diagram of the Anderson model on random regular graphs (RRG) which are endowed with spatial structure. This is motivated by the heuristic connection between many-body localisation on the Fock space and Anderson localisation on high-dimensional graphs. The spatially structured hopping on the RRGs, that we introduce, can be thought of as a simple toy model for capturing rare, long-ranged resonances in the MBL problem which may lead to matrix elements between arbitrary pairs of sites on the Fock-space graph. To incorporate this into an RRG setting, we consider the situation where the hopping matrix element between any two nodes is finite but the magnitude typically decays with the distance between the nodes, with the distance set by the topology of the underlying RRG. Such family of models betrays a rich localisation phase diagram resulting from an interplay of the onsite disorder strength and the lengthscales which control the decay of the hopping matrix elements with the distance on the RRG. We uncover this phase diagram through a combination of numerical and analytical results. Our work can shed light onto how long-ranged resonances and their proliferation may drive the many-body localisation transition.

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Scaling theory for the collapse of a trapped Bose gas in an artificial magnetic field: a critical study at the condensation point

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Although Bose-Einstein condensate (BEC) had been predicted in 1924 by Albert Einstein and Satyendra Nath Bose, the atomic BEC in ultracold gases has been a subject of intense investigation since their proposal by Eric Cornell and Carl Wieman in 1995. In this work, we have analytically explored both zero and finite temperature scaling theory for the collapse of an attractively interacting 3D harmonically trapped Bose gas in an artificial magnetic field. We have considered short-range (contact) attractive inter-particle interactions and the Hartree-Fock approximation for the same. We studied the collapse of the condensate and the thermal cloud below and above the condensation point, respectively. We have obtained anisotropy, artificial magnetic field, and temperature-dependent critical number of particles for the collapse of the condensate. We have found a dramatic change in the critical exponent (from $\alpha = 1$ to 0) of the specific heat ($C_v \propto |T - T_c|^\alpha$) when the thermal cloud is about to collapse with the critical number of particles ($N = N_c$) just below and above the condensation point. Our findings shed light on the intricate interplay between the critical number of particles, critical exponent of specific heat, and artificial magnetic field within the finite temperature scaling theory, offering new avenues for theoretical exploration and experimental verification set-up for the ultracold systems in the magneto-optical traps.

Keywords: Bose-Einstein Condensation, Artificial Magnetic Field, Hartree-Fock Approximation, Critical Exponent of Specific Heat.

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From Chaos to Localization: Decoding Information Scrambling Through Eigenstate Correlations

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We present a unified picture for various diagnostics of the spatiotemporal structure of information scrambling, such as operator entanglement entropy, out of time ordered correlators, and two-point dynamical correlations, with eigenstate correlations involving quartets of eigenstates at the heart of the picture. Our analysis reveals that capturing the essence of information scrambling necessitates considering correlations among at least four eigenstates, and we identify the specific correlations that encode different measures of scrambling. To illustrate these ideas, we analyze (i) Floquet dual-unitary circuits—an exactly solvable class of models with maximal chaotic behavior—and derive exact analytical expressions for the relevant eigenstate correlations in chaotic systems [1], and (ii) many-body localized circuits, where these correlations provide a theoretical framework for the logarithmic entanglement light cone without invoking phenomenological l-bits [2,3]. Our results provide new insights into the microscopic underpinnings of quantum information scrambling and highlight the central role of eigenstate structure in quantum dynamics.

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Title - Floquet realization of prethermal Meissner phase in a two-leg flux ladder

Authors – Biswajit Paul, Tapan Mishra, K. Sengupta

Abstract - We show that a periodically driven two-leg flux ladder hosting interacting hardcore bosons exhibits a prethermal Meissner phase for large drive amplitudes and at special drive frequencies. Such a prethermal Meissner phase is characterized by a finite time-averaged chiral current. We find an analytic expression of these frequencies using Floquet perturbation theory. Our analysis reveals that the presence of the prethermal Meissner phase is tied to the emergence of strong Hilbert space fragmentation in these driven ladders. We support our analytical results by numerical study of finite-size flux ladders using exact diagonalization and discuss experiments using ultracold dipolar atom platforms that may test our theory.

Nonequilibrium dynamics and dissipative chaos in open anisotropic Dicke model

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Abstract: I will discuss the nonequilibrium dynamics of an atom-photon interacting system described by an anisotropic Dicke model in the presence of photon loss. Such systems provide an ideal platform to explore intriguing non-linear dynamical phenomena, including self-trapping phenomena, resulting in a photon population imbalance between the cavities, multistability of nonequilibrium phases, limit cycles, etc. These dynamical phases can be investigated both semiclassically, using stochastic differential equations, and fully quantum mechanically, by analyzing individual quantum trajectories through the stochastic wave-function method. Interestingly, the presence of a limit cycle can give rise to the formation of a time-crystalline phase. The absence of stable dynamical phases leads to the onset of chaos even in the presence of dissipation. Quantum signatures of this chaotic behavior can be identified by analyzing the statistical properties of the emergent steady state within the chaotic regime.

Interface-Driven Enhancement of Resistivity in Au-Ag Nanohybrids

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Abstract

Recent experiments on nanoclusters of silver (Ag) embedded in a gold (Au) matrix have reported a dramatic enhancement in electronic resistivity—both at zero temperature and in the linear-in-temperature regime—as the Ag volume fraction increases. Notably, at approximately 50% Ag concentration, the residual resistivity increases by a factor of 20 and the linear-T resistivity coefficient by nearly 40, relative to pure Au. While both Au and Ag are weakly coupled electron-phonon (EP) systems in bulk, these results suggest that a significant enhancement of EP coupling emerges at the Ag-Au interface.

To model this behavior, we construct two-dimensional nanocluster configurations with tunable Ag content and implement a Holstein model featuring weak EP coupling in the metallic interiors and strong coupling at interfacial sites. Employing an exact diagonalization-based Langevin dynamics approach, we compute the temperature-dependent resistivity across a range of configurations. Our simulations capture both the large residual resistivity and the $\sim$30-fold increase in the linear-T coefficient observed experimentally.

Crucially, we find that the interface is highly inhomogeneous: different segments contribute differently to static and thermal scattering. This spatial variation underpins the enhanced resistive response and highlights the critical role of interface engineering in nanoscale transport phenomena.

Transient behaviours of the Ising ferromagnetic thick cubic shell

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Abstract: We have investigated the nonequilibrium properties of an Ising ferromagnetic thick cubic shell through extensive Monte Carlo simulations. The study focuses on transient responses — specifically relaxation dynamics and metastable behaviour — and their dependence on shell thickness Δ. Exponential magnetic relaxation is observed for all values of shell-thicknesses, with the relaxation time $\tau_{\rm relax}$ decreasing as the thickness Δ increases. The variation of the relaxation time $\tau_{\rm relax}$ with shell-thickness exhibits three distinct regimes: (i) rapid fall region, (ii) plateau region, and (iii) linear region. The decay of the metastable state, another significant transient phenomenon, has also been analyzed in detail. The metastable lifetime $\tau_{\rm meta}$ as a function of external magnetic field follows the predictions of Classical Nucleation Theory, exhibiting three characteristic regimes: (1) strong field regime, (2) coalescence regime, and (3) nucleation regime. Interestingly, when studied as a function of shell-thickness, the metastable lifetime displays a non-monotonic variation, with a specific thickness corresponding to the maximum metastable lifetime.

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Chaos and Ergotropy: Dichotomy Across the Integrability-to-Chaos Transition

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How does chaos influence ergotropy—the maximum work that can be extracted from a quantum system through unitary evolution? This question is fundamental to quantum statistical physics. It also has practical relevance for quantum batteries, where charging and discharging involve energy storage and controlled work extraction. Understanding this interplay is crucial for optimizing energy extraction in chaotic quantum systems. We have demonstrated a dichotomy in the effects of chaos on ergotropy [1]. Since chaos generally enhances entanglement, one might naturally expect it to increase ergotropy as well. However, our findings reveal a more nuanced picture—chaos can either assist or inhibit ergotropy, depending on the observer's knowledge of the system. When the observer has full knowledge of the state, and an ancilla-assisted setup is used, chaos enhances ergotropy by leveraging entanglement growth.

However, when the state is partially unknown, two competing effects emerge—while chaos enhances ergotropy, it simultaneously obstructs state characterization through coarse-grained measurements. This interplay gives rise to an optimal balance, resulting in a sweet spot in the chaos parameter where maximal work extraction occurs. We demonstrate this phenomenon using standard quantum chaos models, the kicked top and kicked Ising chain. Additionally, we extend this idea to more general random matrix ensembles that exhibit a transition from integrability to chaos [2]. Our findings suggest that quantum chaos-assisted batteries could enhance energy extraction. While the chaotic regime is often viewed as detrimental to quantum computing, our results highlight its potential for next-generation energy storage devices, emphasizing the need for further exploration of chaos-assisted battery designs.

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Diagnosing chaos in open quantum systems and isolated many-body systems

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Abstract

Random Matrix Theory (RMT) is a useful tool to study statistical properties of chaotic and non-integrable quantum systems. Quantum chaotic systems with one-dimensional spectra follow spectral correlations of orthogonal (OE), unitary (UE), or symplectic ensembles (SE) of random matrices depending on their invariance under time reversal and rotation.However, open quantum systems are studied using non-Hermitian and non-unitary ensembles whose eigenvalues are distributed in the two dimensional complex plane.Based on the symmetry of matrix elements,we study ensemble of complex symmetric, complex asymmetric (Ginibre), and self-dual matrices of complex quaternions.We show that the fluctuation statistics of these ensembles are universal and quantum chaotic systems belonging to OE, UE,and SE in the presence of a dissipative environment show similar spectral fluctuations. We study the short range correlations using spacing distributions and long range correlations using number variance.We develop a mechanism to unfold a spectra with non-uniform density at a non-local scale and also evaluate the number variance.We find that both short-range and long-range correlations are universal. We verify all our findings on a prototype model of chaos known as quantum kicked top in a dissipative environment.

We also present some interesting results from the study of chaos in quantum many-body systems.We study out-of-time-ordered correlators (OTOC) for diagnosing chaos and information scrambling in disordered quantum spin chains.While the initial rate of change of OTOCs are algebraic for both integrable and chaotic systems, the late scrambling regimes (approach-to-saturation phase) are universal and can be used to distinguish between integrable and chaotic systems. We verify our findings on the random field Heisenberg XXZ model.

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Title of the Poster: Quantum Dynamics of a Spin Model with an Extensive Degeneracy.

Abstract:

In this poster, I present my recent research on quantum dynamics of a one-dimensional spin model having an extensive degenerate manifold of states for a specific value of one of the parameters of its Hamiltonian. The primary focus will be on the role played by extensive degeneracy in shaping the nature of the quantum dynamics of this type of model for both ramp and periodic drive protocols.

For the ramp protocol, this poster will emphasize the deviation from the usual Kibble-Zurek behavior when a linear ramp which takes the spin model through this degenerate point and the dramatic suppression of Stücklberg oscillations for a ramp that passes twice through the degenerate point. Additionally, results will also be presented showing how large degeneracy profoundly alters the dynamical signatures one would normally expect from a system having a quantum critical point.

The poster will also illustrate the periodic dynamics of the model and showcasing the results on existence of special drive frequencies for a large drive amplitude, at which the system exhibits an approximate emergent U(1) symmetry, and will also represent the effect of this emergent symmetry on the correlators of the driven system and demonstrate the existence of dynamic symmetry restoration at these frequencies.

The finding in the poster underscores the complex and rich unconventional quantum dynamic that emerges as a consequence of extensive degeneracy, and it also outlines potential experimental routes to explore and implement these effects using ultracold Rydberg atom setups.

Reference:

K. Ghosh, D. Sen, and K. Sengupta, "Quantum dynamics of a spin model with an extensive degeneracy," arXiv:2502.07609 [quant-ph] (2025).

Rydberg Atoms in a Ladder Geometry: Quench Dynamics and Floquet Engineering

Mainak Pal[1], **Madhumita Sarkar**[2] **K. Sengupta** [1] **and Arnab Sen**[1], **Tista Banerjee**[1]

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Over the past decade, Rydberg atom quantum simulator platforms have emerged as novel quantum simulators for physical systems ranging from condensed matter to particle physics. On a fundamental level, these platforms allow for a direct test of our understanding of the emergence of quantum statistical mechanics starting from the laws of quantum dynamics. In this poster, I focus on the fate of quantum dynamics in a model of Rydberg atoms arranged in a square ladder geometry, with a Rabi frequency 2Ω and a detuning profile which is staggered along the longer direction with amplitude Δ. As the staggering strength Δ is tuned from $\Delta/\Omega = 0 \to \infty$, the model exhibits a wide class of dynamical phenomena, ranging from (i) quantum many-body scars (QMBS) ($\Delta/\Omega \sim 0, 1$), (ii) integrability-induced slow dynamics and approximate Krylov fractures ($\Delta/\Omega \gg 1$) where the system only relaxes to the generalized Gibbs ensemble consistent with the emergent approximate conservation laws. Additionally, I shall show that by leveraging the underlying chiral nature of the spectrum of the Hamiltonian, it is possible to design Floquet protocols leading to dynamical signatures reminiscent of discrete time-crystalline order and exact Floquet flat bands. Finally, I discuss how these dynamical phenomena are affected when we deviate from the ideal model considered, such as accuracy of implementation of the Floquet protocols, long-range van der Waals interactions and inevitable influences from the environment in the form of pure dephasing and the finite lifetime of the Rydberg excited state.

[1] Mainak Pal, Madhumita Sarkar, K. Sengupta and Arnab Sen **Phys. Rev. B 111, L161101 (2025)**

[2] Mainak Pal and Tista Banerjee **(arXiv:2504.15230)**

Non-equilibrium Dynamics of S-wave Superconductivity and Charge Order in a Quenched Attractive Hubbard Model on a Square Lattice

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The non-equilibrium dynamics of superconducting (SC) systems are often studied within a self-consistent mean-field framework[1,2]. Previous studies have identified two key dynamical regimes based on the characteristic timescales of quasiparticle relaxation (τ_{qp}) and the superconducting order parameter (τ_{Δ}). The collisionless limit corresponds to $\tau_{qp} \gg \tau_{\Delta}$, whereas the adiabatic limit is defined by $\tau_{qp} \ll \tau_{\Delta}$. While many studies in the collisionless regime focus on momentum-space dynamics, they often overlook spatial variations that may arise in non-equilibrium conditions. Some recent works have addressed this gap by employing lattice-based models to explore real-space fluctuations.

Motivated by these considerations, we investigate the effects of a quench on the superconducting order parameter, with a particular emphasis on the behavior of the non-equilibrium quasiparticle population. Specifically, we explore (i) how this population modifies the energy landscape of the SC order parameter and (ii) its role in the system's thermalization process. Our approach is based on a mean-field description of the attractive Hubbard model on a square lattice, which captures the crossover from BCS to BEC pairing and is not restricted to the collisionless limit. Most of our analysis focuses on the half-filled case, where the system exhibits an emergent $O(3)$ symmetry, leading to a degenerate ground state between SC and charge-density wave (CDW) order. Upon doping, this degeneracy is lifted, and SC becomes the preferred ground state.

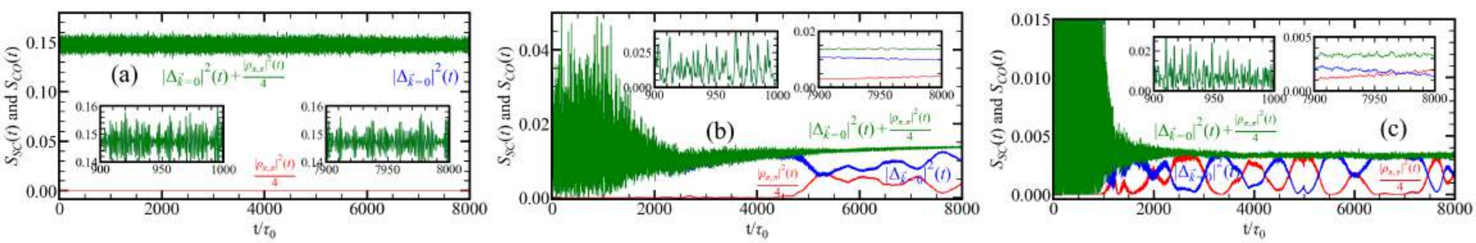
Our key findings[3] reveal distinct non-equilibrium regimes emerging as a function of quench strength. Following the quench, a non-equilibrium quasiparticle population forms and relaxes to a steady state within a characteristic time τ_{relax}. This population is well described by a Fermi distribution with an effective temperatureT_{qp}. However, the SC pairing field Δ_i exhibits a significantly lower effective temperature T_{Δ}, indicating a non-thermal steady state within this framework. Given this non-thermal state, we classify three distinct dynamical regimes at half-filling as the quench strength increases:

(i) The SC order parameter amplitude, $\Delta_{\text{amp}}=\frac{1}{N}\sum_{i}|\Delta_i|$, oscillates around a slightly reduced value.

(ii) Δ_{amp} exhibits a decaying envelope and saturates at a steady-state value.

(iii) Δ_{amp} fully decays to zero.

We provide an explanation for these results based on the non-equilibrium quasiparticle population and its influence on the SC order parameter dynamics.



Weak Quench | Intermediate Quench | Strong Quench

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3. Manuscript under process.

Cavity optomechanical detection of persistent currents in ring-trapped Bose-Einstein condensate

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We introduce a novel approach for detecting the rotation of persistent current in an annularly trapped Bose-Einstein condensate. Our method integrates the concepts of cavity optomechanics with atomic superfluid rotation, allowing for an in situ, in real-time, and minimally destructive detection of the condensate rotation. This is in contrast to currently used methods that completely destroy the condensate. Cavity optomechanics involves the coupling of mechanical motion to electromagnetic fields confined in resonators. By utilizing dispersive light-matter interaction, our approach facilitates minimally destructive measurements of persistent currents. Specifically, we consider a ring-trapped BEC interacting with an optical cavity mode that carries orbital angular momentum. The optical cavity induces Bragg scattering among the atoms in the condensate, leading to BEC density modulation due to the interference among different rotational states. The transmitted light from the cavity picks up these modulations, and the resulting cavity output spectrum reveals the winding number of the persistent current. We employ a mean-field stochastic Gross-Pitaevskii simulation technique to model the persistent current for weakly repulsive interatomic interactions. The cavity transmission spectra, which contain signatures of condensate rotation, are obtained. We also analyze the sensitivity of rotation measurement as a function of the system's response frequency that demonstrates the effectiveness of this optomechanical configuration as a rotation sensor, revealing that the best sensitivity of our method to the BEC rotation is three orders of magnitude better than other available proposals. Our method can have significant implications for characterizing rotating matter waves across various fields, including atomtronics, superfluid hydrodynamics, matter-wave soliton interferometry, and optomechanical sensing.

Name : Nilachal Chakrabarti
Affiliation : Indian Institute of Technology,Gandhinagar
Title: Dynamics of monitored SSH Model in Krylov Space:
From Complexity to Quantum Fisher Information
Abstract:
We have investigate the dynamics of a non-Hermitian Su-Schrieffer–Heeger model that arises out of the no-click limit of a monitored SSH model in the Krylov space. We find that the saturation timescale of the complexity associated with the spread of the state in the Krylov subspace increases with the measurement rate, and late time behaviour differs across the PT symmetry transition point. Furthermore, extending the notion of this complexity for subsystems in Krylov space, we find that the scaling of its late time value with subsystem size shows a discontinuous jump across the PT transition point, indicating that it can be used as a suitable order parameter for such transition but not for the measurement-induced transition. Finally, we show that the measurement-induced transition can be detected using a generalized measure in the Krylov subspace, which contains information about the correlation landscape, such as Quantum Fisher information, which also possesses some structural similarity with the complexity functional.

Measurement-induced phase transition in periodically driven free-fermionic systems

Presenter Name: Pallabi Chatterjee

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Abstract:

It is well known that unitary evolution tends to increase entanglement, whereas continuous monitoring counteracts this growth by pinning the wavefunction trajectories to the eigenstates of the measurement operators. In this work, we investigate the fate of the measurement-induced phase transition in a periodically driven free-fermionic quantum system, where the hopping amplitude is modulated periodically in time using a square pulse. In the high-frequency limit, a renormalization group analysis of the non-Hermitian quantum sine-Gordon model [as proposed in Phys. Rev. X 11, 041004 (2021)] reveals that if the hopping amplitude is varied symmetrically around zero, the system always favors the area-law phase, where the steady-state entanglement entropy is independent of subsystem size. In contrast, asymmetry in the drive amplitudes tends to promote entanglement growth, in excellent agreement with our numerical findings. Furthermore, numerical evidence for the system sizes accessible to us suggests that decreasing the drive frequency typically favors entanglement growth. As a function of the measurement strength, we observe a phase transition between a gapless critical phase—characterized by logarithmic growth of entanglement entropy with subsystem size—and a gapped area-law phase. These two phases are separated by a Berezinskii-Kosterlitz-Thouless (BKT) transition. The fluctuations in the steady-state entanglement entropy also tend to grow as the frequency decreases. However, in the case of a symmetric drive, the system consistently exhibits an area-law phase, regardless of the driving frequency.

References

Measurement-induced phase transition in periodically driven free-fermionic systems; Pallabi Chatterjee, Ranjan Modak; arXiv:2412.01917 (2024).

Insights from the analytical solution of a periodically driven transverse-field Ising chain

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Abstract

We present exact analytical solutions for the non-equilibrium dynamics of a periodically driven transverse field Ising chain after an arbitrary number (n) of drive cycles. Going beyond the conventional Floquet theory approach that is restricted to the asymptotic limit ($n \to \infty$), we obtain closed-form expressions for the time-evolved wavefunction and various observables including excitation probability, defect density, magnetization, and correlation functions. Our analysis reveals a universal decomposition of observables into transient oscillatory components and steady-state saturation values. The analytical framework, developed using properties of SU(2) matrices, enables us to: (i) identify specific driving frequencies that prevent dynamic freezing in the delta-kicked model, (ii) derive exact conditions for dynamical transitions in correlation functions, and (iii) compute the entanglement entropy numerically from correlation matrices. These results provide new insights into finite-time dynamics of driven integrable systems and establish a theoretical foundation for exploring more complex scenarios involving non-Hermitian or long-range interactions.

Reference: Pritam Das and Anirban Dutta, "Insights from the analytical solution of a periodically driven transverse-field Ising chain," *Phys. Rev. B* **111**, 045159 (2025).

Quantum Metrology with DTC Leveraging the LMG Model

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Quantum phase transitions have been shown to be highly beneficial for quantum sensing, owing to diverging quantum Fisher information close to criticality. In this work we consider a periodically modulated Lipkin-Meshkov-Glick model to show that discrete time crystal (DTC) phase transition in this setup can be beneficial for high-accuracy sensing of field strength. We employ a detailed finite-size scaling analysis to determine the critical properties of this second-order phase transition. Finally, by establishing the relationship between the critical exponents, we provide a comprehensive understanding of how quantum criticality in DTCs involving long-range interactions can be harnessed for advanced quantum sensing applications.

Collective Dynamics Of Active Particles In Confinement

Renu Parashar*, Sandipan Dutta†

Active matter comprises particles that self-propel by consuming energy. Unlike equilibrium systems, these particles exhibit a rich array of collective behaviors. This study focuses on the dynamics of Active Ornstein-Uhlenbeck Particles (AOUP) in the presence of an external potential.[1] Our goal is to elucidate the distinctions between the behavior of these active particles and their passive counterparts, particularly in terms of length and time scales.[2] Additionally, we aim to characterize the steady-state phases and collective dynamics arising in these systems under the influence of the external potential.[3]

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Title: Non-Fermi Liquid transport in a mesoscopic device via Topological Kondo effect.

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Abstract: Investigation of Non-Fermi Liquid (NFL) signature of transport, that is deviation from T^2 dependence of resistivity at low temperatures, is a highly active area of research. One major problem is that the NFL behavior occurs at extremely low temperatures and different perturbations can destroy the signature easily, hindering its stability at various experimental platforms. In this work, we provide a robust route to observe NFL transport behavior. Here, the NFL temperature dependence of resistivity occurs through a novel Topological Kondo effect (TKE), which arises due to coupling of conduction electrons and topologically degenerate Majorana fermions [2, 3]. One way to realize such TKE is by using mesoscopic superconducting device that can host Majorana bound states (MBS). Motivated by these, in this work [1] we propose a simple mesoscopic device made of $FeSe_{0.45}Te_{0.55}$ layer, containing magnetic domain walls. We show that this device has strong potential to host MBS. Next, connecting this device with external metallic leads, we show that indeed, in this setup one can achieve TKE at higher temperature, thus giving a more practical route to observe NFL transport. We also show that the TKE is robust against perturbation such as exchange anisotropy in coupling.

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Tittle: Many body localization and skin effect in Non hermitian Floquet systems

Abstract of poster: We have investigated many-body localization (MBL) and the many-body skin effect in non-Hermitian Floquet systems, an emerging and largely unexplored area of research. Our study reveals unique quantum phase transitions induced by frequency variations, a phenomenon that is fundamentally distinct and exclusive to non-Hermitian systems. These findings provide new insights into nonequilibrium quantum dynamics, highlighting the interplay between disorder, non-Hermiticity, and periodic driving.

Saptarshi Mandal

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Title: Partial Projected Ensemble and Spatiotemporal Structure of Information Scrambling

Abstract

Understanding how quantum information spreads and entangles in many-body systems is crucial for characterizing different dynamical phases of matter. The Projected Ensemble framework provides a powerful tool to study information dynamics by incorporating measurement-induced effects into entanglement evolution. Here, we introduce the Partial Projected Ensemble (PPE)—a refined approach that selectively applies projective measurements to subsystems while preserving coherent quantum evolution elsewhere. This enables a more fine-grained analysis of scrambling beyond traditional averaged quantities. We apply PPE to various dynamical settings, including ergodic, many-body localized (MBL) systems in a floquet circuit setup, revealing distinct spatiotemporal structures of information flow. We also relate the spatiotemporal structure of scrambling to experimentally realisable quantities like local bit-string probabilities. We also highlight the late time fate of such local measurement based construction for probing information scrambling in quantum dynamics.

Exact volume-law entangled eigenstates in a large class of spin models

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Exact solutions for excited states in non-integrable quantum Hamiltonians have revealed novel dynamical phenomena that can occur in quantum many-body systems. This work proposes a method to analytically construct a specific set of volume-law-entangled exact excited eigenstates in a large class of spin Hamiltonians. In particular, we show that all spin chains that satisfy a simple set of conditions host exact volume-law eigenstates in the middle of their spectra. Examples of physically relevant spin chains of this type include the transverse-field Ising model, PXP model, spin-S XY model, and spin-S Kitaev chain. Although these eigenstates are highly atypical in their structure, they are thermal with respect to local observables. Our framework also unifies many recent constructions of volume-law entangled eigenstates in the literature. Finally, we show that a similar construction also generalizes to spin models on graphs in arbitrary dimensions.

[1] S. Mohapatra and Ajit C. Balram, Exact volume-law entangled eigenstates in a large class of spin models, arXiv:2410.22773.

Shortcuts to adiabaticity in long-range open quantum critical systems.

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Shortcuts to adiabaticity (STA) is a control protocol that has been proposed to realize effectively adiabatic dynamics in quantum systems driven by Hamiltonians changing at a finite rate in time. In this work, we investigate the role of long-range interaction in designing shortcut to adiabaticity (STA) protocols for open quantum critical systems. Using the long-range Kitaev model, we show that both the strength of the non-unitary control fields and the associated cost of implementing STA decrease with increasing long-range interaction strengths, thus implying the inherent advantage associated with long-range interactions for control of quantum systems driven out of equilibrium. Finally, we extend our control protocol to an infinite-range, all-to-all interacting Lipkin-Meshkov- Glick model.

Transition from Integrability to Chaos in the XXZ Chain via ETH and Submatrix Analysis

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Abstract

The Eigenstate Thermalization Hypothesis (ETH) provides a framework for understanding thermalization in isolated quantum many-body systems by analyzing the structure of observable matrix elements in the energy eigenbasis. We investigate the transition from integrability to chaos in the spin-$1/2$ XXZ chain, perturbed by a local magnetic field, which breaks integrability and drives the system toward quantum chaos. This transition is probed through spectral correlations (both short- and long-range), ETH, and eigenstate entanglement entropy. Although correlations among matrix elements in an operator are crucial for dynamics, we show that submatrices extracted from the full local operator, written in the energy eigenbasis, exhibit random matrix-like properties in their statistical properties of matrix elements and spectral correlations. We study the crossover from integrability to chaos through the spectral correlations of submatrices taken from the local operator. These submatrices capture all transitions at the level of spectral fluctuations, both short-range through spacing ratio distributions and long-range via the spectral form factor, as well as in eigenstates through eigenstate entanglement entropy.

Keywords: Quantum chaos, Eigenstate Thermalization Hypothesis, Eigenstate entanglement entropy, Spectral statistics

Entanglement Generation in Periodically driven XY Model under Stochastic Resetting

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Stochastic resetting in classical stochastic or deterministic processes attracted much attention recently, which proves helpful tool in intermittent search processes (e.g. target search process with brownian motion). Recently, it extends to quantum domain as well. For quantum systems, it accounts for resetting the quantum state to its initial state (or, any other fixed state) at random times in course of time evolution. The stochastic average of density matrix at long time are very different and constitutes Non-Equilibrium Steady State(NESS). We have considered here periodically driven (Floquet) quantum system (XY model with transverse field) under stochastic resetting. Floquet systems are itself of interest as they cast the system out of equilibrium and gives NESS at long time. So, under resetting the NESS corresponding to r (reset rate)=0 gives back the NESS of floquet system without reset. We will mainly focus on the entanglement between two spin and its evolution under Poissonian resetting. And we will show in some cases, stochastic resetting is helpful to enhance the entanglement. For entanglement measurement, we will rely on calculation of concurrence , which is a measure of entanglement of formation for two-qubit mixed state. In the end, we will try to understand the relation between closed quantum dynamics under resetting and effective open quantum dynamics. We will show the renewal equation of density matrix under stochastic resetting can be obtained as a solution of generalized Lindblad Master Equation.

Quasi-Discrete Time Crystals in the quasiperiodically driven Lipkin-Meshkov-Glick model

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Abstract

A discrete time crystal (DTC) is a remarkable non-equilibrium phase of matter characterized by the persistent sub-harmonic oscillations of physical observables. Motivated by the question of whether such a temporal periodic order can persist when the drive becomes aperiodic, we investigate the dynamics of a Lipkin-Meshkov-Glick model under quasiperiodic Thue-Morse driving. Intriguingly, this infinite-range-interacting spin system can host "quasi- discrete time crystal" (quasi-DTC) phases characterized by periodic oscillations of the magnetization. We demonstrate that our model can host the quasi-DTC analog of both period-doubling DTCs as well as higher-order DTCs. These quasi-DTCs are robust to various perturbations, and they originate from the interplay of "all-to-all" interactions and the recursive structure of the TMS. Our results suggest that quasi-periodic driving protocols can provide a promising route for realizing novel non-equilibrium phases of matter in long-range interacting systems.

Statistical entropy of quantum systems

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Understanding the relationship between von Neumann (VN) entropy and thermodynamic (TH) entropy is a fundamental challenge in quantum statistical mechanics. For a quantum system in a random pure state, the average VN entropy of the subsystem scales as $\ln(D_1)$, where D_1 is the subsystem's Hilbert space dimension[1, 2]. We can strengthen this result for thermalized systems. The VN entropy of the subsystem, when averaged over the subspace $(\mathscr{H}_E)$ corresponding to the narrow energy shell $(E, E + \Delta E)$ of the full system, scales as $\ln\left(\widetilde{d_1}\right)$. Here, $\widetilde{d_1} = D_1^\gamma$ represents the effective Hilbert space dimension of the subsystem relevant to $\mathscr{H}_E$, with $\gamma = \ln(d_E)/\ln(D)$, D as the total Hilbert space dimension and d_E as the dimension of $\mathscr{H}_E$. This result demonstrates that the VN entropy of a subsystem in thermal equilibrium is equivalent to its TH entropy, providing a statistical interpretation of TH entropy in the subsystem of quantum systems. Numerical results from a one-dimensional spin-1/2 chain with next-nearest neighbor interactions confirm this scaling, bridging quantum statistical mechanics and thermodynamics [3].

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Investigating the Origin of the Non-uniform Phase in a Bosonic Rydberg System

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(Dated: April 4, 2025)

We have studied a two-level dissipative non-equilibrium bosonic Rydberg system in an optical lattice. We have described the system in terms of the collective behaviour of the atoms occupied in a single site. We have got the dynamical equations for the system with the help of the master equation and taking the mean filed approximation. Three different phases are found in terms of the Rydberg population across the sublattices: the uniform phase, the antiferromagnetic phase and the oscillatory phase. Then, we have proposed an order parameter to characterize those phases and plot it with the on-site interaction parameter, keeping all other parameters fixed. The origin of these three phases can be explained by exploring the stability of the fixed points of the system and also by studying the spatial correlation by semi-classical Monte Carlo simulation. Two types of fixed points are found for the system: three branches of the uniform fixed points and two branches of the non-uniform fixed points. The uniform phase comes from one stable branch of the uniform fixed points, and the antiferromagnetic phase comes from two stable branches of the non-uniform fixed points, here, one branch of the uniform fixed points is present, but it is unstable. In the oscillatory region, there are no stable fixed points, so population imbalance fluctuates a lot. We have studied the spatial correlation between two sites and have plotted the correlation with site differences for the three phases. We have found that the order of the correlation is different in the three different phases. The correlation is maximum in the antiferromagnetic phase and minimum in the uniform phase. The zigzag pattern of the correlation in the antiferromagnetic and the oscillatory phases shows that there is a positive correlation for even site difference and a negative correlation for odd site difference.

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Emergent symmetry assisted quantum Mpemba effect in a class of periodically driven systems

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Entanglement asymmetry is a probe of measuring the degree of a particular symmetry breaking, at the level of a subsystem through the entanglement entropy associated with it. In a non-equilibrium set up, such as quench, there are several works where one starts with an initial state that breaks a particular symmetry, and the system is then evolved via a symmetry preserving Hamiltonian. In such a set up, the symmetry is restored dynamically. There is also an observation of a counter intuitive effect, dubbed as the "quantum Mpemba effect", that demonstrates that for some initial states, more a symmetry is broken in the initial state, the faster it is restored under time evolution. From this viewpoint, the entanglement asymmetry, can also probe the proximity of the reduced density matrix of the subsystem to that of the equilibrium reduced density matrix (by imagining that the rest of the system is acting as a bath to the subsystem of interest). In this poster I will convey, how the dynamical restoration of emergent conservation laws that appear in a class of periodically driven closed quantum many-body systems, give rise to the "quantum Mpemba effect". In such systems, for some specific drive frequencies, the initial entanglement asymmetry decreases with time, and the symmetry is dynamically restored for a long metastable time scale, while, for other frequencies it saturates to a finite value. The presence of this long metastable timescale in these systems, can be understood from the presence of an approximate emergent symmetry in the corresponding Floquet Hamiltonian at these specific frequencies and in the high-drive-amplitude regime. The symmetry is exact in the first-order Floquet Hamiltonian at special frequencies whose quantitative values depend on the nature of the drive protocol. I will demonstrate this idea by considering two specific examples, one is the dynamical symmetry restoration in a driven integrable free-fermionic systems and the the other is the restoration of the emergent symmetry in a chain of periodically driven Rydberg atoms in the strong Rydberg blockaded regime.

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