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School on Quantum Many-Body Phenomena out of Equilibrium: from Chaos to Criticality | (SMR 3867)

21 Aug 2023 - 01 Sep 2023
ICTP, Trieste, Italy

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Criticality-Enhanced Quantum Sensing via Continuous Measurement

P02

Dynamical localization and slow thermalization in a class of disorder-free periodically driven one-dimensional interacting systems

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We study if the interplay between dynamical localization and interactions in periodically driven quantum systems can give rise to anomalous thermalization behavior. Specifically, we consider one-dimensional models with interacting spinless fermions with nearest-neighbor hopping and density-density interactions, and a periodically driven on-site potential with spatial periodicity m=2 and m=4. At a dynamical localization point, these models evade thermalization either due to the presence of an extensive number of conserved quantities (for weak interactions) or due to the kinetic constraints caused by drive-induced resonances (for strong interactions). We further study the decay behaviors of correlators for the period-2 model in the absence of interaction, which exhibit crossover between two different power laws. Our models therefore illustrate interesting mechanisms for generating constrained dynamics in Floquet systems which are difficult to realize in an undriven system.

[1] S. Aditya, S. Samanta, A. Sen, K. Sengupta, and D. Sen, Phys. Rev. B **105**, 104303 (2022).
[2] S Aditya, and D. Sen, arXiv: 2305.06056 (2023).

P03

First-order superradiant phase transition in magnetic cavities: A two-leg ladder model

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Recently, the existence of Dicke-like equilibrium superradiant phase transitions in cavity QED many-body system has been put into question — resulting in no-go theorems on spontaneous photon condensation. Specifically, the no-go theorems tells us that the superradiant phase transition is prohibited as long as a single-mode purely electrical vector potential is considered, with the transition being analogous to a magnetostatic instability. In this work [1] we consider a minimal setting beyond 1D – i.e., a two-leg ladder – where the orbital motion of spinless fermions is coupled through Peierls substitution to a non-uniform cavity mode which generates a fluctuating magnetic field. Thanks to the quasi-one dimensional geometry we are able to scrutinize the accuracy of (mean field) cavity-matter decoupling against large scale density-matrix renormalization group simulations and study light-matter entanglement properties as well as the exact cavity state. Our results show that ladder geometries can indeed photon condensation and in particular they serve as a first simple example of first-order photon condensation in a gauge-invariant scenario; highlighting how, in the quest for new photon condensed phases, looking for instabilities of the normal phase might be limiting.

[1] arXiv:2302.09901v2

P04

Dynamical signatures and steady state behavior of driven non-Hermitian Ising chain

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We study the dynamics of a class of integrable non-Hermitian free-fermionic models driven periodically using a continuous drive protocol characterized by an amplitude g_1 and frequency ω_D. We derive pertubative Floquet Hamiltonian for describing such systems using Floquet perturbation theory with g_1^{-1} being the perturbation parameter. The presence of an approximately conserved quantity at special drive frequencies is reflected in the dynamics of the fidelity, the correlation functions, and the half-chain entanglement entropy of the driven system. It also leaves its imprints on the nature of the steady state of the system. We show that one-dimensional transverse field Ising model, with an imaginary component of the transverse field, serves as an experimentally relevant example of this phenomenon. In this case, the transverse magnetization is approximately conserved; this conservation leads to complete suppression of oscillatory features in the transient dynamics of fidelity, magnetization, and entanglement of the driven chain at special drive frequencies. We discuss the nature of the steady state of the Ising chain near and away from these special frequencies, demonstrate the protocol independence of this phenomenon by showing its existence for discrete drive protocols.

[1] Tista Banerjee, K. Sengupta, Phys. Rev. B **107**, 155117

P05

Tunable Non-Fermi liquid behavior from electrons coupled to two-level systems

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We study a model of electrons coupled to dynamical two-level systems (TLSs) via spatially random interactions. In the limit of a large number of electron flavors and TLSs, we utilize an exact mapping to the Caldeira-Leggett (spin-boson) model, where particle-hole pairs constitute an Ohmic bath to each independent TLS. By considering the backaction of the TLSs, we find that the electrons' self-energy shows continuously varying exponents as a function of the interaction strength, interpolating between Fermi-liquid behavior at weak coupling; marginal Fermi-liquid at intermediate coupling and non-Fermi liquid at strong coupling.

P06

Dissipation dynamics in the ordered phase

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Model A is a simple theoretical model used to study critical non-equilibrium phenomena with non-conserved dynamics. It exhibits dynamical criticality near the second order phase transition where the relaxation time diverges, this behaviour is characterised by the dynamical critical exponent z. The relaxation rate in this model has physical relevance when interpreting effective potentials as input in dynamical transport simulations. We numerically solve coupled renormalisation group flows for the relaxation rate and the effective potential. Using finite-size scaling analysis, we extract the critical dynamic scaling exponent $z = 2.011$, which agrees within error with existing values from the literature. A detailed description and interpretation of how effective potentials and other inputs from renormalisation group calculations can be used in transport or relativistic hydro simulations.

[1] U. C. Tauber, Critical Dynamics: A Field Theory Approach to Equilibrium andNon-Equilibrium Scaling Behavior, (Cambridge University Press, 2014).

[2] L. Canet, H. Chate, and B. Delamotte, General framework of the nonperturbativerenormalization group for non-equilibrium steady states, J. Phys. A 44,495001 (2011).

P07

Preserving non-classical thermal correlations in a hybrid-spin system under random telegraph noise over a longer period

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The engineering features of transmitting mediums and their impact on different characteristics of a quantum system play a significant role in the efficient performance of nonlocal protocols. As such, the dynamics of open quantum systems and coupling mediums are crucial factors to consider. In this work, we investigate the dynamics of quantum correlations in a hybrid qubit-qutrit thermal state. We study its behavior when coupled with a magnetic field and influenced by random telegraph noise. Our investigation takes into account various features of the system parameters to design strategies for preserving qubit-qutrit correlations over longer periods. We observe that temperature has an inverse impact on the initial values of negativity, uncertainty-induced nonlocality, and local quantum Fisher information. Furthermore, the characteristics of the magnetic field lead to different dynamical maps for entanglement, nonlocality, and Fisher information, highlighting their distinct nature. Additionally, we find that the qubit-qutrit correlations undergo repeated revivals when the configuration is restricted to the non-Markovian regime, while in the Markovian regime of the coupled field, they experience an exponential drop with a single minimum. Importantly, our findings demonstrate that the present coupled fields offer several advantages for generating the optimal degree of entanglement, nonlocality, and local quantum Fisher information preservation in quantum dynamical maps.

P08

An effective field theory for out of equilibrium dissipative non-Abelian quantum systems

P09

Abstract for the "School on Quantum Many-Body Phenomena out of Equilibrium: from Chaos to Criticality"

Noise-induced transport in the one-dimensional disordered systems

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Non-equilibrium dynamics of quantum systems has been a topic of great interest in condensed matter and statistical physics, particularly in relation to the study of quantum transport. In this work, I will discuss the quantum transport in a one-dimensional disordered model induced by sparse coupling to a noise source. Such a setup closely mimics the rare inclusion in the disordered interacting system. I will discuss how different configurations of the noisy bath to the system leads to distinct transport regimes.

Three-stage thermalisation of a quasi-integrable system

P10

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Motivation

We study the dynamics of a hard rods (HR) system in the presence of external inhomogeneous fields. We consider both a trapping potential and a spacial dependent mass. This model is integrable [1, 2] and it has been shown to be described at large scale by the Generalized Hydrodynamics (GHD). Therefore, we characterize the relaxation dynamics of the system comparing it with the prediction of GHD [3].

Model

We consider a gas of har rods, namely identical billiard balls of a given radius a in one dimension that scatters elastically at each collision. We also consider external inhomogeneous fields $V_1(x)$ and $V_2(x)$ such that the single particle dynamics is described by the Hamiltonian

$$H(x,\theta) = \frac{\theta^2}{2}\big(1+V_2(x)\big) + V_1(x)\,, \qquad (5)$$

where θ are rapidities of the rods and the potentials V_1 and V_2 are defined as

$$V_1(x) = V_2(x) = \frac{1}{2}\cos\Big(\frac{2\pi x}{\ell}\Big)\,. \qquad (6)$$

The GHD equation

The GHD equation for a hard rods gas with external forces is [4]

$$\partial_t\rho + \partial_x(v^{\rm eff}\rho) + \partial_\theta(a^{\rm eff}\rho) = \frac{1}{2}\Big[\partial_x(\mathfrak{D}\partial_x\rho) + \partial_x(\mathfrak{D}_{\mathfrak{f}}\partial_\theta\rho) + \partial_\theta(\mathfrak{D}_{\mathfrak{f}}\partial_x\rho) + \partial_\theta(\mathfrak{D}_{\mathfrak{f}^2}\partial_\theta\rho)\Big]\,. \qquad (1)$$

Generalizing the argument presented in [5], we give a kinetic interpretation of the diffusive terms of equation 1 as diffusive corrections to ballistic particle spreading

$$\delta x^2(t) \equiv \langle x^2(t)\rangle^{HR}_{\mathbb{E}} - \big(\langle x(t)\rangle^{HR}_{\mathbb{E}}\big)^2 = t\,{\rm diag}(\mathfrak{D}) \qquad (2)$$

$$\delta x\delta\theta(t) \equiv \langle x(t)\theta(t)\rangle^{HR}_{\mathbb{E}} - \langle x(t)\rangle^{HR}_{\mathbb{E}}\langle\theta(t)\rangle^{HR}_{\mathbb{E}} = t\,{\rm diag}(\mathfrak{D}_{\mathfrak{f}}) \qquad (3)$$

$$\delta\theta^2(t) \equiv \langle\theta^2(t)\rangle^{HR}_{\mathbb{E}} - \big(\langle\theta(t)\rangle^{HR}_{\mathbb{E}}\big)^2 = t\,{\rm diag}(\mathfrak{D}_{\mathfrak{f}^2})\,. \qquad (4)$$

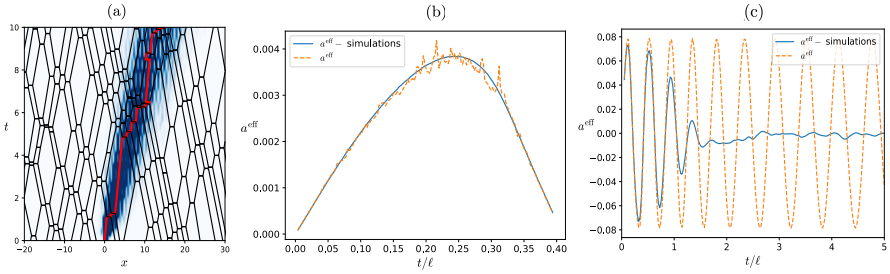
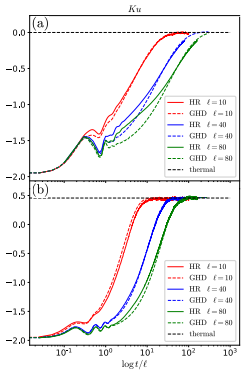


Figure 1: (a) Quasiparticles trajectories in a Hard rods gas. The red line is the trajectory of a test particle with fixed initial coordinates. The heatmap is the trajectory of the test particle averaged over 500 simulations. According to equation 2, the variance of this distribution is $t\,{\rm diag}(\mathfrak{D})$). (b,c) Effective acceleration of a test particle in a HR gas. The dashed line is the GHD effective acceleration. In (a,b) we used $V_1 = 0$ and respectively $\ell = 500$ and $\ell = 80$.

Numerical results for Hard rods dynamics



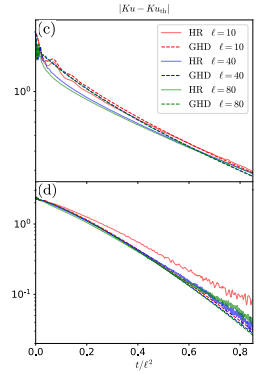


Figure 2: (a,b,c,d) Plot of kurtosis of the rapidty distribution for the HR system compared with the GHD prediction. Figures (a,c) and (b,d) respectively refer to cases $V_2 = 0$ and $V_1 = 0$. Dashed lines in (a,b) show the values of kurtosis of the intergrated density predicted by GHD for the thermal state.

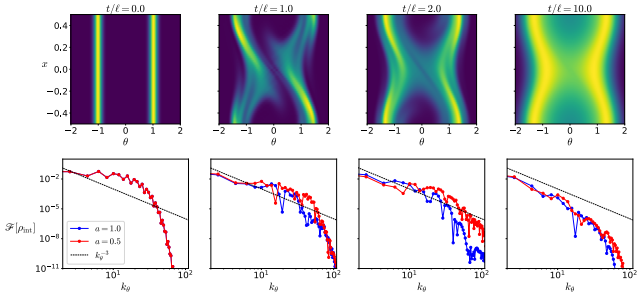


Figure 3: In the upper line we show the density functions $\rho(x,\theta,t)$ predicted by GHD equation for different times in the case $V_2 = 0$. In the lower line it is shown the Fourier transform of the density functions at $x = 0$. In these figures blue (red) dots are referred to the case with rods length $a = 1$ ($a = 1/2$).

Thermalisation stages

The thermalisation dynamics can be split into three main phases in time.

I) **Euler phase**
The integrability is not broken. The dynamics is well described by the Euler GHD equation.

II) **Turbolent phase**
Integrability is strongly broken. In this phase the Fourier transform of the distribution of velocities shows a power law decay. The GHD equation does not capture correctly the behaviour of the system, due to a gradient catastrophe in phase space.

III) **Thermalising phase**
Differently from what was previously stated in the literature [6], the system always thermalises as long as external fields are finite. In particular it approaches the thermal state exponentially in time. In this phase the GHD equation with diffusion and force terms correctly capture quantitatively the dynamics of the gas.

References

[1] C. Boldrighini, R. Dobrushin, and Y. M. Sukhov, "One-dimensional hard rod caricature of hydrodynamics," *Journal of Statistical Physics*, vol. 31, pp. 577–616, 1983.

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[3] B. Doyon and H. Spohn, "Dynamics of hard rods with initial domain wall state," *Journal of Statistical Mechanics: Theory and Experiment*, vol. 2017, p. 073210, jul 2017.

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[5] S. Gopalakrishnan, D. A. Huse, V. Khemani, and R. Vasseur, "Hydrodynamics of operator spreading and quasiparticle diffusion in interacting integrable systems," *Phys. Rev. B*, vol. 98, p. 220303, Dec 2018.

[6] X. Cao, V. B. Bulchandani, and J. E. Moore, "Incomplete thermalization from trap-induced integrability breaking: Lessons from classical hard rods," *Phys. Rev. Lett.*, vol. 120, p. 164101, Apr 2018.

P11

Quench dynamics of the sine-Gordon model in Rydberg atom arrays

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Rydberg atom arrays are a promising platform for analog quantum simulation due to their high flexibility and naturally arising dipole-dipole interactions. In particular, the SO(4)-symmetry of high-dimensional Rydberg manifolds has been proposed for the simulation of quantum field theories, a prominent example thereof being the sine-Gordon model [1]. In this work we further investigate the mapping between the lattice Hamiltonian and the arising continuum sine-Gordon quantum field theory in the limit of large spin length and large system size, and confirm the theoretically predicted relations between lattice parameters and field theoretic quantities. The Rydberg atom array further allows to simulate the non-equilibrium dynamics of the sine-Gordon model. With tensor-network techniques we prepare the system in a state reminiscent of a false vacuum and study its time evolution under a quench. We investigate the dynamics for different initial states and under varying initial conditions.

[1] A. Kruckenhauser, R. van Bijnen, T.V. Zache, M. Di Liberto, P. Zoller, *Quantum Sci. Technol.* **8** 015020 (2023).

P12

Non-thermal behaviour and quantum many-body scars in Fredkin spin chains

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We investigate the properties of a generalized Fredkin spin chain, a multi-parameter model equipped with a kinetic constraint defined through the Fredkin gate, which can be considered the generalization of tilted Markov generators to quantum dynamics [1]. We demonstrate how non-thermal behaviour arises for particular parameter regimes, including metastable timescales and logarithmic growth of entanglement entropy. Related to this slow dynamics is the existence of a number of quantum-many body scars (linear in system size) throughout the energy spectrum; that is, eigenstates with properties that are non-typical when compared to thermal expectations. Using numerical tensor network methods, we are able to determine the properties of the scarred eigenstates for system sizes an order of magnitude beyond exact diagonalization. We provide strong evidence for the existence of the scarred states for large system sizes, showing their local expectation values are far from their thermal expectation. Furthermore, we also show that the scarred states have an entanglement entropy with is constant with system size, thus obeying an entanglement area law. The existence of these scarred eigenstates (and other non-thermal eigenstates) can be explained through the existence of a more constrained dynamics in the strong coupling regime (through the "folding" of the spectrum [2, 3]), allowing for a perturbative treatment of the model.

[1] L. Causer, J. P. Garrahan, A. Lamacraft, Phys. Rev. E **106**, 014128 (2022).

[2] L. Zadnik, M. Fagotti, SciPost Phys. Core (2021)

[3] L. Zadnik, J. P. Garrahan, arXiv: 2304.10394 (2023)

P13

Non-ergodicity in 2D U(1) lattice gauge theories – disorder-free localization and spectral response

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Disorder-free localization occurs in lattice gauge theories on quenching from translationally invariant initial states involving a superposition of multiple superselection sectors induced by gauge invariance. Drawing from the fields of percolation theory, localization in disordered systems and information spreading, we present results on the unique features of such non-ergodicity in the context of a two dimensional U(1) quantum link model [1]. We show that such lattice gauge theories exhibiting disorder-free localization have a characteristic response in spatially averaged spectral functions: a few sharp peaks combined with vanishing response in the zero frequency limit [2]. This reflects the discrete spectra of small clusters of kinetically active regions formed in such gauge theories when they fragment into spatially finite clusters in the localized phase due to the presence of static charges. We obtain the transverse component of the dynamic structure factor, which is probed by neutron scattering experiments, deep in this phase from a combination of analytical estimates and a numerical cluster expansion. We also show that local spectral functions of large finite clusters host discrete peaks whose positions agree with our analytical estimates. Further, information spreading, diagnosed by an unequal time commutator, halts due to real space fragmentation. Our results can be used to distinguish the disorder-free localized phase from conventional paramagnetic counterparts in those frustrated magnets which might realize such an emergent gauge theory.

References

[1] Nilotpal Chakraborty et al. “Disorder-free localization transition in a two-dimensional lattice gauge theory”. In: *Phys. Rev. B* 106 (6), L060308 (2022).

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P14

One-dimensional Lévy Quasicrystal

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1 Abstract:

In this poster, I will present how one can generate a long-range hopping Aubry-André model using space-fractional quantum mechanics which shows the coexistence of delocalized and localized states seperated by mobility edges. Space-fractional quantum mechanics (SFQM) is a generalization of the standard quantum mechanics when the Brownian trajectories in Feynman path integrals are replaced by Lévy flights. Lévy quasicrystal is the discretized version of the space-fractional Schrödinger equation with an on-site quasiperiodic potential. The discretized version of the usual Schrödinger equation maps to the Aubry-André Hamiltonian, which supports localization-delocalization transition even in one dimension. In this poster, I will present the similarities between Lévy quasicrystal and the Aubry-André (AA) model with power-law hopping, and will show that the Lévy quasicrystal supports a delocalization-localization transition as one tunes the quasiperiodic potential strength and shows the coexistence of localized and delocalized states separated by mobility edge. Finally, I will present a recent experimental realization of SFQM in a quasiperiodic lattice which can be a new experimental platform to test the predictions of AA models in the presence of power-law hopping.

2 Reference:

[1] Chatterjee and Modak, arXiv:2210.10772.

P15

Collisional dynamics of symmetric two-dimensional quantum droplets

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The collisional dynamics of two symmetric droplets with equal intraspecies scattering lengths and particle number density for each component is studied by solving the corresponding extended Gross-Pitaevskii equation in two dimensions by including a logarithmic correction term in the usual contact interaction [1]. We find the merging droplet after collision experiences a quadrupole oscillation in its shape and the oscillation period is found to be independent of the incidental momentum for small droplets. With increasing collision momentum the colliding droplets may separate into two, or even more, and finally into small pieces of droplets. For these dynamical phases we manage to present boundaries determined by the remnant particle number in the central area and the damped oscillation of the quadrupole mode. A stability peak for the existence of droplets emerges at the critical particle number $N_c \cong 48$ for the quasi-Gaussian and flat-top shapes of the droplets.

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P16

Spectral and Steady State Properties of Fermionic Random Quadratic Liouvillians

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We study spectral and steady-state properties of generic Markovian dissipative systems described by quadratic fermionic Liouvillian operators of the Lindblad form. The Hamiltonian dynamics is modeled by a generic random quadratic operator, i.e., as a featureless superconductor of class D, whereas the Markovian dissipation is described by M random linear jump operators. By varying the dissipation strength and the ratio of dissipative channels per fermion, $m = M/(2N_F)$, we find two distinct phases where the support of the single-particle spectrum has one or two connected components. In the strongly dissipative regime, this transition occurs for $m = 1/2$ and is concomitant with a qualitative change in both the steady-state and the spectral gap that rules the large-time dynamics. Above this threshold, the spectral gap and the steady-state purity qualitatively agree with the fully generic (i.e., non-quadratic) case studied recently. Below $m = 1/2$, the spectral gap closes in the thermodynamic limit and the steady-state decouples into an ergodic and a nonergodic sector yielding a non-monotonic steady-state purity as a function of the dissipation strength. Our results show that some of the universal features previously observed for fully random Liouvillians are generic for a sufficiently large number of jump operators. On the other hand, if the number of dissipation channels is decreased the system can exhibit nonergodic features, rendering it possible to suppress dissipation in protected subspaces even in the presence of strong system-environment coupling.

P17

Simulating Open Quantum Systems with time-dependent Variational Monte Carlo

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The interest in quantum technologies has grown dramatically in recent years. In particular, the attempt to achieve the supremacy of quantum simulators over the classical counterpart, is one of the most challenging tasks nowadays. In this context, understanding properly the features of open quantum systems could be the key to the development of increasingly large and powerful quantum computers. Furthermore, topics such as quantum dynamics, dissipation effects or monitored quantum systems have recently attracted the attention of the scientific community.
Several approximate approaches were developed in recent years to simulate the dynamics of open quantum systems [1], however the results obtained so far are generally limited to small size systems. Among these, there are the variational methods, which are characterized by two steps. A parametrization of the state of the system in terms of a set of variational parameters and the optimization of a suitable functional, typically by applying a variational principle.
In this context, a very interesting technique is the one proposed by Hartmann and Carleo [2], which consist in a parametrization of the density matrix components in terms of neural network, followed by a stochastic procedure that approximates its dynamics.
In order to avoid the propagation of the entire density matrix, which might be computationally difficult for large systems, we decided to work on the development of a new numerical technique. Our approach is still based on the time-dependent Variational Monte Carlo method, used in [2], but it exploits the so-called unravelling of the master equations to obtain a set of quantum trajectories evolving with Stochastic Schrödinger Equations (SSE). By finding the solution for several independent trajectories, we will then be able to reconstruct time-dependent observables equivalent to those coming from the master equations.

[1] H. Weimer, A. Kshetrimayum and R. Orús, Rev. Mod. Phys. **93**, 1 (2021).
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P18

Exact "hydrophobicity" in deterministic circuits: dynamical fluctuations in the Floquet-East model

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In this poster we explore the (deterministic) Floquet-East model [1], whose discrete-time dynamics is kinetically constrained and implemented through local gates. We use exact techniques to show that, despite being deterministic, the model exhibits pre-transition behaviour, which is a dynamical equivalent of the hydrophobic effect in water. In particular we identify the presence of a first-order phase transition in the dynamical large deviations as well as the existence of an optimal geometry for local phase separation to accommodate space-time solutes. We then discuss related applications.

[1] arXiv:2305.07423

P19

Quantum Effects on the Synchronization Dynamics of the Kuramoto Model

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Spontaneous synchronization is a collective phenomenon observed in many-body interacting systems across diverse fields. With recent advancements in quantum technologies, synchronization can now be observed in the quantum regime. For this reason, understanding this collective phenomenon in a fully quantum regime has become increasingly important, yet theoretical models in this domain are still lacking.

In the classical realm, the Kuramoto Model stands as a prototypical example of synchronization. It describes a system of interacting rotors, exhibiting both a dynamically-disordered phase and a synchronized phase.

This poster proposes a generalized quantum model based on interacting quantum rotors coupled to external baths, extending the Kuramoto Model to the quantum realm. Using a Feynman-Vernon approach, we investigate how quantum fluctuations modify the phase diagram of the mean-field overdamped model. In particular, we derive an analytical expression for the critical coupling, above which the system is synchronized. We demonstrate the existence of a phase transition at any temperature, indicating also the presence of a quantum phase transition, and we analyze the differences from the classical model.

P20

Abstract for poster presentation at ICTP School on Quantum Many-Body Phenomena out of Equilibrium: from Chaos to Criticality

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The investigation of the fundamental nature of quantum dynamics and thermalization in isolated many-body systems is of significant interest. The time evolution of initially localized operators recently emerged as a powerful and far-reaching approach to characterize quantum many-body chaos and lack thereof. Previous studies elucidated this relationship in the context of random unitary circuits and integrable spin chains. In this work, we are interested in the growth of local operators in quantum systems with infinite-range Hamiltonians, which possess the additional property of full permutational invariance. One can make use of this property to construct an analytical framework for studying operator spreading, which can be used to characterize very precisely how the concepts of integrability and chaoticity manifest themselves in the spreading of operators.

P21

Non-thermal steady-states of cavity-mediated phase transitions

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Recent years have seen an increased interest on cavity effects on material physics. As such transitions between different equilibrium phases have been observed when the cavity photons interact with the material quasi-particles. It is in this spirit that we study the non-equilibrium effects of fermion-boson systems in a two-bath scenario where different baths are coupled to each subsystem and the interaction between them leads to unexpected steady-state behavior. We employ Keldysh out-of-equilibrium many-body techniques to calculate the long-time behavior and coupling dependence of these systems so as to elucidate the origin of cavity-mediated phase transitions.

P22

Disentanglement, disorder lines, and Majorana edge states in a solvable quantum chain

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We study the exactly solvable one-dimensional model: the dimerized XY chain with uniform and staggered transverse fields, equivalent upon fermionization to the noninteracting dimerized Kitaev-Majorana chain with modulation. The model has three known gapped phases with local and nonlocal (string) orders, along with the gapless incommensurate (IC) phase in the U (1) limit. The criticality is controlled by the properties of zeros of model's partition function, analytically continued onto the complex wave numbers. In the ground state they become complex zeros of the spectrum of the Hamiltonian. The analysis of those roots yields the phase diagram which contains continuous quantum phase transitions and weaker singularities known as disorder lines (DLs) or modulation transitions. The latter are shown to occur in two types: DLs of the first kind with continuous appearance of the IC oscillations, and DLs of the second kind corresponding to a jump of the wave number of oscillations. The salient property of zeros of the spectrum is that the ground state is shown to be separable (factorized), and the model is disentangled on a subset of the DLs. From analysis of those zeros we also find the Majorana edge states and their wave functions.

[1] Gennady Y. Chitov, **Karun Gadge**, and P. N. Timonin Phys. Rev. B 106, 125146 (2022).

P23

Drive-Induced Fragmentation in a fermionic chain

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We study a fermionic chain with nearest-neighbor hopping and density-density interactions, where the nearest-neighbor interaction term is driven periodically. We show that such a driven chain exhibits prethermal strong Hilbert space fragmentation (HSF) in the high drive amplitude regime at specific drive frequencies ω_m^*. This constitutes the first realization of HSF for out-of-equilibrium systems. We obtain analytic expressions of ω_m^* using a Floquet perturbation theory and provide exact numerical computation of entanglement entropy, equal-time correlation functions, and the density autocorrelation of fermions for finite chains. All of these quantities indicate clear signatures of strong HSF. We study the fate of the HSF as one tunes away from ω_m^* and discuss the extent of the prethermal regime as a function of the drive amplitude.

[1] S. Ghosh, I. Paul and K. Sengupta, Phys. Rev. Lett. **130**, 120401 (2023).

P24

Robust, parallel, arbitrary, individual single-qubit unitaries with global pulses

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Experimental platforms such as neutral atom arrays and trapped ions are generally limited to a global driving field, thus restricting individual control. Three common approaches to local addressing are: (i) locally tunable laser phase, (ii) locally tunable detuning, and (iii) locally tunable laser intensity. Here, we develop several classes of novel composite pulse sequences for parallel, arbitrary single-qubit unitaries robust against field amplitude error, off-resonance error, or both that can be implemented in parallel under each form of individual control. When applicable, our pulse sequences yield higher-fidelity operations than existing composite pulses at almost any level of amplitude error, off-resonance error, and decoherence. Our pulse sequences thus pave the way towards high-fidelity quantum information processing on noisy near-term systems with limited individual control.

P25

Universal approach to non-adiabatic dynamics of finite and extended atomistic systems

P26

Abstract template for

School on Quantum Many-Body Phenomena out of Equilibrium: from Chaos to Criticality

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In this work we discuss the quantum estimation of AC fields with sensors composed by discrete time crystal (DTC) phases. The sensor shows several advantages due its long-range spatial and time ordering. The collective interactions among the spins stabilize their dynamics (and sensing) against noise, turning the sensor robust to imperfections in the protocol and with a well structured response. We also discuss an interesting dual role for the sensor, which could be exploited as a probe to determine the underlying ordering of a general system.

P27

Exploring many-body localization in fermionic systems using semiclassical method

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Understanding and predicting the temporal evolution of quantum systems is essential for the development of theoretical physics and modern quantum technologies. A significant group of models that have been intensively researched in recent years are non-ergodic systems of interacting particles. They open the way to future technological solutions such as quantum memories. In the relaxation process, these systems do not strive for thermal states, which means that the initial quantum information encoded in the initial conditions is not lost. Attempts to understand the physical mechanisms responsible for the above-mentioned anomalous quantum dynamics constitute an important research goal in the theory of non-equilibrium processes. They are extensively studied in condensed matter and high energy physics. Such systems have an experimental implementation on the so-called cold atoms on optical lattices [1, 2]. Their great advantage is that they can be easily applied to various geometries. For this purpose, a semiclassical description of time evolution within the Wigner-Weyl representation will be used [3]. My poster will present spinless fermion model with disorder and interactions. I will show that semiclassical dynamics relaxes faster than the full quantum dynamics. Then I will present that strongly disordered one-dimensional and two-dimensional systems exhibit logarithmic-in-time relaxation, which was established for one-dimensional chains [4, 5, 6].

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[3] A. Polkovnikov, Ann. Phys. **325**, 1790 (2010).
[4] M. Žnidarič, T. Prosen, Phys. Rev. B **77**, 064426 (2008).
[5] M. Mierzejewski, J. Herbrych, Phys. Rev. B **94**, 224207 (2016).
[6] M. Schecter, T. Ladecola, Phys. Rev. B **98**, 174201 (2018).

P28

TBA. At this moment, I am working on two projects related to open quantum systems and disorder. As soon as one of them got its final form, I will submit a title and abstract (in a month). I appreciate it if you give me the chance to submit poster later.

P29

Dual unitary circuits in random geometries

Yusuf Kasim[1], **Tomaž Prosen**[1]

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Recently introduced dual unitary brickwork circuits have been recognised as paradigmatic exactly solvable quantum chaotic many-body systems with tunable degree of ergodicity and mixing. Here we show that regularity of the circuit lattice is not crucial for exact solvability. We consider a circuit where random 2-qubit dual unitary gates sit at intersections of random arrangements of straight lines in two dimensions (*mikado*) and analytically compute the variance of the spatio-temporal correlation function of local operators. Note that the average correlator vanishes due to local Haar randomness of the gates. The result can be physically motivated for two random mikado settings. The first corresponds to the thermal state of free particles carrying internal qubit degrees of freedom which experience interaction at kinematic crossings, while the second represents rotationally symmetric (random euclidean) space-time.

[1] Y. Kasim, T. Prosen, J. Phys. A: Math. Theor. **56**, 025003 (2023).

P30

Continuously Monitored Quantum Systems Beyond Lindblad Dynamics

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9th May 2023

Abstract. The dynamics of a quantum system, undergoing unitary evolution and continuous monitoring, can be described in term of quantum trajectories. Although the averaged state fully characterises expectation values, the entire ensamble of stochastic trajectories goes beyond simple linear observables, keeping a more attentive description of the entire dynamics. Here we go beyond the Lindblad dynamics and study the probability distribution of the expectation value of a given observable over the possible quantum trajectories. The measurements are applied to the entire system, having the effect of projecting the system into a product state. We develop an analytical tool to evaluate this probability distribution at any time t. We illustrate our approach by analyzing two paradigmatic examples: a single qubit subjected to magnetization measurements, and a free hopping particle subjected to position measurements.

P31

First Detected Return of A Disordered Quantum Walker

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The **first detected return time** characterizes the non-equilibrium dynamics of a quantum system. Employing the **stroboscopic measurement protocol** we numerically show that for an unbounded one dimensional quantum walker on an **Anderson lattice** the probability of first detection decays like $(\text{time})^{-2}$. This is in stark contrast to regular quantum walker which decays like $(\text{time})^{-3}$[1]. Preliminary numerical results show a **universal** behaviour in the **strongly disordered** regime for other similarly disordered systems.

References

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P32

Hilbert Space Fragmentation in Open Quantum Systems

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We investigate the phenomenon of Hilbert space fragmentation (HSF) in open quantum systems and find that it can stabilize highly entangled steady states. For concreteness, we consider the Temperley-Lieb model, which exhibits quantum HSF in an entangled basis, and investigate the Lindblad dynamics under two different couplings. First, we couple the system to a dephasing bath that reduces quantum fragmentation to a classical one with the resulting stationary state being separable. We observe that despite vanishing quantum correlations, classical correlations develop due to fluctuations of the remaining conserved quantities, which we show can be captured by a classical stochastic circuit evolution. Second, we use a coupling that preserves the quantum fragmentation structure. We derive a general expression for the steady state, which has a strong coherent memory of the initial state due to the extensive number of non-commuting conserved quantities. We then show that it is highly entangled as quantified by the logarithmic negativity.

P33

Cooling quantum many-body states via engineered dissipation

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The simulation of quantum matter by quantum computers is one of the main areas near-term devices are expected to outperform their classical counterparts, yet efficient preparation of strongly correlated initial states remains a challenge. We introduce a scheme for state preparation in qubit platforms combining periodic application of unitary gates with repeated reset of ancillary qubits. Tuning of reset time and ancilla parameters allows us to resonantly remove quasiparticle excitations from the system, realising a dissipative channel that cools the system to steady states of few quasiparticles (and low energy in the Hamiltonian limit). We derive an effective Lindblad equation for the cooling process, which is exactly solvable for systems of free fermions and boundary ancillas. We give simple formulas for the dynamics and steady-state populations in this case, along with a detailed analysis of the effects of noise: we compare our predictions to extensive numerics for the transverse-field Ising model, and recent experiments using 49 superconducting qubits [1].

[1] X. Mi *et al.*, *arXiv*:2304.13878 (2023).

P34

Purification Timescales in Monitored Fermions

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We investigate the crucial role played by a global symmetry in the purification timescales and the phase transitions of monitored free fermionic systems separating a mixed and a pure phase. Concretely, we study Majorana and Dirac circuits with $\mathbb{Z}_2$ and U(1) symmetries, respectively. In the first case, we demonstrate the mixed phase of L sites has a purification timescale that scales as $\tau_P \sim L \ln L$. At $1 \ll t \ll \tau_P$ the system attains a finite residual entropy, that we use to unveil the critical properties of the purification transition. In contrast, free fermions with U(1) manifest a sublinear purification timescale at any measurement rate and an apparent Berezinskii-Kosterlitz-Thouless criticality. We find the mixed phase is characterized by $\tau_P \sim L^{\alpha(p)}$, with a continuously varying exponent $\alpha(p) < 1$.

P35

Universal robustness to decoherence in the quantum diffusive regime.

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While on-site static disorder in a crystal can induce a Metal-Insulator Transition (MIT) into a localized regime, a local time-dependent noise or any environment may induce decoherence that destroys this localization and enables diffusion. Conversely, in the ballistic regime, decoherence limits the perfect transport. However, the details of how noise and disorder compete to yield the transport properties at the MIT is still an open question. We investigate this by using a paradigmatic 1D system, the Harper-Hofstadter-Aubry-André (HHAA) model, in the presence of a decoherent environment. We show that, at the MIT, a local quantum excitation spreads with an intrinsic diffusion coefficient which remains essentially decoherence-independent until the decoherence time becomes comparable with a time that characterizes the elastic collisions. In this model of local decoherence, the long time decay of the purity or Loschmidt echo is determined only by the diffusion coefficient and thus, it is also independent of the decoherence rate. In order to determine if this is a property of the MIT or a characteristic of quantum diffusion, a supplementary analysis was carried out for two other models whose quantum excitation spreading could be assimilated to diffusion, the Fibonacci chain and the Power-Banded Random Matrices (PBRM), but only the last has a MIT. By rescaling the data we find the diffusion coefficient with the decoherence strength has a universal behavior. This paves the way to understand the crucial role of diffusion in the stabilization of the transport properties under external perturbations.

P36

Electric field- and current-driven dynamics of vortex domain walls in spiral magnets

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Domain wall motion is one of the most compelling problems in spintronics because it is the mechanism underlying the magnetization switching. The majority of existing information storage devices (e.g. hard drives) use a magnetic field for recording, which implies a considerable power consumption and limits the information density. Multiferroics hold promise for allowing magnetization control by an electric field. In type-II magnetoelectric multiferroics, the magnetic order breaks inversion symmetry and induces a ferroelectric polarization. The paradigmatic example is a spiral magnet [1, 2]. The domain wall between two spiral domains with opposite chirality generally consists of a periodic chain of vortices or merons [3]. Combining the Ginzburg-Landau approach and the collective coordinates method [4], we study the electric field- and current-driven dynamics of vortex domain walls in cycloidal spiral magnets. We also discuss the dimerization of the vortex chain that occurs at high fields and possible breakdown scenarios. Analytical solutions are corroborated by atomistic spin dynamics simulations. An important related problem of our current interest is studying the quantum many-body effects when a current drives the domain wall.

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P37

Markovian bosonic systems

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Driven, dissipative non-relativistic bosons at weak interactions have been realized in exciton-polariton condensates in one dimension; their phase has been shown to follow the Kardar-Parisi-Zhang (KPZ) equation.[1] We study the full quantum theory beyond weak interaction using two complementary methods.

First, we investigate the Lindblad master equation with a one-dimensional Bose (and Fermi) Hubbard Hamiltonian and with local jump operators. For jump operators linear in the fields, the non-equilibrium steady-state density matrix is known exactly [2]. We generalize this result to the fermionic case and calculate local steady-state properties. In order to obtain the non-equal time correlation function in the steady state, we exploit the numerical methods of exact diagonalization and quantum trajectories. We find a renormalization of the width of the retarded propagator (related to the decay rate) for increasing interactions, whereas the non-interacting model is exactly solvable through the method of third quantization[3] or the Schwinger-Keldysh formalism.

Second, we derive and analyze the corresponding continuum quantum field theory: The bare action is a non-equilibrium scalar ϕ^4-theory with complex couplings, as done in [4]. We find that including a two-body loss is necessary to obtain the KPZ equation from the Bogoliubov approximation. Furthermore, we investigate the model under two different time-reversal symmetries. The first constraints the model to a classical, equilibrium $O(2)$ theory. The second allows for imaginary couplings, hence, generally, the system is out-of equilibrium, but still describes a classical theory. For this model renormalization group studies [4] showed the existence of a new dissipative fixed point. Currently, we extend this study expecting to recover the KPZ fixed point and to further characterize it.

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P38

Improved Mean-Field Approximate Optimization Algorithm (MFAOA) and its applications

P39

Phonon-induced breakdown of Thouless pumping in the Rice-Mele-Holstein modelp

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Adiabatic and periodic variation of the lattice parameters can make it possible to transport charge through a system even without net external electric or magnetic fields, known as Thouless charge pumping. The amount of charge pumped in a cycle is quantized and entirely determined by the system's topology, which is robust against perturbations such as disorder and interactions. However, coupling to the environment may play a vital role in topological transport in many-body systems. We study the topological Thouless pumping, where the charge carriers interact with local optical phonons. The semiclassical multitrajectory Ehrenfest method is employed to treat the phonon trajectories classically and charge carriers quantum mechanically. We find a breakdown of the quantized charge transport in the presence of phonons. It happens for any finite electron-phonon coupling strength at the resonance condition when the pumping frequency matches the phonon frequency, and it takes finite phonon coupling strength away from the resonance. Moreover, there exist parameter regimes with nonquantized negative and positive charge transport. The modified effective pumping path due to electron-phonon coupling accurately explains the underlying physics. In the large coupling regime where the pumping disappears, the phonons are found to eliminate the staggering of the on-site potentials, which is necessary for the pumping protocol. Finally, we present a stability diagram of quantized pumping as a function of the time period of pumping and phonon coupling strength.

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Nonstabilizerness in the XXZ model

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Nonstabilizerness, or quantum magic, is one of the quantum resources necessary to provide a quantum advantage. Quantifying the magic in a pure state can be challenging in general. We quantify the measure of magic called “Stabiliser Renyi Entropy” [1][2] for one half timestep of XXZ evolution exactly in the thermodynamic limit, for any Renyi parameter, using ZX-calculus methods [3]. We calculate it numerically using transfer tensor methods for one full timestep in the thermodynamic limit.

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P41

Engineering unsteerable quantum states with active feedback

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We propose active steering protocols for quantum state preparation in quantum circuits where each ancilla qubit (detector) is connected to a single system qubit, employing a simple coupling selected from a small set of steering operators. The decision is made such that the expected cost-function gain in one time step is maximized. We apply these protocols to several many-qubit models. Our results are underlined by three remarkable insights. First, we show that the standard fidelity does not give a useful cost function; instead, successful steering is achieved by including local fidelity terms. Second, although the steering dynamics acts on each system qubit separately, entanglement in the generated target state is introduced, and can be tuned at will, by performing Bell measurements on ancilla qubit pairs after every time step (entanglement swapping). Third, our approach is able to reach arbitrarily designated target states, including passively unsteerable states such as the N-qubit W state.

P42

Kardar-Parisi-Zhang Physics in Two-Dimensional Localized Wave Packets

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In this study, we reveal that Anderson localization of wave packets in two dimensions belongs to the Kardar-Parisi-Zhang (KPZ) universality class. The KPZ universality class refers to a class of non-equilibrium stochastic systems displaying scale-invariant fluctuations characterized by a set of universal critical exponents. First introduced by Kardar, Parisi, and Zhang in the study of surface growth phenomena, KPZ physics was found to describe different types of classical systems subjected to noise or disorder. Recently, numerical and experimental observations of KPZ physics in certain quantum systems have attracted widespread attention: quantum magnets, random unitary circuits, polaritons and finally Anderson localization. In this study, we explore the analogy between two-dimensional Anderson localization and KPZ physics in the context of wave packet dynamics, as recently studied experimentally with cold atoms or ultrasounds. In a disordered medium, an initially peaked wave packet undergoes dynamic evolution, resulting in exponential localization at long times and large distances r. We examine the fluctuations of the wave density in this regime where the envelope of the wave-packet is stationary. We present evidence that $-\ln|\psi(r)|^2$ corresponds to a surface height, with the distance r serving as the equivalent of time, in the KPZ process, shown in Fig.1. We find the same critical exponents and statistical distributions controlling KPZ physics. This analogy reveals a new regime of universal fluctuations for Anderson localization. It could make it possible to use the very elaborate analytical understanding of KPZ physics to describe the still imperfectly understood properties of Anderson localization in dimension two and above.

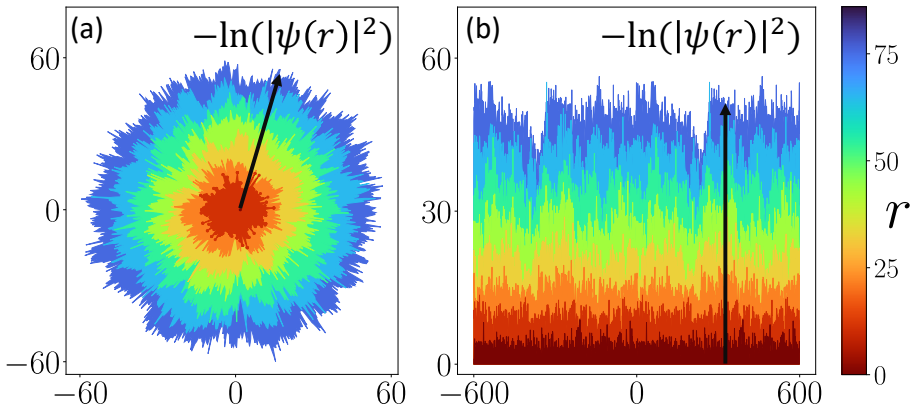

Figure 1: Effective surface growth process mapped from the wave density of a localized wave packet in two dimensions with (a) for circular condition and (b) for flat condition.

P43

Spin Transport in Perturbed Integrable Quantum Systems

P44

Thermodynamics of adiabatic quantum pumping in quantum dots

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Adiabatic pumping is a phenomenon that has been extensively studied in the context of non-interacting quantum dots. Most notably, Brouwer's formula [1] establishes a geometric expression of the pumped charge in the adiabatic limit by performing a cyclic process in the time-dependent parameters of the dot. It has been also proven that, by appropriately choosing the cycle design, one can achieve the transport of a quantized charge.
The objective of our research is to study this problem from the thermodynamical point of view and to investigate the behaviour of the various thermodynamical quantities in the quantization limit. We consider a single-level quantum dot, connected to two fermionic thermal baths. We develop a consistent thermodynamical description of this model, accounting for the variation of the energy level of the dot and the tunnelling rates with the thermal baths. To achieve this, we express the various thermodynamic quantities in terms of the appropriate Green functions, for which we derive an expansion in the adiabatic limit.
This enables us to consider various examples of thermodynamic cycles with these tunable parameters. For these cycles, we compute the relevant thermodynamical quantities, such as the entropy produced and the dissipated power. We compare these quantities with the transport properties of the system, which can be traced back to the existing scientific literature.
From all the examples considered, we learn that the entropy production vanishes in the quantization limit. This establishes a qualitative relationship with the noise of the current. In addition to that, we show that the dissipated power per cycle is proportional to the speed with which the quantity associated with the quantization limit is varied.

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P45

Evolution of the energy density in a driven inhomogeneous CFT

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We discuss the behavior of a conformal field theory (CFT) that describes (possibly interacting) quantum systems in 1+1 dimensions. The main focus is on studying how the energy density changes over time following a sudden quench or in response to a periodic driving. The driving Hamiltonian is taken to be an inhomogeneous deformation of the canonical CFT Hamiltonian. Additionally, we observe the impact of performing multiple quenches with randomly selected strength parameters, which affects the coherent and ballistic oscillations typically associated with CFTs.

P46

A new ytterbium experiment for single-atom resolved many-body physics

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Ultracold atomic systems provide a unique playground for exploring quantum many-body phenomena, owing to an exceptional control over Hamiltonians and to their long coherence times. Novel techniques for the manipulation and detection of individual atoms have recently allowed to reach a single-atom level in the degree of control: in particular, optical tweezer arrays allow the realization of programmable quantum systems for exploring quantum simulation and quantum information schemes [1, 2]. Here I will report on the ongoing development of a new ultracold atom experimental apparatus, where we will employ optical tweezers to manipulate and detect individual ytterbium atoms at state-of-art level. Such degree of control will allow us to engineer artificial quantum systems for investigating mesoscopic many-body systems with a bottom-up approach. In particular, the peculiar features of ytterbium make it ideal for tackling open questions both in quantum impurity problems and collective light-matter interactions. The long-lived clock state provides a natural choice for the implementation of orbital impurities, displaying either ferromagnetic or antiferromagnetic coupling to ground state atoms as well as optically tunable mobility. We will trigger and monitor the dynamics of many-particle systems with the precise tools of interferometric spectroscopy. We will also exploit the rich internal structure of ytterbium to isolate two and three-level systems which show great potential to implement new laser cooling schemes and collective atoms-light interactions.

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P47

Modelling thermal transport in non-collinear magnets

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Magnetic memory and logic devices, including prospective ones based on skyrmions and other non-collinear spin textures, inevitably produce heat. Thus, controlling heat flow is essential for the performance. Here we study thermal conductivity in the most basic non-collinear magnet with a spin spiral ground state. Non-collinearity of spins leads to anharmonic three-magnon interactions, absent in collinear magnets, that give rise to scattering processes where one magnon may split into two or two magnons can merge into one. These additional scattering events imply lower magnon lifetime and the lowering of thermal conductivity compared to a collinear case. Indeed, recent experiments show a significant decrease of thermal conductivity upon the transition from ferromagnetic to spiral state in multiferroic GaV_4S_8 [1].

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P48

Many body localization phase transition, mobility edge and universality of spectral form factor in quantum sun model

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It is currently of great scientific interest to study generic toy models of ergodicity breaking transition, in search for many-body localized (MBL) phase that survives in the thermodynamic limit [1]. Quantum sun model [2], which describes ergodic quantum dot coupled to particles with spin$-1/2$, is example of such toy model. Numerical simulations reveal that this model exhibits transition between ergodic and MBL phase and exactly at the transition properties of the system do not depend on the system size, suggesting stability of this transition in the thermodynamic limit. We extend analysis of [2] by considering a variant of this model with a conserved projection of the total spin $\hat{S}^z_{\text{tot}}$ and analysing the biggest symmetry sector. This makes the model more feasible for an experimental implementation using cold-atom platforms, as $\hat{S}^z_{\text{tot}}$ corresponds then to the particle number. We find that all hallmarks of the original model, like a universal shape of the spectral form factor independent of system size, are preserved in this variant with conservation up to systems with 24 spins. The biggest studied system sizes are calculated using Polynomially Filtered Exact Diagonalization (POLFED) algorithm [3]. Moreover, model with conservation exhibits the presence of the mobility edge (i.e. a boundary between localized and extended states in the spectrum) in the ergodic phase, which is observed by calculating energy spacing ratio r_n: $H\left|\psi_n\right\rangle = E_n\left|\psi_n\right\rangle$, $\quad \delta E_n = E_{n+1} - E_n$, $\quad r_n = \frac{\min\{\delta E_n, \delta E_{n-1}\}}{\max\{\delta E_n, \delta E_{n-1}\}}$, and averaging it over many disorder realisations in different energy windows around rescaled energy $\varepsilon = (E - E_{\min})/(E_{\max} - E_{\min})$, as depicted on Fig. 1.

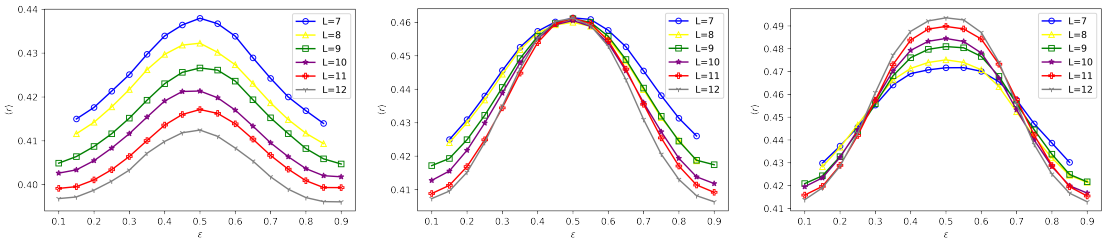

Figure 1: Average value of spacing ratio $\langle r \rangle$ as a function of position in the spectrum ε. Data for quantum dot containing $N = 3$ spins and L spins coupled to the dot. In localized regime (left) all eigenstates localized, in critical regime (middle) for the spectrum center system size independence, in ergodic regime mobility edge: center ergodic, edges localized.

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P49

Quasiballistic transport in the long-range anisotropic Heisenberg model

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Purely ballistic transport is a rare feature even for integrable models. By numerically studying the Heisenberg chain with the power-law exchange, $J \propto 1/r^{\alpha}$ where r is a distance, we show that for spin anisotropy $\Delta \simeq \exp(-\alpha + 2)$ the system exhibits a quasiballistic spin transport and the presence of fermionic excitation, which do not decay up to extremely long times $\sim 10^3/J$. This conclusion is reached on the basis of the dynamics of spin domains, the dynamical spin conductivity, inspection of the matrix elements of the spin-current operator, and analysis of most conserved operators. Our results smoothly connect two models in which fully ballistic transport is present: free particles with nearest-neighbor hopping and the isotropic Haldane-Shastry model.

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P50

Localization and delocalization in networks with varied connectivity

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We study the phenomenon of localization and delocalization in a circuit-QED network with connectivity varying from finite-range coupling to all-to-all coupling [1]. We find a fascinating interplay between interactions and connectivity. In particular, we consider (i) harmonic, (ii) Jaynes-Cummings, and (iii) Bose-Hubbard networks. We start with the initial condition where one of the nodes in the network is populated and then let it evolve in time. The time dynamics and steady state characterize the features of localization (self-trapping) in these large-scale networks. For the case of harmonic networks, exact analytical results are obtained, and we demonstrate that all-to-all connection shows self-trapping whereas the finite-ranged connectivity shows delocalization. The interacting cases (Jaynes-Cummings and Bose-Hubbard networks) are investigated both via exact quantum dynamics and via a semiclassical approach. We obtain an interesting phase diagram when one varies the range of connectivity and the strength of the interaction. We investigate the consequence of imperfections in the cavity or qubit and the role of inevitable disorder. Our results are relevant especially given recent experimental progress in engineering systems with long-range connectivity.

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P51

Digital-analog quantum simulations of the Hubbard-Holstein model

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In the NISQ era, performing fully digital simulations of fermion-boson models on quantum computers is a challenging task due to the number of qubits and circuit depth required. To overcome these challenges, we propose an alternative digital-analog scheme for simulating fermion-boson models. Our approach is based on using resonators coupled to superconducting qubits as computational resources, rather than for readout purposes. By exploiting the additional native gate [1] provided via this coupling, we have developed a simulation framework for fermion-boson models, which we demonstrate using the Hubbard-Holstein model at thermal equilibrium as a proof of concept. This approach offers a promising avenue for simulating complex quantum systems on NISQ-era quantum computers.

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P52

Entanglement renormalization in interacting fermionic systems using single-particle transformations

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One of the most powerful and popular quantum entanglement-based computation methods for the simulation of one-dimensional and quasi-two-dimensional strongly correlated materials is the Density Matrix Renormalization Group (DMRG) technique. A lower quantum entanglement between the system's degrees of freedom will result in a higher accuracy of the method. However, quantum entanglement between two complementary subsystems of a closed system depends on how the degrees of freedom have been distributed between them, and therefore, it is not in general invariant under arbitrary unitary transformations. Entanglement is invariant only under those unitary transformations which do not mix the degrees of freedom associated with the two subsystems. Consequently, a fundamental question is that if it is possible to construct, algorithmically, unitary transformations which minimize entanglement between degrees of freedom of the system and therefore maximize the DMRG technique? A general solution to this problem is highly nontrivial in general. In this paper, we study interacting fermionic models and by considering single-particle unitary transformations only. We define a novel and efficient method to find the optimal single-particle unitary transformations. In this framework, we show that using our algorithm, the accuracy of the DMRG method at a given bond dimension is increased and the ground-state energy is decreased and approaches to its exact value. Our method paves the way toward finding more general (many-particle) optimized unitary transformations and helps us to better understand the behavior of fermions in strongly correlated materials.

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P53

Manipulating exciton binding by floquet engineering in mix-D Hubbard model

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Strong excitations of correlated quantum materials give rise to various non-thermal phases which are not present in their equilibrium counterpart. Recently, it was shown that the one-dimensional Fermi Hubbard Model features charge density wave and η-pairing phases upon photo-doping.

In this study, we explore the non-equilibrium behavior of the mix-D Fermi Hubbard model and employ the Schrieffer-Wolff transformation to map it to a simplified t-J-like model, providing an effective equilibrium description of the photo-doped states. Our investigation highlights the significance of an additional η-exchange coupling between exciton pairs in the presence of doublons. We find the dependence of binding energy of excitons on exchange couplings and show that the application of an electric field along the rung to the hopping term enhances exciton pairing. This floquet manipulation allows to increase the exchange coupling along the rung while keeping the magnitude of hopping constant. This is responsible for increasing the binding energy and in turn the critical temperature of superconductivity. To characterize the ground state of the system, we employ relevant correlators and make notable observations. We show that at strong anisotropy, the ground state encompasses a strongly bound doublon-hole pair along the rung, alongside inter-chain singlets. Additionally, we propose experimental setups to test the predictions put forth by our theory.

P54

Genetic optimization of quantum annealing

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Adiabatic quantum computation was proposed as a new paradigm of quantum computation relying on the adiabatic theorem [1] , and is closely related to quantum annealing [2], which uses quantum fluctuations to reach the minimum of a given objective function. In these procedures, a system is initially prepared in the ground state of a trivial Hamiltonian, and then it is adiabatically evolved towards the ground state of a more complicated one, which encodes the solution to the desired optimization problem. To enhance the probability of a successful dynamics, the latter has to last longer than a typical timescale, which is inversely connected to the minimum gap between the ground state and the first excited state. The minimum gap can vanish in a quantum phase transition the system might encounter in the process, resulting in long annealing times to satisfy the adiabatic condition. However long-time dynamics are often experimentally impractical and lead to a greater susceptibility to noise and decoherence. Therefore our goal was modifying the annealing dynamics in order to achieve high fidelities, even breaking the adiabatic criterion, before decoherence sets in.
In this work we study optimal control of quantum annealing by modulating the pace of evolution and by introducing an optimal driving [4]. We first considered the fully-connected ferromagnetic p-spin model as case study and then, in order to test the feasibility of our method in a more general framework, we additionally studied the performance of this optimization for a random Ising model.
We considered in the first place the time annealing schedules to be polynomial expansions whose coefficients were optimized as chromosomes of genetic algorithms [3], artificial intelligence tools based on the idea of the survival of the fittest. Then we genetically optimized a practically implementable local Hamiltonian composed of only single spin operators which when added to the system Hamiltonian can improve the fidelity of the state of the system. As a further step, we optimized the annealing schedules and the time-dependent coefficients of the local operators together.
With these genetically optimized annealing schedules and/or optimal driving operators, we are able to perform quantum annealing in relatively short time-scales and with larger fidelity compared to traditional approaches.

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P55

Adiabatic eigenstate deformations and weak integrability breaking

P56

Measurement induced entanglement phase transition and logarithmic scaling in monitored transverse field Ising spin chain

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Measurement induced entanglement phase transitions have attracted immense attention in recent years, especially in the context of monitored quantum circuits. In such systems, the dynamics due to unitary evolution competes with the localizing effects of measurements. The quantum phase transition between a trivial volume-law phase of entanglement entropy into an area-law obeying quantum Zeno-like phase for frequent and/or strong measurements is well known in many integrable quantum models with unitary dynamics. However recently an extended critical phase with a logarithmic scaling of the entanglement entropy has been identified in a class of integrable models in presence of dissipation.

We take this one step further and study the critical transition in a non-integrable system – a one dimensional transverse field Ising model, in presence of an integrability-breaking field and dissipation. First, we show that the measurement induced transitions in this system is qualitatively different from the trivial volume-law to area-law transition of the entanglement entropy in integrable systems, then we show how the two otherwise disconnected transitions – (1) from the critical log-law phase to the area-law phase, and (2) from the volume law phase to the area law phase, via an integrability breaking field. We present the phase diagram for this non-integrable system. This sheds new light on the fundamental physics behind entanglement transitions in many-body systems.

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Weak universality, quantum many-body scars and anomalous infinite-temperature autocorrelations in a one-dimensional spin model with duality

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We study a one-dimensional spin-1/2 model with three-spin interactions and a transverse magnetic field h. The model is known to have a $Z_2 \times Z_2$ symmetry, and a duality between h and $1/h$. The self-dual point at $h = 1$ is a quantum critical point with a second-order transition. We find the critical exponents z, β, γ and ν, and the central charge c. We find $c = 1$ and $z = 1$, and the model must therefore be governed by a conformal field theory. It displays weak universality with the ratio of critical exponents being the same as that of the transverse field Ising model and the four-state Potts model, but the critical exponents are separately not the same as those of the other models. The three-spin model therefore lies somewhere on the Ashkin-Teller family of models. Interestingly, for a periodic system with an even number of sites, there are zero-energy states whose number grows exponentially with the system size. A subset of these states is independent of the value of h and has very low half-chain entanglement entropy; hence these can be classified as quantum many-body scars. An energy level spacing analysis shows that the model is not integrable. Finally, we study the infinite-temperature autocorrelation functions at sites close to one end of an open system. We find that some of the autocorrelations relax anomalously in time, with pronounced oscillations and very small decay rates if $h \gg 1$ or $h \ll 1$. However, if h is close to the critical point, the autocorrelations decay quickly to zero. Thus we present a unique non-integrable model showing weak universality, presence of quantum scars as well as anomalous relaxation of autocorrelators.

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Signatures of many-body localization of quasiparticles in a flat band superconductor

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We construct a class of exact eigenstates of the Hamiltonian obtained by projecting the Hubbard interaction term onto the flat band subspace of a generic lattice model. These exact eigenstates are many-body states in which an arbitrary number of localized fermionic particles coexist with a sea of mobile Cooper pairs with zero momentum. By considering the dice lattice as an example, we provide evidence that these exact eigenstates are in fact manifestation of local integrals of motions of the projected Hamiltonian. In particular the spin and particle densities retain memory of the initial state for a very long time, if localized unpaired particles are present at the beginning of the time evolution. This shows that many-body localization of quasiparticles and superfluidity can coexist even in generic two-dimensional lattice models with flat bands, for which it is not known how to construct local conserved quantities. Our results open new perspectives on the old condensed matter problem of the interplay between superconductivity and localization.

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P59

Average entanglement entropy of midspectrum eigenstates of quantum-chaotic interacting Hamiltonians

P60

Collective tunneling of one-dimensional Wigner crystals

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The collective tunneling of a a Wigner necklace – a crystalline state of a small number of strongly interacting electrons confined to a suspended nanotube and subject to a double well potential – is theoretically analyzed and compared with experiments in [1]. Density Matrix Renormalization Group computations, exact diagonalization, and instanton theory provide a consistent description of this very strongly interacting system, and show good agreement with experiments. Experimentally extracted and theoretically computed tunneling amplitudes exhibit a scaling collapse. Collective quantum fluctuations renormalize the tunneling, and substantially enhance it as the number of electrons increases.

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P61

Operator Spreading in the Gaussian Unitary Ensemble

P62

Full counting statistics as probe of measurement-induced transitions in the quantum Ising chain

P63

Adiabatic eigenstate deformations and weak integrability breaking of Heisenberg chain

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We consider the spin-$\frac{1}{2}$ Heisenberg chain (XXX model) weakly perturbed away from integrability by an isotropic next-to-nearest neighbor exchange interaction. Recently, it was conjectured that this model possesses an infinite tower of quasiconserved integrals of motion (charges) [https://doi.org/10.1103/PhysRevB.105.104302D. Kurlov *et al.*, Phys. Rev. B **105**, 104302 (2022)]. In this work we first test this conjecture by investigating how the norm of the adiabatic gauge potential (AGP) scales with the system size, which is known to be a remarkably accurate measure of chaos. We find that for the perturbed XXX chain the behavior of the AGP norm corresponds to neither an integrable nor a chaotic regime, which supports the conjectured quasi-integrability of the model. We then prove the conjecture and explicitly construct the infinite set of quasiconserved charges. Our proof relies on the fact that the XXX chain perturbed by next-to-nearest exchange interaction can be viewed as a truncation of an integrable long-range deformation of the Heisenberg spin chain.

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Abstract

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Title: Dynamical localization and slow dynamics in quasiperiodically-driven quantum systems

Driven quantum systems are a rich playground for interesting non-equilibrium quantum statistical phenomena. Electric field-driven systems are a particular subclass that exhibit a wide range of novel features from the perspective of Floquet engineering. Many recent research works with aperiodic driving have prompted us to investigate the effects of a quasiperiodic electric field. In this poster, we present results for a quasiperiodically driven non-interacting and interacting spinless fermionic system in the absence and presence of disorder. In the clean non-interacting case, we show the emergence of dynamical localization - a phenomenon previously known to exist only for a perfect periodic drive. In contrast, in the presence of disorder, where a high-frequency periodic drive preserves Anderson localization, we show that the quasiperiodic drive destroys it and leads to slow relaxation. Considering the role of interactions, we uncover the phenomenon of quasiperiodic driving-induced logarithmic relaxation, where a suitably tuned drive (corresponding to dynamical localization in the clean, non-interacting limit) slows down the dynamics even when the disorder is small enough for the system to be in the ergodic phase [2]. This is in sharp contrast to the fast relaxation seen in the undriven model, as well as the absence of thermalization (drive-induced MBL) exhibited by a periodically driven model.

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P65

Spectral Reconstruction via Gaussian Process Regression

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The investigation of real-time correlation functions in quantum chromodynamics (QCD) remains a notoriously hard problem. Therefore, lattice calculations and functional methods are generally performed in imaginary time. However, in order to access dynamical properties of QCD, such as transport properties or real-time scattering processes, the knowledge about the real-time correlation functions is necessary. This analytic continuation is an ill-conditioned inverse problem and therefore requires some form of regularization.

We propose Gaussian process regression as a general framework for solving linear inverse problems [1]. This probabilistic framework allows for the consistent inclusion of additional physical information, such as normalization or asymptotic constraints. Including such information can regularize the inverse problem, and we can reliably extract real-time information from Euclidean data.

We have applied this method to different problems ranging from the calculation of bound state masses in Yang-Mills theory [2] over the investigation of real-time scattering amplitudes in QCD [3] to the calculation of the thermal photon rate of the Quark-Gluon Plasma [4]. Additionally, we are currently developing a Python package [5] in order to make this method more accessible.

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P66

Iterative construction of most necessary conserved quantities

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Integrable systems are a rare example of a solvable many-body description of quantum systems. Due to the fine-tuned structure, their realization in nature and experiment is never completely accurate, therefore effects of integrability are observed only transiently. One way to surpass that is to couple nearly integrable systems to baths and driving: these will stabilize integrable effects, encoded in the time dependent and eventually stationary state of form of a generalized Gibbs ensemble, up to arbitrary time [1, 2, 3]. However, the description of such driven dissipative nearly integrable models is challenging and no exact analytical methods have been proposed so far. Here we develop an iterative scheme in which integrability breaking perturbations (baths) determine the most necessary conservation laws to be added into a truncated GGE description [4]. Our scheme significantly reduces the complexity of the problem, paving the way for thermodynamic results.

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P67

Low Temperature GHD with Diffusion

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Here we present work considering small, but non-zero temperatures, where diffusion becomes a relevant correction.

At exactly zero temperature generalized hydrodynamics yields a zero entropy GHD equation characterizing the behaviour of the Fermi points, which is known to reduce to conventional hydrodynamics [1]. Our goal is to extend this analysis to the leading order in temperature, finding that at $O(T)$ the diffusion corrections appear. This low temperature theory can be directly compared with conventional hydrodynamics with diffusion, where it is observed that a Burgers equation type form is obtained.

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P68

Stochastic semiclassical theory of the non-equilibrium dynamics of the Hubbard model

P69

Disorder Induced Time-Reversal Symmetry Breaking in 2d Josephson Junctions

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Twisting and stacking two-dimensional quantum materials has proven to be an extremely powerful tool, both in creating new interesting materials and in probing their properties [1]. It has been proposed that measuring the Josephson coupling between two d-wave superconductors as a function of the relative twist angle, θ, can reveal the pairing symmetry. In a beautiful set of experiments [2], a $|\cos(2\theta)|$ dependence was observed, as should be expected for d-wave. In particular, when $\theta = 45°$, the lowest-order Josephson coupling J1 vanishes by symmetry. It was recently predicted [3] that the second-order Josephson coupling, J2 (corresponding to inter-plane coherent tunneling of two Cooper pairs), favors a spontaneously broken time-reversal symmetry (TRS) state, with phase difference of $\pm\pi/2$. Indeed, the experiment found evidence that at $\theta = 45^\circ$, there is a substantial J2. Both the precise microscopic mechanism of this second-order coupling and whether time-reversal is broken or not remain to be clarified. The extreme anisotropy of BSCCO poses a significant quantitative difficulty with the intrinsic mechanism above. As we will discuss, an estimate based on measured quantities implies a value of J2 that is four orders of magnitude too small to explain the experiments. We propose an alternative mechanism for the generation of J2, driven by the effect of local symmetry-breaking ("nematic") inhomogeneities. We are motivated in this by a host of experimental observations in BSCCO in which such inhomogeneities have been directly imaged. The effect of local nematicity is to induce a spatially varying in sign first-order Josephson coupling, which has previously been shown to generate an effective J2 with the requisite sign to favor time-reversal symmetry breaking [4]. This mechanism can give rise to a value of J2 that agrees with experiment.

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Counterdiabatic Corrections to the Quantum Approximate Optimization Algorithm

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Objectives

- To demonstrate an enhancement in the performance of the Quantum Approximate Optimization Algorithm (QAOA) thanks to counterdiabatic driving.
- To conduct a comprehensive investigation of the optimization parameters involved in the QAOA.

Introduction

Quantum Approximate Optimization Algorithm (QAOA) [2] is a promising hybrid quantum-classical algorithm for solving combinatorial optimization problems. In this poster, we study a generalized QAOA ansatz called QAOA-CD, which is inspired by counterdiabatic driving (CD), using Baker-Campbell-Hausdorff (BCH) expansion [4]. We show that by using higher-order terms of BCH expansion as additional control unitaries, we have a better estimate of the solution before convergence and the algorithm converges with fewer steps than QAOA without corrections.

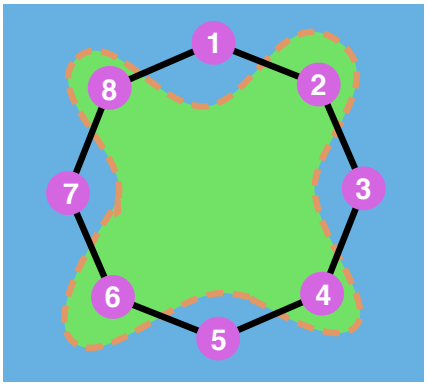

Figure 1: MaxCut representation for a *ring of disagrees* with eight sites. The system is partitioned into two distinct regions, pink and green, such that the dashed curve separating the two areas intersects the maximum number of edges.

MaxCut model

The MaxCut model involves the identification of a closed curve that cuts the maximum number of edges within a given graph. It is an NP-hard problem. It is possible to express the problem in terms of Pauli spin operators:

$$H_T = \sum_{\langle i,j\rangle} J_{i,j}\sigma_i^Z\sigma_j^Z, \tag{1}$$

Mapping the MaxCut problem onto the Ising model allows us to approach it as a groundstate search, which can be addressed by quantum computation techniques.

Quantum Approximate Optimization Algorithm

At each step p, the state

$$|0\rangle = \frac{1}{\sqrt{2^N}}\bigotimes_{i=1}^{N}(|\uparrow\rangle_i - |\downarrow\rangle_i), \tag{2}$$

is transformed into the parametrized state

$$|\psi^{(p)}(\vec{\gamma},\vec{\beta})\rangle = \prod_{k=1}^{p} U^{(k)}(\gamma_k,\beta_k)\,|0\rangle \tag{3}$$

where

$$\mathbf{U^{(k)}}(\gamma,\beta) = \mathbf{e^{-i\beta H_X}e^{-i\gamma H_T}} \tag{4}$$

and H_X is a transverse field:

$$H_X = \sum_{i=1}^{N}\sigma_i^X \tag{5}$$

At each step p, the QAOA angles are optimized by minimizing the cost function

$$\mathbf{E_p}(\tilde{\gamma},\tilde{\beta}) = \langle\psi^{(\mathbf{p})}(\tilde{\gamma},\tilde{\beta})|\mathbf{H_T}|\psi^{(\mathbf{p})}(\tilde{\gamma},\tilde{\beta})\rangle\,. \tag{6}$$

To analyse the results we define at each step

$$\varepsilon_{res} = \frac{E_{max} - E_p(\vec{\gamma},\vec{\beta})}{E_{max} - E_{min}} \tag{7}$$

where $E_{max(min)}$ is the largest (smallest) eigenvalue.

Main Result

Our results indicate that QAOA-CD achieves convergence in fewer iterations compared to standard QAOA (left panel of Fig. 2). Furthermore, QAOA-CD outperforms the multi-angle QAOA [3] with the same set of parameters (right panel of Fig. 2), as evidenced in our analysis.

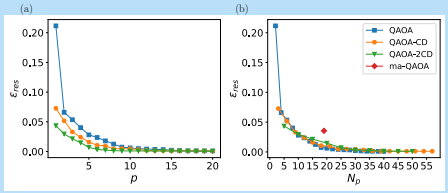

Figure 2: (a) ε_{res} for a 10-spin chain with random couplings and open boundary conditions vs number of steps p. (b) ε_{res} for a 10-spin chain with random couplings and open boundary conditions vs number of parameters N_p

Counterdiabatic Corrections

In our study, we incorporate unitary transformations corresponding to higher orders of the Baker-Campbell-Hausdorff formula up to the second order. So we consider QAOA-CD [6, 1]

$$U_{CD}^{(k)}(\gamma,\beta,\alpha) = U^{(k)}(\gamma,\beta)e^{-i\alpha[H_X,H_T]} \tag{8}$$

and we define **QAOA-2CD**

$$\mathbf{U_{2CD}^{(k)}}(\gamma,\beta,\alpha,\delta,\zeta) = \\ = \mathbf{U_{CD}^{(k)}}(\gamma,\beta,\alpha)\mathbf{e^{-i(\delta[H_X,[H_X,H_T]]-\zeta[H_T,[H_X,H_T]])}} \tag{9}$$

Parameter study

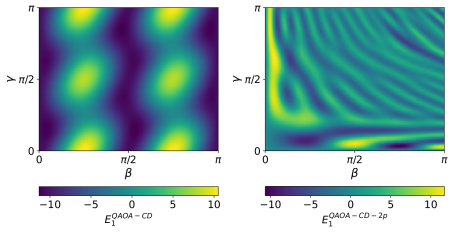

Figure 3: Cost function of the generalized QAOA ansatz including first-order BCH correction at step $p = 1$. Left panel: free BCH angle. Right panel: constrained BCH angle. The cost function landscape is evidently rougher in the right panel.

The counterdiabatic corrections involve adding 5 parameters to the cost function, 2 from QAOA (γ, β) and 3 from the corrections (α, δ, ζ). These 5 parameters are not independent, in principle, because BCH poses some constraints. However simulations show that relaxing these constraints allows for a more efficient minimization.

Conclusions

QAOA is a widely used hybrid algorithm for solving combinatorial optimization problems. At each step p, the quantum part of the algorithm acts with unitaries transformations described in Eq. (4), while the classical part is a minimization of the functional described in Eq. (6). At each step p the quantum component employs unitary transformations as described in Eq. (4) and, in the classical part of the algorithm, there is a minimization of the functional outlined in Eq. (6). Our results indicate that incorporating the terms described in the Eqs. (8) and (9) **improves the algorithm's performance.** Moreover, having 5 variational parameters at each step is more advantageous than having just 2.

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P71

Theory of free fermions under random projective measurements

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We develop an analytical approach to the study of one-dimensional free fermions subject to random projective measurements of local site occupation number, based on the Keldysh path-integral formalism and replica trick. In the limit of rare measurements, $\gamma/J \ll 1$ (where γ is measurement rate per cite and J is hopping constant in the tight-binding model), we derive a non-linear sigma model (NLSM) as an effective field theory of the problem. Its replica-symmetric sector is described by a $U(2)/U(1) \times U(1) \simeq S_2$ sigma model with diffusive behavior, and the replica-asymmetric sector is a two-dimensional NLSM defined on $SU(R)$ manifold with the replica limit $R \to 1$. On the Gaussian level, valid in the limit $\gamma/J \to 0$, this model predicts a logarithmic behavior for the second cumulant of number of particles in a subsystem and for the entanglement entropy. However, the one-loop renormalization group analysis allows us to demonstrate that this logarithmic growth saturates at a finite value $\sim (J/\gamma)^2$ even for rare measurements, which corresponds to the area-law phase. This implies the absence of a measurement-induced entanglement phase transition for free fermions. The crossover between logarithmic growth and saturation, however, happens at exponentially large scale, $\ln l_{\mathrm{corr}} \sim J/\gamma$. This makes this crossover very sharp as a function of the measurement frequency γ/J, which can be easily confused with a transition from the logarithmic to area law in finite-size numerical calculations. We have performed a careful numerical analysis, which supports our analytical predictions .

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Evolution of entanglement entropy of strongly correlated bosons in an optical lattice

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Entanglement plays a crucial role in various quantum many-body phenomena, including the thermalization of isolated quantum systems and the information paradox of black holes. Notably, the second-order Rényi entropy (RE), a measure of entanglement, was successfully measured in the system of bosons in an optical lattice [1]. Motivated by this experiment, we investigate the time evolution of the second-order RE of bosons in the one-dimensional optical lattice after a sudden quench of the hopping amplitude J. Specifically, we examine systems that are quenched into the strongly correlated Mott-insulating (MI) regime with $U/J \gg 1$ (U denotes the strength of the on-site repulsive interaction) from the MI limit with $J=0$.

In this regime, the low-energy excited states are described by the effective theory of fermionic quasiparticles known as doublons and holons [2], which are excited in entangled pairs during the quench dynamics. By developing the effective theory, we derive the direct relation between the RE and correlation functions associated with doublons and holons. This connection enables us to analytically calculate the RE and to gain a physical understanding of its behavior, both in the ground state and in the time-evolved state after the quench, in terms of entangled doublon-holon pairs. In particular, we show that the RE is proportional to the population of doublon-holon pairs spanning the boundary of the subsystem [3].

Our quasiparticle picture reveals novel characteristics absent in previous studies on the dynamics of entanglement entropy in free-fermion models [4]. It provides valuable insights into the behavior of entanglement entropy in strongly correlated systems.

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P73

Temporal Entanglement in Dual-Unitary Clifford Circuits with Projective Measurements

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We report on the dynamics of temporal entanglement in dual-unitary Clifford circuits with probabilistic projective measurements preserving spatial unitarity. We present exact results for characterizing the temporal entanglement barrier in the measurement-free regime. In the finite-measurement-rate regime, we numerically study the interplay between projective measurement rate and bath size and present an exact transfer-matrix approach for understanding how the system approaches the perfect-dephaser limit. We further remark on the presence of exceptional-point at intermediate measurement rate and its effect on the dynamics.

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Quantum chaos in cascaded nonlinear processes

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Transition from insulating to conducting states in the bilayer Hubbard model by perpendicular quench field

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Abstract: A many-body quantum system with different parameters may support two distinct quantum states in the same energy shell. It allows the dynamical transition from the ground state of pre-quench Hamiltonian to a steady state of post-quench one. We study the dynamical response of the ground states of a two-layer half-filled Hubbard model to a perpendicular electric field. We show that the steady state is conducting state when the field is resonant to the on-site repulsion, while the initial state is a Mott-insulating state. In addition, two layers exhibit the same conducting behavior due to the formation of the long-lived dopings, which are manifested by the performance of the charge fluctuation. The key to achieving this dynamic transition is the cooperation between on-site interaction and the resonant field rather than the role of either. Our finding provides an alternative mechanism for field-induced conductivity in a strongly correlated system.