Geometry of quantum dynamics

Report of Contributions

Contribution ID: **3** Type: **not specified**

Quantum Frequential Computing: a quadratic run time advantage for all algorithms

Wednesday, August 28, 2024 9:45 AM (1 hour)

Quantum control is the research field focused on designing control fields that manipulate quantum systems. In traditional approaches, these control fields are treated classically. Quantum computers are a notable example where quantum control is employed to implement quantum logic gates. In this work, we explore quantum-quantum control, where both the system to be controlled and the controlling field are quantum. We prove that non-classical states of the control field are required to achieve the maximum speed at which sequential gates can be applied. Additionally, we show that the optimal rate is quadratically faster (for the same power and interaction strength) compared to what is possible in an optimal semi-classical control scenario. Quantum computers are currently projected to not provide a real-world quantum advantage for algorithms with quadratic or cubic speedups due to very slow gate speeds, at least for the next 30 years. This work opens up the possibility of drastically improving gate speeds without increasing power consumption, energy dissipation, or the required interaction strengths.

Presenter: WOODS, Mischa

Contribution ID: **4** Type: **not specified**

Maximal steady-state entanglement in autonomous quantum thermal machines

Wednesday, August 28, 2024 10:45 AM (30 minutes)

It is well-known that failure to isolate a quantum system leads to its decoherence. However, quantum thermal machines offer an interesting perspective on this common wisdom. These are systems that explicitly use spontaneous interactions with the environment to perform a task. For these quantum systems, the environment is not detrimental but a resource. A basic conceptual question is therefore whether an autonomous quantum thermal machine, which uses no source of work, external driving or time-coherent control, can generate the strong forms of quantum correlations exclusively from spontaneous interactions with classical reservoirs. It was shown in an earlier work [1] that such a machine actually can generate entanglement between two qubits, only by leveraging a temperature bias. While the entanglement was both weak and noisy, it motivated the following natural question: how strong entanglement is actually possible to produce with these thermodynamically minimalistic resources? In the years since, a series of works have step by step strengthened the entanglement –sometimes at the price of introducing some extra resources. Still, the best entanglement so far obtained is far from optimal. In our work [2], we conclusively solve this problem. We propose a quantum thermal machine which only uses a chemical potential bias in order to generate a maximally entangled qubit pair, or in fact, any desired pure two-qubit entangled state, emerging as a dark state of the system. The key insight is the addition of an extra qubit which serves as an aid for generating the entanglement between other constituents of the machine. The three qubit architecture resembles a generalised coherent population trapping setup from atomic physics. Crucially, we prove that this is the minimal thermal machine that can produce maximal entanglement. Going beyond bipartite entanglement, we generalise our thermal machine to produce genuinely multipartite entangled states of n qubits using an architecture of 2n-1 qubits. Remarkably, the architecture is able to produce W states of an arbitrary number of qubits using only local pairwise interactions and a chemical potential bias. Our results reveal the striking fundamental capabilities of autonomous quantum evolution. [1] New J. Phys. 17, 113029 (2015). [2] arXiv:2401.01776 (2024)

Presenter: KHANDELWAL, Shishir

Contribution ID: **5** Type: **not specified**

Quantum temporal correlation and tensors

Wednesday, August 28, 2024 11:15 AM (30 minutes)

In this talk I will discuss some results and some challenges involving temporal correlations in scenarios modeled by high-order quantum maps (tensors).

Presenter: SILVA VIEIRA SANTOS, Leonardo

Contribution ID: **6** Type: **not specified**

Reachability and Observability in Quantum Systems Theory: Aspects of a Unified Lie Frame

Wednesday, August 28, 2024 2:00 PM (1 hour)

Among the questions arising in quantum engineering there is a pair of practical yet fundamental ones: for a controlled quantum dynamical system, (1) what is the reachable set of sates given an initial condition?(2) For which observables (or more generally POVMs) can measurements give full information for system identification? In finite-dimensional closed systems, a unified (Lie) frame of quantum systems theory settles these reachability and observability problems—as will be illustrated in paradigmatic n-qubit systems. Implications and generalisations will be outlined as well.

Presenter: SCHULTE-HERBRÜGGEN, Thomas

Contribution ID: **7** Type: **not specified**

State reachability in isolated systems

Wednesday, August 28, 2024 3:00 PM (30 minutes)

Presenter: SZYMAŃSKI, Konrad

Contribution ID: **8** Type: **not specified**

Partial tomography of fermionic quantum simulators

Wednesday, August 28, 2024 3:30 PM (30 minutes)

Presenter: GHOSHAL, Ahana

Contribution ID: **9** Type: **not specified**

Newton's laws of motion can generate gravity-mediated entanglement

Wednesday, August 28, 2024 4:15 PM (30 minutes)

Presenter: MARIA MARCHESE, Marta

Contribution ID: **10** Type: **not specified**

SDP bounds on uncertainty relations and quantum codes

Thursday, August 29, 2024 9:30 AM (1 hour)

I will introduce the framework of state polynomial optimization, a variant of the NPA hierarchy. It can be used to construct complete SDP hierarchies for quantum uncertainty relations and bounding the parameters of quantum codes. In both cases the Lovász theta number from graph theory plays a key role, and there are a range of relaxations available to make these SDPs numerically useful.

Presenter: HUBER, Felix

Contribution ID: **11** Type: **not specified**

Rotational covariance restricts available quantum states

Thursday, August 29, 2024 10:30 AM (30 minutes)

Presenter: OTTO, Fynn

Contribution ID: **12** Type: **not specified**

Nonclassicality, Entanglement and Positive Polynomials

Thursday, August 29, 2024 11:00 AM (20 minutes)

Understanding quantum phenomena which go beyond classical concepts is a focus of modern quantum physics. Here, we show how the theory of nonnegative polynomials emerging around Hilbert's 17th problem, can be used to optimally exploit data capturing the nonclassical nature of light. Specifically, we show that nonnegative polynomials can reveal nonclassicality in data even when it is hidden from standard detection methods up to now. Moreover, the abstract language of nonnegative polynomials also leads to a unified mathematical approach to nonclassicality for light and spin systems, allowing us to map methods for one to the other. Conversely, the physical problems arising also inspire several mathematical insights into characterisation of nonnegative polynomials.

Presenter: OHST, Ties-Albrecht

Contribution ID: **13** Type: **not specified**

Quantum speed limit for perturbed open systems

Thursday, August 29, 2024 11:45 AM (30 minutes)

Quantum speed limits provide upper bounds on the rate with which a quantum system can move away from its initial state. Here, we provide a different kind of speed limit, describing the divergence of a perturbed open system from its unperturbed trajectory. In the case of weak coupling, we show that the divergence speed is bounded by the quantum Fisher information under a perturbing Hamiltonian, up to an error which can be estimated from system and bath timescales. We give three applications of our speed limit. First, it enables experimental estimation of quantum Fisher information in the presence of decoherence that is not fully characterized. Second, it implies that large quantum work fluctuations are necessary for a thermal system to be driven quickly out of equilibrium under a quench. Moreover, it can be used to bound the response to perturbations of expectation values of observables in open systems.

Presenter: YADIN, Benjamin

Contribution ID: **14** Type: **not specified**

Geometry and dynamics of non-Hermitian Hamiltonians

Thursday, August 29, 2024 12:15 PM (30 minutes)

In this talk, I will present our latest results in the study of geometrical properties of non-Hermitian Hamiltonians and their link to unprecedented dynamics.

Presenter: SEPTEMBRE, Ismaël

Contribution ID: **15** Type: **not specified**

Spin squeezing and many-body entanglement estimation

Thursday, August 29, 2024 2:30 PM (1 hour)

Presenter: VITIGLIANO, Giuseppe

Contribution ID: **16** Type: **not specified**

Estimation of entanglement monotones in permutationally invariant spin systems

Thursday, August 29, 2024 3:30 PM (30 minutes)

We are interested in finding optimal entanglement witnesses and thereby bound entanglement monotones for interacting many-body systems that can be connected to experimentally relevant collective observables. For spin observables corresponding to two-body correlators, generalized spin squeezing inequalities [1, 2] are generally considered optimal witnesses. To begin with, we study thermal states of fully connected spin systems in the mean-field approximation which are permutationally invariant. We illustrate how this connection can be used to estimate entanglement monotones of such states, how this connects to the spin squeezing inequalities, and how this approach compares to numerical studies. More specifically, we present general strategies to find both lower and upper bounds to entanglement monotones and show specific calculations and results for some interesting models. These examples also illustrate how we can leverage additional symmetries to more efficiently calculate these bounds for many particles. In addition, we elaborate on extensions of our work to non-Hermitian collective spin observables, and on how our findings connect to entanglement measures other than those we have already considered. [1] G. Tóth, C. Knapp, O. Gühne, H.J. Briegel, Journal, Physical Review A, 79.4 (2009) 042334 [2] G. Vitagliano, I. Apellaniz, I. Egusquiza, G. Tóth, Physical Review A, 89(3), 032307

Presenter: MATHE, Julia

Contribution ID: **17** Type: **not specified**

Metrological usefulness of entanglement and nonlinear Hamiltonians

Thursday, August 29, 2024 4:00 PM (30 minutes)

A central task in quantum metrology is to exploit quantum correlations to outperform classical sensitivity limits. Metrologically useful entanglement is identified when the quantum Fisher information (QFI) exceeds a separability bound for a given parameter-encoding Hamiltonian. However, so far, only results for linear Hamiltonians are well-established. Here, we characterize metrologically useful entanglement for nonlinear Hamiltonians, presenting separability bounds for collective angular momenta. Also, we provide a general expression for entangled states maximizing the QFI, showing that these are not always GHZ-like states. Finally, we compare the metrological usefulness of linear and nonlinear cases, in terms of entanglement detection and random symmetric states.

Presenter: IMAI, Satoya

Contribution ID: **18** Type: **not specified**

Thermalization via scattering events

Thursday, August 29, 2024 4:45 PM (30 minutes)

The equilibration of physical systems in contact to a thermal environment is one of the core assumptions of thermodynamics and has a variety of useful physical implications. While consequences of thermalization can be observed frequently in our everyday life, the dynamical processes behind this phenomenon have yet not been fully explored. In my talk i will consider the internal degrees of freedom (dofs) of a quantum system subjected to a diluted gas of ancilla particles, consisting of motional and internal dofs. I treat the interactions with full quantum mechanical, inelastic scattering theory and discuss the conceptional hurdles in order to derive a master equation for the internal dofs. Finally, i argue that the system will eventually thermalize under very general conditions.

Presenter: GAIDA, Michael

Contribution ID: **19** Type: **not specified**

Non-equilibrium dynamics, disorder and entanglement

Friday, August 30, 2024 9:00 AM (1 hour)

I aim to first discuss results on the relation between entanglement in energy eigenstates and the presence or absence of thermalisation in many-body systems and relate these to recent results showing the presence of reviving product states in the disordered Heisenberg chain based on tensor network methods.

Presenter: WILMING, Henrik

Contribution ID: **20** Type: **not specified**

Magic states in the Asymmetric Quantum Rabi Model

Friday, August 30, 2024 10:00 AM (30 minutes)

The asymmetric quantum Rabi model (AQRM) is a modified version of the paradigmatic quantum Rabi model, which describes the interaction between a two-level system (qubit) and a quantum harmonic oscillator, typically a single mode of radiation field. The interplay of these degrees of freedom and its feasible experimental realizations in the context of quantum information setups make the AQRM a suitable hybrid system to study diverse phenomena such as correlations and hidden symmetries. In this work, we analyze the existence of magic states in the AQRM. Here, the quantum resource known as magic or non-stabilizerness is a critical ingredient that provides quantum computing an advantage over its classical counterpart. We study magic witnesses in the qubit subsystem of the AQRM and adapted measures for the same quantity in the bosonic subsystem, making, in this way, one of the first tryouts of magic within a different branch of physics besides fault-tolerant quantum computation.

Presenter: BENÍTEZ RODRÍGUEZ, Ernesto

Contribution ID: **21** Type: **not specified**

Quantum features from classical entropies

Friday, August 30, 2024 10:30 AM (30 minutes)

The scaling of local quantum entropies is of utmost interest for characterizing quantum fields, many-body systems and gravity. Despite their importance, being nonlinear functionals of the underlying quantum state often hinders their theoretical as well as experimental accessibility. Here, we show that suitably chosen classical entropies of standard measurement distributions capture the very same features as their quantum analogs. We demonstrate the presence of the celebrated area law for classical entropies for typical states such as ground and excited states of a scalar quantum field. Further, we consider the post-quench dynamics of a multi-well spin-1 Bose-Einstein condensate from an initial product state, in which case we observe the dynamical build-up of quantum correlations signaled by the area law, as well as local thermalization revealed by a transition to a volume law, both in regimes characterized by non-Gaussian quantum states and small sample numbers. arXiv:2404.12320, 2404.12321, 2404.12323

Presenter: HAAS, Tobi

Contribution ID: **22** Type: **not specified**

Quantum Control of Radical-Pair Dynamics beyond Time-Local Optimization

Friday, August 30, 2024 11:00 AM (30 minutes)

We realize arbitrary-wave-form-based control of spin-selective recombination reactions of radical pairs in the low-magnetic-field regime. To this end, we extend the gradient-ascent pulse engineering (GRAPE) paradigm to allow for optimizing reaction yields. This overcomes drawbacks of previously suggested time-local optimization approaches for the reaction control of radical pairs, which were limited to high biasing fields. We demonstrate how efficient time-global optimization of the recombination yields can be realized by gradient-based methods augmented by time blocking, sparse sampling of the yield, and evaluation of the central single time-step propagators and their Fréchet derivatives using iterated Trotter-Suzuki splittings. Results are shown for both a toy model, previously used to demonstrate coherent control of radical-pair reactions in the simpler high-field scenario and, furthermore, for a realistic exciplex-forming donor-acceptor system comprising 16 nuclear spins. This raises prospects for the spin control of actual radical-pair systems in ambient magnetic fields, by suppressing or boosting radical reaction yields using purpose-specific radio-frequency wave forms, paving the way for reaction-yield-dependent quantum magnetometry and potentially applications of quantum control to biochemical radical-pair reactions. We demonstrate the latter aspect for two radical pairs implicated in quantum biology.
(https://journals.aps.org/prxquantum/abstract/10.1103/PRXQuantum.5.020303)

Presenter: CHOWDHURY, Farhan Tanvir