Q 30: Quantum Information: Concepts and Methods V

Time: Wednesday 11:00–13:00 Location: e214

Q 30.1 Wed 11:00 e214

Approaching equilibrium: Fermionic Gaussification — Marek Gluza[1], •Christian Krumnow[1], Mathis Friesdorf[1], Christian Gogolin[2,3], and Jens Eisert[1] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Berlin, Germany — [2]ICFO-The Institute of Photonic Sciences, Mediterranean Technology Park, Barcelona, Spain — [3]Max-Planck-Institut für Quantenoptik, Garching, Germany

When and by which mechanism do closed quantum many-body systems equilibrate? This fundamental question has been in the focus of attention for many years. It lies at the very basis of the connection between thermodynamics, quantum mechanics of many constituents and condensed matter theory. In the setting of free fermionic evolutions, we rigorously capture the time evolution in abstract terms and by basing our proof on intuitive mathematical concepts like Lieb-Robinson bounds, notions of particle transport and an algebraic expansion of operators, we uncover the underlying mechanism how local memory of the initial conditions is forgotten. Specifically, starting from an initially short range correlated fermionic states which can be very far from Gaussian, we show that if the Hamiltonian provides sufficient transport, the system approaches a state that cannot be distinguished from a corresponding Gaussian state by local measurements. For experimentally relevant instances of ultra-cold fermions in optical lattices, our result implies equilibration on realistic physical time scales. Moreover, we characterise the equilibrium state, finding an instance of a rigorous convergence to a fermionic Generalized Gibbs ensemble.

Q 30.2 Wed 11:15 e214

A road to Non-Markovian Quantum Thermodynamics — •Rebecca Schmidt[1,2], Sabrina Maniscalco[2], and Tapio Ala-Nissilä[1] — [1]CQE and COMP, Department of Applied Physics, Aalto University School of Science, P.O.Box 11100, 00076 Aalto, Finland — [2]TCQP, Department of Physics and Astronomy, University of Turku, FI-20014, Turun Yliopisto, Finland

Common assumptions in the theoretical description of open quantum system dynamics, such as non-Markovianity or perturbative treatments, do not hold for state-of-the-art realisations of mesoscopic quantum devices. There is a need for a consistent description of non-Markovian open quantum dynamics to form the theoretical framework for ongoing and upcoming experiments in quantum thermodynamics. Also, there is evidence that non-Markovianity can be exploited as a resource to enhance the performance of quantum thermodynamic devices [1]. To bridge the gap between an information theoretic and a thermodynamic description, we applied the information theoretic measures of non-Markovianity [2] to the quantum thermodynamic setting of a generic driven Spin-Boson model [3].

[1] B. Bylicka, D. Chruscinski and S. Maniscalco, Sci. Rep. 4, 5720 (2014); S.F. Huelga, A. Rivas, and M.B. Plenio, PRL 108, 160402 (2012) [2] S. Wissmann, A. Karlsson, E.-M. Laine, J. Piilo, and H.-P. Breuer, PRA 86, 062108 (2012); C. Benedetti, M. G. A. Paris, S. Maniscalco, PRA 89, 012114 (2014). [3] R. S., M.F. Carusela, J.P. Pekola, S. Suomela and J. Ankerhold, PRB 91, 224303 (2015).

Q 30.3 Wed 11:30 e214

The energy cost of quantum measurements — •Kais Abdelkhalek[1], David Reeb[1], and Yoshifumi Nakata[2] — [1]Institut für Theoretische Physik, Leibniz Universität Hannover, Germany — [2]Universitat Autonoma de Barcelona, Spain

We investigate the energy cost for performing a quantum measurement. In a general, microscopic model employing all systems involved in the measurement process, we establish a new fundamental lower bound on the energy cost for general measurements. We show that, in contrast to naïve intuition and previous results by [Sagawa/Ueda] valid only for a small class of measurements, our result implies that useful energy can, in principle, be extracted by general measurements. In the important special case of projective measurements we prove that the corresponding energy cost is proportional to the Shannon entropy of the outcome probability distribution. We elucidate immediate consequences of these results for examples in quantum control theory and measurement-based feedback processes (such as quantum error correction) and highlight a link to quantum thermodynamics.

Q 30.4 Wed 11:45 e214

Memory Cost for Simulating all Contextuality Correlations in the Peres-Mermin Square — •Gabriel Fagundes Camargo[1,2] and Matthias Kleinmann[2] — [1]Federal University of Minas Gerais, Belo Horizonte, Brazil — [2]University of the Basque Country, Leioa, Spain

Contextuality is a feature of quantum theory which classical models can not reproduce. However, for contextuality scenarios realized in sequential measurements, the capabilities of the classical models may embrace an additional feature: internal memory. For the Peres-Mermin square, three internal states are required to be not in contradiction with quantum theory [1]. We extend this analysis and compute the memory needed for fully agreeing with quantum correlations, i.e., to agree with the predicitons of any quantum state of any compatible sequence of measurements. Despite this comprehensive approach we find that three internal states are sufficient and then in particular allow to violate any corresponding non-contextuality inequality.

[1] M. Kleinmann, O. Gühne, J. R. Portillo, J.-A. Larsson, and A. Cabello, New J. Phys. **13**, 113011 (2011)

Q 30.5 Wed 12:00 e214

Collisional model approach to quantum memory effects — Silvan Kretschmer, •Kimmo Luoma, and Walter Strunz — Institut für Theoretische Physik, Technische Universität Dresden, Dresden, Germany

Collisional models offer an alternative route to open quantum system dynamics. A collision model consists of a system that interacts with localized environment particles in sequential manner. As such, in collisional models the dynamics is given discretely in time in terms of maps instead of usual continuous in time master equations. The description of the dynamics using sequential collisions is appealing because it guarantees the complete positivity of the open system dynamics by its construction.

A scenario where the system interacts at each collision with a new uncorrelated environment particle leads to dynamical map with semigroup structure, ie. to Markovian evolution.

In this work we construct a collisional model with an interaction between the environment particles. The interaction allows to propagate system environment correlations forward in time. With our construction we can simulate multimode Jaynes-Cummings model discretely in time and in the continuous time limit we can produce the well known analytical results.

Q 30.6 Wed 12:15 e214

Mixing properties of local diffusion processes on the unitary group — •Emilio Onorati, Winton Brown, Oliver Buerschaper, Martin Kliesch, Albert Werner, and Jens Eisert — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

In recent years, random quantum processes have been the object of numerous investigations. Random quantum circuits are discrete processes of this type: unitary local gates are randomly chosen according to some distribution and repeatedly applied to quantum states. Continuous-time evolutions belong to this class too, e.g. the ones induced by fluctuating local Hamiltonians.

In this work, we prove that a diffusion process on the unitary group generated by a fluctuating local Hamiltonian has mixing properties analogous to those shown for random quantum circuits, hence providing a unifying picture for the two frameworks. More precisely, we show that local Wiener processes are approximate unitary k-designs after a polynomial run time. This result follows from previous techniques developed for random quantum circuits as well as new insights from representation theory.

In addition, we show that decoupling, a relevant concept for a large variety of applications in both physics and quantum information, can be obtained with almost linear scaling in the system size in the setting of fluctuating local Hamiltonians. To prove this, we construct an abstract continuous-time random walk over Pauli strings and show that it satisfies a certain mixing criterion which then implies decoupling.

Q 30.7 Wed 12:30 e214

Quantum information processing in phase space: A modu-

lar variables approach — •Andreas Ketterer[1], Arne Keller[2], Stephen P. Walborn[3], Thomas Coudreau[1], and Pérola Milman[1] — [1]Laboratoire Matériaux et Phénomènes Quantique, Université Paris Diderot, Paris, France — [2]Institut de Sciences Moléculaires d'Orsay, Université Paris-Sud, Orsay, France — [3]Instituto de Física, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil

Binary quantum information can be fault tolerantly encoded in states defined in infinite dimensional Hilbert spaces [1]. Such states define a logical basis, and permit a perfect equivalence between continuous and discrete universal operations. The drawback of this encoding is that the corresponding logical states are unphysical, meaning infinitely localized in phase space. In this talk, we apply the modular variables formalism to show theoretically that, in a number of protocols relevant for quantum information and for the realization of fundamental tests of quantum mechanics, it is possible to loosen the requirements on the encoded subspace without jeopardizing neither their usefulness nor their successful implementation. Such protocols involve measurements of appropriately chosen modular observables that permit the readout of encoded discrete quantum information from the corresponding logical states [2,3].

[1] D. Gottesman et al., Phys. Rev. A **64**, 012310 (2001)
[2] A. Ketterer et al., *in preparation* (2015)
[3] A. Ketterer et al., Phys. Rev. A **91**, 012106 (2015)

Q 30.8 Wed 12:45 e214

Certified efficient simulation of local unitary dynamics by ground state preparations — •Dominik Hangleiter, Martin Kliesch, Martin Schwarz, and Jens Eisert — Freie Universität Berlin

Typically, one cannot expect to find efficient classical simulation schemes for quantum systems. Hence, the usual scientific method to "predict-and-test" in order to falsify a theory is not guaranteed to work in the context of quantum many-body systems. So, is there at all a way to certify such systems? Recent experimental advances allowing for precise engineering of, and high-resolution measurements on large-scale quantum systems have brought this question from the theorist's desk into the lab. In this work, we explore alternative strategies to certify that a system engineered in the lab – a quantum simulator – is indeed well described by some target model. We find that there are conceivable physical systems that can be certified and which are, indeed, expected to be classically intractable. For example, this is the case for frustration-free and gapped Hamiltonians: their ground states can be certified by local energy measurements and encode the full complexity of quantum computers. This example shows: we do not need to merely trust quantum simulators but can also certify their outcome. To show our results, we bring together methods from quantum tomography and Hamiltonian complexity, in particular, constructions based on the Feynman-Kitaev Hamiltonian used to prove the QMA-hardness of the Local Hamiltonian Problem.