Open Quantum Systems - MAQM

Rapport sur les contributions

https://indico.math.cnrs.fr/e/maqm-oqs

ID de Contribution: **1** Type: **Non spécifié**

Analytic theory of system-bath correlations in nonequilibrium fermionic impurities

lundi 11 mars 2024 14:00 (1 heure)

Coupling of the system to its environment inevitably leads to the generation of system-bath correlations. Such correlations are often thought to be negligible in the weak-coupling Markovian regime. This is because the Markovian master equations are commonly derived using Born approximation that assumes factorization of the system-bath state. However, recent numerical studies have demonstrated that information-theoretic measures of system-bath correlations can take non-negligible values also in the Markovian regime. In particular, the system-bath mutual information can approach the Araki-Lieb bound on its maximum value.

Here we present an analytic theory quantitatively describing the system-bath correlation measures, such as mutual information or entanglement negativity, in single fermionic levels coupled to a fermionic bath in the weak-coupling Markovian regime [1]. In this regime, correlations are shown to depend only on the reduced state of the system and intensive thermodynamic parameters of the bath (temperature and chemical potential). For a situation when the impurity is initialized in an out-of-equilibrium state and then relaxes to equilibrium, the theory shows the generation of transient system-bath correlations, which are maximized at the relaxation half-time and vanish in the long-time limit. In the case when impurity is driven to a nonequilibrium steady state by the applied voltage (i.e., the difference of chemical potentials of two baths), the theory demonstrates the presence of a steady-state system-bath entanglement above a certain threshold voltage, which depends only on the temperature and asymmetry of coupling strengths to the baths. The validity of this theory and its range of applicability are established by numerical simulations.

[1] K. Ptaszyński, M. Esposito, arXiv:2306.09680 (accepted in Phys. Rev. B).

Orateur: PTASZYŃSKI, Krzysztof (University of Luxembourg)

ID de Contribution: **2** Type: **Non spécifié**

Quantum trajectory of the one atom maser model

lundi 11 mars 2024 15:00 (1 heure)

The evolution of a quantum system undergoing repeated indirect measurements naturally leads to a Markov chain on the set of states, and which is called a quantum trajectory. When the system under consideration is finite dimensional, and under some natural assumption related to the non-existence of so-called dark subspaces, the state of the system tends to become pure along the trajectory, a result which goes back to Kummerer and Maassen (’2006). This purification result is then a key step to the analysis of invariant measures: uniqueness, convergence towards it (Benoist et al. 2019). After a brief review of what is known in finite dimension I will present some results concerning purification and invariant measure(s) for the quantum trajectory associated to the (infinite dimensional) one atom maser model.
This talk is based on a joint work with T. Benoist and C. Pellegrini

Orateur: BRUNEAU, Laurent (CY University)

ID de Contribution: **3** Type: **Non spécifié**

Stochastic boundary with deterministic bulk dynamics: exactly solvable cases

lundi 11 mars 2024 16:30 (1 heure)

I will review some exactly solvable cases of classical deterministic and quantum unitary interacting 1D lattices driven by stochastic reservoirs at the ends. While in most cases the steady state can be written in terms of a homogeneous matrix product ansatz, I will outline a few situations where a compact inhomogeneous ansatz is needed.

Orateur: PROZEN, Tomaz (University of Ljubljana)

ID de Contribution: **4** Type: **Non spécifié**

On entropy production in quantum statistical mechanics II

vendredi 15 mars 2024 09:30 (1 heure)

This talk is the continuation of the previous one.
In this second talk the two times quantum measurement entropy production is introduced. We will discuss a surprising stability result regarding statistics of this entropy production that impacts the respective quantum Evans-Searles and Gallavotti-Cohen fluctuation theorem. Finally, we will also discuss the ancilla state tomography that gives a novel theoretical and experimental perspective on quantum entropy production.

Orateur: PANATI, Annalisa (Toulon University)

ID de Contribution: **5** Type: **Non spécifié**

On entropy production in quantum statistical mechanics I

jeudi 14 mars 2024 15:00 (1 heure)

This talk and the following one form a series.
In this first talk we review the notion of entropy production of classical dynamical system based on the phase space contraction rate and discuss classical Evans-Searles and Gallavotti-Cohen fluctuation theorems. The passage to quantum mechanics by direct quantization of phase space contraction rate via modular theory runs into difficulties that will be described in the second part.

Orateur: JAKSIC, Vojkan (McGill University)

ID de Contribution: **6** Type: **Non spécifié**

Rapid thermalisation of quantum dissipative many-body systems

mardi 12 mars 2024 14:00 (1 heure)

Quantum systems typically reach thermal equilibrium when in weak contact with a large external bath. Understanding the speed of this thermalisation is a challenging problem, especially in the context of quantum many-body systems where direct calculations are intractable. The usual way of bounding the speed of this process is by estimating the spectral gap of the dissipative generator, but this does not always yield a reasonable estimate for the thermalisation time. When the system satisfies instead a modified logarithmic Sobolev inequality (MLSI), the thermalisation time is at most logarithmic in the system size, yielding wide-ranging applications to the study of many-body in and out-of-equilibrium quantum systems, such as stability against local perturbations (in the generator), efficient preparation of Gibbs states (the equilibria of these processes), etc.

In this talk, I will present an overview on a strategy to prove that a system satisfies a MLSI provided that correlations decay sufficiently fast between spatially separated regions on the Gibbs state of a local, commuting Hamiltonian. This will allow us to conclude that any Davies or Schmidt dissipative generator converging to a 2-local, commuting Hamiltonian at high-enough temperature thermalises in a time logarithmic in the system size.

Orateur: CAPEL, Angela (Tubingen University)

ID de Contribution: **7** Type: **Non spécifié**

Entropy Production and Two-Time Measurement Protocol of Markovian Quantum Dynamics

mardi 12 mars 2024 15:00 (1 heure)

We provide an expression of the entropy production associated to a Markovian quantum dynamics defined by Lebowitz and Spohn, in terms of the two-time measurement protocol of the entropy observable, according to Kurchan. We do so under the detailed balance condition and, as a byproduct, we show that the probabilities of outcomes of two-time measurements are given by a continuous time Markov process determined by the Lindblad generator of the Markovian quantum dynamics. This is joint work with C.-A. Pillet.

Orateur: JOYE, Alain (Grenoble-Alpes University)

ID de Contribution: **8** Type: **Non spécifié**

Exact Model reduction for Quantum Walks and Open Systems

mardi 12 mars 2024 16:30 (1 heure)

When we aim to accurately simulate the behaviour of complex and networked dynamical systems, the problem of finding simpler representations for the model of interest becomes critical. We focus on completely-positive dynamics, which can be used to describe a wide variety of relevant systems for quantum and classical information, including quantum walks and open systems, as well as classical hidden-Markov models (HMM). For these models, a reduction approach is derived that leverages information on initial conditions and outputs of interests to obtain reduced models whose output matches the one of the target system while, if needed, maintaining the key characteristics of the original model. In doing this, we highlight the minimal memory resources needed to perfectly simulate a given process, probe its "quantum-ness", and tackle an old open problem for HMM.

Orateur: TICOZZI, Francesco (Padova University)

ID de Contribution: **9** Type: **Non spécifié**

Construction of KMS Dirichlet forms and superbounded markovian semigroups on von Neumann algebras

mercredi 13 mars 2024 09:30 (1 heure)

We introduce a construction of Dirichlet forms on von Neumann algebras M associated to any eigenvalue of the Araki modular Hamiltonian of a f. n. non-tracial state, providing also conditions by which the associated Markovian semigroups are GNS symmetric. The structure of these Dirichlet forms is described in terms of unbounded spatial derivations, coercivity bounds are proved and the spectral growth is derived.
We then introduce superboundedness of positivity preserving semigroups, in terms of the symmetric embedding of M into its standard space.
These tools are applied to a general construction of the quantum Ornstein–Uhlembeck semigroups of the Canonical Commutation Relations CCR and some of their non-perturbative deformations.

Orateur: CIPRIANI, Fabio (Politecnico Milano)

ID de Contribution: **10** Type: **Non spécifié**

Gaussian Quantum Markov Semigroups and Entangled Stationary States

mercredi 13 mars 2024 11:00 (1 heure)

We first introduce GQMS, describe the GKLS structure of their generators and briefly discuss their structure and some issues related with invariant states. Then we consider some special 2-mode system with quadratic Hamiltonian in creation and annihilation operators in which each mode interacts with a reservoir.
We show that any initial state converges to a certain stationary state whose the partial trace on the 2-mode system is entangled if the two reservoirs have small enough temperatures.
This talk is based on a joint work with A. Dhahri, D. Poletti and H.J. Yoo.

Orateur: FAGNOLA, Franco (Politecnico Milano)

ID de Contribution: **11** Type: **Non spécifié**

Heisenberg scaling in parameter estimation for quantum Markov dynamics

jeudi 14 mars 2024 09:30 (1 heure)

The estimation of an unknown parameter in quantum mechanical systems is a fundamental task for practical applications regarding quantum technologies. In the typical metrological scenario the unknown parameter is encoded in the state of n probes via local unitary operators; if the initial state is suitably engineered, one can estimate the parameter with a mean square error of the order of 1/n^2 (which improves the standard scaling of 1/n corresponding to initial uncorrelated states) and this is what is known as Heisenberg scaling. However, the achievement of the Heisenberg scaling is usually hindered by the presence of noise due to the interaction between the probes and the environment. In our talk we are going to discuss whether and under which conditions the Heisenberg scaling is restored in the case where the parameter to estimate is encoded by a Markovian dissipative dynamic, distinguishing the situation in which we can perform an arbitrary measurement, or we can only measure either the system or the environment. The talk is based on ongoing joint work with Madalin Guta.

Orateur: GIROTTI, Federico (Politecnico Milano)

ID de Contribution: **12** Type: **Non spécifié**

Optimal estimation of quantum Markov chains using coherent absorbers and displaced-null measurements

jeudi 14 mars 2024 11:00 (1 heure)

In this presentation I will discuss the problem of estimating dynamical parameters of a quantum Markov chain. The key tool will be the use of a coherent quantum absorber which transforms the problem into a simpler one pertaining to a system with a pure stationary state at a reference parameter value. Motivated by the proposal in [1] I will consider counting output measurements and show how the statistics of the counts can be used to compute a simple, asymptotically optimal estimator of the unknown parameter. For this, I will introduce translationally invariant modes (TIMs) of the output and show that these modes are Gaussian in the limit of large times and capture the entire quantum Fisher information of the output. Moreover, the counting measurement provides an effective joint measurement of the TIMs number operators. The unknown parameter is estimated using a two stage estimation procedure. A rough estimator is first computed using a simple measurement, and is used to set the absorber parameter. Due to non-identifiability issues of the counting measurement the reference parameter needs to be shifted away from the initial rough estimator, as shown in the displaced-null measurements theory [2]. Finally, an optimal estimator is computed in terms of the total number of excitations of the TIMs, avoiding the need for expensive estimation procedures.

[1] D. Yang, S. F. Huelga, and M. B. Plenio PRX Quantum 13, 031012 (2023)
[2] F. Girotti, A. Godley and M. Guta, arXiv: 2310.06767

Orateur: GUTA, Madalin (Nottingham University)

ID de Contribution: **13** Type: **Non spécifié**

Probabilistic properties of quantum channels

jeudi 14 mars 2024 14:00 (1 heure)

We investigate quantum channels, and in general quantum Markov evolutions, employing a probabilistic approach. Our interest is to study and analyze a systematic extension of the classical Markov chain theory into the quantum realm, a subject that has seen significant contributions from multiple authors in the past two decades. This seminar will specifically address absorption probabilities (absorption in invariant domains of the evolution). We address this issue by introducing appropriate positive operators, examining their structure and basic properties, their implications on accessibility relations, on the structure of fixed points and on the study of asymptotic results.
If time permits, we will try to describe some more current studies in the direction of return probabilities and expected return times.
The seminar will be mainly based on a paper in collaboration with Federico Girotti (RC, F.Girotti, Absorption in Invariant Domains for Semigroups of Quantum Channels, AHP 2021)

Orateur: CARBONE, Raffaella (University of Pavia)

ID de Contribution: **14** Type: **Non spécifié**

Quantum trajectories and spontaneous decoherence

mardi 12 mars 2024 09:30 (1 heure)

Quantum trajectories arise when we couple a quantum system to a sequence of ancillas consecutively, and perform von Neumann measurements on the ancillas. Let the average evolution of the system be described by a semigroup (T^n). Then the ergodic components of the random outcome sequence are in one-to-one correspondence with the minimal projections in the center of the Kraus algebra of T.
If we omit the measurements, and only perform the couplings, then the sequence of ancillas goes into a so-called finitely correlated state. This state defines via the GNS-construction a von Neumann algebra extension of the product of the ancilla algebras. We show that again the center of this algebra is isomorphic to the center of the Kraus algebra.
We discuss the connection to discussions of the measurement problem by Klaus Hepp and Jürg Fröhlich.

Orateur: MAASSEN, Hans (Radboud University)

ID de Contribution: **15** Type: **Non spécifié**

Limit theorems for quantum trajectories

jeudi 14 mars 2024 16:30 (1 heure)

Quantum trajectories are Markov chains modeling the evolution of a quantum system under repeated indirect measurements. The goal of this talk is to show how to prove limit theorems for these Markov chains. In particular, we show that the Markov operator associated to the Markov chain has a spectral gap, and we show that there exists an analytic perturbation of this operator. Then, by applying the theory of perturbation, we deduce limit theorems for the empirical mean and the Lyapunov exponent.
It is a joint work with T. Benoist and C. Pellegrini. [arXiv:2402.03879]

Orateur: HAUTECŒUR, Arnaud (Toulouse 3 University)

ID de Contribution: **16** Type: **Non spécifié**

Invariant measures for quantum trajectories and dark subspaces

mardi 12 mars 2024 11:00 (1 heure)

Quantum trajectories are Markov chains modeling the evolution of a quantum system subject to repeated indirect measurements. It was shown by Kümmerer and Maassen that, asymptotically, a quantum trajectory performs a random walk between the so-called 'dark subspaces'. We show that this random walk admits a unique invariant probability measure and that the convergence towards this measure is geometric. We also provide a classification of invariant measures for quantum trajectories inside dark subspaces. Joint work with T. Benoist and C. Pellegrini.

Orateur: SZCZEPANEK, Anna (Toulouse 3 University)

ID de Contribution: **17** Type: **Non spécifié**

Generators of Symmetric Quantum Markov Semigroups

vendredi 15 mars 2024 11:00 (1 heure)

Several symmetry conditions have been introduced to describe the dissipative part of a quantum Markov semigroup in detailed balance, most prominently the GNS and KMS symmetry condition. I will give an overview over recent results concerning the generators of GNS-symmetric and KMS-symmetric quantum Markov semigroups on arbitrary von Neumann algebras and their connections to derivations, building on earlier work by Cipriani and Sauvageot in the tracially symmetric case. This talk is partly based on joint work with Matthijs Vernooij.

Orateur: WIRTH, Melchior (IST Austria)