Tristan Benoist (ENS Paris)

Repeated nondemolition measurements and wave function collapse

Quantum nondemolition (QND) indirect measurements are often used in quantum optics in order to gain information on a system without destroying it or getting it out of its site. In a joint work with Michel Bauer and Denis Bernard, we tried to understand how repeated QND measurements could lead to a wave function collapse. I will present this work.

Our study was inspired by an experiment done by Serge Haroche's group at LKB-ENS. Starting from this example, Michel Bauer and Denis Bernard found that the wave function collapse is related to some martingale convergence and that this convergence is exponential. Then we generalized this convergence result and found how the convergence rate is modified when using different types of QND indirect measurements. We also studied the stability of the convergence with respect to a trial state, degenerate cases and the continuous time approximation of our model using martingale change of measure.

Denis Bernard (ENS Paris)

Open quantum random walks: bi-stability and ballistic diffusion

Open Quantum Random Walks (OQRWs) deal with quantum random motions on the line for systems with internal and orbital degrees of freedom. The internal system behaves as a quantum random gyroscope coding for the direction of the orbital moves. We shall discuss a transition, depending on OQRW moduli, in the internal system behaviors from simple oscillations to random flips between two unstable pure states. This induces a transition in the orbital motions from usual diffusion to ballistically induced diffusion with large mean free path and large effective diffusion constant at large time.

Stephan de Bièvre (Lille)

On stochastic acceleration

A classical particle undergoing random inelastic scattering events with a time-dependent potential is modeled through a Markov chain in which the individual scattering events are described through a Hamiltonian evolution. We give a rigorous proof in this framework of the fact that the kinetic energy of the particle grows as $t^{2/5}$, a phenomenon known as "stochastic acceleration". (Joint work with E. Soret)

Laurent Bruneau (Cergy)

Large time asymptotics of repeated interaction systems

We will review results obtained during the last years about the large time behaviour of repeated interaction quantum systems (existence/uniqueness of an asymptotic state, energy variation, entropy production) in various situations: identical interactions, random interactions, leaky interactions.

Jan Dereziński (Warsaw)

Excitation spectrum of interacting bosons in the mean field infinite volume limit

I would like to describe recent results obtained together with M. Napiorkowski and inspired by an earlier work of R. Seiringer. We prove that the excitation spectrum of the Bose gas has the form predicted by the Bogoliubov approximation in an appropriate limit involving both the mean field and large volume approximation.

Franco Fagnola (Politecnico di Milano)

On the decoherence-free subalgebra of a quantum Markov semigroup

Let $\mathcal{T}$ be a norm-continuous quantum Markov semigroup on $\mathcal{B}(\mathsf{h})$ with generator $\mathcal{L}$ in GKSL form

$$\mathcal{L}(x) = G^*x + \sum_\ell L_\ell^* x L_\ell + xG$$

with $L_\ell, G \in \mathcal{B}(\mathsf{h})$. The operator G can be written in the form $G = -\mathrm{i}H - \frac{1}{2}\sum_\ell L_\ell^* L_\ell$ for a self-adjoint H on h

The decoherence-free subalgebra of $\mathcal{T}$ is the von Neumann subalgebra of $\mathcal{B}(\mathsf{h})$ (see F. Fagnola, R. Rebolledo, Algebraic conditions for convergence of a quantum Markov semigroup to a steady state. *Infin. Dimens. Anal. Quantum Probab. Relat. Top.*, **11** (2008) 467–474. and the references therein)

$$\mathcal{N}(\mathcal{T}) = \{\, x \in \mathcal{B}(\mathsf{h}) \mid \mathcal{T}_t(x^*x) = \mathcal{T}_t(x^*)\mathcal{T}_t(x),\ \mathcal{T}_t(xx^*) = \mathcal{T}_t(x)\mathcal{T}_t(x^*),\ \forall t \geq 0 \,\}.$$

It can be shown that $\mathcal{N}(\mathcal{T})$ is $\mathcal{T}$-invariant. When h is finite-dimensional and $\mathcal{N}(\mathcal{T})$ is a factor, there exist spaces k and m such that $\mathcal{N}(\mathcal{T}) = \mathcal{B}(\mathsf{k}) \otimes \mathbb{1}_{\mathsf{m}}$.

Here we prove that, the operators L_ℓ and G also factorise, namely, there exist operators M_ℓ and a self-adjoint K on k and a self-adjoint K_{m} on m such that

$$L_\ell = \mathbb{1}_{\mathsf{k}} \otimes M_\ell, \qquad H = K \otimes \mathbb{1}_{\mathsf{m}} + \mathbb{1}_{\mathsf{k}} \otimes K_{\mathsf{m}}.$$

As a consequence the generator $\mathcal{L}$ can be decomposed as the sum

$$\mathcal{L}(x) = \mathrm{i}\,[\mathbb{1}_{\mathsf{k}} \otimes K_{\mathsf{m}}, x] + \left(I_{\mathcal{B}(\mathsf{k})} \otimes \mathcal{L}_{\mathsf{m}}\right)(x)$$

($I_{\mathcal{B}(\mathsf{k})}$ denotes the identity map on $\mathcal{B}(\mathsf{k})$ and $\mathcal{L}_{\mathsf{m}}$ a GKSL generator on $\mathcal{B}(\mathsf{m})$) showing a factorisation between noiseless and noisy part of the action of $\mathcal{T}$.

Matteo Gregoratti (Politecnico di Milano)

Quantum measurements in continuous time, non Markovian evolutions and feedback

We present a non Markovian version of quantum trajectory theory, based on the the stochastic Schrödinger equation with stochastic coefficients. In this framework we can model the non Markovian evolution a two-level atom stimulated by a laser, in the case of imperfections in the stimulating laser, and of a feedback loop based on the detection of the fluorescence light. Indeed, realistic descriptions of a feedback loop have to include delay and thus need a non Markovian theory of measurements in continuous time and measurement based feedback. In particular, chosen a specific feedback, we explicitly compute the homodyne spectrum of the fluorescence light in order to control its fluorescence light (squeezing). Let us stress the change of point of view with respect to the usual applications of control theory. Here the "system" is the two-level atom, but we do not want to control its state. Our aim is to control the properties of the emitted light; moreover, we want to control the spectrum, which is not a property at a single time, but involves a long interval of times (a Fourier transform of the autocorrelation function of the observed output is needed).

Martin Fraas (ETH Zürich)

Adiabatic theory for Lindblad equation

Adiabatic theory describes the evolution of a slowly driven (quantum) system. In my talk I first outline the theory and review its historical development with a focus on the open quantum case. Then I explain its key applications: Linear response theory, optimal control and quantum adiabatic computation.

Vojkan Jakšić (McGill)

Entropic Functionals and Liouvilleans

In this talk I will describe the basic entropic functionals of classical and quantum non-equilibrium statistical mechanics and how they can be characterized in terms of a specific class of self-adjoint operators called Liouvilleans. The structural theory will be illustrated with a number of examples.

Alain Joye (Grenoble)

Transport properties of random quantum walks

We consider the discrete unitary dynamics of a particle with spin in on the lattice defined by simple quantum walks. Such walks consist in the repeated action of a unitary spin matrix on the internal degree of freedom followed by a shift on the lattice conditioned on the spin state. We review recent results on the characteristic features of the transport properties they possess when the spin matrices are random in space and/or time.

Spectral transition for random quantum walks on trees

We consider random quantum walks on a homogeneous tree of degree 3 describing the discrete time evolution of a quantum particle with internal degree of freedom in $\mathbb{C}^3$ hopping on the neighboring sites of the tree in presence of static disorder. The one time step random unitary evolution operator of the particle depends on a unitary matrix $C \in U(3)$ which monitors the strength of the disorder. We show the existence of open sets of matrices in $U(3)$ for which the random evolution has either pure point spectrum almost surely or purely absolutely continuous spectrum. We also establish properties of the spectral diagram which provide a description of the spectral transition driven by $C \in U(3)$.

Benjamin Landon (McGill)

Entropic fluctuations of XY quantum spin chains

We consider an XY quantum spin chain that consists of a left, center and right part initially at thermal equilibrium at inverse temperatures β_l, β_c, and β_r, respectively. The left and right systems are infinitely extended thermal reservoirs and the central system is a small quantum system linking these two reservoirs. If there is a temperature differential, then heat and entropy will flow from one part of the chain to the other. We consider the Evans-Searles and Gallavotti-Cohen functionals which describe the fluctuations of this flux with respect to the initial state of the system and the non-equilibrium steady state reached by the system in the large time limit. We also define the full counting statistics for the XY chain and consider the associated entropic functional, as well a natural class of functionals that interpolate between the full counting statistics functional and the direct quantization of the variational characterization of the Evans-Searles functional which appears in classical non-equilibrium statistical mechanics. The Jordan-Wigner transformation associates a free Fermi gas and Jacobi matrix to our XY chain. Using this representation we are able to compute the entropic functionals in the large time limit in terms of the scattering data of the underlying Jacobi matrix. We show that the Gallavotti-Cohen and Evans-Searles functionals are identical in this limit. Furthermore, we show that all of these entropic functionals are equal in the large time limit if and only if the underlying Jacobi matrix is reflectionless.

Hans Maassen (Nijmegen)

Asymptotic behaviour of quantum trajectories

We discuss three theorems concerning the long time behaviour of repeated interactions: an ergodic theorem for the detection records, an ergodic theorem for the trajectories themselves, and necessary and sufficient conditions for the trajectories to become pure in the limit.

Andrea Mantile (Reims)

Quantum evolution in the conduction band for a model of resonant heterostructure with artificial interface conditions in 1D

We consider a simple modification of the 1D-Laplacian where non-mixed interface conditions occurs at the boundaries of a finite interval. It has recently been shown that Schrdinger operators having this form allow a new approach to the transverse quantum transport through resonant heterostructures. In this perspective, it is important to control the deformations effects introduced on the time propagator by this class of non-selfadjont perturbations. When a suitable energy constraint condition is assumed for the initial states, our analysis adapts to the modelling of 1D quantum systems in the regime of quantum wells in a semiclassical island. In this framework, we show that artificial interface conditions introduce perturbations on the dynamics which are controlled by the ratio between the deformation parameter, associated to the boundary conditions, and some power of the parameter fixing the 'quantum scale' of the system.

Marco Merkli (St. Johns)

Quantum measurements of scattered particles

A sequence of quantum particles, the "probes", are sent to interact sequentially with a fixed quantum system, the "scatterer". After exiting the scattering process, a quantum measurement is made on the outcoming probes. The measurement history, *i.e.*, the collection of all measurement results, is a stochastic process. We analyze the convergence and fluctuation properties of this process. This is a joint work with Mark Penney.

Ion Nechita (CNRS–Toulouse)

On the additivity of the minimum entropy of certain subspaces of tensor products

Given a subspace V of a tensor product of two finite dimensional vector spaces, we define its minimum entropy as the smallest entropy of singular value vectors among all unit vectors in V. It is known that, in general, this quantity is not additive with respect to tensor products. We discuss some new results of additivity and non-additivity, both for random subspaces and for some non-random examples. This is based on joint work with S. Belinschi, B. Collins and M. Fukuda.

Annalisa Panati (CPT–Toulon & McGill)

Non-equilibrium statistical mechanics of the spin-boson system

In this talk I will describe open quantum systems describing interaction of a finite level quantum system $\mathcal{S}$ with finitely many heat reservoirs $\mathcal{R}_j$, $j = 1, \ldots, M$. We shall assume that each reservoir $\mathcal{R}_j$ is an infinitely extended free Bose gas in thermal equilibrium at inverse temperature β_j. The dynamics of the coupled system $\mathcal{S} + \sum_j \mathcal{R}_j$ is described by a standard Liouvillean $\mathfrak{L}$, a self-adjoint operator acting on the GNS representation Hilbert space $\mathcal{H}$ induced by the initial state of the system. We introduce a family of deformations $(\mathfrak{L}_\alpha)_{\alpha\in\mathbb{R}^M}$ of $\mathfrak{L}$ with the following property: if Ω is the unit vector in $\mathcal{H}$ describing the initial state of the the coupled system, and $\mathbb{P}_t$ is the full counting statistics of the coupled system (the probability measure on $\mathbb{R}^M$ describing the statistics of the operationally defined entropy/energy flow out of the reservoirs during the time interval $[0, t]$), then $\langle\Omega|e^{it\mathfrak{L}_\alpha}\Omega\rangle = \int_{\mathbb{R}^M} e^{-t\alpha\cdot\varsigma} d\mathbb{P}_t(\varsigma)$. Using this basic identity we study the statistical properties of $\mathbb{P}_t$ (Central Limit Theorem, Large Deviation Principle, etc) by relating the large time limit of the cumulant generating function $\lim_{t\to\infty} \frac{1}{t} \log \int_{\mathbb{R}^M} e^{-t\alpha\cdot\varsigma} d\mathbb{P}_t(\varsigma) = e(\alpha)$ to the spectral resonances of $\mathfrak{L}_\alpha$. We show that, besides the celebrated Evans-Searles symmetry, the function $e(\alpha)$ also satisfies the translation symmetry recently discovered by Andrieux *et al.*, and that in the linear regime near equilibrium these two symmetries yield Kubo's and Onsager's linear response relations for steady state heat fluxes out of reservoirs. We further use the resonance structure of the family $\mathfrak{L}_\alpha$ to prove that coupled system relaxes exponentially fast to non-equilibrium steady state (NESS) and we study the properties of the NESS. This talk is based on a joint work with V. Jakšić, C-A. Pillet and M. Westrich.

Clément Pellegrini (Toulouse)

Quantum repeated measurements and continuous time limit

In this mini course I will present the model of quantum repeated measurements. This consists in introducing the principle of indirect measurements in the model of quantum repeated interactions. Next adapting the convergence results of S. Attal and Y. Pautrat concerning quantum repeated interactions and quantum Langevin equations, we show that the quantum repeated measurements provide an interesting and intuitive justification of the model of stochastic master equations. These stochastic master equations are "classical" stochastic differential equations describing the evolution of a quantum system undergoing indirect measurements. Finally I will present some considerations concerning problem of estimation and modelization in presence of thermal bath.

Claude-Alain Pillet (CPT–Toulon)

Entropic fluctuations of quantum dynamical semigroups

We study finite dimensional quantum dynamical semigroups whose generator $\mathcal{L}$ is a sum of Lindbladians satisfying the detailed balance condition. Such semigroups arise in the weak coupling (van Hove) limit of Hamiltonian dynamical systems describing open quantum systems out of equilibrium. We prove a general entropic fluctuation theorem for this class of semigroups by relating the cumulant generating function of entropy transport to the spectrum of a family of deformations of the generator $\mathcal{L}$. We show that, besides the celebrated Evans-Searles symmetry, this cumulant generating function also satisfies the translation symmetry recently discovered by Andrieux *et al.*, and that in the linear regime near equilibrium these two symmetries yield Kubo's and Onsager's linear response relations. This is joint work with V. Jakšić and M. Westrich.

Thierry Platini (Coventry)

Quasi free fermionic systems and nonequilibrium steady states induced by repeated interactions

When studying the properties of open quantum systems, we often focus on the evolution of the density matrix. In this work we develop a method, based on the repeated interaction process applied on quasi fermionic chains, where a full description of the system is given by the two points correlations. General results are presented for arbitrary structure of the interactions. In particular we present the exact stationary state of a finite XX chain coupled at its boundaries to quantum reservoirs. It is shown that the steady state is completely characterized by the magnetization profile and the associated current. The steady-state current shows a nonmonotonic behavior with respect to the system-reservoir coupling strength, with an optimal current state for a finite value of the coupling.

Dominique Spehner (Grenoble)

Quantum correlations in open quantum systems

In these two lectures, I will discuss how quantum correlations present initially in a bipartite quantum system are affected when the system is coupled to its environment. The first lecture will be devoted to introducing the notions of entanglement and nonclassicality for mixed states in a quantum system composed of two subsystems. I will review some quantities commonly used to measure quantum correlations in such systems: the entanglement of formation, concurrence, quantum discord, and geometric measures based on the Bures distance. In the second lecture, I will describe the evolution of these measures for two qubits coupled either to independent baths or to a common bath, by using some simple markovian models. I will show that, if the dynamics is given by quantum trajectories corresponding to local measurements on the two independent baths, then the mean concurrence of the qubits decreases exponentially, despite the fact that the 2-qubit density matrix may become separable after a finite time.

Francesco Ticozzi (Padua)

Quantum Dynamical Semigroup for Entangled State Preparation

Interactions of a quantum system with its environment have long been considered adversarial to the effective implementations of quantum information processing tasks, as well as a potential reason for the loss of superpositions in the classical to quantum transition. Nonetheless we show that a suitably engineered Markovian environment can be instrumental to quantum information tasks, and can actually help in generating entanglement on multipartite systems. We show how to characterize and construct time-independent Markovian dynamics that drive a finite- dimensional multipartite quantum system into a target (pure) entangled steady state, subject to physical locality constraints. In situations where the desired stabilization task can not be attained solely based on local dissipative means, we allow for local Hamiltonian control and show that doing this effectively enlarges the set of stabilizable states. We provide algorithms for constructing a master equation that achieves the intended objective based on randomization. In particular, we present quasi-local control protocols for dissipatively engineering multipartite GHZ cat states and W states on n qubits. Interestingly, for both entanglement classes, we show that quasi-local stabilization may be scalably achieved conditional to initialization of the system in a large, appropriately chosen subspace.