AQM 2015

Modena, 23-25 Giugno 2015

Simone Cialdi
Dario Tamascelli
Bassano Vacchini
Stefano Olivares
Claudia Benedetti

Matteo Bina
Antonio Mandarino
Jacopo Trapani
Matteo Rossi
Carmen Porto

Giacomo Guarnieri
Francesco Albarelli
Paola Verrucchi
Caterina Foti
Matteo Paris

PROGRAMMA

Mar 23/6

14:00 (breve) escursione centro storico Modena (ritrovo ai piedi della Ghirlandina)

17:00 - 17:45 **Stefano Olivares** Squeezed light and interferometry: is that all, Folks?
17:45 - 18:15 **Bassano Vacchini** Non-Markovianity and complete positivity
18:15 - 19:00 **Simone Ciald**i Generazione di stati squeezed ed entangled @ AQM

20:30 Cena La Baccelliera

Mer 24/6

10:00 **Matteo Rossi** When and how entanglement is useful to characterize classical noise
10:25 **Jacopo Trapani** Two mode system correlations: the influence of classical noise
10:50 **Paola Verrucch**i Dynamics of a harmonic oscillator in a large-S magnetic environment

11:30 pausa

11:45 **Claudia Benedetti** Continuous time quantum walks: a brief tutorial
12:05 **Dario Tamascelli** Quantum transport via Bloch oscillations

12:50 pranzo La Baccelliera

15:15 Museo del Balsamico, Spilamberto
17:00 Rocca di Vignola, scala del Barozzi

18:30 Escursione lungo il Panaro

21:00 Cena (Borlenghi, Gramigna, Gnocco, Tigelle): Trattoria La Campagnola

Gio 25/6

9:30 **Giacomo Guarnieri** Energy backflow in non-Markovian open quantum systems
9:50 **Carmen Porto** Generation and manipulation of sidebands states in homodyne detection
10:10 **Antonio Mandarino** Some remarks when trusting someone else fidelity
10:30 **Matteo Bina** Phase monitoring and state discrimination: an adaptive BPSK...

11:00 pausa

11:30 **Francesco Albarelli** Nonlinearity as a resource for non classicality
11:55 **Matteo Paris** The Landau bound in quantum thermometry

12:15 Conclusione
12:50 pranzo La Baccelliera

Stefano Olivares

Squeezed light and interferometry: is that all, Folks?

Quantum interferometry is one of the amazing aspects of quantum mechanics. Single-particle interference has always exited scientists leading them to a better understanding (or maybe not) of the quantum weirdness. Furthermore, interference phenomena are exploited to investigate the very properties of the physical world: optical interferometry is among the most precise measurement techniques available in physics. The possibility of increasing the performances of interferometers by exploiting quantum light represents one of the relevant uses of quantum states for overcoming classical limits of measurements. Recent theoretical and experimental results have shown that the current quantum-noise-limited sensitivity of squeezed-light- enhanced gravitational wave detectors is very close to the ultimate bounds imposed by quantum mechanics (given a fixed total energy and considering the possible sources of noise). Therefore, the question that naturally arises is: "Is that all?" In this brief journey, we will travel from the fundamental quantum interferometry bounds to (possible) experimental quantum gravity tests. In particular, I will review the basic aspects of quantum estimation theory applied to interferometry illustrating the main contributions of AQM group to this field of research. Eventually, I will discuss the new exciting possibilities offered by two interferometers correlated by quantum light, as the measurement of faint correlated signals that would remain otherwise undetectable even using the most sensitive individual interferometric devices.

Bassano Vacchini

Non-Markovianity and complete positivity

Giacomo Guarnieri

Energy backflow in non-Markovian open quantum systems

Manipulation of heat at microscopic level has been intensively studied in recent years and it is possible to find several proposal of heat engines/pumps which consist of a finite dimensional quantum system coupled to multiple environments. The results in these contributions have mainly been derived in the Born-Markov approximation, therefore allowing for a quantum dynamical semigroup description. The latter however, despite providing faithful descriptions in the long-time limit, represents quite a strict condition to hold in many situations. More realistic scenarios have therefore been intensively studied in the last years, in which memory effects, i.e. non-Markovian dynamics, play a central role. In particular, much effort has been devoted to precisely define and measure the degree of non-Markovianity of a dynamics and now one of the most stimulating challenges is to try to exploit non-Markovianity as a resource to improve thermodynamical properties and quantum communication protocols. At variance with what happens in the semigroup regime, where a one-way only energy current from high to low temperature can occur, in non-Markovian dynamics the rate by which system and environment exchange energy can oscillate in time and energy can even come back from one to the other. The present work, topic of this talk, is inserted in this framework and is in particular devoted to study the behavior of the energy flow between an open system and its environment, using the formalism of the so-called Full Counting Statistics. After a brief review of this formalism, we will introduce a condition and a quantitative estimator for the energy backflow. We will then move to apply this construction to a paradigmatic open quantum system, the spin-boson model. Finally we will discuss the connection between the newly introduced estimator for the energy backflow and the occurrence of non-Markovianity as introduced by Breuer, Laine and Piilo in Phys. Rev. Lett. **103**, 210401 (2009).

Antonio Mandarino

Some remarks when trusting someone else fidelity

Fidelity is a figure of merit widely employed in quantum technology in order to quantify similarity between quantum states and values above a given threshold close to unit, say, 0.9 or 0.99 are usually considered as a sign that the two states are close to each other, and so share nearly identical properties. One of the pillars in quantum enhanced protocols resides in the experimental ability to produce a given state with some specific properties. In order to quantify how well the task has been performed is a usual procedure to compute the Uhlmann fidelity between the experimental state and the expected. On the other hand, we have recently shown that high fidelities may be achieved by pairs of states with considerably different physical properties, including separable and entangled states or classical and nonclassical ones [1, 2]. Therefore, fidelity alone cannot be used to asses the very quantum properties of two states. By considering examples both for qubits and continuous variable systems, here we show that given a quantum target state, we can find sets of states with a very high fidelity to the target but with extremely different properties even when imposing some other physical constraint.

[1] M. Bina et al., Phys. Rev. A **89**, 012305 (2014).
[2] A. Mandarino et al., Int. J. Quantum Inform. **12**, 1461015 (2014).

Matteo Rossi
When and how entanglement is useful to characterize classical noise

Jacopo Trapani
Two mode system correlations: the influence of classical noise

Paola Verrucchi
Dynamics of a harmonic oscillator in a large-S magnetic

We consider a composite system made of a quantum harmonic oscillator and a magnetic system with fixed total spin S, interacting via a Dicke-like Hamiltonian. In the large-S limit, the global unitary dynamics is found to result from the composition of two propagators, separately describing the energy exchange from the oscillator to the environment, and viceversa. The corresponding reduced dynamics for the oscillator is then studied by the parametric representation with environmental coherent states, and the case when the environment is initially prepared in the state with S_z=-S is specifically addressed. Connections with the behaviour of an oscillator in a fluctuating classical field emerge, as well as indications about the role played by the internal symmetry of the environment, that ensures S is constant.

Claudia Benedetti
Continuous time quantum walks: a brief tutorial

Quantum walks, the quantum counterpart of the classical random walks, are largely employed to model phenomena in different fields, such as physics, chemistry, biology and quantum algorithms. The peculiar effects of quantum interference in a quantum walk lead to a very different dynamical evolution with respect to the classical random walk. Recently, a large number of physical systems have been proved to be suitable candidates for the experimental implementation of quantum walks. These technological advances demand for more sophisticated theoretical models which account for the decoherence induced by the noisy environment. In this talk I will present a brief overview of continuous time quantum walks, including their historical background, their definition and specific terminology and the relation to classical continuous time random walk. I will also discuss possible extensions to continuous time quantum walks on a discrete 1D lattice with dynamical disorder, described as stochastic terms in the system Hamiltonian, in order to understand the roles of the noise amplitude and noise correlation time on the dynamics of the walker.

Dario Tamascelli
Quantum transport via Bloch oscillations

Simone Cialdi
Generazione di stati squeezed ed entangled @ AQM

Carmen Porto
Generation and manipulation of sidebands states in homodyne detection scheme

Matteo Bina
Phase monitoring and state discrimination: an adaptive BPSK communication scheme

We consider a communication scheme in which the binary information is encoded in two coherent states with opposite phases. The advantage of using the most classical states of light is at the expense of a limited state discrimination, due to the non-orthogonality of coherent states. The key ingredient for reducing the error probability of the discrimination protocol is to let the signal interfere with a local oscillator (LO), fixing the value of the relative phase. A precise and continuous monitoring of this phase is needed in order to ensure a reliable communication scheme. We propose an adaptive scheme based on photon-number-resolved (PNR) detection and Bayesian strategies, which allows to retrieve information on the relative phase between signal and LO in real-time and to strongly reduce the error probability in discrimination. In particular we performed numerical simulations and collected experimental data to validate our model, including sources of phase noise, unbalanced signals and different types of detection.

Francesco Albarelli

Nonlinearity as a resource for non classicality

Nonclassical states are fundamental for quantum technology and nonclassicality can be considered a resource for various application; moreover it is an important concept in the study of macrosopic coherence as well. The relationship between the nonlinearity of a potential (intended as its anharmonicity) and the nonclassicality of the corresponding ground state will be explored. Various measures to quantify nonclassicality of a state will be reviewed, underlining differences between the ones based on the Glauber P function and the ones based on the Wigner function. In order to quantify the nonlinearity of a potential the nonGaussianity of its groundstate will be employed, for this reason an entropic measure of nonGaussianity will also be introduced. After reviewing all the tools I will present the results of the analysis of some exactly solvable potentials and of a generic even perturbation. These results quantitatively support the intuitive idea that the more nonlinear a potential the more nonclassical its groundstate.

Matteo Paris

The Landau bound in quantum thermometry

We address estimation of temperature for finite quantum systems at thermal equilibrium and show that the Landau bound to precision, $\Delta T^2 = T^2/C$, where C is the heat capacity, originally derived for a classical not too small system being a portion of a large isolated system at thermal equilibrium, may be also achieved by energy measurement in microscopic quantum systems exhibiting vanishing gap as a function of some control parameter. On the contrary, for any quantum system with a non-vanishing gap Δ, precision of any temperature estimator diverges at least as $\Delta T^2 = T^4 e^{\Delta/T}$.