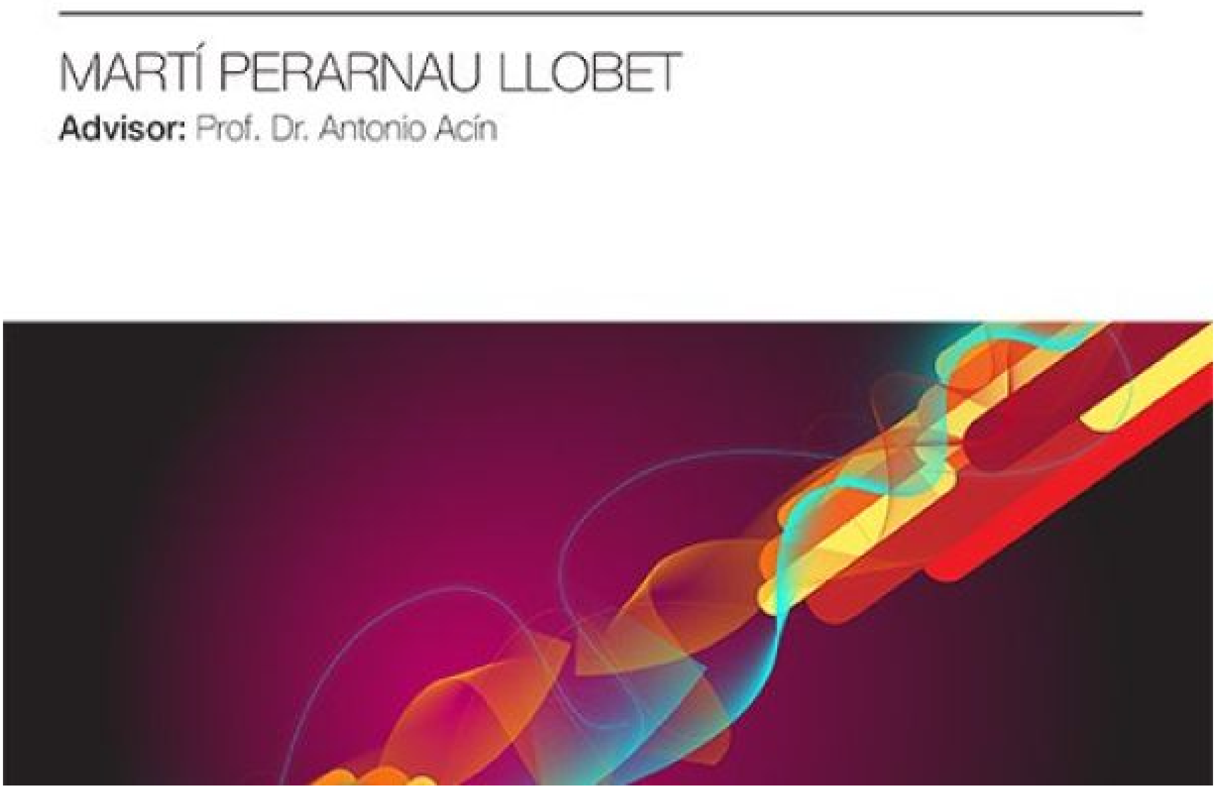

PhD Thesis Defense MARTI PERARNAU 'Thermodynamics and Quantum Correlations'

MARTI PERARNAU

June 06, 2016

Monday, June 6, 11:00. ICFO Auditorium

MARTI PERARNAU

Quantum Information Theory

ICFO-The Institute of Photonic Sciences

Thermodynamics traditionally deals with macroscopic systems at thermal equilibrium. However, since the very beginning of the theory, its range of applicability has only increased, nowadays being applied to virtually every field of science, and to systems of extremely different size.

This thesis is devoted to the study of thermodynamics in the quantum regime. It contains original results on topics that include: Work extraction from quantum systems, fluctuations of work, the energetic value of correlations and entanglement, and the thermodynamics of closed quantum many body systems.

First, we study work extraction from thermally isolated systems. Here the notion of passive states naturally arises, as those quantum states from which no work can be extracted. We start by characterising the set of passive states, and find the most energetic passive states, a dual family to the well known Gibbs (or thermal) states. Remarkably, passive states have the property of activation: When considered as a whole, several copies of passive states can become nonpassive. We study the dynamics of activation processes, and find a relation between the entanglement generated and the speed of the process.

Next, we consider the possibility of extracting work from a system using an auxiliary thermal bath. In this case, according to the second law of thermodynamics, the amount of work is bounded by the free energy difference.
We develop corrections to this law which arise from the finite size and the structure of the bath.

We go on by studying the fluctuations of work. Fluctuations are particularly relevant for small systems, where their relative size is comparable to the average value itself. However, characterising the fluctuations in the quantum regime is particularly difficult, as measurements generically disturb the state. In fact, we derive a no go result, showing that it is not possible to exactly measure the fluctuations of work in quantum coherent processes. Despite this result, we develop a new scheme that allows for their approximate measurement.

An important part of this thesis is devoted to the relation between quantum correlations and work. We start by considering a set of correlated states which are thermal at the local level, in which case the extractable work can only come from the correlations. We compute the

amount of work that can be stored in entangled, separable and correlated states with a fixed entropy, by finding the corresponding optimal states and protocols. These results provide fundamental bounds on the potential of different type of correlations for work storage and extraction. Next, we consider the converse scenario, and study the creation of correlations from thermal states. We find thresholds on the maximal temperature for the generation of entanglement. We also work out the minimal work cost of creating different types of correlations, including total correlations, entanglement, and genuine multipartite entanglement.

Finally, we study the thermodynamics of closed quantum systems. Here we use one of the most important recent insights from the study of equilibration in quantum systems: Closed many body systems do not equilibrate, but can be effectively described as if they had equilibrated when looking at a restricted, physically relevant, class of observables. Importantly, the corresponding equilibrium state is not necessarily a Gibbs state, but may be very well given by a Generalized Gibbs ensemble state. With this in mind, we develop a framework for studying entropy production and work extraction in closed quantum systems.

Monday June 6th, 11:00 h. ICFO Auditorium

Thesis Director: Prof Dr Antonio Acin