- ## Thiago V. Acconcia

Zero excess work in finite time quantum processes

An ubiquitous goal in thermodynamics is to optimize finite times processes by minimizing the dissipated or excess work. For the parametric harmonic oscillator we derive a family of degenerated finite-time optimal protocols for which the excess work during a non-equilibrium process vanishes exactly. Our findings can be derived by means of Linear Response theory, and we show that further physical understanding can be achieved with the help of adiabatic invariants. Furthermore, we see that our results hold true for both, the classical as well as the quantum harmonic oscillator. Finally, we discuss the range of validity of our approach, which can be quantified in terms of the thermodynamic length.

- ## Felix A. Pollock

The thermodynamics of excitation transfer in molecular networks

The dynamics of electronic excitations in molecular networks has received a great deal of attention in recent years, due to the experimental observation of quantum coherence in biological molecules such as the Fenna-Matthews-Olsen complex and suggestions that this may contribute to the efficiency of intramolecular energy transfer. Here we investigate the thermodynamics of these processes using concepts only recently developed for quantum systems and how it relates to relevant dynamical properties such as the transfer efficiency.

- ## Felipe Barra

Spin chains in Three Non-equilibrium setups

We study spin chains driven out of equilibrium. We consider three different driving mechanisms. First we consider infinite chains that evolve unitarily but reach a non-equilibrium steady state (NESS) as defined by Ruelle [1] and developed in [2]. We analyze the thermodynamic properties of the NESS and their non-equilibrium phase transitions for the XX and XY chain [3]. We then consider the NESS of spin chains coupled to two reservoirs at different temperatures and introduce an approximate scheme that succeeded in describing the properties of fermionic systems out of equilibrium [4]. The scheme is based on the approach of [5] where it was noticed that the usual Born-Markov secular approximation that allows a description of the non-equilibrium system in a Lindblad from fail to describe the current inside driven systems and proposed an alternative approximation. We then consider the NESS of boundary driven spin chains a model intensively studied [6,7] and recently criticized in [8]. We show the differences and similarities in the thermodynamics behaviors of the spin chains under these three conditions.

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• Edgardo Solano-Carrillo

Entropy Production in Isolated Quantum Many-Body Systems

Beginning with the Liouville-von Neumann equation for the density matrix of an isolated quantum many-body system, and applying well-known projection-operator techniques, we derive an equation of motion for the rate of change of the thermodynamic entropy, valid to arbitrary order in the perturbation. To lowest order, a balance equation is obtained which coincides with the one defining the entropy production in irreversible thermodynamics. We apply the results to clarify the "thermalization problem" inherent in the Jaynes-Cummings model for the interaction of two-level atoms with a single-mode quantized electromagnetic field in a cavity.

• Luis Pedro García-Pintos

Time scales of equilibration for a system interacting with a bath

We address the problem of understanding, from first principles, under what conditions a closed quantum system equilibrates quickly with respect to some observable. Recently there have been promising advances. In particular, we have learnt that typical (drawn from

the Haar measure) observables equilibrate rapidly, and yet one can construct observables which take an extremely long time to approach equilibrium (in a time proportional to the Hilbert space dimension d). However, these results tell us little about the times for a single given physical observable. In this work we provide a new upper bound on the equilibration time scales for a given observable. Under the assumption that the initial state is spread over many energy levels, and certain assumptions about the distribution of the matrix elements of an observable, we find that for very mixed initial states this new bound gives much better results than previously known; results which do not scale with the Hilbert space dimension d. We apply our result to the situation of a small system interacting with a thermal bath, and contrast it with a simple analytic example, finding a tight result for high temperatures. This is a first result towards understanding the conditions under which a small system in contact with an environment equilibrate rapidly.

- **Philipp Kammerlander**

Non-diagonal quantum thermodynamic resource theories

A central goal of the research effort in quantum thermodynamics is the extension of standard thermodynamics to include small-scale and quantum effects. Recent progress led to various new insights, among them the effect of stronger than classical correlations on thermodynamic tasks, such as work extraction during erasure [1], and a first experimental test of the quantum Jarzynski equality [2]. However, many results in this field are classical in the sense that they only consider states that are diagonal in the energy eigenbasis of the system on which a thermodynamic transformation takes place [3,4]. In this talk I will use standard assumptions made in quantum thermodynamics and show what would be required to adapt the concepts commonly used in resource theories such that non-diagonal states can be treated. We will then restrict ourselves to the analysis of average quantities [5] and establish a link between these results and the quantum Jarzynski realtion [6]. Going out from these insights I will discuss differences between quantum and classical thermodynamics.

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- **Gabriel T. Landi**

Entropy production in an a optomechanical oscillator

We study the entropy production in a Fabry-Perot cavity coupled via radiation pressure to the cavity field and in contact with a heat bath at a temperature T. The system is modeled in terms of coupled quantum Langevin equations, which are linearized assuming the limit of large laser power. The resulting system of equations may be described by a Fokker-Planck equation with a non-negative distribution function. Due to this fact, we are able to apply known expressions from classical stochastic processes to study the entropy production rate of the system, both as a function of time and in the steady-state. It is shown that the entropy production rate is strongly influenced by the population of modes in the cavity.We are also able to separate the different contributions to the entropy production rate, stemming from non-adiabaticity and the lack of detailed balance. The behavior of each as a function of time is studied in detail.

- **Philippe Faist**

Gibbs-Preserving Maps outperform Thermal Operations in the quantum regime

In the study of the thermodynamics of small systems, one is led to precisely specify thermodynamical concepts, such as which processes are permitted. There are many different frameworks which come up with well-motivated definitions for these notions, and they usually recover various forms of standard results such as the second law of thermodynamics. Here, we argue that before we can unify these frameworks, one first has to solve the fundamental conceptual question of how much, and which, resources are required to manipulate coherent superpositions of energy levels. Indeed, several of the existing frameworks are nonequivalent in the quantum regime, even though they are equivalent classically. More specifically, we focus on two frameworks in particular: Thermal Operations and Gibbs-Preserving Maps. Thermal Operations are defined operationally by restricting an agent to operations which conserve energy on a system and a heat bath. The second framework allows, more generally, any operation which preserves the Gibbs state at a given temperature. Classically, these frameworks are equivalent—Gibbs-Preserving Maps are no more powerful than Thermal Operations. This equivalence no longer holds in the quantum regime: Thermal Operations may not create superpositions of energy levels; however this is possible using Gibbs-Preserving Maps. In particular, our result exposes a problem of time control as a resource, which is an aspect that most current efforts in modeling thermodynamics of quantum systems have ignored until now.

- ## Saleh Rahimi-Keshari

Operational discord measure for Gaussian states with Gaussian measurements

Quantum correlations play a central role as a resource in quantum information processing tasks. Quantum discord was proposed as a general measure of quantum correlations that can capture correlations beyond quantum entanglement. However, this measure might not be the most useful figure of merit for quantum protocols involving particular classes of quantum states and measurements. In this presentation, I introduce a new measure for quantifying nonclassical correlations in bipartite Gaussian states, based solely on Gaussian measurements. This measure is defined as the difference between the continuous Shannon entropies of two conditional probability distributions associated to one subsystem that are obtained by performing optimal local and joint Gaussian measurements. This measure is referred to as operational Gaussian discord, as it has an operational significance in terms of a quantum protocol [1] that only involves Gaussian states, operations, and measurements. In this protocol a classical signal with a Gaussian probability distribution is encoded on one subsystem of a bipartite Gaussian state, and one tries to retrieve the signal from the noise associated with the joint state and the measurement. I show that in the limit of large variances for the signal probability distribution, the difference between the maximum classical mutual informations between the signal and the measurement outcome, which are obtained by optimal joint and local Gaussian measurements, is equal to the operational Gaussian discord of the bipartite Gaussian state.

- ## Ines de Vega

On hierarchically structured master equations

We present a derivation of a master equation for an open quantum system without the use of the weak coupling or rotating wave approximations, and without the use of any projection operator technique. Our departure point is the exact stochastic Liouville von-Neumann (SLN) equation, which depends on two correlated noises and describes exactly the dynamics of an oscillator (which can be either harmonic or present an anharmonicity) coupled to an environment at thermal equilibrium. The newly derived master equation is obtained by performing analytically the average over different noise trajectories. It is found to have a complex hierarchical structure that might be helpful to explain the convergence problems occurring when performing numerically the stochastic average of trajectories given by the SLN equation.

• Takaaki Monnai

Typical pure states and nonequilibrium statistical mechanics

A fundamental question of the statistical mechanics is to understand how it works for relatively small systems such as various nano systems, 30-site quantum spin chains, and relaxation of cold atoms. In the context of the quantum ergodic theory, this issue has been explained by an intrinsic thermal nature of typical pure states on an energy shell. In this presentation, we show that the thermal nature is available also for the analysis of nonequilibrium processes starting from an equilibrium. In particular, we explore how accurately we can analyze the full statistics of entropy production in nonequilibrium mesoscopic systems. A subtlety is that the full statistics requires expectation values of many linearly independent observables. We can explain how to resolve this problem of the state tomography. The thermal nature is also applicable to the nonequilibrium steady state of quantum junctions on the basis of the scattering approach for a well-defined thermodynamic limit. In this way, we can access the full information on higher-order fluctuations including the large deviation regime far from equilibrium.

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• Nadja Kolb Bernardes

Environmental correlations and Markovian to non-Markovian transitions in collisional models

The dynamics of open quantum systems is characterized for continuous Markov processes in terms of master equations in the so-called Lindblad form. However, the required assumption of a memoryless environment is in reality, in most of the cases, an approximation. In general, the environment presents memory effects that may lead to non-Markovian dynamics. Understanding these effects is an important fundamental question with potential applications in the engineering of reservoirs for quantum computation and as a resource for quantum information processing such as quantum key distribution, quantum metrology, quantum teleportation, and quantum communication. We present in this work a new collisional model for the study of open quantum systems [1]. The smallest set of requirements for inducing non-Markovian dynamics in this model is investigated.

This is done by introducing correlations in the state of the environment and analyzing the divisibility of the quantum maps from consecutive time steps. Our model and results serve as a platform for the microscopic study of non-Markovian behavior as well as an example of a simple scenario of non-Markovianity with purely contractive maps, i.e. with no back-flow of information between system and environment.

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- ## Alan Costa dos Santos

Shortcut to adiabatic gate teleportation

As shown by Gottesman & Chuang, quantum teleportation can be used as a universal computational primitive. In this scenario, Bacon & Flammia proposed a scheme to adiabatically perform gate teleportation, which aims at building a universal quantum computer by piecewise adiabatic evolutions. In essence, this constitutes a hybrid protocol based both on measurement-based and adiabatic quantum computing. In this work, we implement a shortcut to the Bacon-Flammia model, providing a superadiabatic theory for realizing quantum computation. In particular, we provide the counteradiabatic dynamics and discuss the success probability of the method. Moreover, we investigate the thermodynamic cost of the superadiabatic approach.

- ## Christian Gogolin

Locality of Temperature

This work is concerned with thermal quantum states of Hamiltonians on spin- and fermionic-lattice systems with short-range interactions. We provide results leading to a local definition of temperature, thereby extending the notion of "intensivity of temperature" to interacting quantum models. More precisely, we derive a perturbation formula for thermal states. The influence of the perturbation is exactly given in terms of a generalized covariance. For this covariance, we prove exponential clustering of correlations above a universal critical temperature that upper bounds physical critical temperatures such as the Curie temperature. As a corollary, we obtain that above the critical temperature, thermal states are stable against distant Hamiltonian perturbations. Moreover, our results imply that above the critical temperature, local expectation values can be approximated efficiently in the error and the system size.

- **Antonio di Lorenzo**

Post-selection induced entanglement

We show that a single particle in a superposition of different paths can entangle two objects located on each path. The entanglement has its maximum visibility for intermediate coupling strengths. In particular, when the two quantum systems with which the particle interacts are detectors that measure its presence and its polarization, a peculiar situation of entanglement in two separated systems that have never mutually interacted is realized.

- **John Peterson Pinheiro da Silva**

Experimental demonstration of information to energy conversion in a quantum system at the Landauer Limit

Landauer's principle sets fundamental thermodynamic constraints for classical and quantum information processing. Here we measure, for the first time, the heat dissipated in elementary quantum logic gates, at the Landauer limit, implemented in a Nuclear Magnetic Resonance system. This allows for the detailed study of irreversible entropy production in quantum information processors.

- **Ana Cristina Sprotte Costa**

  – **Bayes' rule, generalized discord, and nonextensive thermodynamics**

Generalized measures of quantum correlations are derived by taking Bayes' rule as the only fundamental principle. The resulting quantifiers satisfy several desirable conditions for a measure of quantum correlations and are shown to admit operational interpretation in terms of the difference in efficiency of quantum and classical demons in allowing for the extraction of generalized work from a heat bath. The link with discord is established by adopting the q entropy as entropic principle. This allows us to reproduce, within a one-parameter formalism, both the entropic and the geometric measures of discord and physically distinguish them within the context of the nonextensive thermodynamics. Besides offering a unified view of several measures of correlations in terms of the Bayesian principle and its connection with thermodynamics, our approach unveils a bridge to the nonextensive statistical mechanics.

– **Monogamy and backflow of mutual information in non-Markovian thermal baths**

We investigate the dynamics of information among the parties of tripartite systems. We prove two results concerning the monogamy of mutual information. Then, we analyze the internal dynamics of tripartite systems whose parties do not exchange energy. Moreover, we show that (i) the information flow is reversible for finite thermal baths at low temperatures, (ii) monogamy of mutual information is respected throughout the dynamics, and (iii) genuine tripartite correlations are typically present. Finally, we analytically calculate a quantity capable of revealing favorable regimes for non-Markovianity in our model.

- ## David Dávalos González

Coherent state evolution in a non-symmetric family of models

We study the set of spin coherent states evolved with both symmetric and non-symmetric kicked Ising models. We put our attention in the non-Markovianity and its relation with effective dimension and localization respect to the dynamics eigenbase. We show that there are non-trivial correlations between non-Markovianity and localization, as an structure in the non-Markovianity mapped with the coherent states parameters, that is robust respect to system perturbations. Such structure have a relevant role in quantum thermodynamics.

- ## Kais Abdelkhalek

Work cost of quantum measurements: Improving and generalising the Sagawa-Ueda bound

We investigate the amount of work necessary to perform a general quantum measurement on a finite-dimensional quantum system. Additionally, we explore the cost of resetting the measurement device to its initial state, thus allowing for repeated uses of the measurement apparatus. The sum of these work costs can be thought of as the cost of a complete run of the measurement device. The bounds we derive extend to general quantum measurements previous results by Sagawa and Ueda (PRL 102, 250602), which we show to be valid only for a small subset of quantum measurements. Additionally, our bound improves the Sagawa-Ueda bound even within the class of measurements their bound is valid for. As applications we consider the energy costs for specific classes of sharp (rank-1) measurements, for stabilising a quantum state via Zeno measurements and for running a Szilard engine.

- ## Kaonan Campos Micadei Bueno

Thermodynamic cost of acquiring information

The intricate information-thermodynamics relation entails a fundamental limit on parameter estimation, establishing a thermodynamic cost for information acquisition. The amount of information that can be encoded in a physical system by means of a unitary process is limited by the dissipated work during the implementation of the process. This includes a thermodynamic tradeoff for information acquisition. Likewise, the information acquisition process is ultimately limited by the second law of thermodynamics.

- ## Thiago Werlang de Oliveira

Energy transport between two pure-dephasing reservoirs

A pure-dephasing reservoir acting on an individual quantum system induces loss of coherence without energy exchange. When acting on composite quantum systems, dephasing reservoirs can lead to a radically different behavior. Transport of energy between two pure-dephasing markovian reservoirs is predicted in this work. They are connected through a chain of coupled sites. The baths are kept in thermal equilibrium at distinct temperatures. Quantum coherence between sites is generated in the steady-state regime and results in the underlying mechanism sustaining the effect. A quantum model for the reservoirs is a necessary condition for the existence of stationary energy transport. A microscopic derivation of the non-unitary system-bath interaction is employed, valid in the ultrastrong inter-site coupling regime. The model assumes that each site-reservoir coupling is local.

- ## Alba Marcela Herrera Trujillo

Improvement of a Quantum Heat Engine: Speeding up the adiabatic processes

Employing the quantum adiabatic dynamics has been an important tool for implementing non-transitional evolutions. This approach is based in the adiabatic theorem, which imposes a "speed limit" on the evolution of a quantum system. Moreover, using the symmetry properties present in the Hamiltonian, we can obtain a new Hamiltonian which ensure a non-transitional dynamics outside the adiabatic regime. This new kind of dynamics, allow us to obtain a shortcut to the adiabatic evolution. Exploiting this shortcut, we study the performance of a quantum heat engine, besides a experimental implementation of such an improved engine.

- ## Alejandro Carrillo Lozada

Quantum simulation of the Anderson Hamiltonian with a chain of coupled nanoresonators: delocalization and thermalization effects.

The possibility of using nanoelectromechanical systems (NEMS) as a simulation tool for quantum many-body effects is explored. Specifically, it is proposed a chain of electrostatically coupled nanoresonators which can be described through a Bose-Hubbard model in the non-interacting regime, i.e. an Anderson tight-binding Hamiltonian. Employing a density matrix formalism with a Jaynes-Cummings-like coupling with a bosonic thermal bath, we study the interplay between disorder and thermalization, focusing on the delocalization process. It is found that the phonon population remains localized for low enough temperatures even if the total population of excitations is lost from the chain due to dissipative effects; with increasing temperatures the localization is lost due to thermal pumping of excitations into the chain, producing in the steady regime a fully thermalized system. Finally, we propose a possible experimental design to measure the phonon population of each nanoresonator by means of a superconducting qubit coupled to the chain.

- ## Márcio Fernando Cornelio

A model for a brownian motor

We build a model for a brownian motor based on a sawfish potential which is turned on and off periodically. This model is based on biological systems which shows similar mechanism for transport of particles inside the cell. Based on statistical mechanics assumptions and random walk theory, we calculate the efficiency of the process and relate it to its speed.

- ## Jonhy Syllas dos Santos Ferreira

Conservation law for entanglement and discord in multipartite systems

We extend the conservation law for the distribution of entanglement of formation and discord (Fanchini et al, PRA 84 012313, 2011) to four-partite and five-partite systems. We also obtain generalised n-partite conservation relations. An interesting difference between systems of even and odd parts shows up. For systems with odd number of parts, we obtain equalities like in the three-partite system. However, for systems with even number of parts, we obtain inequalities. We also show that there are basically two types of conservation laws: one is based in a key system and the other one is based in a loop over all the systems.

- **Rodrigo Zanatto dos Santos**

Feynman ratchet efficiency

The Feynman ratchet thermal machine is known to operate at Carnot efficiency if the process is performed infinitely slowly. In this context, we consider the possibility of operating it as real thermal machine at finite speed. Relating the Brownian motion to the random walk theory, we obtain a closed formula for its efficiency in terms of the ratio of forward and backward probabilities.

- **Marcelo Amorim Marchiori**

Optimal rectification in the ultrastrong coupling regime

We study the effect of ultrastrong coupling on the transport of heat. In particular, we present a condition for optimal rectification, i.e., flow of heat in one direction and complete isolation in the opposite direction. We show that the strong-coupling formalism is necessary for correctly describing heat flow in a wide range of parameters, including moderate to low couplings. We present a situation in which the strong-coupling formalism predicts optimal rectification whereas the phenomenological approach predicts no heat flow in any direction, for the same parameter values.

- **Juan Jose Mendoza Arenas**

Coexistence of energy diffusion and local thermalization in nonequilibrium XXZ spin chains with integrability breaking

In this work we analyze the simultaneous emergence of diffusive energy transport and local thermalization in a nonequilibrium one-dimensional quantum system, as a result of integrability breaking. Specifically, we discuss the local properties of the steady state induced by thermal boundary driving in a XXZ spin chain with staggered magnetic field. By means of efficient large-scale matrix product simulations of the equation of motion of the system, we calculate its steady state in the long-time limit. We start by discussing the energy transport supported by the system, finding it to be ballistic in the integrable limit and diffusive when the staggered field is finite. Subsequently we examine the reduced density operators of neighboring sites and find that for large systems they are well approximated by local thermal states of the underlying Hamiltonian in the non-integrable regime, even for weak staggered fields. In the integrable limit, on the other hand, this behavior is lost, and the identification of local temperatures is no longer possible. Our results agree with the intuitive connection between energy diffusion and thermalization.

- # Edgard Pacheco Moreira Amorim

Entangling Power of Disordered Quantum Walks

We investigate how different types of disorder affects the generation of entanglement between the internal (spin) and external (position) degrees of freedom in a one-dimensional discrete time quantum random walk. The disorder is modeled by introducing an extra random aspect to quantum random walk: a classical two-sided (or infinitely-sided) coin that randomly dictates which quantum coin drives the system's time evolution at each position and/or at each time step, giving rise to three distinct kinds of disorder. The dynamic disorder is position- independent, with every position having the same coin at a given time, the static disorder is time-independent, while the fluctuating disorder has time and position dependent randomness. We show for several levels of disorder that dynamic disorder is the most powerful entanglement generator [1], followed closely by fluctuating disorder, both lead to maximally entangled states asymptotically in time for any initial condition [2]. We study the number of steps the system must move to be within a small fixed neighborhood of its asymptotic limit. Static disorder is the less efficient entangler, being almost always less efficient than the ordered case, has no asymptotic limit and, similarly to the ordered case, has a long time behavior highly sensitive to the initial condition. We also propose two experiments current technology based where these ideas can be tested [3-5].

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- # Carlos Albert Parra Murillo

Diffusion-driven effective thermalization in a resonant tunneling scenario

We present recent results on relaxation dynamics and thermalization in a many-body implementation of the Wannier-Stark system [1]. It is shown that the induced delocalization of instantaneous eigenstates via cascade of Landau-Zener transition triggers an effective thermalization process in finite time evolution. We show that not only single particle observables but two-particle ones approach their thermal average values and a way to define the effective temperature of the system based on the mixing properties of the quantum spectrum.

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• Marina Vasques Moreira

Monogamy relations for the entanglement of assistance

Quantum entanglement is one of the most distinctive characteristics of quantum mechanics, and besides its importance in the basis of this theory, it is quite relevant as a resource for quantum tasks. In this sense, it is pertinent to quantify and characterize the entanglement present in a quantum state. Unlike classical correlations, entanglement can't be distributed at will among the parts of a system; this aspect of entanglemet is called monogamy. Monogamy is not present in classical correlations, and although not all quantum correlation measures exibit monogamic behavior, it is a distinguishing trait of quantum correlations. As examples of monogamic entanglement measures we have distillable entanglement and the squared entanglement of formation; examples of non-monogamic entanglement measures include the cost of entanglement and the entanglement of formation. We extend these ideas to a specific measure called entanglement of assistance, and establish some relations for this measure.

• Leandro Raffhael da Silva Mendes

New bound for the strong subadditivity of the von Neumann entropy and it's role in the quantum data processing inequality

The strong subadditivity inequality of the von Neumann entropy is connected with a large number of important results in quantum information theory, such like limiting bounds in the information transmitted in quantum channels and results about the additivity of information measures. Recently in Fanchini et al. Phys. Rev. A 84,012313 (2011), a new possible upper bound for the strong subadditivity, depending on the Entanglement of Formation and the Quantum Discord of the system, was derived. Following Hayden et al. Commun. Math. Phys. 246, 359 (2004) we investigate the structure of states satisfying this new relation of subadditivity and examine the consequences of this bound in the quantum data processing inequality.

- ## Alvaro Andres Cifuentes Garcia

Non-equilibrium Thermodynamics of a Sudden Quench in a Trapped Ion System

In this work, we study the work and irreversibility when a classical electromagnetic field interacts with a trapped ion. The interaction time is taken to be infinitesimally small i.e., a "quench" process. Our motivation comes from the fact that in the past few decades there has been an increasing interest in the research about thermodynamics of out-of-equilibrium processes, such as a quench, both in the classical and quantum realms. Some of the most prominent achievements are the so-called Fluctuation Relations, which stablish equivalences between the variations of thermodynamical quantities along a quasistatic process, and their ensemble averages in a non-equilibrium operation. Two different figures of merit are used in this work to quantify the degree of irreversibility in our protocol. The first one is related to the "Dissipated Work" or "Non-equilibrium Lag", defined as the difference between the ensemble average of work done in the system during an irreversible process, and the variation of free energy in a quasistatic process. The second quantifier follows from a mechanical model of equilibrium thermodynamics, de so-called Volume Entropy, which is related to volumes in phase space. The quantum version of this quantifier is also studied here and contrasted with the Non-equilibrium lag.

- ## Armando Figueroa Ortiz

Entropy-energy inequalities for qudit states

We establish a procedure to

nd the extremal density matrices for any finite Hamiltonian of a qudit system. These extremal density matrices provide an approximate description of the energy spectra of the Hamiltonian. In the case of restricting the extremal density matrices by pure states, we show that the energy spectra of the Hamiltonian is recovered for d = 2 and 3. We conjecture that by means of this approach the energy spectra can be recovered for the Hamiltonian of an arbitrary finite qudit system. For a given qudit system Hamiltonian, we

find new inequalities connecting the mean value of the Hamiltonian and the entropy of an arbitrary state. We demonstrate that these inequalities take place for both the considered extremal density matrices and generic ones.

- ## Lisan Marcos Marques Durão

Statistical Entropy of Open Quantum Systems

The main goal of our project is the characterization of open quantum systems by means of a statistical entropy. Entropy is a fundamental physical quantity and is usually interpreted as the lack of knowledge about the state of the system, which means it is an informational metric. The statistical mechanical program for non-isolated quantum systems consists in creating a Hamiltonian for the "universe" within the so-called system-plus-reservoir approach from which one can evaluate the reduced density operator of the system of interest through the partial trace of the full density operator with respect to the reservoir coordinates. Notice that, in so doing we are tacitly assuming that the equilibrium state of the whole universe can be described by a Gibbsian distribution. Alternatively one can evaluate the Von Neumman entropy for the whole universe from which the above mentioned full density operator can be obtained via the maximum entropy priciple, and then, by the same partial tracing procedure, obtain the desired reduced density operator. Now we can ask ourselves what happens if one insists in obtaining a density operator for the system of interest directly from a maximum entropy principle. Such a task can require the use of other forms of entropy not necessarily extensive. Starting from the system-plus-reservoir approach we study the entropy and mean values of a Brownian particle coupled to a harmonic reservoir and a $1/r^2$ Ising Chain, mapped onto Spin-Boson Model. Using this as the starting point to the maximization of non-extensive "parameter depending" entropies, we aim at finding a correspondence between the constants arising from our model and the adjustable parameters of some well-known generalized entropies which may turn out to be more appropriate to our needs.

- **Felipe Fanchini**

Role of the environment initial condition on non-Markovian dynamics

We study the flow of information and its relation to non-Markovianity in a decoherence setting where there might exist correlations between the measurement apparatus of a system and the environment initially. To quantify information flow, we investigate the amount of entanglement and mutual information between the principal system and its measurement apparatus, which have a direct interpretation in terms of accessible information and quantum loss, respectively. In the case where there is no correlation between the apparatus and environment, we demonstrate that the amount of information flow is very susceptible to the initial state of the environment. In fact, even the presence of an initial single excitation in the environment can significantly decrease the flow of information throughout the dynamics. Furthermore, we show that whereas the flow of information in terms of accessible information can freeze for an instant of time, this phenomenon does not occur when the flow is quantified using quantum loss. For initially correlated apparatus and environment states, we discuss the relation of information flow to the definition of non-Markovianity in terms of divisibility of completely positive trace preserving maps.

• Diego Paiva Pires

Quantum speed limit from information geometry

Quantum mechanics proved to be restrictive in the acquisition of information about a given physical system by imposing uncertainties on the accuracy of measures and observations. Similarly, quantum mechanics also imposes fundamental limits on the maximum evolution speed between two quantum states. Several results in this direction appeared in literature, particularly relations between this limit and quantum computation and thermo- dynamics [1, 2]. In this work we are interested in the following question: how fast a quantum state can change? For closed quantum systems, the minimum evolution time (towards an orthogonal state and also for non-orthogonal states) is given by the variance of the Hamiltonian [3] or in terms of the mean energy of the system [4]. Recently, the minimal evolution time for open dynamical systems was derived through a geometrical approach based on the Bures angle [5, 6]. Here we use a new geometric approach to derive a quantum speed limit for closed quantum systems. Our description is based on the geometrization of the space of quantum states by introducing an information metric defining the statistical distance between two closed mixed states. Moreover, we show that the speed limit is inversely pro- portional to the sum of two contributions with physically distinct origins: the first, which is associated with the populations, depends on the Fisher information rather than the variance of the Hamiltonian. The second one is constrained to the coherences through the dependence of the density operator eigenstates in the set of variables which defines the parameter space. Therefore, the speed limit between initial and final states must be bigger than in the case where the coherences does not exist. We hope to extend these results to the open dynamical systems using Kraus operators and analyzing the phase damping and amplitude damping regimes. Moreover, given the general feature of our information metric, we try to find its relation with the thermodynamic length and dissipated work involving quantum protocols at finite temperature by adopting a suitable thermodynamic parameters space.

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- ## Osvaldo Jiménez Farías

Quantum information by weaving quantum Talbot carpets

Single photon interference due to passage through a periodic grating is considered in a novel proposal for processing D-dimensional quantum systems (quDits) encoded in the spatial degrees of freedom of light. We show that free space propagation naturally implements basic single quDit gates by means of the Talbot effect: an intricate time-space carpet of light in the near field diffraction regime. Adding a diagonal phase gate, we show that a complete set of single quDit gates can be implemented. We then introduce a spatially-dependent beam splitter that allows implementation of controlled operations between two quDits. A new form of universal quantum information processing can then be implemented with linear optics and ancilla photons. Though we consider photons, our scheme should be directly applicable to a number of other physical systems. Interpretation of the Talbot effect as a quantum logic operation provides a beautiful and interesting way to visualize quantum computation through wave propagation and interference.

- ## Ruben Auccaise

Generation of Schrodinger cat states in a NMR quadrupolar system

One of the most intriguing theoretical concept between classical and quantum mechanics is the Schrodinger cat state [1,2], which plays a distinguished role in quantum computation as a resource for universal computation and a good control for quantum systems. Therefore, a challenging task is the development of efficient strategies for achieving an experimental implementation of a Cat state. On this behalf, experimental demonstrations of the efficiency of quantum protocols using trapped ions [3], and also a pair of photons [4], allowed the recognition of their quantum advantages. Thus, the effort of extending those systems for more qubits became a major issue for many experimentalists. Later, this kind of state was implemented using six-atoms in a cavity at ultra cold temperatures [5], also, in the light scenario, in which up to several dozens of photons were used [6,7], and also in superconducting devices with the number equivalence of five photons [8]. The main strategy in those implementations was exploring the atom-field interaction [6,7], but that is not the only possible strategy. In the context of atomic physics there is a theoretical proposal which explores the atom-atom interaction [9]. This strategy was developed using the total angular momentum description from the SU(2) algebra and with the appropriate coupling strength between particles of a two mode Bose-Einstein Condensate.

From the point of view of algebraic structures, the spin angular momentum description belongs and obeys the SU(2) algebra, and this special characteristic allows us to transfer the knowledge developed for a many body system into a spin system [10]. In this work, we will show how a nuclear spin system, I=7/2, achieves an analogous behaviour of a few ultra-cold atoms particles, N=7, in a trap.

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- ## Eduardo I. Duzzioni

Investigating Dicke Superradiance through Wigner-Yanase-Dyson Skew Information

In literature the Superradiance Dicke model [1] is treated as a coherent radiative phenomenon due to cooperative atomic effects [2]. Recently, the Wigner-Yanase-Dyson skew information (WYDSI) was proposed as a quantifier of quantum coherence in macroscopic quantum systems [3]. In this work it is shown that this measure of quantum coherence is able to capture the time of maximum emission of radiation t_R in the Dicke model in the limite of a great number of atoms. For a single atom operator (Pauli matrix) in the z direction the WYDSI achieves its maximum value at t_R, while for a collective atomic operator (sum of Pauli matrices) in any direction the WYDSI achieves its minimum value at t_R. This result indicates that quantum coherence in Dicke Superradiance model exists only locally with respect to a basis of eigenstates of angular momentum operators.

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- ## Tiago Barbin Batalhão

Irreversibility and the arrow of time in a quenched quantum system

Irreversibility is one of the most intriguing concepts in physics. While the microscopic laws of classical and quantum mechanics are time symmetric, and hence reversible, macroscopic phenomena are not time-reversal invariant. This fundamental asymmetry defines a preferred direction of time that is characterized by a mean entropy production that, regardless of the details and nature of the evolution at hand, is bound to be positive by the second law of thermodynamics. Since its introduction by Eddington in 1927, the thermodynamic arrow of time has not been tested experimentally at the level of a single quantum system. Here, using an NMR setup, we measure the nonequilibrium entropy produced in an isolated spin-1/2 system following fast quenches of an external magnetic field. We demonstrate that the macroscopic average entropy production is equal to the entropic distance, quantified by the Kullback-Leibler divergence, between a microscopic process and its time-reverse. This result provides a microscopic foundation of irreversibility beyond the linear response regime and both elucidates and quantifies the physical origin of the arrow of time in a quantum setting.

- ## Milton Alexandre da Silva Júnior

Tightness of entropic uncertainty relations in the presence of a quantum memory under relativistic motion

Quantum mechanics and relativity theory lie at the heart of modern physics. Unfortunately, we do have so far a quantum theory of gravity, i.e. we do not know how to quantize the gravitational field itself (although far away from the Planck scale one can treat gravity as a quantum effective field theory). However, the application of information theory to quantum systems in relative motion had brought some useful insights on the behaviour of such systems. Here we study the tightness of an entropic formulation of the uncertainty relation, a fundamental stone of quantum theory, as perceived by an observer holding quantum information about the system being measured when this observer is in a non-inertial frame. Our results show that, although in the inertial configuration the certainty one could predict the result of a given measurement remains the same, when the Unruh effect comes into play, this certainty is affected by the thermal Unruh bath and the tightness of the entropic uncertainty principle is also motion dependent.

- **Felix Binder**

Quantacell - the quantum advantage for powerful driving

We study the problem of charging of a quantum battery in finite time with a focus on powerful driving. The first main result establishes optimal driving for the case of a single qubit. Extending the analysis to an array of N qubits it is demonstrated that an N-fold advantage in power per qubit can be achieved when global operations are permitted. This even holds when, with cyclic operation in mind, initial and final state are required to be separable.