Quantum Statistical Mechanics - MAQM

Rapport sur les contributions

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

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

Symmetry shapes thermodynamics of macroscopic quantum systems

mercredi 29 mai 2024 14:00 (55 minutes)

Symmetries play a fundamental role in shaping physical theories, from quantum mechanics to thermodynamics. Studying the entropic, energetic, or dynamic signatures of underlying symmetries in quantum systems is an active field of research, from fundamental questions about entropy scalings, ground state properties, or thermalization, to the optimization of quantum computing or numerical simulation procedures, and is gaining momentum due to rapid experimental advances, particularly in cold atoms [1].

In this work [2], we derive a systematic approach to the thermodynamics of quantum systems based on the underlying symmetry groups. We show that the entropy of a system can be described in terms of group-theoretical quantities that are largely independent of the details of its density matrix.
We apply our technique to generic N identical interacting d-level quantum systems. Using permutation invariance, we find that, for large N, the entropy displays a universal large deviation behavior with a rate function s(x) that is completely independent of the microscopic details of the model, but depends only on the size of the irreducible representations of the permutation group.
In turn, the partition function is shown to satisfy a large deviation principle with a free energy f(x)=e(x)-s(x)/β, where e(x) is a rate function that only depends on the ground state energy of particular subspaces determined by group representation theory.
We demonstrate the power of our approach by applying it to the nontrivial task of describing phase transitions governed by the interplay of quantum and thermal fluctuations in the transverse-field Curie-Weiss model.

[1] Masahito Ueda. "Quantum equilibration, thermalization and prethermalization in ultracold atoms."Nat. Rev. Phys., 2(12):669, 2020.

[2] Vasco Cavina, Ariane Soret, Timur Aslyamov, Krzysztof Ptaszyński, and Massimiliano Esposito. "Symmetry shapes thermodynamics of macroscopic quantum systems". arXiv:2402.04214, 2024.

Orateur: SORET, Ariane (University of Luxembourg)

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

Approach to equilibrium in translation-invariant quantum systems

jeudi 30 mai 2024 09:00 (55 minutes)

In this talk I will formulate the problem of approach to equilibrium in algebraic quantum statistical mechanics and study some of its structural aspects, focusing on the relation between the zeroth law of thermodynamics (approach to equilibrium) and the second law (increase of entropy). The main result is that approach to equilibrium is necessarily accompanied by a strict increase of the specific (mean) entropy. In the course of our analysis, I will introduce the concept of quantum weak Gibbs state which is of independent interest.
This talk is based on joint work with Vojkan Jaksic and Claude-Alain Pillet.

Orateur: TAUBER, Clément (CEREMADE, Paris)

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

Geometric correlation inequalities for spin systems

lundi 27 mai 2024 16:15 (55 minutes)

I will review correlation inequalities for the two-point function of classical and quantum spin systems. These inequalities are "geometric"when they involve lattice sites. I will review the Simon-Lieb-Rivasseau, Messager-Miracle-Sole, and Lees-Taggi inequalities. I will point out that the Messager-Miracle-Sole inequalities can be extended to the spin-1/2 quantum XY model.

Orateur: UELTSCHI, Daniel (University of Warwick)

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

Adiabatic Time Evolution and Quasi-Static Processes in Translation-Invariant Quantum Systems

jeudi 30 mai 2024 10:00 (55 minutes)

We study the slowly varying, non-autonomous dynamics of a translation-invariant quantum spin system on the lattice Z^d . This system is assumed to be initially in thermal equilibrium, and we consider realizations of quasi-static processes in the adiabatic limit. By combining the Gibbs variational principle with the notion of quantum weak Gibbs states, we establish a number of general structural results regarding such realizations. In particular, we show that such a quasi-static process is incompatible with the property of approach to equilibrium.
This is a joint work with V. Jaksic and C. Tauber.

Orateur: PILLET, Claude-Alain (CPT, Toulon)

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

On the self-consistent Landauer-Büttiker formalism

lundi 27 mai 2024 15:00 (55 minutes)

We provide sufficient conditions such that the time evolution of a mesoscopic tight-binding open system with a local Hartree-Fock non-linearity converges to a self-consistent non-equilibrium steady state, which is independent of the initial condition from the "small sample". We also show that the steady charge current intensities are given by Landauer-Büttiker-like formulas, and make the connection with the case of weakly self-interacting many-body systems. This is a joint work with Horia D. Cornean https://arxiv.org/abs/2309.01564.

Orateur: MARCELLI, Giovanna (Università di Roma Tre)

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

Anyons in a tight wave-guide and the Tonks-Girardeau gas

lundi 27 mai 2024 14:00 (55 minutes)

Anyons with a statistical phase parameter \alpha \in (0,2) are quasi-particles interpolating between bosons and fermions. For topological reasons, they only exist in a 1D or 2D world, ie as excitations of special 2D or 1D systems. There exists a main agreed-upon 2D model (equivalent to usual bosons or fermions carrying Aharonov-Bohm magnetic fluxes of intensity \alpha) but several 1D models. We ask which one, if any, of the latter is selected as the 1D limit of the 2D theory.

We hence consider the dimensional reduction for a 2D system of anyons in a tight wave-guide and prove that both the eigenenergies and the eigenfunctions are asymptotically decoupled into the loose confining direction and the tight confining direction. The limit 1D system in the loose direction is given by the impenetrable Tonks-Girardeau Bose gas independently of \alpha. No trace is thus left, at leading order, of the long-range interactions of the 2D model. This comes about via the acquisition of a special phase factor, which gauges magnetic interactions away for aligned particles.

Orateur: ROUGERIE, Nicolas (UMPA, Lyon)

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

The gapped phases of O(n) quantum spin chains

lundi 27 mai 2024 09:00 (55 minutes)

The ground state phase diagram of the O(n) quantum spin chains with nearest neighbor interactions, for n≥$ or larger, shows two gapped phases separated by a critical point often referred to as the Reshetikhin point. One of the phases contains the SU(n) invariant -P^{(0)} model which has been analyzed using the Temperley-Lieb algebra and, more recently, by a random loop model. These works show the ground state to be dimerized. The other phase contains a special point with exact MPS ground states that generalize the AKLT state (corresponding to the case n=3). For even n, that point too is a phase with breaking of the translation invariance down to period 2. We show that it is not dimerized in the usual sense of the term and uncover other interesting new properties(joint work with Michael Ragone).

Orateur: NACHTERGAELE, Bruno (UC Davis)

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

The Quantum Symmetric Simple Exclusion Process

lundi 27 mai 2024 10:00 (55 minutes)

An alternative title could have been « How to characterise coherences and fluctuations in diffusive out-of-equilibrium many-body quantum systems ? ».
In general, the difficulty to characterise non-equilibrium systems lies in the fact that there is no analog of the Boltzmann distribution to describe thermodynamic variables and their fluctuations. Over the last 20 years, however, it was observed that fluctuations of diffusive transport show universal properties that do not depend on the microscopic details. The general framework to characterise these systems from a macroscopic point of view is now called the Macroscopic Fluctuation Theory. A natural question is whether this framework can be extended to quantum mechanics to describe the statistics of purely quantum mechanical effects such as interference or entanglement in diffusive out-of-equilibrium systems. With this aim in mind, I will introduce the Quantum Symmetric Simple Exclusion Process (QSSEP), a microscopic model system of fluctuating quantum diffusion. I will in particular present the recent observation that fluctuations of coherences in QSSEP have a natural interpretation as free cumulants, a concept from free probability theory, and heuristic arguments why we expect free probability theory to be an appropriate framework to describe coherent fluctuations in generic mesoscopic systems.

Orateur: BERNARD, Denis (LPENS, Paris)

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

Energy-momentum spectrum and effective mass of a strongly coupled polaron

lundi 27 mai 2024 11:15 (55 minutes)

We explain recent bounds on the quantum corrections to the (classical) Pekar approximation of the ground state energy of the Fröhlich polaron model in the strong coupling limit, and their consequence on the existence of excited states and the polaron's effective mass.

Orateur: SEIRINGER, Robert (IST Austria)

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

Quasi periodic 2D Ising and Weyl semimetals

mardi 28 mai 2024 09:00 (55 minutes)

I will present results on the stability of the critical behavior of the 2D Ising Model and of an interacting Weyl semimetal in presence of quasi-periodic disorder.
The analysis is based on fermionic RG combined with methods inspired by KAM theory.

Orateur: MASTROPIETRO, Vieri (Università di Milano)

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

The eigenstate thermalization hypothesis and free probability

mardi 28 mai 2024 11:15 (55 minutes)

The eigenstate thermalization hypothesis (ETH) was developed to explain the mechanism by which "chaotic" systems reach thermal equilibrium from a generic state. ETH is an ansatz for the matrix elements of physical operators in the basis of the Hamiltonian, and since its postulation, numerous studies have characterized these quantities in increasingly fine detail, providing a solid framework for understanding the (thermo)dynamics of quantum many-body systems. ETH can be viewed as a generalisation of random matrix theory and, in fact, within this ansatz matrix elements are modeled as random variables.
In our work, we have generalized the ETH ansatz in order to take into account correlations between matrix elements which are essential to describe high-order correlation functions. By analogy with the theory of random matrices, one can assume a certain hierarchy between these correlations and show how this generalized ansatz underlies a relationship between ETH and free probability. This relationship allowed us to unveil a particular structure of the time-dependent correlation functions in thermal equilibrium in terms of free cumulants.

Orateur: FOINI, Laura (IPhT, Paris-Saclay)

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

Boundary states of a bulk gapped ground state in 2-D quantum spin systems

mardi 28 mai 2024 10:00 (55 minutes)

We introduce a natural mathematical definition of boundary states of a bulk gapped ground state in the operator algebraic framework of 2-D quantum spin systems.
With the approximate Haag duality at the boundary, we derive a C*-tensor category M out of such boundary state. Under a non-triviality condition of the braiding in the bulk, we show that the Drinfeld center (with an asymptotic constraint) of M is equivalent to the bulk braided C*-tensor category.

Orateur: OGATA, Yoshiko (Kyoto University)

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

TBA

mardi 28 mai 2024 14:00 (55 minutes)

Orateur: DE ROECK, Wojciech (K.U. Leuven University)

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

TBA

mardi 28 mai 2024 15:00 (55 minutes)

Orateur: FRAAS, Martin (UC Davis)

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

Wannier localizability as a tool to distinguish topological phases of matter

mardi 28 mai 2024 16:15 (55 minutes)

The talk concerns the correspondence between the topological triviality of gapped quantum systems and the existence of an orthonormal basis of well-localized Wannier functions spanning the range of the Fermi projection.
For periodic systems in dimension 2 and 3 such a correspondence has been noticed and proved, and dubbed Localization Dichotomy. Under general assumptions, it has been proved that:
(i) either there exists a composite Wannier basis which is exponentially localized, and, correspondingly, the Chern class of the Fermi projection is zero; or
(ii) any possible choice of a composite Wannier basis yields an infinite expectation value of the squared position operator (in numerical simulations, such a value diverges when the spacing of the grid in quasi-momentum space tends to zero).
I will report on recent attempts to generalize such a Localization Dichotomy to non-periodic gapped quantum systems. These methods offer a way to describe topological non-triviality directly in position space, without using the decomposition with respect to quasi-momentum.
The results are based on joint works with G. Marcelli, M. Moscolari, and V. Rossi.

Orateur: PANATI, Gianluca (Università di Roma ”La Sapienza”)

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

Continuous monitoring of a single random walker on a lattice, classical or quantum, and KPZ physics.

mercredi 29 mai 2024 09:00 (55 minutes)

I will present some of our recent results concerning the dynamical fluctuations of single, classical or quantum, random walker on a lattice, subject to external continuous monitoring. Exploiting analogies with KPZ physics, I will show that these systems have non trivial scaling of their fluctuations and can exhibit a phase transition in dimensions higher than 1.

Orateur: JIN, Tony (INPHYNI, Nice)

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

Quantum measurements and generalized Porter-Thomas distribution in many body dynamic

mercredi 29 mai 2024 10:00 (55 minutes)

Orateur: DE LUCA, Andrea (LPTM, Cergy)

ID de Contribution: **18** Type: **Non spécifié**

Thermalization in quantum spin systems

mercredi 29 mai 2024 11:15 (55 minutes)

Motivated by understanding how temperature affects topological order, I will present some recent estimates for the mixing time of Davies dynamics in quantum spin systems.

Orateur: PÉREZ GARCIA, David (Universidad Complutense de Madrid)

ID de Contribution: **19** Type: **Non spécifié**

Many-body adiabatic dynamics via convergent expansions

jeudi 30 mai 2024 11:15 (55 minutes)

I will discuss how to represent the real-time dynamics of lattice fermionic systems exposed to slowly varying time-dependent perturbations in terms of Euclidean (i.e. imaginary time) correlation functions. The advantage is that, in many situations, time-ordered Euclidean correlation functions satisfy much better space-time decay estimates than their real-time counterparts. As an application, I will discuss how the cluster expansion for Euclidean correlations can be used to prove the convergence of the real-time Duhamel series for gapped, weakly interacting many-body fermionic systems, and the many-body adiabatic theorem at low temperature. In the last part of the talk, I will focus on gapless models, and I will show how the framework can be used to study the validity of linear response for non-interacting 1d systems and for edge currents. Based on a joint work with R. L. Greenblatt, M. Lange, G. Marcelli, and on ongoing work with H. P. Singh.

Orateur: PORTA, Marcello (SISSA, Trieste)

ID de Contribution: **20** Type: **Non spécifié**

Chiral spin liquids: tensor network framework and quantum state preparation

jeudi 30 mai 2024 14:00 (55 minutes)

Chiral spin liquids are topological-ordered states of matter, quantum spin analogs of the celebrated electronic Fractional Quantum Hall states. I will discuss how they can be represented in terms of tensor networks (despite a no-go theorem!). In a second step, I will discuss recent efforts for adiabatic preparation of such states using Floquet engineering.

Orateur: POILBLANC, Didier (LPT, Toulouse)

ID de Contribution: **21** Type: **Non spécifié**

The weakly interacting Bose gas at positive temperature

jeudi 30 mai 2024 15:00 (55 minutes)

We discuss a homogeneous system of interacting bosons in the mean-field regime where the temperature is comparable to the critical temperature for the Bose-Einstein condensation (BEC). By a rigorous implementation of Bogoliubov's approximation, we derive asymptotic formulas for the free energy and the reduced density matrices of the corresponding Gibbs state. In particular, our method allows to analyze explicitly the U(1) symmetry breaking for BEC and superfluidity. This is joint work with Andreas Deuchert and Marcin Napiórkowski.

Orateur: THÀNH NAM, Phan (LMU, Munich)

ID de Contribution: **22** Type: **Non spécifié**

Bosonization of Large Systems of Interacting Fermions

jeudi 30 mai 2024 16:15 (55 minutes)

The behavior of electrons in a metal presents a wide variety of emergent behavior including a number of phase transitions. The mean-field scaling limit acts as a simplified model capturing part of this complexity. In this limit, results going beyond the precision of Hartree-Fock theory have recently been obtained by bosonization methods. I will review the expansion of the ground state energy and present results extending to the dynamics and momentum distribution of excitations.

Orateur: BENEDIKTER, Niels (Università degli Studi di Milano)