Quantum Transport and Universality

From Topological Materials to Quantum Hydrodynamics

Workshop in Rome, 23–25/09/2019
Accademia Nazionale dei Lincei, Palazzo Corsini
Via della Lungara 10, 00165 Roma (IT)
Aula delle Scienze Fisiche

Programme

		Monday			**Tuesday**	**Wednesday**
8:30	9:30	*Registration*				
9:30	10:20	Spohn	9:30	10:20	Fröhlich	Gawedzki
10:20	10:50	*Coffee break*	10:20	10:50	*Coffee break*	*Coffee break*
10:50	11:40	Garrahan	10:50	11:40	Panati	Calabrese
11:40	12:30	Fagotti	11:40	12:30	Mastropietro	Zotos
12:30	14:00	*Lunch break*	12:30	14:00	*Lunch break*	*Lunch break*
14:00	14:50	Doyon	14:00	14:50	Vozmediano	Cornean
14:50	15:40	De Roeck	14:50	15:20	*Coffee break*	*Coffee break*
15:40	16:10	*Coffee break*	15:20	16:10	Burkov	Herbut
16:10	17:00	Imbrie	16:10	18:00	*Round table / Discussions*	
17:00	17:50	Scardicchio				
20:00		*Social dinner*				

Abstracts

Anton Burkov (University of Waterloo)
Fractional Quantum Hall Effect in Weyl Semimetals

Weyl semimetal may be thought of as a gapless topological phase protected by the chiral anomaly, where the symmetries involved in the anomaly are the $U(1)$ charge conservation and the crystal translational symmetry. The absence of a band gap in a weakly-interacting Wey semimetal is mandated by the electronic structure topology and is guaranteed as long as the symmetries and the anomaly are intact. The nontrivial topology also manifests in the Fermi arc surface states and topological response, in particular taking the form of an anomalous Hall effect in magnetic Weyl semimetals, whose magnitude is only determined by the location of the Weyl nodes in the Brillouin zone. I will describe the situation when the interactions

are not weak and ask whether it is possible to open a gap in a magnetic Weyl semimetal while preserving its nontrivial electronic structure topology along with the translational and the charge conservation symmetries. Surprisingly, the answer turns out to be yes. The resulting topologically ordered state provides a nontrivial realization of the fractional quantum Hall effect in three spatial dimensions in the absence of an external magnetic field, which cannot be viewed as a stack of two dimensional states. This state contains loop excitations with nontrivial braiding statistics when linked with lattice dislocations.

Pasquale Calabrese (SISSA)
Entanglement and thermodynamics in non-equilibrium quantum systems

Entanglement and entropy are key concepts standing at the foundations of quantum and statistical mechanics. In the last decade the study of the non-equilibrium dynamics of isolated quantum systems revealed that these two concepts are intricately intertwined. Although the unitary time evolution ensuing from a pure initial state maintains the system globally at zero entropy, at long time after the quench local properties are captured by an appropriate statistical ensemble with non-zero thermodynamic entropy, which can be interpreted as the entanglement accumulated during the dynamics. Therefore, understanding the post-quench entanglement evolution unveils how thermodynamics emerges in isolated quantum systems.

Horia Cornean (University of Aalborg)
A mathematical account of the N(on)E(quilibrium)G(reen)F(unction) formalism

Our main goal has been to put on solid mathematical grounds the so-called non-equilibrium Green's function transport formalism for open systems. In particular, we derive the Jauho-Meir-Wingreen formula for the time-dependent current through an interacting sample coupled to non-interacting leads. Our proofs are non-perturbative and use neither complex-time Keldysh contours nor Langreth rules of "analytic continuation." If time allows, we will also discuss other technical identities (Langreth, Keldysh) involving various many-body Green's functions.

This is joint work with C.-A. Pillet (Toulon) and V. Moldoveanu (Bucharest).

Wojciech De Roeck (KU Leuven)
Prethermalization beyond the high frequency regime

Prethermalization has been a widely debated topic. In this talk, the phenomenon is understood as a very slow heating/thermalization rate. Very slow means "smaller than any power in some perturbative parameter". The slowness of the heating allows then for a long lived quasi-stationary state, but this is much harder to exhibit rigorously. If we focus attention at periodic driving, then prethermalization has been well-understood in the high-frequency regime. One of the aims of our work is to extend this understanding beyond high frequency, at the cost of assuming that the driving is weak. We show that under some additional assumptions, which are very often met in concrete models, there is indeed such slow heating. This clarifies certain observations in the recent literature.

Benjamin Doyon (King's College London)
Large deviations in transport and correlation functions from hydrodynamics

Hydrodynamics is a powerful framework for large-wavelength phenomena in many-body systems. It was extended recently to include integrable models, giving "generalised hydrodynamics". In this talk, I will explain how hydrodynamics gives access to the exact large-time fluctuations in the transport of quantities in one dimension such as particles or energy — their so-called full counting statistics. This generalises the free-fermion Levitov–Lesovik formulae, and the formula obtained by Denis Bernard and myself in one-dimensional conformal field theory, to a very large family of interacting theories. This works in Gibbs and generalised Gibbs ensembles, including in nonequilibrium steady states. Interestingly, I will explain how the same framework gives exact exponential decays of "twist field" correlation functions, such as the exponential field in the sine-Gordon model.

Work in collaboration with my student J. Myers, and M. J. Bhaseen and R. Harris.

Maurizio Fagotti (Université Paris-Sud)
Entanglement evolution and generalised hydrodynamics

I consider the dynamics of bipartite entanglement after the sudden junction of two leads in integrable models. By combining the quasiparticle picture for the entanglement spreading with "generalised hydrodynamics", I show how to derive an analytical prediction for the dynamics of the entanglement entropy between a finite subsystem and the rest. I show that, in interacting integrable systems, the entanglement rate between the two leads depends only on the physics at the interface and differs from the rate of exchange of thermodynamic entropy. This contrasts with the behaviour in free or homogeneous interacting integrable systems, where the two rates coincide.

Jürg Fröhlich (ETH Zürich)
Gauge invariance and gauge anomalies in condensed matter physics

I sketch applications of gauge invariance, gauge anomalies and topological field theory in the study of time-reversal invariant topological insulators, Weyl semi-metals and possibly further systems of condensed matter physics.

Juan Garrahan (University of Nottingham)
Slow dynamics in kinetically constrained models, from classical to quantum

I will describe the rich dynamics that emerges in simple models endowed with kinetic constraints. I will consider the classification of stochastic kinetically constrained models (KCMs), and the range of behaviour that they can display. I will discuss how these classical ideas can be adapted to the problem of slow thermalisation and (apparent) non-ergodicity in quantum systems in the absence of quenched disorder. Particular focus will be put on the so-called quantum East model as a paradigmatic quantum KCM displaying a range of interesting dynamical behaviour. Time permitting I will discuss similar concepts in the context of discrete "Floquet" circuit settings.

Krzysztof Gawedzki (ENS Lyon)
Full Counting Statistics of energy transfers in (1+1)D CFT

I shall discuss heat transport in simple nonequilibrium states of (1+1)D CFT that can be fully described using representation theory of the group of circle diffeomorphisms. In particular, I shall present an exact formula for the Full Counting Statistics (FCS) of heat transfers in such states that is based on the extension of the characters of positive energy representations of $\mathrm{Diff}(S^1)$ to general 1-parameter subgroups. Such an extension, of independent interest, is obtained using the "conformal welding" technique. In the thermodynamic limit the FCS formula takes a universal form dependingon the CFT only through its central charge.

Based on joint work with K. Kozlowski, `arXiv:1906.04276`.

Igor Herbut (Simon Fraser University)
Fixed point collisions and tensorial order parameters in Luttinger semimetals and some popular field theories

I will discuss the role of Coulomb interaction in Luttinger three-dimensional semimetals with the chemical potential at the point of quadratic band touching. The renormalization group treatment of the problem that includes both the long-range and the short-range parts of the Coulomb interaction exhibits a collision between the Abrikosov's non-Fermi liquid fixed point and the quantum critical point as the (spatial) dimensionality of the system is reduced from four towards two. In physical three dimensions we typically find only the slow runaway flow, which should be understood as signifying a low-energy instability towards an insulating phase with (tensorial) nematic ordering. General characteristics of the fixed-point collision scenario and its likely relevance to some other field theories, such as the QED3 for example, will also be discussed, time permitting.

John Imbrie (University of Virginia)
Many-body localization, LIOMs, and rare-region effects

Certain strongly disordered many-body quantum systems fail to equilibrate. One characterization of the so-called many-body localized phase is the existence of a complete set of local integrals of motion (LIOMs). These may be found via perturbative approximations, but rare regions with weak disorder (Griffiths regions) have the potential to bypass barriers to thermalization. I will discuss why these effects do not destroy the MBL phase in one dimension, at least if one has a natural scaling of eigenvalue spacings with system size. In higher dimensions, rare-region effects may indeed restore thermalization on a very long time scale.

Vieri Mastropietro (Università di Milano)
Anomaly non-renormalization in interacting Weyl semimetals

For a class of interacting 3D lattice Weyl semimetals, we prove that the quadratic response of the quasi-particle flow between the Weyl points to an external electromagnetic field, which is the condensed-matter analogue of the chiral anomaly, is exactly independent of the model parameters, most notably of the interaction. Therefore, this response can be added to the limited list of universal transport coefficients in condensed matter. This universality phenomenon can be seen as a manifestation of the Adler-Bardeen non-renormalization property in a crystal, despite the breaking of relativistic symmetries due to the lattice. Our proof relies on constructive bounds on correlations, combined with lattice Ward Identies. Non-perturbative

effects are rigorously excluded and irrelevant terms, which play a major role in the cancellation mechanism, are fully taken into account.

Work in collaboration with A. Giuliani and M. Porta.

Gianluca Panati ("Sapienza" Università di Roma)
The Localization-Topology Correspondence for gapped quantum systems: ordinary vs Chern insulators

A relevant Transport-Topology Correspondence for periodic gapped 2D systems has been discovered by Thouless *et al.* in 1982: A non-vanishing Hall conductivity of the system corresponds to a non-trivial topology of the space of occupied states, decomposed with respect to the crystal momentum (the Bloch bundle).

More recently, a related Localization-Topology Correspondence has been noticed and mathematically proved for 2D and 3D periodic gapped quantum system. The result states that the Bloch bundle is Chern trivial if and only if there exists a system of composite Wannier functions on which the expectation value of the squared position operator is finite. In other words, whenever the system is in a Chern-non-trivial phase, the composite Wannier functions are very delocalized, while in the Chern trivial phase they can be chosen exponentially localized (joint work with D. Monaco, A. Pisante and S. Teufel).

During my talk, I will report on this result and the essential ideas of its proof, as well as on the ongoing attempt to generalize this correspondence to non-periodic gapped quantum systems (work in progress with G. Marcelli and M. Moscolari).

Antonello Scardicchio (ICTP)
Peculiarities of slow transport in disordered quantum systems

A recent surge of activity in the study of disordered, generic quantum systems has revealed a wide range of possible behaviors with respect to transport properties. From suppression of transport (many-body localization) to subdiffusion and a more familiar diffusive transport, the macroscopic properties of these systems are a result of the interplay of various factors including degree of disorder, dimensionality and symmetries of the Hamiltonian. I will give a review of analytical and numerical results on this topic.

Herbert Spohn (TUM Munich)
Hydrodynamics of the classical Toda lattice

Over the past four years there have been many activities, mostly on the quantum side, to study the dynamics of integrable many-particle systems at non-zero temperatures. On the Eulerian scale, apparently a universal structure becomes valid. The classical Toda chain will serve as an interesting example in illustrating the advances.

Marìa A. H. Vozmediano (Instituto de Ciencia de Materiales de Madrid)
Effects of strain in Dirac matter

The coupling of lattice deformations to the electronic excitations in graphene — the most popular Dirac material — as effective elastic gauge fields has given rise to a vast field of theoretical, experimental results and applications. In this talk we will review the situation in the novel 3D Dirac and Weyl semimetals with special focus on the interplay between strain and the chiral and gravitational anomalies.

Xenophon Zotos (University of Crete)
Open issues in the 1D Heisenberg dynamics

I will present some recent developments and open issues in the thermodynamics and dynamics of the 1D Heisenberg model from the point of view of dressed excitations, as well as a study on the scattering of spinon excitations from potentials.