

Granada Seminar

2017

Steady state
Ballistic
Diffusion
Coherent transport
Quantum devices
Langevin
Electrons
Phonons
Phononics
Hamiltonian
Current
Flux
Density
Energy

Quantum information
Emergent
Stochastic thermodynamics
Landauer principle
Quantum processes
Long-lasting coherence
Microscopic models
Experiments

Boson currents
Quantum measurement
Lattice gas

Conservation laws
Reservoir
Backaction
Temperature
Disorder
Phase transitions

Quantum Systems
Equilibrium
Non-equilibrium
Fundamentals
Dynamics
Applications

Applications
Master equation
Lindblad
Redfield
Born Markov
Rotating wave
Second law
Entropy
Fluctuation theorem

Strongly correlated
Steady states
Currents
Thermal equilibrium
Emergent causality
N-photon
Scattering matrix
QED
Many body
Entanglement

Correlations
Annealing
Excited atoms

Environment
Simulation
Memory
Quantum transport
Photosynthesis
Cold atoms
Networks
Disorder
Particles
Interaction
Nanoscale
Spins
Bosons
Fermions
Energy transfer

Dissipation
Open quantum systems
Reversible
Irreversible
Glasses
Slow relaxation

Quantum Fluctuations
Large Deviations
Quantum Thermodynamics
Entanglement
Many body

Coupling
Self similarity
Dimension
Gradient
Information
Computation
Photonics
Optical lattice
Long range
Full counting statistics
Finite size

Environment
Ansatz
Hubbard model
Integrable
Typicality
Scattering
Stochastic
Langevin equation
Gibbs
Bath
Boundary

Quantum Thermalization
Quantum transport
Quantum Macroscopic Systems
Condensed matter
Biology
Quantum Computation

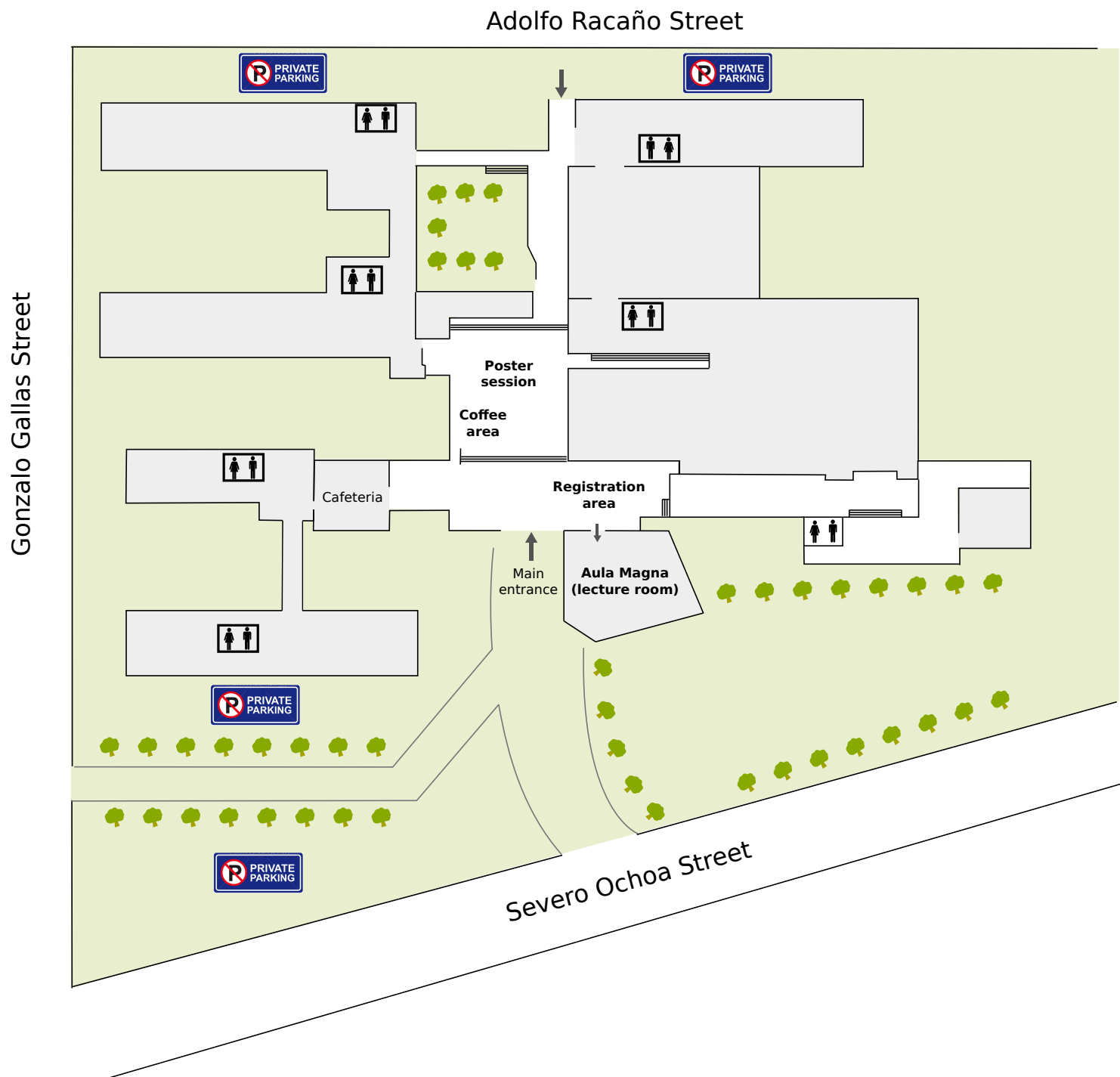
Protocol
Glasses
Optimization
Adiabatic theorem
Rydberg atoms
Ions
Traps
Gas
Time
Order
Fields
Qubits
Lattice

Heat transport
Simulation
Quantum dynamics
Networks
Interactions
Quantum transport
Coherence
Symmetry
Diffusivity

Dissipative
Annealing
Boltzmann
Many body
Models
Kinetic
Emergent
Ground state

Faculty of Sciences Building

All talks are held in the *Aula Magna*.



Welcome

It is our great pleasure to welcome you to the 14th Granada Seminar on Computational and Statistical Physics. We have worked hard – together with a local team and a large number of dedicated chairs – to bring you a high-quality and varied scientific programme. This booklet has been put together to help you find your way through the conference and make the most of your stay in Granada.

The 14th Granada Seminar is organized by the Institute *Carlos I* for Theoretical and Computational Physics and sponsored by the University of Granada through the Department of Electromagnetism and Physics of the Matter and the Faculty of Sciences, the Spanish Minister of Economy, Industry and Competitiveness, and the European Physical Society.

We are grateful to the Local Organizing Committee, José Manuel Martín, Irene Adroher, Nicolás Tizón, and Paula Villa, for their substantial contribution of time and effort.

No conference would be possible without a team of dedicated volunteers, and we gratefully acknowledge the help of the following PhD students:

Serena di Santo
Matteo Sireci
Juan Carlos Bolívar

Irene V. Toranzo
Pablo Martín
David Puertas

Javier Aguilera
Carlos Gutiérrez

During the week they can be recognised by their distinctive badges with the Granada Seminar logo. Please talk to them if you have any questions, they are there to help.

Pedro Garrido, Pablo Hurtado, Daniel Manzano and Francisco de los Santos
cphys@onsager.ugr.es



UNIVERSIDAD
DE GRANADA



Facultad de Ciencias

Instructions for Participants

General Information

- Internet access: WiFi will be available in the Aula Magna and nearby vicinity. Select the network *cviugr*; user, *seminar@invitados.ugr.es*; password required, *sem&UGR-17*. Access is limited to web browsing. If you already have an eduroam account you can use that.
- University security: 958 249 393
- Emergency services (Police, Fire and Rescue Service, Emergency Medical Service): 112.

Instructions for Speakers

- All presentations will be held in the *Aula Magna*.
- Speakers can bring their own laptop except for “rapid fire” poster presentations (VGA or HDMI required).
- A volunteer will be on hand to help in the conference room.
- Please arrive 10 minutes before the session starts to check the equipment works, and, if you will not be using your own laptop, to upload your slides from your USB drive.

Instructions for Poster Presenters

- The poster exhibition area will be near the Faculty Cafeteria and the sessions will run parallel to the coffee breaks.
- Presenters will be given the opportunity to explain their posters to the full audience in the Aula Magna. These short presentations should last 3 minutes (plus 2 minutes for speaker change) and are limited to two slides.
- Each presenter will be provided with DIN A0 84.1 cm x 118.9 cm poster board.
- Poster boards are assigned a number displayed following the poster title in this program book; material to attach the poster will be provided by the conference.
- Presenters should remove their poster at the end of the conference.
- The European Physical Society will grant a 200€ Poster Prize to the best poster prepared by a PhD student. The poster prize will be announced by the poster prize committee at the end of Friday 23th June.

Granada Public Transportation

- Granada public buses website: www.transportesrober.com (in Spanish).
- Fares: Single ticket 1.20€. Free transfer within 60 minutes since ticket validation. Credibús: a contactless, non-personal and rechargeable (5€, 10€ and 20€) card at 0.79€/trip (issue cost, 2€).
- More information (in English): www.lovegranada.com/transport/granada-city-buses; <http://granadainfo.com/buses.htm>.
- Taxis in Granada are white with a green stripe. There are two taxi companies operating in the centre of Granada: TELERADIO TAXI (958 280 654) and RADIOTAXI GENIL (958 132 323). More information at www.grnadainfo.com/taxiinfo.htm (in English).
- Metro/tram is not functioning as yet.

Miscellaneous

- Certificates of attendance will be given at the registration desk to all registered attendants.
- Meals: The cafeteria at the Faculty of Sciences will offer meals at a discounted prices for conference participants. For other choices, see the pages at the end of this brochure.
- Coffee and cookies will be served during the morning break times next to the poster exhibition area.
- Secretariat office:
 - During the conference: Registration desk in front of the Aula Magna.
 - After the conference: Avenida Constitución, 18 - Bloque 4, bajo, 18012 Granada; Phone (+34) 958 209 361; e-mail eurocongres@eurocongres.es.
- Gala dinner: June 22th at 20:30 at Carmen de los Chapiteles. You will find how to get there on the inside back cover. Google maps locator <http://goo.gl/5tspN8>.
- Check out the website ergodic.ugr.es/cp for last minute updates of the conference program.

Session Program

Tuesday Sessions at a Glance	4
Tuesday Morning Sessions with Abstracts	6
Tuesday Afternoon Sessions with Abstracts	11
Wednesday Sessions at a Glance	15
Wednesday Morning Sessions with Abstracts	17
Wednesday Afternoon Sessions with Abstracts	21
Thursday Sessions at a Glance	24
Thursday Morning Sessions with Abstracts	26
Thursday Afternoon Sessions with Abstracts	31
Friday Sessions at a Glance	34
Friday Morning Sessions with Abstracts	35
Friday Afternoon Sessions with Abstracts	39

Tuesday Sessions at a Glance

Tuesday Morning A

09:25–10:05	Quantum dynamics on networks - the interplay of structure, indistinguishability, and interactions <i>Andreas Buchleitner</i>
10:05–10:30	Dissipation in open quantum systems <i>Massimiliano Esposito</i>
10:30–10:45	Stabilization by dissipation and resonant activation in quantum metastable systems <i>B. Spagnolo, L. Magazzù, P. Hanggi, A. Carollo, D. Valenti</i>
10:45–11:00	Entanglement prethermalization in one-dimensional Bose gases <i>E. Kaminishi, T. Mori, T. N. Ikeda, and M. Ueda</i>
11:00–11:15	Control of electronic heat flows in coupled quantum dots <i>Rafael Sánchez</i>

Tuesday Morning B

11:45–12:25	Quantum Transport: Coherence, and Symmetry, and Diffusivity <i>Jianshu Cao</i>	
12:25–12:50	Energy transport in bosonic ladders: Interplay between interactions, gauge fields and geometry of system-bath coupling <i>C. Guo and D. Poletti</i>	
12:50–12:55	Large deviation implies First and Second Laws of Thermodynamics <i>H. Tajima, E. Wakakuwa, T. Ogawa</i>	P1
12:55–13:00	On Non-Markovianity of Qubit Evolution under Action of Spin Environment <i>Dipankar Mandal, Sagnik Chakraborty, Arindam Mallick, Sibasish Ghosh</i>	P2
13:00–13:05	Integrable Supersymmetric Many-Body Systems and Many-Body Localization <i>Pramod Padmanabhan, Soo-Jong Rey, Daniel Teixeira, Diego Trancanelli</i>	P3
13:05–13:10	Master equation approach to transient quantum transport in nanostructures <i>Pei-Yun Yang, Wei-Min Zhang</i>	P4
13:10–13:15	Entanglement critical length at the many-body localization transition <i>F. Pietracaprina, Giorgio Parisi, Angelo Mariano, Saverio Pascazio, Antonello Scardicchio</i>	P5

Tuesday Sessions at a Glance

Tuesday Afternoon A

- 15:30–16:10 **Noninvasive measurement of dynamic correlation functions**
M. Kastner
- 16:10–16:35 **Trapsensor: electronic coupling between two ions stored in different traps**
M. J. Gutiérrez, F. Domínguez, J. Berrocal, J. J. del Pozo, R. A. Rica, and D. Rodríguez
- 16:35–16:50 **Scrambling the spectral form factor**
J. Molina-Vilaplana, A. del Campo, J. Sonner

Tuesday Afternoon B

- 17:20–17:35 **Fluctuation-induced forces in confined free and imperfect Bose gases**
H. W. Diehl and *Sergei B. Rutkevich*
- 17:35–17:50 **Floquet-Magnus theory and generic transient dynamics in periodically driven many-body quantum systems**
T. Mori, *T. Kuwahara, and K. Saito*
- 17:50–18:05 **A novel class of quantum phase transitions: from bounded to extensive entanglement.**
Israel Klich
- 18:05–18:10 **Entropic uncertainty measures of the D -dimensional hydrogenic system in the Rydberg and pseudoclassical limits** P6
D. Puertas-Centeno, I. V. Toranzo, and J. S. Dehesa
- 18:10–18:15 **Phase transition in quantum annealing of hard problems detected by fidelity susceptibility** P7
Jun Takahashi and *Koji Hukushima*
- 18:15–18:20 **Ultralong-range polyatomic Rydberg molecules** P8
Javier Aguilera-Fernández and *Rosario González-Férez*
- 18:20–18:25 **Universal short-time response and formation of correlations after quantum quenches** P9
Klaus Morawetz
- 18:25–18:30 **Optimal performance of generalized heat engines with finite-size baths of multiple conserved quantities beyond i.i.d. scaling** P10
K. Ito and *M. Hayashi*

09:25–10:05 **Quantum dynamics on networks - the interplay of structure, indistinguishability, and interactions**

Andreas Buchleitner

We discuss some fundamental aspects of quantum transport in structured materials, in physical settings which reach from photosynthetic light harvesting to photonic circuitry and cold atoms. We identify finite networks with variable structural properties - from dominant symmetries to dominant disorder - as a versatile framework to assess nontrivial quantum dynamical effects which allow to characterize and/or control transport on complex structures. In particular, we seek to disentangle the role of the network structure, of particle statistics and (in-) distinguishability, and of interactions for the actual dynamical evolution.

10:05–10:30 **Dissipation in open quantum systems**

Massimiliano Esposito

The nature of dissipation in open quantum system and its information- theoretic will be discussed. I will first present an exact second law-like identity for an externally driven quantum systems interacting with a finite reservoir, i.e. another quantum system that is initially at equilibrium. I will then consider various specific scenarios where the system dynamics can be described by a closed quantum master equation and formulate its corresponding second-law.

10:30–10:45 **Stabilization by dissipation and resonant activation in quantum metastable systems**

B. Spagnolo, L. Magazzù, P. Hanggi, A. Carollo, D. Valenti

Common wisdom is that environmental fluctuations always enhance the escape from a quantum metastable state. A critical issue of great importance is whether the dissipation can enhance the stability of a quantum metastable state. We show first that dissipation can enhance the stability of a quantum metastable system, consisting of a particle moving in a strongly asymmetric double well potential, interacting with a thermal bath and starting from a nonequilibrium initial condition. We find that the escape time from the metastable region has a nonmonotonic behavior versus the system-bath coupling and the temperature, producing a stabilizing effect. In particular, the escape dynamics is characterized by a nonmonotonic behavior, with a maximum, as a function of the damping strength: there is an optimal value of the damping strength which maximizes the escape time, producing a stabilizing effect in the quantum system. We also find that the behavior of the escape time versus the temperature is nonmonotonic, and in particular is characterized by the presence of a minimum. Therefore, as the temperature increases, an enhancement of the escape time is observed, increasing the stability of the metastable state. These results shed new light on the role of the environmental fluctuations in stabilizing quantum metastable systems.

We investigate then, how the combined effects of strong Ohmic dissipation and monochromatic driving affect the stability of a quantum system with a metastable state. We find that, by increasing the coupling with the environment, the escape time makes a transition from a regime in which it is substantially controlled by the driving, displaying resonant peaks and dips, to a regime of frequency-independent escape time with a peak followed by a steep fall off. The quantum noise enhanced stability phenomenon is observed in the system investigated.

Thirdly, we analyze the resonantly activated escape from a quantum metastable state by tunneling in the spin-boson model at strong Ohmic dissipation in the presence of fluctuating and periodical driving fields. Resonant activation, the presence of a minimum in the mean escape time, occurs when the time scale of the modulations is the same as the characteristic time scale of the systems dynamics, essentially determined by dissipation-induced renormalization of the bare tunneling amplitude. The simple quantum system considered displays as well the general features that at slow modulations the mean escape time is dominated by the slowest configuration assumed by the system, while at fast modulations the escape dynamics is determined by the average configuration.

Tuesday Sessions, with Abstracts

10:45–11:00 **Entanglement prethermalization in one-dimensional Bose gases**

E. Kaminishi, T. Mori, T. N. Ikeda, and M. Ueda

A well-isolated system often shows relaxation to a quasi-stationary state before reaching thermal equilibrium. Such a prethermalization has attracted considerable interest recently in association with closely related fundamental problems of relaxation and thermalization of isolated quantum systems. Motivated by the recent experiment in ultracold atoms, we study the dynamics of a one-dimensional Bose gas which is split into two subsystems, and find that individual subsystems relax to Gibbs states, yet the entire system does not due to quantum entanglement. In other words, each individual subsystem subsequently relaxes to a stationary state which can be well described by the canonical ensemble at an effective temperature, whereas the stationary state of the total system cannot be described by the canonical ensemble at any temperature due to quantum entanglement between the subsystems. In this work, we analyze the phenomenon of entanglement prethermalization in one-dimensional Bose gas. Firstly, we consider the relaxation dynamics of the Tomonaga-Luttinger model split into the two subsystems. We find the above mentioned phenomenology of entanglement prethermalization in this model. The steady state is described by the generalized Gibbs ensemble with non-local conserved quantities associated with both subsystems. Secondly, we discuss entanglement prethermalization in the Lieb-Liniger model and find that entanglement prethermalization occurs for small numbers of particles[1]. Entanglement prethermalization in the Lieb-Liniger model is originated from the combination of the time-reversal symmetry and the translational symmetry.

[1] E. Kaminishi, T. Mori, T. N. Ikeda and M. Ueda, *Nature Physics*, 11, 1050 (2015).

11:00–11:15 **Control of electronic heat flows in coupled quantum dots**

Rafael Sánchez

Electronic charge and heat flows can be separated in multi-terminal conductors. Two terminals support the charge current with the other ones serving as heat sources. The properties of the mesoscopic junction determine how the injected heat currents affects the charge and energy transport in the conductor. This way, the system can be designed to work as a non-local heat engine (if heat is converted into useful power). This effect has been recently observed in coupled quantum dot configurations where the heat transfer is mediated by electron-electron interactions [1,2,3,4]. They furthermore allow one to manipulate the heat flows in all-thermal operations such as a thermal transistor or a thermal diode [5].

Different to macroscopic thermocouples, mesoscopic systems may remain in a non-thermalized state. Then the non-local coupling to the heat sources also leads to the unprecedented generation of electrical power with no net absorbed heat [6].

[1] R. Sánchez, M. Büttiker, Optimal energy quanta to current conversion, *Phys. Rev. B* 83, 085428 (2011). [2] H. Thierschmann et al., Three-terminal energy harvester with coupled quantum dots, *Nature Nanotech.* 10, 854 (2015). [3] B. Roche et al., Harvesting dissipated energy with a mesoscopic ratchet, *Nature Comm.* 6, 6738 (2015). [4] F. Hartmann et al., Voltage Fluctuation to Current Converter with Coulomb-Coupled Quantum Dots, *Phys. Rev. Lett.* 10, 14, 146805 (2015). [5] R. Sánchez, H. Thierschmann and L. W. Molenkamp, All-thermal transistor based on stochastic switching, *arXiv:1701.00382* (2017). [6] R. S. Whitney, R. Sánchez, F. Haupt, and J. Splettstoesser, Thermoelectricity without absorbing energy from the heat sources, *Physica E* 75, 257 (2016).

11:45–12:25 **Quantum Transport: Coherence, and Symmetry, and Diffusivity**
Jianshu Cao

Transport in nano-scale systems often display intriguing quantum mechanical effects, which will be illustrated using examples such as the non-equilibrium spin-boson model, energy transfer networks, and three-level energy transfer systems. Using these examples, we hope to demonstrate non-trivial quantum effects: polaron-induced coherence, multiple steady-state solutions, and ballistic-diffusive transition. Our analysis will shed light on the coherent nature in quantum transport and will be relevant for the design and control of nano-scale quantum devices.

[1] Dynamical signatures of molecular symmetries in non-equilibrium quantum transport. J. Thingna, D. Manzano, and J. Cao, *Sci. Rep.* 6, 28027 (2016). [2] Quantum transport in d-dimensional lattices. D. Manzano, C. Chuang, and J. Cao, *New J. Phys.* 18, 043044 (2016). [3] Polaron effects on the performance of light-harvesting systems: A quantum heat engine perspective. D. Xu, C. Wang, Y. Zhao, and J. Cao, *New J. Phys.* 18, 023003 (2016). [4] Nonequilibrium energy transfer at nanoscale: A unified theory from weak to strong coupling. C. Wang, R. Jie, and J. Cao, *Sci. Rep.* 5, 11787 (2015). [5] Unifying quantum heat transfer in non-equilibrium spin-boson model with full counting statistics, Chen Wang, Jie Ren, and Jianshu Cao *Phys. Rev. A* (2017).

12:25–12:50 **Energy transport in bosonic ladders: Interplay between interactions, gauge fields and geometry of system-bath coupling**
C. Guo and D. Poletti

Quantum systems in contact with an environment display a rich physics emerging from the interplay between dissipative and Hamiltonian terms. Here we consider a dissipative boundary driven ladder in presence of a gauge field which can be implemented with ion microtraps arrays. We focus on the interplay between the gauge field and the position of the coupling between the system and the baths. First we analyze the non-interacting case. We show that, depending on the geometry, the gauge field can drive two nonequilibrium phase transitions. In the different phases both the magnitude of the current and its spatial distribution are significantly different. Strong interactions significantly suppress the dependence of the current with the magnetic field and they result also in negative differential conductivity.

[1] C. Guo, D. Poletti, *Phys. Rev. A* 94, 033610 (2016). [2] C. Guo, D. Poletti, manuscript in preparation (2017).

12:50–12:55 **Large deviation implies First and Second Laws of Thermodynamics**
H. Tajima, E. Wakakuwa, T. Ogawa

P1

To reconstruct thermodynamics based on the microscopic laws is one of the most important goals of statistical physics. Here, we show [1] that the first law and the second law for adiabatic processes are derived from a natural assumption that “probability distributions of energy in Gibbs states satisfy the large deviation principle”, which is widely accepted as a property of thermodynamic equilibrium states. As a starting point of discussions, we define an adiabatic transformation on thermodynamic systems as a randomized energy-preserving unitary transformation over the many-body systems and the external work storage, where the many-body systems are initially in a set of Gibbs states. As the second law, we show the principle of the entropy increase. Namely, we show that an adiabatic transformation from the initial state (a set of Gibbs states) to the final state (another set of Gibbs states) is possible if and only if the regularized von Neumann entropy of the final state is larger than or equal to that of the initial state. As the first law, we show that the difference of energy in the many-body systems before and after the adiabatic transformation is stored in the work storage as “work” in the following sense: (i) the energy of the work storage takes certain values macroscopically in the initial state and the final state. (ii) the entropy of the work storage does not change macroscopically before and after the process. As corollaries of the above results, we also give other forms of first and second laws of thermodynamics, e.g., the principle of maximum work and the first law for the isothermal processes. The more detailed background, formulation, result and derivation are given in arXiv manuscript arXiv:1611.06614.

[1] H. Tajima, E. Wakakuwa and T. Ogawa, arXiv:1611.06614 (2016).

Tuesday Sessions, with Abstracts

12:55–13:00

On Non-Markovianity of Qubit Evolution under Action of Spin Environment

P2

Dipanjan Mandal, Sagnik Chakraborty, Arindam Mallick, Sibasish Ghosh

In open system dynamics, a very important feature is the Markovianity or non-Markovianity of the environment. We consider a toy model here, with a qubit acting as a system and an environment consisting of a collection of non-interacting qubits. The interaction Hamiltonian is given by,

$$H_{se}(t) = \hbar\alpha \left[|1\rangle_s \langle 0| \otimes \sum_{n=1}^N g_n^*(t) |0\dots 0_n\dots 0\rangle_e \langle 0\dots 1_n\dots 0| + |0\rangle_s \langle 1| \otimes \sum_{n=1}^N g_n(t) |0\dots 1_n\dots 0\rangle_e \langle 0\dots 0_n\dots 0| \right]$$

where the coupling strength $g_n(t)$ is in general time-dependent and site-dependent, and α is a real parameter that scales with the interaction strength. So, although a toy model, it depicts a physical scenario where a two-level system exchanges an energy quantum with one of the environment qubits while the rest of the environment qubits are in their ground state. We take a superposition of this exchange interaction for each individual environment qubit, coupled with suitable strength $g_n(t)$. Following the idea of Rivas, Huelga, and Plenio, (2010) we devise a non-Markovianity witness for the model. An additional ancilla qubit (which is not a part of the environment) is used for constructing the Witness. We examine the system-environment dynamics of our model for different types of coupling. We find that completely time-independent coupling and space-independent time-polynomial coupling gives rise to non-Markovianity. Also for space-independent exponentially decaying (in time) coupling, non-Markovianity is witnessed in certain regions of parameter values. We further analyse space and time-dependent coupling for some special cases and found extremal values of the coupling parameter that gives rise to non-Markovianity. These extremal values can be seen as transition values from fully non-Markovian to possibly Markovian dynamics. We also provide some support that would suggest this region of possible Markovianity is actually Markovian.

[1] D. Mandal, S. Chakraborty, A. Mallick and S. Ghosh. arXiv:1703.02749, (2017).

13:00–13:05

Integrable Supersymmetric Many-Body Systems and Many-Body Localization

P3

Pramod Padmanabhan, Soo-Jong Rey, Daniel Teixeira, Diego Trancanelli

In this work we use partial symmetry algebras, described by generalized group structures known as symmetric inverse semigroups to realize supersymmetry in (0+1) dimensions and to build many-body quantum systems on a chain. The algebras of partial symmetries naturally realize the fermionic algebra and more generally they give rise to centrally extended fermionic algebras. Using these the construction of the SUSY system then goes by associating appropriate supercharges to chain sites, in analogy to what is done in spin chains. For simple enough choices of supercharges, we show that the resulting states have a finite non-zero Witten index, which is invariant under perturbations, therefore defining supersymmetric phases of matter protected by the index. The Hamiltonians we obtain are integrable and display a spectrum containing both product and entangled states. By introducing disorder and studying the out-of-time-ordered correlators (OTOC), we find that these systems are in the many-body localized phase and do not thermalize. Finally, we reformulate a theorem relating the growth of the second Renyi entropy to the OTOC on a thermal state in terms of partial symmetries.

[1] Pramod Padmanabhan, S. J. Rey, D. Teixeira, D. Trancanelli, Supersymmetric Many-Body Systems from Partial Symmetries: Integrability, Localization and Scrambling, arXiv:1702.02091 [hep-th] and to be published in JHEP.

13:05–13:10

Master equation approach to transient quantum transport in nanostructures

P4

Pei-Yun Yang, Wei-Min Zhang

We present a non-equilibrium quantum transport theory for transient electron dynamics in nanodevices based on exact master equation derived with the path integral method in the fermion coherent-state representation. Applying the exact master equation to nanodevices, we also establish the connection of the reduced density matrix and the transient quantum transport current with the Keldysh nonequilibrium Green functions. The theory enables us to study transient quantum transport in nanostructures with back-reaction effects from the contacts, with non-Markovian dissipation and decoherence being fully taken into account. In applications, we utilize the theory to specific quantum transport systems, a variety of quantum decoherence and quantum transport phenomena involving the non-Markovian memory effect are investigated in both transient and stationary scenarios at arbitrary initial temperatures of the contacts.

[1] P. Y. Yang and W. M. Zhang, Front. Phys. 12(4), 127204 (2017).

Tuesday Sessions, with Abstracts

13:10–13:15

Entanglement critical length at the many-body localization transition

P5

F. Pietracaprina, Giorgio Parisi, Angelo Mariano, Saverio Pascazio, Antonello Scardicchio

We study the details of the distribution of the entanglement spectrum (eigenvalues of the reduced density matrix) of a disordered spin chain exhibiting a many-body localization (MBL) transition. In the thermalizing region we identify the evolution under increasing system size of the eigenvalue distribution function, whose thermodynamic limit is close to (but possibly different from) the Marchenko-Pastur distribution. The aim of this talk is to show that deviations from Marchenko-Pastur of the probability distribution of the entanglement spectrum in the ergodic phase provide an important characterization of the ergodic phase of such a disordered system. Moreover, such deviations from Marchenko-Pastur can be used to define a correlation length $L_s(h)$, which determines the minimum system size to enter the asymptotic region and diverges at the MBL transition, and to predict the location and finite-size scaling exponents of the MBL transition. Finally, we discuss the nature of the subleading corrections to the entanglement spectrum distribution and to the entanglement entropy. We show that the entanglement spectrum therefore appears to be a crucial quantity, being able to identify even the most subtle correlations that are present in the ergodic phase of a disordered quantum system.

[1] Francesca Pietracaprina, Giorgio Parisi, Angelo Mariano, Saverio Pascazio, Antonello Scardicchio, Entanglement critical length at the many-body localization transition, arXiv:1610.09316 (2016).

15:30–16:10 **Noninvasive measurement of dynamic correlation functions**
M. Kastner

Dynamic (2-time) correlation functions of quantum systems are complex quantities, and their experimental accessibility is complicated by measurement backaction. We prove that the real part of dynamical correlation functions is not affected by backaction, and hence can be obtained by projective measurements. To measure the imaginary part of dynamic correlation functions we introduce a protocol based on noninvasive measurements, which are achieved by weak ancilla-system couplings, thus reducing disturbances due to the early time measurements to a minimum. The deviation of the measured correlation functions from the theoretical, unitarily-evolved ones is quantified, and this allows us to optimize the parameters of the weak measurement protocol. Through these results, experimental measurement of dynamic correlations in nonequilibrium quantum systems becomes feasible. Implementations of the protocol in trapped ions and other experimental platforms are discussed. An outlook will be given on the measurement of out-of-time-ordered correlation functions.

16:10–16:35 **Trapsensor: electronic coupling between two ions stored in different traps**
M. J. Gutiérrez, F. Domínguez, J. Berrocal, J. J. del Pozo, R. A. Rica, and D. Rodríguez

The coupling of ions stored in different traps through the charges they induce in a common electrode was proposed in Ref. [1], but it has not been accomplished yet. The completion of such a system would be an outstanding technological breakthrough in quantum electronics and would pave the way for the implementation of hybrids systems for quantum information. A pioneer work using radiofrequency traps started at the UC Berkeley several years ago (see e.g. [2]). With the same technical objective, but now using 7-T Penning traps, and aiming at different application first [3], we started to build the TRAPSENSOR facility at the University of Granada in 2012. The first outstanding goal is to achieve energy transfer between Doppler-cooled ions ($\langle n \rangle \sim 1000$ phonons) stored in different traps [4]. In this contribution we will present the full facility, report on the status of this singular experiment, and will present the studies carried out and the on-going work with prospects to reach the single energy quanta exchange level ($\langle n \rangle = 0$).

[1] D. J. Heinzen and D. J. Wineland, Phys. Rev. A 42, 2977 (1990). [2] N. Daniilidis et al., J. Phys. B 42, 144012 (2009). [3] D. Rodríguez, Appl. Phys. B 107, 1031 (2012). [4] J. M. Cornejo et al., Int. J. Mass Spectrom. 410C, 22 (2016).

16:35–16:50 **Scrambling the spectral form factor**
J. Molina-Vilaplana, A. del Campo, J. Sonner

Quantum speed limits set an upper bound to the rate at which a quantum system can evolve and as such can be used to analyze the scrambling of information. To this end, we consider the survival probability of a thermofield double state under unitary time-evolution which is related to the analytic continuation of the partition function. We provide an exponential lower bound to the survival probability with a rate governed by the inverse of the energy fluctuations of the initial state. Further, we elucidate universal features of the non-exponential behavior at short and long times of evolution that follow from the analytic properties of the survival probability and its Fourier transform, both for systems with a continuous and a discrete energy spectrum. We find the spectral form factor in a number of illustrative models, notably we obtain the exact answer in the Gaussian unitary ensemble for any N with excellent agreement with recent numerical studies. We also discuss the relationship of our findings to models of black hole information loss, such as the Sachdev-Ye-Kitaev model dual to AdS_2 as well as higher-dimensional versions of AdS/CFT .

[1] A. del Campo, J. Molina-Vilaplana, J. Sonner, arXiv:1702.04350 [hep-th]

17:20–17:35 Fluctuation-induced forces in confined free and imperfect Bose gases

H. W. Diehl and Sergei B. Rutkevich

Ideal and interacting Bose gases confined to a d -dimensional Im of size $\infty^{d-1} \times D$ with periodic (P), antiperiodic (A), Dirichlet-Dirichlet (DD), Neumann-Neumann (NN), and Robin (R) boundary conditions (BCs) are investigated for $2 < d < 4$. The scaling functions $\Upsilon_d^{BC}(x_\lambda = D/\lambda_{th}, x_\xi = D/\xi)$ of the D -dependent residual part $\phi_{d,res}^{BC} = D^{-(d-1)} \Upsilon_d^{BC}(x_\lambda, x_\xi)$ of the grand potential per cross-sectional area and $k_B T$ and their analogs for the fluctuation-induced (“Casimir”) force $\beta \mathcal{F}_C^{BC} = -\partial \phi_{d,res}^{BC} / \partial D$ are determined for the ideal gas case with these BCs, where λ_{th} and ξ are the thermal de-Broglie wavelength and the bulk correlation length, respectively. The associated limiting scaling functions $\Theta_d^{BC}(x_\xi) \equiv \Upsilon_d^{BC}(\infty, x_\xi)$ describing the critical behavior at the bulk condensation transition are shown to agree with those previously determined from a massive free $O(2)$ theory for BC = P, A, DD, DN, NN. For $d = 3$, they are expressed in closed analytical form in terms of polylogarithms. The analogous scaling function $\Theta_d^R(x_\xi, c_1 D, c_2 D)$ under the RBCs $(\partial_z - c_1)\phi|_{z=0} = (\partial_z + c_2)\phi|_{z=D} = 0$ with $c_1 \geq 0$ and $c_2 \geq 0$ is also determined. The corresponding scaling functions $\Upsilon_{\infty,d}^P(x_\lambda, x_\xi)$ and $\Phi_{\infty,d}^P(x_\xi)$ for the imperfect Bose gas are shown to agree with those of the interacting Bose gas with n internal degrees of freedom in the limit $n \rightarrow \infty$. Hence for $d = 3$, $\Phi_{\infty,d}^P(x_\xi)$ is known exactly in closed analytic form. To account for the breakdown of translation invariance in the direction perpendicular to the boundary planes implied by free BCs such as DDBC, a modified imperfect Bose-gas model is introduced that corresponds to the limit $n \rightarrow \infty$ of this interacting Bose gas. Numerically and analytically exact results for the scaling function $\Theta_{\infty,3}^{DD}(x_\xi)$ therefore follow from those of the $O(2n)$ ϕ^4 model for $n \rightarrow \infty$.

17:35–17:50 Floquet-Magnus theory and generic transient dynamics in periodically driven many-body quantum systems

T. Mori, T. Kuwahara, and K. Saito

We explore the universal nature of relaxation in isolated many-body quantum systems subjected to global and strong periodic driving. In the thermodynamic limit, such systems are known to heat up to infinite temperature states in the long-time limit, which kills all the specific properties of the system. In our work [1,2], instead of considering infinitely long-time scale, we aim to provide a general framework to understand the long but finite time behavior of a periodically driven system in the high-frequency regime. In our analysis, we focus on the Floquet-Magnus expansion that gives a formal expression of the effective Hamiltonian on the system. Although in general the full series expansion is not convergent in the thermodynamic limit, we give a clear relationship between the Floquet-Magnus expansion and the transient dynamics. More precisely, we rigorously show that a truncated version of the Floquet-Magnus expansion accurately describes the exact dynamics for a certain time-scale, which is at least exponentially long with respect to the frequency of the driving field. Our theory reveals an experimental timescale for which nontrivial dynamical phenomena can be reliably observed. Based on the above result, we discuss the prethermalization phenomenon in an isolated quantum system under a high-frequency driving field.

[1] T. Kuwahara, T. Mori, and K. Saito, Ann. Phys. 367, 96 (2016). [2] T. Mori, T. Kuwahara, and K. Saito, Phys. Rev. Lett. 116, 120401 (2016).

17:50–18:05 A novel class of quantum phase transitions: from bounded to extensive entanglement.

Israel Klich

I will describe continuous families of frustration-free Hamiltonians with exactly solvable ground states. The ground state of the model is non-degenerate and exhibits a novel quantum phase transition from bounded entanglement entropy to a massively entangled state with volume entropy scaling. The ground state may be interpreted as a deformation away from the uniform superposition of colored Motzkin paths, showed by Movassagh and Shor to have a large (square-root) but sub-extensive scaling of entanglement into a state with an extensive entropy. This novel transition shows that entanglement in many body systems may be enhanced under special circumstances with a potential for generating useful entanglement for the purpose of quantum computing and that the full implications of locality and its restrictions on possible ground states may hold further surprises.

[1] Zhao Zhang, Amr Ahmadain and Israel Klich, Quantum phase transition from bounded to extensive entanglement entropy in a frustration-free spin chain, PNAS early edition 2017, doi: 10.1073/PNAS.1702029114 (arXiv:1606.07795). [2] O. Salberger, T. Udagawa, Z. Zhang, H. Katsura, I. Klich and V. Korepin, Deformed Fredkin Spin Chain with Extensive Entanglement, arXiv:1611.04983. [3] Zhao Zhang and Israel Klich, Entropy, gap and a multi-parameter deformation of the Fredkin spin chain, arXiv:1702.03581

18:05-18:10 **Entropic uncertainty measures of the D -dimensional hydrogenic system in the Rydberg and pseudoclassical limits** **P6**
D. Puertas-Centeno, I. V. Toranzo, and J. S. Dehesa

An informational-theoretical analysis of the quantum probability distribution of the D -dimensional hydrogenic system is done in a fully analytical manner by means of dispersion (variance, moments around the origin, logarithmic moments), entropic (Shannon and Rényi entropies, Fisher information) and complexity (Crámer-Rao, Fisher-Shannon and LMC) measures. The results are expressed in terms of the dimensionality D , the nuclear charge Z and the radial and angular hyperquantum numbers characterizing the states. Emphasis is made for the pseudoclassical states (i.e., states with fixed hyperquantum numbers for high-dimensional D) and the Rydberg states (i.e., states with very high radial hyperquantum number for fixed D), where the numerical computation is most difficult to be performed. Novel analytical results for these states are given and discussed.

[1] D. Puertas-Centeno, N.M. Temme, I. V. Toranzo and J.S. Dehesa. Entropic uncertainty measures for large dimensional hydrogenic systems. *J. Math. Phys.* (submitted) [2] I. V. Toranzo, D. Puertas-Centeno and J. S. Dehesa. Entropic properties of D -dimensional Rydberg systems. *Physica A* 462 (2016) 11971206. [3] J. S. Dehesa, S. López-Rosa, A. Martinez-Finkelshtein, and R.J. Yáñez, Information theory of D -dimensional hydrogenic systems: Application to circular and Rydberg states, *Int. J. Quantum Chem.* 110 (2010) 1529.

18:10–18:15 **Phase transition in quantum annealing of hard problems detected by fidelity susceptibility** **P7**
Jun Takahashi and Koji Hukushima

We numerically analyze the quantum annealing of an NP-hard problem, namely the maximum independent set problem in the hard regime. The system is expressed by a Hamiltonian of the form

$$\hat{H}(\lambda) = (1 - \lambda) \left(\sum_{\langle ij \rangle} J_{ij} \hat{\sigma}_i^z \hat{\sigma}_j^z + \sum_i h_i \hat{\sigma}_i^z \right) + \lambda \left(\sum_i \hat{\sigma}_i^x \right),$$

which $\{J_{ij}\}$ and $\{h_i\}$ are randomly chosen according to a certain probability distribution. We find first order phase transitions in terms of the spin glass order parameter $q := 1/N \sum_i \langle \hat{\sigma}_i^z \rangle^2$ for individual realization of disorders. Those first order transitions are strongly sample-dependent, resembling behaviors of physical quantities within the spin glass phase with non-self averaging properties. However, no singularity is found for the sample-averaged spin glass order parameter $\bar{q}$, nor for other thermodynamic quantities such as the specific heat, spin glass susceptibility etc. This indicates that there is no spin glass phase for this model. Thus, the fidelity susceptibility (quantum SLD-Fisher information) χ^F , which is a quantity inspired from quantum information theory, is measured. We see that the sample-averaged fidelity susceptibility $\bar{\chi}^F$ has a diverging point, which comes before the individual first order transitions. This suggests that a novel quantum phase detected by χ^F induces the first order transitions causing the failure of quantum annealing.

[1] J. Takahashi and K. Hukushima, arXiv:1612.08554 (2016).

18:15–18:20 **Ultralong-range polyatomic Rydberg molecules** **P8**
Javier Aguilera-Fernández and Rosario González-Férez

Ultralong-range triatomic Rydberg molecules might be formed by a Rydberg atom and a heteronuclear diatomic molecule [1-3]. This species exhibits novel binding properties due to the interaction of the electric field induced by the Rydberg electron and core and the permanent dipole moment of the diatomic polar molecule. The coupling of the Rydberg electron and internal rotational states of the polar ground state dimer creates a series of undulating Born-Oppenheimer potential curves, which reflects the oscillating character of the Rydberg electron wave function. By applying additional electric fields of a few Vcm^{-1} , the electronic structure of these giant molecules could be controlled and manipulated [3] [4]. In this work, we consider polyatomic molecules formed by a Rydberg rubidium atom and ground state KRb polar molecules [4] [5]. Within the Born-Oppenheimer, we investigate the electronic structure of the systems $KRb - Rb^*$ and $KRb - Rb^* - KRb$. The Born-Oppenheimer potentials are investigated as the internuclear separations between the KRb dimer (or dimers) and the Rb core varies. We also analyze the metamorphosis of the Born-Oppenheimer potential curves with varying electric field and analyze the resulting properties such as the alignment and orientation of the polar diatomic molecule.

[1] S.T. Rittenhouse, and H.R. Sadeghpour *Phys. Rev. Lett.* 104, 243002 (2010). [2] S. T. Rittenhouse, M. Mayle, P. Schmelcher, and H. R. Sadeghpour *J. Phys. B* 44, 184005 (2011). [3] M. Mayle, S. T. Rittenhouse, P. Schmelcher, and H. R. Sadeghpour *Phys. Rev. A* 85, 052511 (2012). [4] R. González-Férez, H. R. Sadeghpour and P. Schmelcher, *New J. Physics* 17, 013021 (2015). [5] J. Aguilera-Fernández, H. R. Sadeghpour, P. Schmelcher and R. González-Férez, *J. Phys. Conference Series* 635, 012023 (2015).

Tuesday Sessions, with Abstracts

18:20–18:25 **Universal short-time response and formation of correlations after quantum quenches** **P9**

Klaus Morawetz

The short-time evolution of two distinct systems, the pump and probe experiments with femtosecond lasers in semiconductors and the sudden quench of cold atoms in an optical lattice, is found to be described by the same universal response function. This analytic formula at short time scales is derived from the quantum kinetic theory approach observing that correlations need a certain time to be formed. The influence of a finite trapping potential is derived and discussed as well as Singwi-Sjlander local field corrections. The quantum kinetic equation allows to understand how two-particle correlations are formed and how the screening and collective modes are build up.

[1] K. Morawetz: Phys. Rev. B 90 (2014) 075303. [2] K. Morawetz, P. Lipavský, M. Schreiber: Phys. Rev. B 72 (2005) 233203, [3] K. Morawetz: Phys. Rev. E 66 (2002) 022103. [4] K. Morawetz, M. Bonitz, V. G. Morozov, G. Röpke, D. Kremp: Phys. Rev. E 63 (2001) 20102. [5] K. Morawetz, V. Spicka, P. Lipavský: Phys. Lett. A 246 (1998) 311.

18:25–18:30 **Optimal performance of generalized heat engines with finite-size baths of multiple conserved quantities beyond i.i.d. scaling** **P10**

K. Ito and M. Hayashi

We focus on the optimal performance of generalized quantum heat engines concerning multiple conserved quantities of types A and B [1] with finite-size baths as indicated in the figure. We obtain the fine-grained Carnot bound

$$\Delta W_A \leq \left(1 - \frac{\beta_2}{\beta_1}\right) \Delta Q_A - \sum_{i=1}^2 \frac{\gamma_i}{\beta_1} \Delta Q_{B,i} - C_{AA} \frac{\Delta Q_A^2}{\lambda} - C_{AB}^i \sum_{i=1}^2 \frac{\Delta Q_A \Delta Q_B^i}{\lambda} - \sum_{1 \leq i \leq j \leq 2} C_{BB}^{i,j} \frac{\Delta Q_B^i \Delta Q_B^j}{\lambda}$$

in response to the scale the baths λ by extending [2]. The coefficients are given not only in terms of generalized inverse temperatures β_i, γ_i but also of the canonical correlations between the baths quantities. Especially, baths state is not necessarily i.i.d. state differently from conventional researches. Just assuming the asymptotic extensivity, we treat the generic scaling covering wide range of physical systems, e.g. gases scaled by the volume of its container. We also give a general protocol to achieve the bound.

[1] Y. Guryanova et al. Nat. Commun. 7, 12049 (2016). [2] H. Tajima et al. arXiv:1405.6457 (2014).

Wednesday Sessions at a Glance

Wednesday Morning A

09:00–09:40	From quantum information thermodynamics to stochastic thermodynamics <i>Jonathan Oppenheim</i>
09:40–10:05	Exploring far-from-equilibrium physics of dissipative spin systems with highly excited atoms <i>Igor Lesanovsky</i>
10:05–10:30	Topological heat transport and symmetry-protected boson currents <i>Miguel Ángel Martín-Delgado</i>
10:30–10:45	Thermodynamics of trajectories for quantum harmonic oscillators <i>S. Pigeon, L. Fusco, A. Xuereb, G. De Chiara, M. Paternostro</i>
10:45–11:00	Counterexamples to Eigenstate Thermalization Hypothesis <i>Naoto Shiraishi, Takashi Mori</i>
11:00–11:15	Topological Transitions in Spin Interferometers and Resonators by Geometric Phase Engineering <i>D. Frustaglia, H. Saarikoski, J.P. Baltanás, A.A. Reynoso, and J. Nitta</i>

Wednesday Morning B

11:45–12:25	Landauers principle for non-equilibrium quantum processes <i>Mauro Paternostro</i>	
12:25–12:50	Long-lasting coherence in biological complexes: from microscopic models to actual experiments <i>Javier Prior</i>	
12:50–12:55	Magnetic field enhancement of organic photovoltaic cells performance <i>S. Oviedo-Casado, A. Urbina, and J. Prior</i>	P11
12:55–13:00	Information Theory of D-dimensional Harmonic Systems. Application to Rydberg and Pseudoclassical States <i>I. V. Toranzo, D. Puertas-Centeno, and J. S. Dehesa</i>	P12
13:00–13:05	Quantum generalized entropies and measures of quantum correlations <i>M. Portesi, S. Zozor, G. Bellomo, G.M. Bosyk, F. Holik, and P.W. Lamberti</i>	P13
13:05–13:10	Classical limit from a logical perspective <i>M. Losada and S. Fortin</i>	P14
13:10–13:15	Identifying topological phase transitions by means of electron currents in silicene and other 2D Dirac materials <i>J. C. Bolívar, J. B. Roldán, F. de los Santos, and E. Romera</i>	P15

Wednesday Sessions at a Glance

Wednesday Afternoon A

- 15:30-16:10 **What is thermal equilibrium and how do we get there?**
Hal Tasaki
- 16:10-16:35 **Nonlocal quantum kinetic theory to simulate strong correlations**
Klaus Morawetz
- 16:35-16:50 **Exploring statistical physics and quantum mechanics at the mesoscale with levitated nanoparticles**
R.A. Rica, F. Ricci, G.P. Conangla, I. Alda, J. Gieseler, J. Berthelot, R. Quidant

Wednesday Afternoon B

- 17:20-17:35 **The quantum first detection problem**
Felix Thiel, David A. Kessler, and Eli Barkai
- 17:35-17:50 **Non-ergodic and insulating phases of Josephson Junctions Arrays**
Manuel Pino
- 17:50-18:05 **No-Go Theorem for the Characterization of Work Fluctuations in Coherent Quantum Systems**
M. Perarnau-Llobet, E. Bäumer, K. V. Hovhannisyanyan, M. Huber, and A. Acín
- 18:05-18:10 **Limitations on coherent work extraction in open quantum systems** P16
P. Menczel, C. Flindt, and K. Brandner
- 18:10-18:15 **Optimal quantum spatial search on random temporal networks** P17
Shantanav Chakraborty, L. Novo S. D. Giorgio, Y. Omar
- 18:15-18:20 **Spatial search by quantum walk is optimal for almost all graphs** P18
Shantanav Chakraborty, Leonardo Novo, Andris Ambainis, and Yasser Omar
- 18:20-18:25 **When Anderson localization makes quantum particles move backward** P19
T. Prat, D. Delande, and N. Cherroret
- 18:25-18:30 **Phase Transitions in a Molecular Zipper: Lee-Yang Zeros and Large Deviation Statistics** P20
Aydin Deger, Kay Brandner, and Christian Flindt

09:00–09:40 **From quantum information thermodynamics to stochastic thermodynamics**
Jonathan Oppenheim

09:40–10:05 **Exploring far-from-equilibrium physics of dissipative spin systems with highly excited atoms**
Igor Lesanovsky

In recent years cold atomic gases have been established as a versatile platform for the study of quantum many-body phenomena. Especially atoms excited to highly-lying electronic states so-called Rydberg atoms offer rather intriguing possibilities for the exploration of strongly correlated dynamics. In this talk I will show that the out-of-equilibrium behaviour of these systems is governed by emergent kinetic constraints, which are often used to mimic dynamical arrest or excluded volume effects in idealised models of glass forming substances. In Rydberg gases exposed to a noisy environment these constraints emerge naturally and lead to a remarkably rich dynamics although the final stationary state might be entirely uncorrelated and trivial. Dynamical features include a self-similar relaxation, the existence of correlated growth as well as the emergence of non-equilibrium phase transitions of the directed percolation universality class, whose experimental observation so far has been challenging. Moreover, Rydberg gases offer an opportunity for the systematic exploration of the role of competing quantum and classical dynamical effects on the aforementioned non-equilibrium phase transitions.

10:05–10:30 **Topological heat transport and symmetry-protected boson currents**
Miguel Ángel Martín-Delgado

The study of non-equilibrium properties in topological systems is of practical and fundamental importance. Here, we analyze the stationary properties of a two-dimensional boson topological insulator coupled to two thermal baths in the quantum open-system formalism. Novel phenomena appear like chiral edge heat currents that are the out-of-equilibrium counterparts of the zero-temperature edge currents. We find the new set of discrete symmetries that protect these topological heat currents, differing from the zero-temperature limit. Remarkably, one of these currents flows opposite to the decreasing external temperature gradient. As the starting point, we consider the case of a single external reservoir showing prominent results like thermal erasure effects and topological thermal currents. Our results are experimentally accessible with platforms like photonics systems and optical lattices.

10:30–10:45 **Thermodynamics of trajectories for quantum harmonic oscillators**
S. Pigeon, L. Fusco, A. Xuereb, G. De Chiara, M. Paternostro

The description of the dynamics resulting from the interaction of a quantum system with its environment is one of the key goals of modern quantum physics. Recently, a promising approach came to light, combining the quantum master equation and large-deviation theory [1]. Unlike others, this approach applies to any dissipative quantum systems, paving the way to a standard description of dynamic of open quantum system in terms of thermodynamics of trajectories. We consider a paradigmatic system in quantum mechanics, quantum harmonic oscillators connected to baths whose dynamics is governed by a quadratic master equation in Lindblad form. This system is a fundamental building block used to describe a large variety of quantum degrees of freedom. I will present how for a single harmonic oscillator, our approach, based on quantum optics methods yields an analytical expression for the large-deviation function encoding the statistics of exchange between the system and the environment [2]. Furthermore, the same approach, generalised to any network of harmonic oscillator undergoing quadratic dynamic [3]. From it we can access to possible fluctuation theorem and more generally key thermodynamic quantities such as irreversible entropy produced for a large variety of quantum open systems [3]. We also derive a systematic algorithm to derive, step by step, the full-statistics of the exchange thermodynamics [4].

[1] J. P. Garrahan and I. Lesanovsky, *Phys. Rev. Lett.* 104, 160601 (2010). [2] S. Pigeon, L. Fusco, A. Xuereb, G. De Chiara, and M. Paternostro, *Phys. Rev. A* 92, 013844 (2015). [3] S. Pigeon, L. Fusco, A. Xuereb, G. De Chiara, and M. Paternostro *New J. Phys* 18, 013009 (2016). [4] S. Pigeon and A. Xuereb, *J. Stat. Mech. Theor. Exp* 063203 (2016).

10:45–11:00 **Counterexamples to Eigenstate Thermalization Hypothesis**
Naoto Shiraishi, Takashi Mori

Thermalization of an isolated quantum system to the equilibrium state is one of the most profound problems in theoretical physics. Recently, the eigenstate thermalization hypothesis (ETH) [1-5] has been considered to play a key role to understand thermalization, which claims that all energy eigenstates of a given Hamiltonian are thermal (i.e., all macroscopic observables take the same expectation value as corresponding microcanonical ensemble). The ETH guarantees the presence of thermalization. In addition, many numerical simulations [5-7] have shown that systems with (i) shift-invariant, (ii) no local conserved quantity, (iii) far from integrable, and (iv) local interactions, satisfy the ETH and show thermal-

Wednesday Sessions, with Abstracts

ization, while some non-thermalizing systems including integrable systems and localized systems do not satisfy the ETH. Thus, it is expected that a system with (i)-(iv) satisfy the ETH, and that the ETH is not only a sufficient condition but also a necessary condition for thermalization. Contrary to such widely-accepted beliefs, in this presentation, we construct counterexamples to the ETH [8,9]. We introduce a general method of embedding, and using this we systematically construct Hamiltonians which satisfy (i)-(iv) but do not satisfy the ETH. The violation of the ETH is proven analytically. In addition, numerical simulations show that the constructed models indeed thermalize after a physically-plausible quench. Our models also show a novel type of prethermalization phenomena, which is triggered by a certain class of initial states. Our findings shed new light on the conventional understanding of thermalization.

[1] J. von Neumann, Z. Phys. 57, 30 (1929). [2] J. M. Deutsch, Phys. Rev. A 43, 2046 (1991). [3] M. Srednicki, Phys. Rev. E 50, 888 (1994). [4] M. Rigol, V. Dunjko, M. Olshanii, Nature 452, 854 (2008). [5] G. Biroli, C. Kollath, and A. Lauchli, Phys. Rev. Lett. 105, 250401 (2010). [6] H. Kim, T. N. Ikeda, and D. A. Huse, Phys. Rev. E 90, 052105 (2014). [7] C. Gogolin and J. Eisert, Rep. Prog. Phys. 79, 056001 (2016). [8] N. Shiraishi and T. Mori, arXiv:1702.08227 (2017). [9] T. Mori and N. Shiraishi, in preparation.

11:00–11:15 **Topological Transitions in Spin Interferometers and Resonators by Geometric Phase Engineering**

D. Frustaglia, H. Saarikoski, J.P. Baltanás, A.A. Reynoso, and J. Nitta

Research on spin geometric (Berry) phases in mesoscopic systems has been active for about 25 years already. During this time, several proposals were put forward for the detection of topological effects in spin interferometers subject to magnetic textures, accompanied by experimental attempts of modest success. Incontrovertible evidence of spin geometric phases was found only recently [1] in mesoscopic rings under the action to spin-orbit coupling (Rashba rings) in agreement with theoretical predictions [2], giving a new impulse to the field. Here, after a brief account of previous achievements, we discuss some new possibilities for electronic manipulation based on the control of the spin geometric phases in nanodevices such as Rashba interferometers subject to additional magnetic fields. These run from a purely geometric manipulation of electron spins (for weak fields) [3] to topological transitions (for large fields) [4]. Moreover, similar physics plays a role in spin resonance under driving fields that undergo a topological transition. There we find [5] that, despite the strongly non-adiabatic effects dominating the spin dynamics, the fields topology appears clearly imprinted in the quasienergy of Floquet spin states. This has remarkable consequences on the spin resonance condition, suggesting a whole new class of experiments to spot topological transitions in the dynamics of spins and other two-level systems (from nuclear magnetic resonance to strongly-driven superconducting qubits).

[1] F. Nagasawa, J. Takagi, Y. Kunihashi, M. Kohda, and J. Nitta, Phys. Rev. Lett. 108, 086801 (2012); K. Richter, Physics 5, 22 (2012). [2] D. Frustaglia and K. Richter, Phys. Rev. B 69, 235310 (2004). [3] F. Nagasawa, D. Frustaglia, H. Saarikoski, K. Richter, and J. Nitta, Nature Comm. 4, 2526 (2013). [4] H. Saarikoski, J.E. Vázquez-Lozano, J.P. Baltanás, F. Nagasawa, J. Nitta, and D. Frustaglia, Phys. Rev. B 91, 241406(R) (2015). [5] A.A. Reynoso, J.P. Baltan as, H. Saarikoski, J.E. Vázquez-Lozano, J. Nitta, and D. Frustaglia, arXiv:1702.01781.

11:45–12:25 **Landauers principle for non-equilibrium quantum processes**

Mauro Paternostro

I will discuss the full counting statistics of dissipated heat to explore the relation with Landauers principle. Combining a two-time measurement protocol for the reconstruction of the statistics of heat with the minimal set of assumptions for Landauers principle to hold, I will derive a general one-parameter family of upper and lower bounds on the mean dissipated heat from a system to its environment. Furthermore, I will establish a connection with the degree of non-unitality of the systems dynamics and show that if a large deviation function exists, this can be used to witness dynamical phase transitions. For the purpose of demonstration, I will apply these bounds to a three level system coupled to a non-equilibrium finite-size environment.

12:25–12:50 **Long-lasting coherence in biological complexes: from microscopic models to actual experiments**

Javier Prior

Recent observations of oscillatory features in the optical response of photosynthetic complexes have revealed evidence for surprisingly long-lasting electronic coherences which can coexist with energy transport. This observation has generated different questions like: Is quantum coherence responsible for the surprisingly high efficiency of natural light harvesters? If so, how do such systems avoid the loss of coherence due to interactions with their warm, wet and noisy environments? The answer to these important questions rests in the beneficial interplay between electronic and vibrational degrees of freedom.

12:50–12:55 **Magnetic field enhancement of organic photovoltaic cells performance**

P11

S. Oviedo-Casado, A. Urbina, and J. Prior

Charge separation is a critical process for achieving high efficiencies in organic photovoltaic cells. The initial tightly bound excitonic electron-hole pair has to dissociate fast enough in order to avoid photocurrent generation and thus power conversion efficiency loss via geminate recombination. Such process is currently thought to take place assisted by transitional states that lie between the initial exciton and the free charge state [2]. As a consequence of spin conservation rules, these intermediate charge transfer states typically have singlet character. Here we propose a donor-acceptor model for a generic organic photovoltaic cell in which the process of charge separation is modulated by a magnetic field which tunes the energy levels. The impact of a magnetic field is to intensify the generation of charge transfer states with triplet character via inter-system crossing. As the ground state of the system has singlet character, triplet states are recombination-protected, thus leading to a higher probability of successful charge separation[3]. Using the open quantum systems formalism we demonstrate that not only the population of triplet charge transfer states grows in the presence of a magnetic field, but also how the power outcome of an organic photovoltaic cell is in that way increased.

[1] S. Oviedo-Casado et al. ArXiv e-print, 1702.05130 (2017). [2] S. Gélinas et al. Science 343, 512 (2014). [3] A. Rao et al. Nature 500, 435 (2013).

12:55-13:00 **Information Theory of D-dimensional Harmonic Systems. Application to Rydberg and Pseudoclassical States**

P12

I. V. Toranzo, D. Puertas-Centeno, and J. S. Dehesa

The spreading properties of the quantum probability distribution of the ground and excited states of the D-dimensional harmonic system (i.e., a particle moving under the action of a quadratic potential) are examined by means of dispersion (variance, moments around the origin, logarithmic moments), entropic (Shannon and Rényi entropies, Fisher information) and complexity (Crámer-Rao, Fisher-Shannon and LMC) measures. This is done in a fully analytical manner in terms of the dimensionality D and the radial and angular hyperquantum numbers characterizing the states. Emphasis is made for the Rydberg states (i.e., states with very high radial hyperquantum number for fixed D) and the quasiclassical states (i.e., states with fixed hyperquantum numbers for high-dimensional D), where the numerical computation is most difficult to be performed. Novel analytical results for these states and about the measures of complexity of arbitrary states are given.

[1] I. V. Toranzo and J. S. Dehesa, Information theory of the D-dimensional harmonic systems. Application to Rydberg and quasiclassical states. Preprint in preparation. [2] J. S. Dehesa, I. V. Toranzo and D. Puertas-Centeno, Int. J. Quantum Chem. 117, 48-56 (2017). [3] D. Puertas-Centeno, I. V. Toranzo and J. S. Dehesa, Entropy 2017, 19, 164.

Wednesday Sessions, with Abstracts

13:00–13:05 **Quantum generalized entropies and measures of quantum correlations** **P13**

M. Portesi, S. Zozor, G. Bellomo, G.M. Bosyk, F. Holik, and P.W. Lamberti

The properties of quantum generalized entropies, which are inspired in the family of (h, ϕ) -functionals given by Salicrú et al for classical distributions, are studied. The quantum versions comprise some known cases as von Neumann and others, and provide a plethora of entropies the behaviour of which we analyze under the action of quantum operations. For given subfamilies of the quantum (h, ϕ) -entropies, the problem of detection of quantum entanglement is addressed and the application as measures of quantum correlations for bipartite systems is discussed.

[1] G.M. Bosyk et al. Quantum Inf Process 15, 3393 (2016). [2] G.M. Bosyk et al. Physica A 462, 390 (2016).

13:05–13:10 **Classical limit from a logical perspective** **P14**

M. Losada and S. Fortin

If a quantum system undergoes a physical process such that its behavior becomes classic, then the logical structure of its properties should undergo a transition from a quantum logic to a classical logic. In order to give an adequate description of the logic structure transition, we propose to study the classical limit in terms of the Heisenberg picture, which allows to study the time evolution of the lattice of properties and how it becomes distributive [1]. For describing the quantum-to-classical transition of the logical structure of the system we need to consider non-unitary time evolutions [2].

[1] S. Fortin and L. Vanni. Foundation of Physics 44, 1258-1268 (2014). [2] S. Fortin, F. Holik and L. Vanni. Non-unitary Evolution of Quantum Log-ics. In: Bagarello F., Passante R., Trapani C. (eds) NonHermitian Hamiltonians in Quantum Physics. Springer Proceedings in Physics 184. Springer, Cham (2016).

13:10–13:15 **Identifying topological phase transitions by means of electron currents in silicene and other 2D Dirac materials** **P15**

J. C. Bolívar, J. B. Roldán, F. de los Santos, and E. Romera

In this work, we have studied the time evolution of electron wave packets in a monolayer of silicene under perpendicular magnetic and electric fields to characterize the topological-band insulator transitions. We have found that the periodicities exhibited by the wave packets dynamics (zitterbewegung, classical and revival times) reach maximum values at the charge neutrality points (CNP). Additionally, we have discovered that electron currents reflect the transitions from a topological insulator to a band insulator at CNP too. These results are valid for other 2D gapped Dirac materials analogous to silicene with a buckled honeycomb structure and a significant spin-orbit coupling [1-5].

[1] E. Romera, J. C. Bolívar, J. B. Roldán and F. de los Santos, Revivals of electron currents and topological-band insulator transitions in 2D gapped Dirac materials, EPL, 115, 20008 (2016). [2] M. Calixto and E. Romera, Inverse participation ratio and localization in topological insulator phase transitions, Journal of Statistical Mechanics, P06029 (2015). [3] E. Romera and M. Calixto, Uncertainty relations and topological-band insulator transitions in 2D gapped Dirac materials, Journal of Physics: Condensed Matter, 27, 175003 (2015). [4] M. Calixto and E. Romera, Identifying topological-band insulator transitions in silicene and other 2D gapped Dirac materials by means of Rényi-Wehrl entropy, EPL, 109, 40003 (2015). [5] J. C. Bolívar and E. Romera, Rényi entropies and topological quantum numbers in 2D gapped Dirac materials, Physics Letters A, 381 (2017) 1753 - 1756.

15:30-16:10 What is thermal equilibrium and how do we get there?

Hal Tasaki

We discuss the foundation of equilibrium statistical mechanics in terms of isolated macroscopic quantum systems. We shall characterize thermal equilibrium based on typicality picture and a large-deviation point of view. We then present a simple (and hopefully realistic) condition based on the notion of effective dimension which guarantees that a nonequilibrium initial state evolves into the thermal equilibrium. We shall argue that strong entanglement in energy eigenstates may lead to a necessary large effective dimension. We also discuss a related scenario based on ETH (energy eigenstate thermalization hypothesis).

16:10–16:35 Nonlocal quantum kinetic theory to simulate strong correlations

Klaus Morawetz

A quantum kinetic equation which unifies the achievements of transport in dense gases with the quantum transport of dense Fermi systems is presented [1,2,6]. The quasiparticle drift of Landau's equation is connected with a dissipation governed by a nonlocal and non-instant scattering integral in the spirit of Enskog corrections. These corrections are expressed in terms of shifts in space and time that characterize non-locality of the scattering process [3]. In this way quantum transport is possible to recast into a quasi-classical picture. Compared to the Boltzmann equation, the presented form of virial corrections only slightly increases the numerical demands in implementations [4]. In order to achieve this, large cancellations in the off-shell motion have been used which are buried usually in non-Markovian behaviors. The remaining effects are: (i) off-shell tails of the Wigner distribution, (ii) renormalization of scattering rates and (iii) of the single-particle energy, (iv) collision delay and (v) related non-local corrections to the scattering integral. The balance equations for the density, momentum and energy include quasiparticle contributions and the correlated two-particle contributions beyond the Landau theory. The medium effects on binary collisions are shown to mediate the latent heat, i.e., an energy conversion between correlation and thermal energy [5,6]. The two-particle form of the entropy is derived which extends the Landau quasiparticle picture by two-particle molecular contributions and the H-theorem is proved.

[1] V. Špička, P. Lipavský, K. Morawetz, PRB. 55 (1997) 5084 and 5095 [2] V. Špička, P. Lipavský, and K. Morawetz, Phys. Lett. A 240 (1998) 160 [3] K. Morawetz, V. Špička, P. Lipavský, H.N. Kwong, PRC 59 (1999) 3052 [4] K. Morawetz, V. Špička, P. Lipavský, G. Kortemeyer, Ch. Kuhrt, R. Nebauer, PRL 82 (1999) 3767 PRC 62 (2000) 44606; K. Morawetz, M. Płoszajczak, V.D. Toneev, PRC 62 (2000) 64602; K. Morawetz, P. Lipavský, J. Normand, D. Cussol, J. Colin, B. Tamain, PRC 63 (2001) 034619; [5] P. Lipavský, V. Špička, K. Morawetz, PRE 59 (1999) R1291 [6] P. Lipavský, K. Morawetz, and V. Špička, Annales de Physique, Paris (2001) No. 26, 1, ISBN 2-86883-541-4

16:35–16:50 Exploring statistical physics and quantum mechanics at the mesoscale with levitated nanoparticles

R.A. Rica, F. Ricci, G.P. Conangla, I. Alda, J. Gieseler, J. Berthelot, R. Quidant

Levitated nanoparticles in high vacuum have emerged as a rich playground for exploring different frontiers of physics, particularly on stochastic thermodynamics and the applicability of quantum mechanics at the mesoscale [1-4]. Here, we present recent progress on the implementation of different levitation schemes, allowing for exquisite control over the dynamics of a nanoparticle. In particular, we first report on the precise control of the nonlinear and stochastic bistable dynamics of a levitated nanoparticle in high vacuum. We demonstrate how it can lead to efficient signal amplification schemes, including stochastic resonance [5]. Finally, we describe our progress towards the control of nanoparticles with internal degrees of freedom (nanodiamonds with NV centers) by means of a RF ion trap [6,7].

[1] J. Gieseler et al. Phys. Rev. Lett. 109, 103603 (2012). [2] J. Gieseler et al. Nature Nano. 9, 358-364 (2014). [3] V. Jain et al. Phys. Rev. Lett. 116 243601 (2016). [4] N. Kiesel et al. PNAS 110 1418014185 (2013). [5] F. Ricci et al. Nature Comms. In press (2017). [6] I. Alda et al. Appl. Phys. Lett. 109 163105 (2016). [7] G.P. Conangla et al. In preparation (2017).

17:20–17:35 **The quantum first detection problem**

Felix Thiel, David A. Kessler, and Eli Barkai

We consider the question of when a quantum system initially prepared in state A first “arrives” in state B, i.e. the first arrival problem in quantum physics. To determine the arrival, the observer attempts to detect the system stroboscopically with fixed period via a projective measurement. The time of the first successful detection attempt is the first detection time. The corresponding probability of the event is the first detection probability. For systems with a continuous energy spectrum, this quantity can be expressed in terms of the spectral measure of the evolution operator (which is related to the density of energy states). This allows us to present an exact formula for the total probability of detection and to derive the long-time asymptotic behaviour of the first detection probabilities. It is shown that the latter decays like a power law with superimposed oscillations. The exponent of the power law is determined by the spectral (or fracton) dimension of the spectral measures. The total probability of detection is always less than unity.

17:35–17:50 **Non-ergodic and insulating phases of Josephson Junctions Arrays**

Manuel Pino

We show that chaotic dynamic may not result in thermalization in certain bosonic model that can be realized as an array of Josephson junctions. This model exhibits a many-body localization transition which separates insulating and metallic phases. Localization prevents the system to show thermal behaviour in the Many-Body localized phase. We argue that there is a intermediate region in the phase diagram, between Many-Body localized and ergodic phases, in which the system behaves as a metal but exhibits non-thermal properties.

[1] M. Pino, L. B. Ioffe, and B. L. Altshuler, PNAS 2016 113 (3) 536-541, 2015, doi:10.1073/pnas.1520033113. [2] M. Pino, V. E. Kravtsov, B. L. Altshuler and L. B. Ioffe, arXiv:1704.07393 (2017).

17:50–18:05 **No-Go Theorem for the Characterization of Work Fluctuations in Coherent Quantum Systems**

M. Perarnau-Llobet, E. Bäumer, K. V. Hovhannisyan, M. Huber, and A. Acín

An open question in quantum thermodynamics is how to describe the fluctuations of work for quantum coherent processes. In the standard approach, based on a projective energy measurement both at the beginning and at the end of the process [1], the first measurement destroys any initial coherence in the energy basis. Here we seek extensions of this approach which can possibly account for initially coherent states. We consider all measurement schemes to estimate work and require that (i) the difference of average energy corresponds to average work for closed quantum systems and that (ii) the work statistics agree with the standard two-measurement scheme for states with no coherence in the energy basis. We first show that such a scheme cannot exist. Next, we consider the possibility of performing collective measurements on several copies of the state and prove that it is still impossible to simultaneously satisfy requirements (i) and (ii). This represents our main result [2], as it means that there is no notion of (measurable) fluctuating quantum work that, while agreeing with standard stochastic thermodynamics, can be successfully extended to describe all quantum coherent processes. In other words, there is always a price to measure work. Despite this no-go result, the idea of performing collective measurements opens new possibilities, and in fact we develop a measurement scheme that acts simultaneously on two copies of the state and allows us to describe a whole class of coherent transformations. We will discuss the possibilities and limitations of this scheme, and how it extends the standard two-projective-measurement scheme to estimate work. This second part is also based on [2] but contains some new unpublished results.

[1] P. Talkner et al, Phys. Rev. E 75, 050102(R) (2007). [2] M. Perarnau-Llobet et al, Phys. Rev. Lett. 118, 070601 (2017).

18:05–18:10 **Limitations on coherent work extraction in open quantum systems**

P16

P. Menczel, C. Flindt, and K. Brandner

As the miniaturization of thermal machines advances towards ever-smaller scales [2], the question arises how quantum effects such as coherence will influence their performance, see for example [3]. Here, we investigate this problem for heat engines operating periodically and under weak-coupling conditions. To assess the role of quantum effects, the total energy content of the working substance is divided into a passive part and one which can be extracted through coherent operations [4]. Using this scheme, we obtain a refined version of the first law, which allows us to derive a general criterion necessary for coherent work extraction. Specializing to Lindblad dynamics, we identify different universality classes of systems in which quantum effects can only decrease the total power. In the limit of small driving amplitudes, we recover previously obtained bounds for the linear-response regime [5]. Our new bounds are, however, valid also arbitrarily far from equilibrium, that is, for strong and fast driving. Thus, our results are a step towards a systematic understanding of

the role of coherence for power generation in open quantum systems.

[1] P. Menczel, C. Flindt and K. Brandner, in preparation (2017). [2] J. Ronagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, and K. Singer, *Science* 352, 325 (2016). [3] J. P. Pekola, *Nat. Phys.* 11, 118 (2015). [4] A. E. Allahverdyan, R. Balian, and T. M. Nieuwenhuizen, *EPL* 67, 565 (2004). [5] K. Brandner, M. Bauer and U. Seifert, arXiv:1703.02464

18:10–18:15

Optimal quantum spatial search on random temporal networks

P17

Shantanav Chakraborty, L. Novo S. D. Giorgio, Y. Omar

To investigate the performance of quantum information tasks on networks whose topology changes in time, we study the spatial search algorithm by continuous time quantum walk to find a marked node on a random temporal network. We consider a network of n nodes constituted by a time-ordered sequence of Erdős-Rényi random graphs $G(n, p)$, where p is the probability that any two given nodes are connected: after every time interval τ , a new graph $G(n, p)$ replaces the previous one. We prove analytically that for any given p , there is always a range of values of τ for which the running time of the algorithm is optimal, i.e. $O(\sqrt{n})$, even when search on the individual static graphs constituting the temporal network is sub-optimal. On the other hand, there are regimes of τ where the algorithm is sub-optimal even when each of the underlying static graphs are sufficiently connected to perform optimal search on them. From this first study of quantum spatial search on a time-dependent network, it emerges that the non-trivial interplay between temporality and connectivity is key to the algorithmic performance. Moreover, our work can be extended to establish high-fidelity qubit transfer between any two nodes of the network. Overall, our findings show that one can exploit temporality to achieve optimal quantum information tasks on dynamical random networks.

18:15–18:20

Spatial search by quantum walk is optimal for almost all graphs

P18

Shantanav Chakraborty, Leonardo Novo, Andris Ambainis, and Yasser Omar

The problem of finding a marked node in a graph can be solved by the spatial search algorithm based on continuous-time quantum walks (CTQW). However, this algorithm is known to run in optimal time only for a handful of graphs. In this work, we prove that for Erdős-Rényi random graphs, i.e. graphs of n vertices where each edge exists with probability p , search by CTQW is almost surely optimal as long as $p \log^{3/2}(n)/n$. Consequently, we show that quantum spatial search is in fact optimal for almost all graphs, meaning that the fraction of graphs of n vertices for which this optimality holds tends to one in the asymptotic limit. We obtain this result by proving that search is optimal on graphs where the ratio between the second largest and the largest eigenvalue is bounded by a constant smaller than 1. Finally, we show that we can extend our results on search to establish high fidelity quantum communication between two arbitrary nodes of a random network of interacting qubits, namely to perform quantum state transfer, as well as entanglement generation. Our work shows that quantum information tasks typically designed for structured systems retain performance in very disordered structures.

18:20–18:25

When Anderson localization makes quantum particles move backward

P19

T. Prat, D. Delande, and N. Cherroret

We unveil a novel and unexpected manifestation of Anderson localization of matter wave packets that carry a finite average velocity: after an initial ballistic motion, the packet center-of-mass experiences a retroreflection and slowly returns to its initial position. We describe this effect both numerically and analytically in dimension 1, and show that it is destroyed by weak particle interactions which act as a decoherence process. The retroreflection is also present in higher dimensions, provided the dynamics is Anderson localized.

18:25–18:30

Phase Transitions in a Molecular Zipper: Lee-Yang Zeros and Large Deviation Statistics

P20

Aydin Deger, Kay Brandner, and Christian Flindt

Originally introduced to explain the behavior of a condensing gas, Lee-Yang zeros have nowadays become a universal and powerful tool for the unified description of phase transitions in equilibrium, non-equilibrium and dynamical systems, see for example [1, 2]. Here, we use Lee-Yang zeros to analyze a paradigmatic model for thermal phase transitions in molecular systems. For the most simple version of this model, we explicitly calculate the Lee-Yang zeros with respect to inverse temperature. Extrapolation then allows us to infer a phase transition in the macroscopic limit, from the analysis of systems containing only a few molecular units. In a second step, we increase the complexity of the model. The Lee-Yang zeros can still be obtained using a recently established relation involving high-order cumulants of the energy. Finally, we show that, even when the system does not undergo a phase-transition, the Lee-Yang zeros still encode valuable physical information; they crucially determine the large deviation statistics of energy fluctuations. Specifically we show that the large deviation function generically has the form of an ellipse, whose tilt and width can be inferred from the complex Lee-Yang zeros. Our analysis reveals an interesting duality between the energy fluctuations of small-size systems in equilibrium and their phase behavior in the thermodynamic limit [3]. To what extent this relation is valid in more complex systems, such as the two-dimensional Ising model, is a topic of future research.

Thursday Sessions at a Glance

Thursday Morning A

- 09:00–09:40 **Detecting entanglement and non-locality in many-body quantum systems**
Antonio Acín
- 09:40–10:05 **The quantum Langevin approach for transport**
Abhishek Dhar
- 10:05–10:30 **Topological properties of a dense atomic lattice gas**
Beatriz Olmos
- 10:30–10:45 **Entropy production and thermodynamic power of the squeezed thermal reservoir**
Gonzalo Manzano, F. Galve, R. Zambrini, and J. M. R. Parrondo
- 10:45–11:00 **Interference at avoided crossings: transport, decoherence, and bichromatic driving**
Sigmund Kohler
- 11:00–11:15 **Floquet Gibbs state in time periodically driven open quantum systems**
T. Shirai, T. Mori, and S. Miyashita

Thursday Morning B

- 11:45–12:25 **Projective simulation for learning and agency**
Hans J. Briegel
- 12:25–12:50 **Experimental Determination of Dynamical Lee-Yang Zeros**
K. Brandner, V. F. Maisi, J. P. Pekola, J. P. Garrahan, and C. Flindt
- 12:50–12:55 **Undamped oscillations in the long-time magnetization dynamics of a quantum spin chain P21**
A. O. García Rodríguez and G. G. Cabrera
- 12:55–13:00 **Competitiveness of an adsorbing-state quantum system coupled weakly to the environment P22**
Oleksiy L. Kapitanchuk and Victor I. Teslenko
- 13:00–13:05 **“Perturbative method” to compute frequency-filtered and time-resolved correlation functions P23**
David I. H. Holdaway, Valentina Notararigo, Alexandra Olaya-Castro
- 13:05–13:10 **From points to patterns in wigner framework, 1: quantum states as sheaves P24**
Antonina N. Fedorova and Michael G. Zeitlin
- 13:10–13:15 **From points to patterns in wigner framework, 2: dynamics and control of ensembles in multi-scales P25**
Antonina N. Fedorova and Michael G. Zeitlin

Thursday Sessions at a Glance

Thursday Afternoon A

- 15:30-16:10 **Dynamics of quantum measurement and the quantum measurement problem**
T.M. Nieuwenhuizen
- 16:10-16:35 **Stochastic thermodynamics for quantum maps with and without equilibrium and some consequences for the thermodynamics of systems with Lindblad dynamics.**
Felipe Barra
- 16:35-16:50 **Fluctuating hydrodynamics, current fluctuations and hyperuniformity in boundary-driven open quantum chains**
Federico Carollo, Juan P. Garrahan, Igor Lesanovsky, and Carlos Pérez-Espigares

Thursday Afternoon B

- 17:20-17:35 **Exact non-adiabatic holonomic spin-orbit qubit manipulation**
Anton Ramsak, Lara Ulcakar, Ambroz Kregar, and Tilen Cadez
- 17:35-17:50 **Third law of thermodynamics as a single inequality**
H. Wilming and R. Gallego
- 17:50-18:05 **Dynamics of a driven quantum dot interacting with finite reservoirs**
J. Thingna, F. Barra, and M. Esposito
- 18:05-18:20 **The implementation of a quantum absorption refrigerator with trapped ions**
J. Dai, S. Nimmrichter, A. Roulet, and V. Scarani
- 18:20-18:25 **Nonequilibrium steady state calorimetry: from classical to quantum** P26
Karel Netočný
- 18:25-18:30 **Quantifying Entanglement of Identical Particles** P27
E. Sindici and M. Piani

09:00–09:40 **Detecting entanglement and non-locality in many-body quantum systems**
Antonio Acín

Understanding and detecting relevant properties of many-body quantum systems represents an important challenge due to the huge number of parameters needed for their characterisation. The talk reviews new approaches to detect the presence of entanglement and Bell correlations in these systems that are scalable and experimentally friendly.

09:40–10:05 **The quantum Langevin approach for transport**
Abhishek Dhar

The talk will review the quantum Langevin equations (QLE) approach for transport in quantum systems, both electronic and phononic, that are described by quadratic Hamiltonians. This approach leads to closed-form exact results for steady state transport properties such as current and profiles of density and energy. Some recent applications of this approach and comparisons with master equation approaches will also be discussed.

10:05–10:30 **Topological properties of a dense atomic lattice gas**
Beatriz Olmos

We investigate the existence of topological phases in a dense two-dimensional atomic lattice gas. The coupling of the atoms to the radiation field gives rise to dissipation and a non-trivial coherent long-range exchange interaction whose form goes beyond a simple power-law. The far-field terms of the potential which are particularly relevant for atomic separations comparable to the atomic transition wavelength can give rise to energy spectra with one-sided divergences in the Brillouin zone. The long-ranged character of the interactions has another important consequence: it can break the standard bulk-boundary relation in topological insulators. We show that topological properties such as the transport of an excitation along the edge of the lattice are robust with respect to the presence of lattice defects and dissipation. The latter is of particular relevance as dissipation and coherent interactions are inevitably connected in our setting.

10:30–10:45 **Entropy production and thermodynamic power of the squeezed thermal reservoir**
Gonzalo Manzano, F. Galve, R. Zambrini, and J. M. R. Parrondo

Thermodynamic theory was developed from the analysis of real heat engines, such as the steam engine along the 19th century [1]. Those macroscopic engines have quantum analogues, whose analysis constitute an important branch of research in quantum thermodynamics [2]. Clarifying the impact of quantumness in the operation and properties of thermal machines represents a major challenge. Quantum effects can arise in the working substance and environment and, from the pioneering proposal of M. O. Scully et. al. [3], there have been different works in the literature pointing that nonequilibrium quantum reservoirs may be used to increase both power and efficiency of quantum machines. Nevertheless, a solid understanding of these enhancements and their optimization has remained elusive, as it requires a precise formulation of the second law of thermodynamics in such nonequilibrium situations. Using recent proposals in quantum fluctuation theorems [4], we analyze the entropy production and the maximal extractable work from a squeezed thermal reservoir. The quantum nature of the reservoir induces genuine nonequilibrium features such as an entropy transfer with a coherent contribution. These nonequilibrium features allow for work extraction from a single reservoir, and are the responsible of power and efficiency enhancements for quantum heat engines operating with this kind of reservoirs. Here we consider in detail a heat engine performing a (modified) quantum Otto cycle [2, 5], optimize it, and discuss its many striking consequences, like the appearance of multi-task regimes in which the heat engine may extract work and refrigerate a cold reservoir at the same time [6]. Moreover, we show how our approach leads to the introduction of a thermodynamic efficiency based on the concept of nonequilibrium free energy, which naturally accounts for the performance of both classical and quantum thermodynamic resources. Our results hint at possible applications like squeezing-fueled batteries, multi-task thermal machines, or erasure devices operating below Landauer's limit. In the Figure, we show a phase diagram with the four regimes of operation of the Otto cycle (I, II, III, IV) as a function of the working substance frequency modulation during the isentropic strokes, $\omega_1 \rightarrow \omega_2$, and the squeezing parameter $r \geq 0$. The color scale corresponds to the energetic efficiency of the cycle $\eta = W_{\text{out}}/Q_{\text{in}}$ as a heat engine, for inverse temperatures in the reservoirs $\beta_2 = 0.2\beta_1$, yielding a Carnot efficiency $\eta_c = 0.8$ (white dashed curve). In the right side the direction of the arrows represents the sign of the energy fluxes for each regime.

[1] L. N. S. Carnot, *Réflexions sur la puissance motrice du feu* (Bachelier, Paris, 1824). [2] S. Vinjanampathy and J. Anders, *Contemp. Phys.* 57, 1-35 (2016). [3] M. O. Scully, M. S. Zubairy, G. S. Agarwal, and H. Walther, *Science* 299, 862864 (2003). [4] G. Manzano, J. M. Horowitz, and J. M. R. Parrondo, *Phys. Rev. E* 92, 032129 (2015). [5] J. Ronagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, and K. Singer, *Science* 352, 325329 (2016). [6] G. Manzano, F. Galve, R. Zambrini, and J. M. R. Parrondo, *Phys. Rev. E* 93, 052120 (2016).

Thursday Sessions, with Abstracts

10:45–11:00 **Interference at avoided crossings: transport, decoherence, and bichromatic driving**

Sigmund Kohler

Double quantum dots with long coherence times allow the implementation of coherent tunnel phenomena. For instance, if an energy level of one dot is swept such that it crosses a level of the other dot, one observes Landau-Zener transitions. Repeated sweeps lead to the so-called Landau-Zener-Stückelberg-Majorana interference visible in a characteristic pattern as a function of the detuning and the amplitude of the sweeps. The experimentally observed fading of this interference pattern with increasing temperature is explained in terms of a transport calculation for which a coupling to bulk phonons causes decoherence. The comparison with experimental data allows us to determine the parameters of the system-bath model and to draw conclusions about the coherence time of charge qubits implemented with double quantum dots [1]. When driving the system with two frequencies, the symmetry of the interference pattern depends on their commensurability. In particular, for commensurable frequencies, the symmetry depends on the relative phase between the two components, while in the incommensurable case, one finds the higher symmetry which otherwise is only found for certain phases. These predictions are confirmed by measurements [2].

[1] F. Forster, G. Petersen, S. Manus, P. Hänggi, D. Schuh, W. Wegscheider, S. Kohler, and S. Ludwig, *Phys. Rev. Lett.* 112, 116803 (2014). [2] F. Forster, M. Mühlbacher, R. Blattmann, D. Schuh, W. Wegscheider, S. Ludwig, and S. Kohler, *Phys. Rev. B* 92, 245422 (2015).

11:00–11:15 **Floquet Gibbs state in time periodically driven open quantum systems**

T. Shirai, T. Mori, and S. Miyashita

In this work we study long-time asymptotic states of time-periodically driven system coupled to a thermal bath. In order to describe the subclass of such a system, we introduce the Floquet-Gibbs state, i.e., the state whose density matrix is described in a diagonal form in the basis of the Floquet states and its diagonal elements are given by a Boltzmann distribution over its Floquet quasienergies. We obtain the sufficient conditions for the realization of the Floquet-Gibbs state in a system with infinitesimal system-bath coupling [1] as follows:

1. The driving frequency is much larger than the spectral width of the system Hamiltonian
2. The driving Hamiltonians commute with itself at different instants of time
3. The driving Hamiltonian and the system-bath interaction Hamiltonian commute.

These conditions severely restrict a class of suitable physical models attaining the Floquet-Gibbs state. The condition 1 restricts the system with a relatively small Hilbert space and the condition 3 requires a fine tuning of the system-bath coupling. With the aid of a truncated Floquet Hamiltonian in the Floquet-Magnus expansion and without the rotating wave approximation, we lift the condition of the infinitesimal coupling strength and extend the idea of the Floquet-Gibbs state to a broader subclass of open quantum system with a finite dissipation effect. We show in a numerical simulation that the conditions 1 and/or 3 can be lifted by imposing conditions on timescales of the three constituents, the system of interest, heat bath, and driving field.

[1] T. Shirai, T. Mori, and S. Miyashita *Phys. Rev. E* 91, 030101 (2015). [2] T. Shirai, J. Thingna, T. Mori, S. Denisov, P. Hänggi, S. Miyashita, *NJP* 18, 053008 (2016)

11:45–12:25 **Projective simulation for learning and agency**

Hans J. Briegel

I will first present the model of projective simulation (PS) [1] for a learning agent whose interaction with the environment is governed by a simulation-based projection. PS agents use a random walk in their episodic and compositional memory (ECM) to project themselves into future situations before they take real action. The PS model can solve basic tasks in reinforcement learning but it also allows for the implementation of advanced concepts such as generalization and meta-learning [2]. Notably, projective simulation can be quantized, allowing for a quantum mechanical speed-up in the agents deliberation process [3, 4]. I will also discuss recent applications of the PS model in robotics and in the philosophy of action, as well as the question to what extent learning agents can help in quantum experiments.

[1] H. J. Briegel and G. De las Cuevas, Projective simulation for artificial intelligence, *Sci. Rep.* 2, 400 (2012). [2] A. Makmal, A. A. Melnikov, V. Dunjko, and H. J. Briegel, Meta-learning within projective simulation, *IEEE Access* 4, 2110 (2016). [3] G. Paparo, V. Dunjko, A. Makmal, M. A. Martin-Delgado, and H. J. Briegel, Quantum speed-up for active learning agents, *Phys. Rev. X* 4, 031002 (2014). [4] V. Dunjko, J. M. Taylor, and H. J. Briegel, Quantum-enhanced machine learning, *Phys. Rev. Lett.* 117, 130501 (2016).

12:25–12:50 **Experimental Determination of Dynamical Lee-Yang Zeros**

K. Brandner, V. F. Maisi, J. P. Pekola, J. P. Garrahan, and C. Flindt

Conventional phase transitions involve abrupt changes of a macroscopic system in response to small variations of an external control parameter. This exceptional behavior can be understood from the complex zeros of the partition function of the finite-sized system: in the thermodynamic limit, these Lee-Yang zeros, which correspond to logarithmic singularities of the free energy, approach the critical value of the control parameter on the real axis. This general scheme also applies to dynamical phase transitions in nonequilibrium systems. The partition function is thereby replaced with the moment-generating function of a stochastic process with the counting field playing the role of the external control parameter. Here, we demonstrate that the corresponding dynamical Lee-Yang zeros are not only a theoretical concept but physical observables, which encode remarkable information on the long-time statistics and the dynamical fluctuations of the system [1]. To this end, we analyze a stochastic process involving Andreev-tunneling events in a mesoscopic device consisting of a normal-state island and two superconducting leads. From measurements of the dynamical activity, we extract the Lee-Yang zeros, which reveal a smeared dynamical phase transition outside the range of direct observations. Being obtained only from short-time data, this information allows us to predict the large-deviation statistics of the dynamical activity at long times, which is otherwise difficult to measure. Our method paves the way for further experiments on the statistical mechanics of many-body systems out of equilibrium.

[1] K. Brandner, V. F. Maisi, J. P. Pekola, J. P. Garrahan, C. Flindt, Experimental Observation of Dynamical Lee-Yang Zeros, arXiv: 1610.08669 (2016), to appear in *Phys. Rev. Lett.*

12:50–12:55 **Undamped oscillations in the long-time magnetization dynamics of a quantum spin chain P21**

A. O. García Rodríguez and G. G. Cabrera

We study the magnetization dynamics of a semi-infinite XY quantum spin-1/2 chain with an impurity at site $n = 0$. The model has exact diagonalization. Besides a continuous band there are two localized states, called impurity states, which exist only for some regions in the system parameter space. Assuming a general initial state in which each atom can be found in state up or down, exact analytical expressions are obtained for the site magnetization. The long-time behavior is derived using the stationary phase approximation. Six characteristic regions in the parameter space are identified implying each a different qualitative long-time behavior. By considering a specific initial state it is shown that the existence of impurity states leads to different asymptotic values of the magnetization at the chain sites (figures below, where $\tau = \hbar/|J|$, being J the host exchange-interaction constant). When two impurity states exist, the quantum interference between them yields magnetization oscillations which settle over time with a constant amplitude (second figure below). The study of the dynamics of quantum spin chains is of interest to the general theory of non-equilibrium processes in quantum many-body systems and is also relevant in the proposal to use spin chains as quantum information transfer channels. [1]

[1] S. Bose et al., Spin chains as data buses, logic buses and entanglers, in *Quantum state transfer and network engineering* (Springer, 2014), p. 1.

Thursday Sessions, with Abstracts

12:55–13:00 **Competitiveness of an adsorbing-state quantum system coupled weakly to the environment**
P22

Oleksiy L. Kapitanchuk and Victor I. Teslenko

Competitivity is applicable for many realizations of transition processes in the natural, life, economic and information chains. The finite state supply chain lies at the heart of interpreting a time evolution of many kinetic processes. For instance, a Markov chain is widely used for modeling the multistage dynamics of multidimensional states in physics, chemistry and biology. Competitiveness of a particular system depends on the number of its characteristics, which as a rule are interrelated and can not be considered in isolation. Main factors include: the initial conditions for population of input states, the time evolution of population of functionally significant intermediate and output states, and the kinetic coefficients providing a growth of population with the probabilities to transit some states of interest toward others due to their weak competitive coupling with the environment. We report on the microscopic description of the nonequilibrium quantum system with fluctuating energy levels weakly coupled to the equilibrium environment. The corresponding kinetic equation for diagonal elements of the density matrix of the nonequilibrium system and the master equation for population of the different modules of a systems states are derived analytically [1]. Rate constants of transitions between the modules corresponding to the aggregated transition probabilities in an absorbing state system are computed. The proposed master equation formalism is used to describe the possibility for peak population amplitudes of two nonstationary states in a 3-stage linear kinetic system to be endowed with an untraditional physical quantity - competitiveness, established in regard to the differences for the degree of the peak responses to a change in the input rate constants. Calculated coefficients of competitiveness are found to agree with observations of performance for the three optical materials with respect to their reliability in different operating windows. It is concluded that, for nonequilibrium linear kinetic system, the competitiveness constitutes a common dynamic property of its nonstationary states and, in the case of their directed irreversible evolution, comprises the property of systems anti-cooperativity.

[1] O.L. Kapitanchuk et al, Chem. Phys. 472, 249 (2016).

13:00–13:05 **“Perturbative method” to compute frequency-filtered and time-resolved correlation functions**
P23

David I. H. Holdaway, Valentina Notararigo, Alexandra Olaya-Castro

We propose a perturbative formalism for calculating frequency-filtered and time-resolved second order correlation functions from a driven light-emitting system in the steady state. This is an alternative formulation of the sensor method [1] in which additional sensors are coupled to the system of interest. Our method has the advantage of not requiring any small parameters for numerical computation of the second-order optical coherence besides giving an insight on the main physical processes contributing to the time-resolved correlation function.

[1] E. del Valle, A.Gonzales-Tudela, F.P.Laussy, C.Tejedor, and M.J.Hartmann, Phys. Rev. Lett. 109, 183601 (2012).

13:05–13:10 **From points to patterns in wigner framework, 1: quantum states as sheaves**
P24

Antonina N. Fedorova and Michael G. Zeitlin

We consider some generalization of the theory of quantum states, which is based on the analysis of long standing problems and unsatisfactory situation with existing interpretations of quantum mechanics. We demonstrate that the consideration of quantum states as sheaves can provide, in principle, more deep understanding of some well-known phenomena. The key ingredients of the proposed construction are the families of sections of sheaves with values in the proper category of the functional realizations of infinite-dimensional Hilbert spaces with special (multiscale) filtrations decomposed into the (entangled) orbits generated by actions/representations of internal hidden symmetries. In such a way, we open a possibility for the exact description of a lot of phenomena like entanglement and measurement, wave function collapse, self-interference, instantaneous quantum interaction, manyWorlds, hidden variables, etc. In the companion paper we consider the machinery needed for the generation of a zoo of the complex quantum patterns in ensembles during Wigner-Weyl-Moyal evolution together with constructive algebraic control.

[1] Antonina N. Fedorova, Michael G. Zeitlin, Quantum multiresolution: tower of scales, arXiv:1703.09556. [2] Antonina N. Fedorova, Michael G. Zeitlin, Quantum objects in a sheaf framework, arXiv:1703.09546.

Thursday Sessions, with Abstracts

13:10–13:15 **From points to patterns in wigner framework, 2: dynamics and control of ensembles in multiscales** **P25**

Antonina N. Fedorova and Michael G. Zeitlin

We present a family of methods which can describe complex behaviour in quantum ensembles. We demonstrate the creation of nontrivial (meta) stable states (patterns), localized, chaotic, entangled or decoherent, from the basic localized modes in various collective models arising from the quantum hierarchy described by Wigner-like equations. The advantages of such an approach are as follows: the natural realization of localized states in any proper functional realization of (Hilbert) space of states, the representation of hidden symmetry of a chosen realization of the functional model describes the (whole) spectrum of possible states via the so-called multiresolution decomposition. Effects we are interested in are as follows: a hierarchy of internal/hidden scales (time, space, phase space); non-perturbative multiscales: from slow to fast contributions, from the coarser to the finer level of resolution/decomposition; the coexistence of the levels of hierarchy of multiscale dynamics with transitions between scales; the realization of the key features of the complex quantum world such as the existence of chaotic and/or entangled states with possible destruction in open/dissipative regimes due to interactions with quantum/classical environment and transition to decoherent states. The numerical simulation demonstrates the formation of various (meta) stable patterns or orbits generated by internal hidden symmetry from generic high-localized fundamental modes. These (nonlinear) eigenmodes are more realistic for the modeling of (quasi)classical/quantum dynamical process than the (linear) gaussian-like coherent states. In addition, we can control the type of behaviour on the pure algebraic level by means of properly reduced algebraic systems (generalized dispersion relations).

[1] Antonina N. Fedorova, Michael G. Zeitlin, Quantum multiresolution: tower of scales, arXiv:1703.09556. [2] Antonina N. Fedorova, Michael G. Zeitlin, Quantum objects in a sheaf framework, arXiv:1703.09546.

15:30-16:10 Dynamics of quantum measurement and the quantum measurement problem

T.M. Nieuwenhuizen

To elucidate ideal measurements, one must explain how individual events emerge from quantum theory which deals with statistical ensembles, and how different may end up with different final states. This so-called "measurement problem" is tackled with two guidelines. On the one hand, the dynamics of the macroscopic apparatus A coupled to the tested system S is described mathematically within a standard quantum formalism, where "q-probabilities" remain devoid of interpretation. On the other hand, interpretative principles are introduced to account for the expected features of ideal measurements. Most of the five principles, which relate the quantum formalism to physical reality, are straightforward and refer to macroscopic variables. The process can be identified with a relaxation of S+A to thermodynamic equilibrium, not only for a large ensemble $\mathcal{E}$ of runs but even for its sub-ensembles. The different mechanisms of quantum statistical dynamics that ensure the relaxation are exhibited. The additional information provided by the sub-ensembles remove Schrödinger's quantum ambiguity of the final density operator for $\mathcal{E}$ which hinders its direct interpretation, and bring out a commutative behaviour of the pointer observable at the final time. The latter property supports the introduction of a last principle, needed to switch from the statistical ensembles and sub-ensembles described by quantum theory to individual experimental events. It amounts to identify some formal "q-probabilities" with ordinary frequencies, but only those which refer to the final pointer indications. The desired properties of ideal measurements, in particular the uniqueness of the result for each individual run and von Neumann's reduction, are thereby recovered with economic interpretations. The status of Born's rule involving both A and S is re-evaluated, and contextuality is made obvious.

16:10-16:35 Stochastic thermodynamics for quantum maps with and without equilibrium and some consequences for the thermodynamics of systems with Lindblad dynamics.

Felipe Barra

We develop stochastic thermodynamic [1] for CPTP maps with special attention to the case that the system of interest is driven by the coupling with the bath, i.e., a time dependent coupling (and not a time-dependent Hamiltonian for the system of interest). This will allow us to discuss the stochastic thermodynamics of open quantum systems described by boundary driven Lindblad equations [2]. We study in detail the case of CPTP maps that admit an equilibrium state. If this equilibrium state is not the Gibbs state some interesting observations are made. We can show that, in this case, the thermodynamic quantities can be evaluated with the knowledge of the state of the system without the need of the full system-bath state [3]. Finally, a comparison is made between the thermodynamics of driven systems in the repeated interaction scheme [4] and autonomous system of scattering type [5].

[1] J. M. Horowitz and J.M.R. Parrondo, New J. Phys. 15, 085028 (2013); G. Manzano, J. M. Horowitz and J. M. R. Parrondo, Phys. Rev. E 95, 032129 (2015); M. Esposito, K. Lindenberg and C. Van den Broeck, New J. Phys. 12, 013013 (2010). [2] T. Prosen, Phys. Rev. Lett. 107, 137201 (2011); D. Karevski, V. Popkov and G. M. Schütz, Phys. Rev. Lett. 110, 047201 (2013). [3] F. Barra and C. Lled, arXiv:1704.06029v1 (2017). [4] F. Barra, Sci. Rep. 5, 14873 (2015). [5] F. Barra and J.M. Parrondo, in preparation.

16:35–16:50 Fluctuating hydrodynamics, current fluctuations and hyperuniformity in boundary-driven open quantum chains

Federico Carollo, Juan P. Garrahan, Igor Lesanovsky, and Carlos Pérez-Espigares

We consider a class of either fermionic or bosonic open quantum chains driven by dissipative interactions at the boundaries and study the interplay of coherent transport and dissipative processes, such as bulk dephasing and diffusion. Starting from the microscopic formulation, we show that the dynamics on large scales can be described in terms of fluctuating hydrodynamics (FH). This is an important simplification as it allows to apply the methods of macroscopic fluctuation theory (MFT) to compute the large deviation (LD) statistics of time-integrated currents. In particular, fermionic open chains display a third-order dynamical phase transition in LD functions. We show that this transition is manifested in a singular change in the structure of trajectories: while typical trajectories are diffusive, rare trajectories associated to atypical currents are ballistic and hyperuniform in their spatial structure. We confirm these results by numerically simulating ensembles of rare trajectories, via the cloning method, including the computation of their structure factors.

17:20–17:35 Exact non-adiabatic holonomic spin-orbit qubit manipulation

Anton Ramsak, Lara Ulcakar, Ambroz Kregar, and Tilen Cadez

We will present exact solutions for an electron in a quantum wire with time dependent spin-orbit interaction and driven by external time-dependent potential [1,2]. The corresponding geometric Anandan phase or in the adiabatic limit the Wilczek-Zee phase will be given analytically. Next the result will be generalized and an exact solution will be presented for the time-dependent wavefunction of a Kramers doublet which propagates around a quantum ring with tuneable Rashba spin-orbit interaction [3]. By propagating in segments it will be shown that Kramers-doublet qubits may be defined for which transformations on the Bloch sphere may be performed for an integral number of revolutions around the ring. Prospects and challenges for possible realizations will be discussed for which rings based on InAs quantum wires are promising candidates [4]. Various types of potential noise in gates controlling non-adiabatic holonomic transformations of spin-qubits will be presented. It will be shown how exact results can be derived for deviations of spin rotation angle and fidelity of the qubit transformation. It will be demonstrated how the drivings can be tuned to optimise the final fidelity of the transformation and to minimise the variances of the qubit transformation [5].

[1] T. Cadez, J. H. Jefferson, and A. Ramsak, New J. Phys. 15, 013029 (2013). [2] T. Cadez, J. H. Jefferson, and A. Ramsak, Phys. Rev. Lett. 112, 150402 (2014). [3] A. Kregar, J. H. Jefferson, and A. Ramsak, Phys. Rev. B 93, 075432 (2016). [4] A. Kregar and A. Ramsak, Int. J. Mod. Phys. B 30, 1642016 (2016). [5] L. Ulcakar and A. Ramsak, submitted to New J. Phys. (2017).

17:35–17:50 Third law of thermodynamics as a single inequality

H. Wilming and R. Gallego

The third law of thermodynamics in the form of the unattainability principle states that exact ground-state cooling requires infinite resources. In this contribution, based on Ref. [1], we will focus on quantifying in full generality the expenditure of fuel represented by arbitrary systems out of equilibrium that are needed for approximate cooling. Our scenario is similar to the one considered in algorithmic cooling, but here we treat the full thermodynamics of the problem by allowing for resources with non-trivial Hamiltonians and accounting for the energy conservation of the total process. The task of cooling that we are considering can be phrased as finding a cooling protocol between an arbitrary resource playing the role of the fuel described by the state and Hamiltonian ρ_R and H_R respectively, and a target system described at the end of the process by ρ_S and H_S so that ρ_S is a thermal state with temperature T_S as low as possible. The protocol is done in an environment at inverse temperature β . We are concerned with the ultimate bounds on T_S as a function of the initial resource and β , hence we allow as cooling protocol for any possible energy-preserving unitary on the compound. Our main result is that, in the limit of sufficiently small T_S , a single condition is sufficient and necessary for the cooling protocol to exist. In particular, we find a state function $\mathcal{V}_\beta$ so that the cooling protocol under reasonable assumptions is possible iff

$$\mathcal{V}_\beta(\rho_R, H_R) \geq \mathcal{V}_\beta(\rho_S, H_S). \quad (1)$$

This formulation of the third law, as the requirement that a state function decreases in the process, has a profound explanatory power, since it puts it in a form that is analagous in various ways to the second law. First, note that the second law, in many of its equivalent formulations, can be put, similarly to Eq. (1), as the decrease of a state function the non-equilibrium free energy when a system evolves together with an environment at inverse temperature β . Secondly, we find that $\mathcal{V}$ displays a surprising symmetry with the free energy: both functions are defined as the quantum relative entropy S between the same pair of quantum states, in such a way $\mathcal{V} \propto S(\rho \parallel \sigma)$ while the non-equilibrium free energy is proportional to $S(\sigma \parallel \rho)$.

[1] H. Wilming and R. Gallego arXiv:1701.07478 (2017).

17:50–18:05 Dynamics of a driven quantum dot interacting with finite reservoirs

J. Thingna, F. Barra, and M. Esposito

Ill discuss the kinetic regimes of a linearly driven quantum system connected to a finite reservoir. When the reservoir is large (dense), we require a strong mixing [1] between the reservoir and the system for the Redfield-type kinetic description to hold, which is similar to the autonomous case. In the other extreme, where the reservoir is sparse we find that the Landau-Zener (LZ) physics plays a crucial role. Here, we develop a kinetic description [2] that in the diabatic limit has the same mathematical form as the Redfield-type description [3]. This implies that a driving could compensate for the sparseness of the reservoir and mimic an effective kinetic description, which is traditionally valid for an infinite reservoir. Importantly, the underlying physical assumptions on the validity of these descriptions are distinct and can be characterized by the various timescales of the problem. The existence of these kinetic regimes persists even if the system is connected to multiple reservoirs and in all cases we can systematically build thermodynamic first and second laws that are consistent

in the full Hilbert space and the kinetic description [4].

[1] M. Esposito and P. Gaspard, Phys. Rev. E 68, 066112 (2003). [2] F. Barra and M. Esposito, Phys. Rev. E 93, 062118 (2016). [3] J. Thingna, F. Barra, and M. Esposito (in preparation). [4] H. Zhou, J. Thingna, P. Hanggi, J.-S. Wang, and B. Li, Sci. Rep. 5, 14870 (2015).

18:05–18:20 The implementation of a quantum absorption refrigerator with trapped ions

J. Dai, S. Nimmrichter, A. Roulet, and V. Scarani

Thermodynamics is one of the oldest and well-established branches of physics that started as studies on macroscopic systems. Recently, remarkable progress has been made in the miniaturization of thermal machines such as heat engines all the way to the single Brownian particle as well as to a single atom. Despite several theoretical proposals, the implementation of heat machines in the fully quantum regime remains a challenge. In this work [1], we first report an experimental realization of a quantum absorption refrigerator [2] in a system of three trapped ions, with three of its normal modes of motion coupled by a trilinear Hamiltonian such that heat transfer between two modes refrigerates the third. Cooling below both the steady-state energy and the benchmark predicted by the classical thermodynamics treatment has been demonstrated. We also investigate theoretically the dynamics and steady-state properties of this system and compare its cooling capability under various situations. Cooling or heating of the cold mode is found consistent with the recently developed virtual qubit model [3], even though the resulting steady state statistics is not thermal. By studying incoherent energy exchange among the modes, we elucidate that enhanced single-shot cooling in the transient regime is related to the coherence developed due to the interaction Hamiltonian [4,5]. However, we show that the effect also appears in an entirely classical framework. This system is further found to exhibit features of quantum equilibration, see for example [6], where the expectation values of observables quickly reach and stay close to the infinite-time average values for subsequent dynamics.

[1] G. Maslennikov et al., arXiv:1702.08672(2017). [2] A. Levy and R. Kosloff, Phys. Rev. Lett. 108, 070604(2012). [3] N. Brunner et al., Phys. Rev. E 85, 051117 (2012). [4] J. B. Brask and N. Brunner, Phys. Rev. E 92, 062101(2012). [5] M. T. Mitchison, et al., New J. Phys. 17, 115013 (2015). [6] A. J. Short and T. C. Farrelly, New J. Phys. 14, 013063 (2012).

18:20–18:25 Nonequilibrium steady state calorimetry: from classical to quantum

P26

Karel Netočný

Analogously as in equilibrium thermodynamics, systems driven out of equilibrium can be probed by measuring the heat exchange in response to variations in ambient temperature. The corresponding finite “excess” heat is then characterized by the steady state heat capacity [1] and depending on driving conditions it interpolates between its equilibrium value and anomalous features like non-positivity when far from equilibrium. To be specific we consider a quantum dot both incoherently and coherently coupled to leads imposing a current, and we analyze dependence of the steady state heat capacity on the level energy. When the latter approaches the electrochemical potential of either of the leads, the heat capacity is shown to obtain negative values.

[1] E. Boksenbojm, C. Maes, K. Netočný et al, Europhys. Lett. 96, 40001 (2011).

18:25–18:30 Quantifying Entanglement of Identical Particles

P27

E. Sindici and M. Piani

For systems with a particle-number super-selection rule, entanglement may be studied alternatively between modes or between particles, with mode entanglement and particle entanglement two distinct physical properties [1]. While the entanglement of modes, which by definition are distinguishable, is a well-defined and well-studied concept, the inter-particle entanglement of identical bosons and fermions is less understood and still the source of debate, despite the fact that it is a key feature of interest in quantum information processing, quantum-enhanced interferometry and many-body cold atom systems [2]. Indeed, there are difficulties in characterising entanglement of identical particles, as the (anti)symmetrization requirement makes factorizability an unsatisfactory separability criteria for pure states. We adopt an existing entanglement criterion for the particle-entanglement of identical particles that is based on the possibility or impossibility of assigning to a particle a full set of physical properties [3]. We put forward an entanglement measure for the case of bosons and fermions, based on the notion of minimum entanglement that must be present prior to (anti)symmetrization in order to obtain the physical (anti)symmetrized state. When the entanglement measure adopted is the negativity, this problem may be cast as a Semi-Definite Program, which ensures an efficient numerical evaluation. Our scheme applies to a broad range of physical systems and we report the case of two fermions in a double well potential, which may be studied, e.g., in cold-atom experiments.

[1] R. Demkowicz-Dobrzanski et al., Progress in Optics 60, 345 (2015). [2] M. C. Tichy et al., J. Phys. B: At. Mol. Opt. Phys. 44, 192001 (2011). [3] Ghirardi et al., J. Stat. Phys., Vol. 108, 49-121 (2002).

Friday Sessions at a Glance

Friday Morning A

- 09:00–09:40 **Equivalence ‘reversible-irreversible’ for NS and other equations**
Giovanni Gallavotti
- 09:40–10:05 **Speeding up thermalization in quantum thermal engines**
Sai Vinjanampathy, Nischay Suri, Felix Binder, Bhaskaran Muraidharan
- 10:05–10:30 **Irreversibility and correlations in open quantum systems**
Matteo Brunelli
- 10:30–10:45 **Microscopic origins of collective dissipation in extended systems**
F. Galve, R. Zambrini, A. Mandarino, M. G. A. Paris, C. Benedetti, J. Alonso
- 10:45–11:00 **Non-ergodic states in quantum spin chains**
A. O. García Rodríguez and Guillermo G. Cabrera
- 11:00–11:15 **Low-temperature thermometry in many-body systems**
Karen V. Hovhannisyan and Luis A. Correa

Friday Morning B

- 11:45–12:25 **Glasses, dynamical constraints, and slow relaxation in quantum many-body systems**
Juan P. Garrahan
- 12:25–12:50 **Topological Quantum Error Correcting Codes: Efficient Preparation, Optimisation and Characterisation**
M. Müller
- 12:50–13:05 **Non-markovian, strong coupling quantum transport: fluctuation theorems and measurement schemes**
Javier Cerrillo
- 13:05–13:20 **Equilibration via Gaussification: Theory and experiment**
M. Gluza, C. Krumnow and J. Eisert

Friday Afternoon A

- 15:30–16:10 **Strongly correlated nonequilibrium steady states with currents classical and quantum picture**
Tomasz Prosen
- 16:10–16:35 **Rydberg optical feshbach resonances in cold gases**
Rosario González-Férez, Nóra Sándor, Paul S. Julienne, Guido Pupillo
- 16:35–16:50 **Justification of statistical ensembles from thermodynamic transitions**
P. Boës, H. Wilming, J. Eisert, and R. Gallego

Friday Afternoon B

- 17:20–17:35 **Temporal nonlocality in quantum dynamics**
R. Hilfer
- 17:35–18:00 **On Quantum Decoherence and Thermalization**
Israel Michael Sigal
- 18:00–18:25 **Emergent Causality and the N -photon Scattering Matrix in Waveguide QED**
David Zueco

09:00–09:40 **Equivalence ‘reversible-irreversible’ for NS and other equations**
Giovanni Gallavotti

Conjectures and results about reversible models for systems usually modeled by irreversible equations, like the Lorez96 equation, the shell models and the NS equations in 2 or 3 dimensions. The conjectures and a few recent developments.

09:40–10:05 **Speeding up thermalization in quantum thermal engines**
Sai Vinjanampathy, Nischay Suri, Felix Binder, Bhaskaran Muraidharan

We present a contribution to the ongoing discussion about the interplay between thermal engines and quantum physics. Does having a working fluid be quantum help or hinder the performance of a quantum engine? To contribute to this question, we consider a two-stroke ergotropy engine operating between two temperatures. The two heat baths are taken to be non-collinear spin baths at different temperatures. By non-collinear baths, we mean that the two spin baths are polarized along different directions. The working fluid is composed of a double quantum dot system. Such a working fluid undergoes two strokes, namely: (a) a thermalization stroke by coupling one qubit to the hot bath and the other qubit to the cold bath and (b) a work stroke composed of an optimal two-qubit unitary. The power of the engine per stroke is defined as the work extracted per cycle divided by the time for the stroke. Since the time to implement the optimal unitary operator is usually very fast, the power per stroke of such engines typically is dominated by the thermalization times. We show that this power can be improved by using quantum control techniques in order to speed up thermalization. We prove uniform convergence of a generalized Krotov algorithm for open quantum systems in Liouville space and use it to improve the thermalization time. Such a control protocol injects work and heat into the engine and is expected to reduce the efficiency, in keeping with similar engines operating at finite time. We calculate the work, the power and the commensurate loss in efficiency of the engine. We propose an experimental implementation of the engine using a quantum dot spin valve setup.

10:05–10:30 **Irreversibility and correlations in open quantum systems**
Matteo Brunelli

Correlations shared within composite quantum systems are the fundamental resource for several tasks in quantum information processing. When considering an open dynamics, such correlations are necessarily accompanied by the production of entropy. We address the link between irreversibility and correlations in the non-equilibrium steady state of coupled quantum harmonic oscillators. We present a theoretical framework to assess the rate of entropy produced by an open quantum system in a non-equilibrium steady state. The entropy production rate is expressed in terms of accessible quantities. Our results can be applied to a nano-mechanical resonator or a Bose-Einstein condensate interacting with a cavity field. Then, we unveil a quantitative relation between the entropy production rate and the correlations, both total and quantum, built between the two oscillators. In the small coupling limit we show that the entropy production rate is proportional to both the mutual information and the quantum correlations.

[1] M. Brunelli et al, arXiv:1602.06958 (2016). [2] M. Brunelli and M. Paternostro, arXiv:1610.01172 (2016).

10:30–10:45 **Microscopic origins of collective dissipation in extended systems**
F. Galve, R. Zambrini, A. Mandarino, M. G. A. Paris, C. Benedetti, J. Alonso

Practical implementations of quantum technology are limited by unavoidable effects of decoherence and dissipation. With achieved experimental control for individual atoms and photons, more complex platforms composed by several units can be assembled enabling distinctive forms of dissipation and decoherence, in independent (separate) heat baths (SB) or collectively into a common bath (CB), with dramatic consequences for the preservation of quantum coherence. The cross-over between these two regimes has been widely attributed in the literature to the system units being farther apart than the baths correlation length. Starting from a microscopic model of a structured environment (a crystal) sensed by two bosonic probes [2], here we show the failure of such conceptual relation, and identify the exact physical mechanism underlying this cross-over, showing that it is not only a matter of system size. Peculiar scenarios in 1D environments or beyond isotropic dispersion relations are predicted, with collective dissipation possible for very large distances between probes, opening new avenues to deal with dissipation in phononic baths. Further, we investigate the scenario of anomalous heating in ion traps [2], a major promising platform for quantum information processing, where this limiting factor in the rush for miniaturization is believed to be caused by a yet unknown source of dipole fluctuations in the electrodes surfaces. A geometric crossover between CB and SB, and back to anti-CB (a common bath which dissipates the relative motion instead of the center of mass) is predicted which strongly depends on spatial correlations between dipoles, and also on their orientation. We propose a protocol to measure this peculiar effect in recent state of the art segmented Paul traps, allowing for a better insight into the microscopic origin of this elusive phenomenon.

[1] F. Galve, A. Mandarino, M. G. A. Paris, C. Benedetti and R. Zambrini, Scientific Reports 7, 42050 (2017). [2] F. Galve, J. Alonso and R. Zambrini, manuscript in preparation.

Friday Sessions, with Abstracts

10:45–11:00 **Non-ergodic states in quantum spin chains**

A. O. García Rodríguez and Guillermo G. Cabrera

The time evolution of non-equilibrium states in interacting quantum systems is discussed. In the thermodynamic limit, the fundamental assumption of quantum ergodicity asserts that arbitrary initial states should relax to equilibrium at asymptotically long times [1]. But the above assumption is not completely universal, and a number of quantum systems, including experimental demonstrations, have been proposed for non-ergodic behavior [2]. In the present contribution, we discuss an illustrative example for the preparation of non-ergodic states. We found that underlying properties of the energy spectrum are essential to get the above behavior, with the presence of a continuous branch plus localized levels. The interplay of the continuous and discrete parts of spectrum, determines the way that the system evolves at very long times. The semi-infinite XY spin chain with an impurity at the boundary has been chosen as a prototype system to test our working hypothesis. In the thermodynamic limit, the model is exactly solvable and the spectrum has a mixed character, with a continuous band and localized levels [3]. After the preparation of an arbitrary initial state, we portray the dynamics of this system by observing the site magnetization along the chain. Its long-time behavior is estimated using the stationary phase method. When two impurity states exist, the quantum interference between them leads to magnetization oscillations which settle over very long times with the absence of damping, the system being never stationary, nor homogeneous. The frequency of the remanent oscillation is recognized as being the Rabi frequency of the localized levels.

[1] S. Goldstein, J. L. Lebowitz, R. Tumulka, N. Zanghi, *Eur. Phys. J. H* 35, 173 (2010). [2] T. Kinoshita, T. Wenger, D. S. Weiss, *Nature* 440, 900 (2006), and references therein. [3] A. O. García Rodríguez and G. G. Cabrera, arXiv:1703.03446 [cond- mat.stat-mech].

11:00–11:15 **Low-temperature thermometry in many-body systems**

Karen V. Hovhannisyan and Luis A. Correa

We consider the problem of estimating the temperature of a very cold equilibrium sample with an individual quantum probe in the regime of strong probe-sample interaction. It is well-known that, in the weak coupling regime, thermometry at low temperatures is inefficient exponentially with the inverse of the temperature. We show that the same holds for probes interacting with many-body samples with arbitrary strength provided that the interactions are of short range and the overall system is out of criticality. In the search for efficient low-temperature thermometry we are thus forced to turn to gapless and possibly long-range interacting many-body systems. To this end, we prove that a wide class of gapless translationally invariant one-dimensional harmonic lattices with arbitrary interactions is equivalent to the Caldeira-Leggett model with Ohmic spectral density, when viewed from the perspective of a single lattice site. This allows us to use the powerful analytical tools developed for the Caldeira-Leggett model and show, among other things, that in critical systems one can beat the exponential suppression of the temperature estimation and achieve precision only quadratically decaying with the inverse temperature.

11:45–12:25 **Glasses, dynamical constraints, and slow relaxation in quantum many-body systems**
Juan P. Garrahan

12:25–12:50 **Topological Quantum Error Correcting Codes: Efficient Preparation, Optimisation and Characterisation**
M. Müller

In recent years, topological quantum error correcting codes have become one of the most promising and actively pursued routes towards the practical realisation of fault-tolerant quantum computers. In this talk, I will show how recently developed iterative state preparation and optimisation techniques [1] as well as efficiently measurable local entanglement witnesses constitute valuable, scalable tools for the control and characterisation of correlated many-particle quantum systems. I will illustrate how these techniques have been essential in the recent realisation of a minimal topological color code with trapped ions [2], and I will comment on ongoing work on fault-tolerant coupling of logical qubits of increasing size and robustness.

[1] M. Müller et al., Iterative Phase Optimization of Elementary Quantum Error Correcting Codes, *Phys. Rev. X* 6, 031030 (2016). [2] D. Nigg, M. Müller et al., Quantum computations on a topologically encoded qubit, *Science* 345, 302 (2014).

12:50–13:05 **Non-markovian, strong coupling quantum transport: fluctuation theorems and measurement schemes**
Javier Cerrillo

The possibility to extract full counting statistics (FCS) of transport processes in experimental settings exposes the necessity to upgrade existing simulation methods to gain access to environmental degrees of freedom. The techniques stemming from the theory of generating functions make it possible to encode all cumulants of the outcome of a specific measurement scheme in the form of a generalized density matrix. With this spirit we have developed a countingfield-resolved hierarchy of equations of motion (FCS-HEOM) which extends this ability to the case of strong-coupling, non-Markovian open quantum systems [1]. Exploiting the flexibility to define the underlying measurement scheme, we show that the comparison of two of them reveals transport coefficients which are the non-equilibrium generalization of energy or particle conductances. An alternative approach to the observation of environmental dynamics comes from the field of driven open systems. An analytical solution of the dynamics of both the system and the environment for a large class of systems is possible and can be interpreted as the effect of a static Hamiltonian on a continuous class of operators [2]. This novel perspective on the Floquet theory allows us to explore transient polaron dynamics in a straight-forward fashion. Both FCS results and Floquet simulation benefit strongly from the application of the transfer tensor method (TTM) [3], which is an approach to propose an optimized propagation alternative based on short time evolution samples. This extends the simulation power of existing exact approaches, like the chain-mapping DMRG-based simulation method known as TEDOPA [4]. This proposal departs from the traditional bottom-up approach of simulation method designs based on microscopic principles, and attempts to take a top-down perspective in placing the dynamical map as the central (and the only experimentally accessible) object.

[1] J. Cerrillo, M. Buser, T. Brandes, *Phys. Rev. B* 94, 214308 (2016). [2] S. Restrepo, J. Cerrillo, V.M. Bastidas, D.G. Angelakis, T. Brandes, *Phys. Rev. Lett.* 117, 250401 (2016). [3] J. Cerrillo, J. Cao, *Phys. Rev. Lett.* 112, 110401 (2014).

13:05–13:20 **Equilibration via Gaussification: Theory and experiment**
M. Gluza, C. Krumnow and J. Eisert

When and by which mechanism do closed quantum many-body systems equilibrate? This fundamental question lies at the very basis of the connection between thermodynamics, many-body quantum mechanics and condensed matter theory. In the setting of free fermionic evolution, we uncover an underlying mechanism how local memory of the initial conditions is forgotten[1]. Specifically, starting from an initially short range correlated fermionic states which can be very far from Gaussian, we show that if the Hamiltonian provides sufficient transport, the system approaches a state that locally cannot be distinguished from a corresponding Gaussian state. In this way, strongly correlated states, as encountered in the Fermi-Hubbard model, will become locally Gaussian during the evolution under a hopping Hamiltonian, leading to density-density correlations that factor according to Wick's theorem. Our result can be used to infer realistic physical time scales for equilibration and we additionally characterize the equilibrium state, finding an instance of a rigorous convergence to a Generalized Gibbs ensemble. Recently, a Generalized Gibbs ensemble was observed experimentally on

Friday Sessions, with Abstracts

an atomchip experiment[2]. We are currently studying the quantitative predictions of the mean-field model that governs the dynamics of the system as applied to the experimental data which opens a way to assessing observables that are not directly measurable in the setup. Based on a Galerkin discretization approach to the continuum problem we set out to tomographically reconstruct the Gaussian contribution to the steady state, asses the possible non-Gaussian effects and quantify entanglement present in the system.

[1] M. Gluza, C. Krumnow, M. Friesdorf, C. Gogolin, J. Eisert. Phys. Rev. Lett. 117.19 (2016): 190602. [2] Langen, Tim, et al. Science 348.6231 (2015): 207-211.

15:30–16:10 **Strongly correlated nonequilibrium steady states with currents classical and quantum picture**
Tomaž Prosen

In my talk I will introduce several explicit models of strongly correlated stationary states of conservative systems in one dimension that are driven out of equilibrium with the dissipative couplings at the system boundaries. All these models share a simple algebraic matrix product structure of the exact solution. In the framework of quantum physics, the main examples of such models are integrable spin chains, e.g. the XXZ model, or Fermi-Hubbard model, while in the realm of classical physics we have an example of a reversible and integrable cellular automaton. I will outline general features of solving nonequilibrium stationary states in terms of matrix product ansatz and its generalizations and stress some of the most interesting and outstanding open problems.

16:10–16:35 **Rydberg optical feshbach resonances in cold gases**
Rosario González-Férez, Nóra Sándor, Paul S. Julienne, Guido Pupillo

In this work, we present a novel scheme to efficiently tune the scattering length of two colliding ground-state atoms by off-resonantly coupling the scattering-state to an excited Rydberg-molecular state using laser light. For the s -wave scattering of two colliding ^{87}Rb atoms, we demonstrate that the effective optical length and pole strength of this Rydberg optical Feshbach resonance can be tuned over several orders of magnitude, while incoherent processes and losses are minimised [1]. Due to the ubiquity of Rydberg molecular states, this technique should be generally applicable to homonuclear atomic pairs, non bi-alkali mixtures, as well as to other atomic mixtures with s -wave scattering and p -wave scattering.

[1] N. Sándor, R. González-Férez, P. S. Julienne and G. Pupillo, arXiv:1611.07091.

16:35–16:50 **Justification of statistical ensembles from thermodynamic transitions**
P. Bošs, H. Wilming, J. Eisert, and R. Gallego

Maximum-entropy ensembles have proven to be a very useful primitive from which emergent thermodynamic properties can be derived. Several approaches have been put forward in order to justify, from minimal assumptions, the use of these ensembles as an statistical description of most systems. However, there is to date no generally accepted justification, mainly because most arguments are based on a notion of typicality according to some measure on the state space. Here, we provide a new approach to justify the use of maximum-entropy ensembles. We look at the set of possible transitions that a system can undergo together with an environment, when one only has partial information about both system and environment. In particular, we ask which final states of a given quantum system we can reach deterministically if the only information that we have about the initial states of *both* the system and the environment are their mean energies. Given a system Hamiltonian H , if a thermodynamic transition from every quantum state of initial mean part. inf. energy e to the same final state ρ_f is possible, we write $(e, H) \xrightarrow{\text{part. inf.}} \rho_f$. We compare this with the possible thermodynamic transitions that can be implemented on a system if one has full knowledge of both its initial state and that of the environment, $\rho \xrightarrow{\text{full inf.}} \rho_f$. Our main result is that, for all e, H

$$(e, H) \xrightarrow{\text{part. inf.}} \rho_f \Leftrightarrow \gamma_e(H) \xrightarrow{\text{full inf.}} \rho_f, \quad (2)$$

where $\gamma_e(H)$ is the (canonical) maximum-entropy ensemble compatible with the partial information. (1) says that the canonical ensemble is operationally equivalent to states of partial information in the sense that a thermodynamic transition can be induced on the latter states if and only if it can be induced on the system in the corresponding canonical ensemble state. Note that comparing partial information states and ensemble states in terms of their possible thermodynamic transitions is very natural, because most thermodynamic tasks as well as the laws of thermodynamics can be formulated in terms of state transitions, so that our results allow us to re-derive many standard results of phenomenological, such as work extraction bounds or the Clausius inequality, without requiring the usual assumption that the system is in the canonical ensemble state. In this sense, our results justify the overwhelming success of maximum-entropy ensembles to derive thermodynamic laws and provides a derivation that neither relies on any probability measure nor considerations about typical states.

17:20–17:35 Temporal nonlocality in quantum dynamics

R. Hilfer

The mathematical analysis of quantum many body systems requires the study of long time limits. This work discusses the interdisciplinary problem of local stationarity in time. A mathematical definition of almost invariant and nearly indistinguishable states on C^* -algebras is introduced. It is based on functions of bounded mean oscillation [1]. Rescaling of time yields generalized time flows of almost invariant and macroscopically indistinguishable states, that are mathematically related to stable convolution semigroups. The infinitesimal generator of coarse grained semigroups are operators that are nonlocal in time [2]. Applications of the analysis are given to irreversibility and experiment.

[1] R. Hilfer, *Mathematics* 3, 626 (2015). [2] R. Hilfer, *Analysis* 36, 49 (2016).

17:35–18:00 On Quantum Decoherence and Thermalization

Israel Michael Sigal

I present rigorous results on the standard model of decoherence involving a small quantum system interacting with the environment, with the latter described by a massless Bose or Fermi quantum field. In particular, I will describe a careful mathematical formulation of the problem and the connection of the decoherence and the quantum resonances of the Liouvillean dynamics of the total system, leading to estimates of the decoherence and thermalization times. If time permits I will describe use of the rigorous renormalization group in this problem. The talk is based on the paper in preparation stemming from the joint work with G.Berman and M.Merkli ([1]–[4]).

[1] G. Berman, M. Merkli, I.M. Sigal. *Physical Review Letters* Vol. 98, No.13, 30 March 2007. [2] G. Berman, M. Merkli, I.M. Sigal. *Virtual Journal of Quantum Information, Annals Physics*, 323(2) 373412, 2008. [3] G. Berman, M. Merkli, I.M. Sigal. *Adv Math Phys* Vol. 2010, Article ID 169710, 2010. [4] G. Berman, M. Merkli, I.M. Sigal *J. Math. Phys* 52 no. 9, 092201, 2011.

18:00–18:25 Emergent Causality and the N -photon Scattering Matrix in Waveguide QED

David Zueco

In this talk we discuss the emergence of approximate causality in a general setup from waveguide QED —i.e. a one-dimensional propagating field interacting with a scatterer. We discuss that this emergent causality fixes the form for the N -photon scattering matrix. Our theory builds on the derivation of a Lieb-Robinson-type bounds for the continuum and for all coupling strengths and other intermediate results, of which we remark (i) the asymptotic independence of space-like separated wavepackets, (ii) the proper definition of input and output scattering states, and (iii) the characterization of the ground state and correlations in the model. We illustrate the formal results by analyzing the two-photon scattering from a quantum impurity in the ultrastrong coupling regime, verifying the cluster decomposition and ground-state nature. Besides, We generalize the cluster decomposition if inelastic or Raman scattering occurs. Finally, the decay of the fluorescence (photon-photon correlations) is discussed.

Notes

Notes

Notes

Map legend

Coffee shops

- 1 Cafetería Facultad de Ciencias (€)
- 2 Menorca (€)
- 3 Lucena (€)
- 4 Mundi Salado (€)
- 5 Pastelería Ysla (€€)
- 6 El cafetín (€)
- 7 Endulce (€)
- 8 Bohemia Jazz Café (€€)

Daily menu

- 1 Cafetería Facultad de Ciencias (€)
- 2 Escuela Técnica Superior de Ingeniería de Caminos, Canales y Puertos (€)
- 3 Escuela Técnica Superior de Ingeniería de Edificación (€)
- 4 Hotel Granada Center (€€€)
- 5 Café Bar Lilo (€€)
- 6 La Tutoria (€€)
- 7 Hipercor (€€€)
- 8 American Beer (€€)
- 9 Restaurante Jotadalia (€€)
- 10 El Guiño (€€)

Tapas bars*

- 1 Grifos y tapas (€-€€)
- 2 Los Pípos (€-€€)
- 3 Boqué (€€-€€€)
- 4 Bocao (€€-€€€)
- 5 Rincón de Rodri (€-€€)
- 6 Chantarella (€-€€)
- 7 Om-Kalsum (€-€€)
- 8 El Asturiano (€-€€)
- 9 La bodega de Antonio (€-€€)
- 10 Poë (€-€€)
- 11 Sancho original (€€-€€€)
- 12 Bella Kurva (€-€€)
- 13 Saint Germain (€-€€)
- 14 Bodegas Castañeda (€€-€€€)
- 15 Los Diamantes (€€-€€€)
- 16 Los Manueles (€€-€€€)
- 17 La Cueva de 1900 (€€-€€€)
- 18 Los Diamantes (€€-€€€)
- 19 Los Diamantes II (€€-€€€)
- 20 La Cueva de 1900 (€€-€€€)

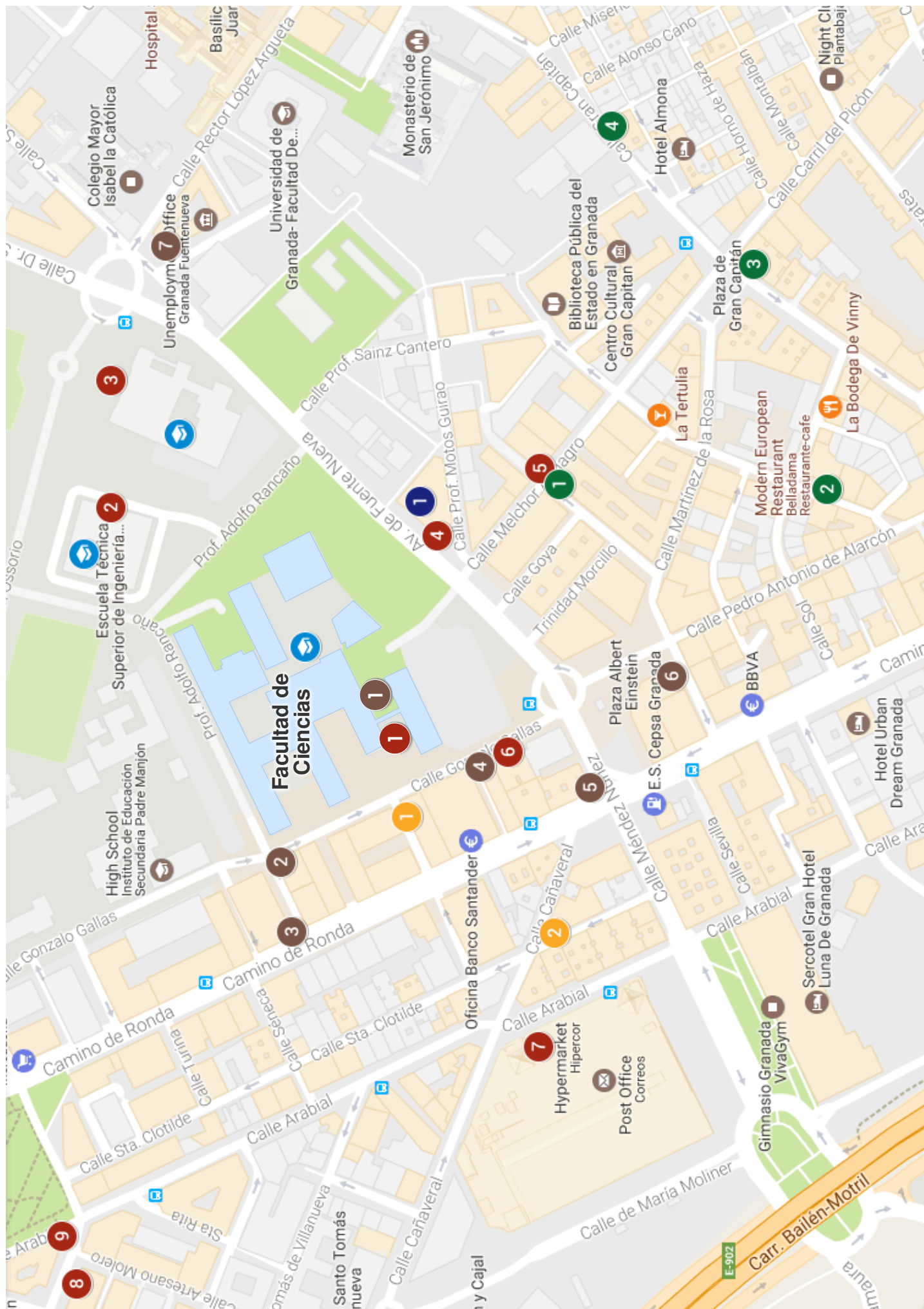
Restaurants

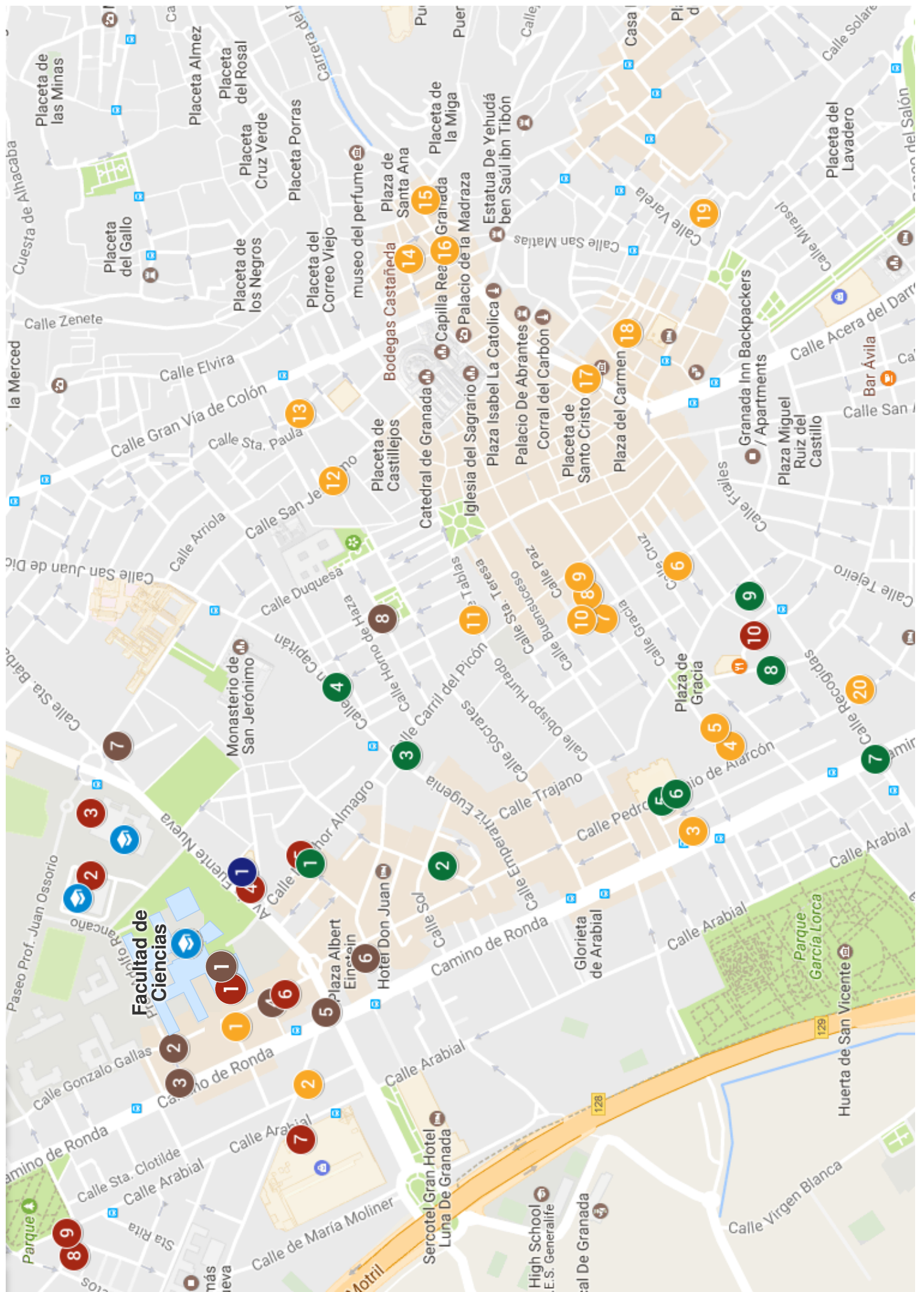
- 1 Antonio Pérez (€€€)
- 2 Belladama (€€-€€€)
- 3 La Pataleta (€€€)
- 4 Pizzametro (€€)
- 5 Kudam Edel (€€€-€€€€)
- 6 Poetas Andaluces II (€€€-€€€€)
- 7 La Tagliatella (€€-€€€)
- 8 Las Tinajas (€€€-€€€€)
- 9 Hotel Palacio de los Patos (€€€-€€€€)

Hotels

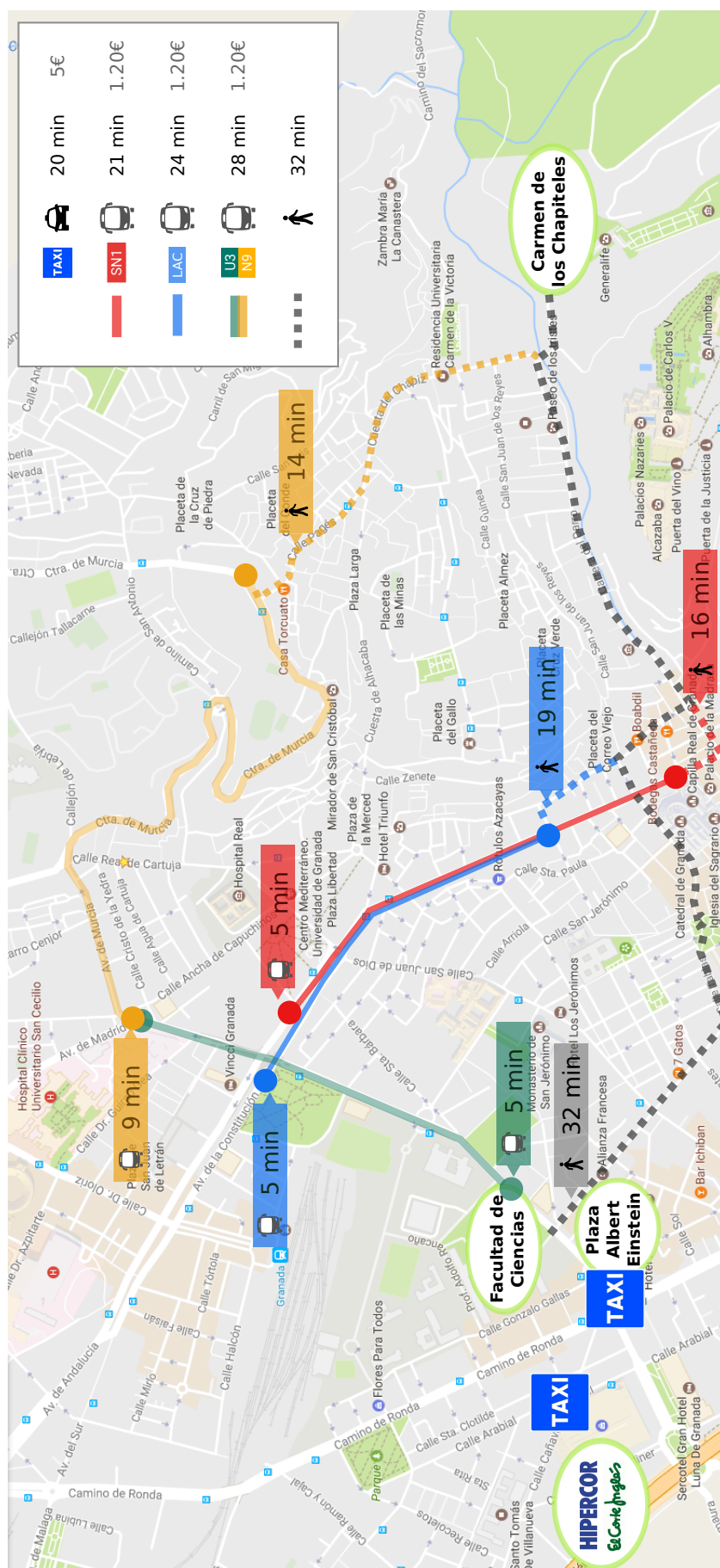
- 1 Hotel Granada Center
- 2 Hotel Vincici Granada

* In "tapas bars" you always get a snack or small dish of food included in the price of the drink, although you can order more dishes if you wish.
** The prices shown here are only illustrative.





Find your way to the *Carmen de los Chapiteles*



14th Granada Seminar – Quantum Systems in and Out of Equilibrium
Institute “Carlos I” for Theoretical and Computational Physics.
Facultad de Ciencias (Granada) 20–23 June 2017

	Tuesday 20	Wednesday 21	Thursday 22	Friday 23
9:00-9:40	Opening (9:00-9:25)	Oppenheim	Acín	Gallavotti
9:40-10:05	Buchleitner (9:25-10:05)	Lesanovsky	Dhar	Vinjanampathy
10:05-10:30	Esposito	Martín-Delgado	Olmos	Brunelli
10:30-11:15	Spagnolo	Pigeon	Manzano	Galve
	Kaminishi	Shiraishi	Kohler	Cabrera
	Sánchez	Frustaglia	Shirai	Hovhannisyan
11:15-11:45	COFFEE BREAK			
11:45-12:25	Cao	Paternostro	Briegel	Garrahan
12:25-12:50	Poletti	Prior	Brandner	Müller
12:50-12:55	Tajima	Oviedo-Casado	García-Rodríguez	Cerrillo
12:55-13:00	Sagnik Chakraborty	Toranzo	Kapitanchuk	
13:00-13:05	Padmanabhan	Portesi	Notarariago	
13:05-13:10	Yang	Losada	Zeitlin	Gluza
13:10-13:15	Pietracaprina	Bolívar	Fedorova	
13:15-15:30	LUNCH BREAK			
15:30-16:10	Kastner	Tasaki	Nieuwenhuizen	Prosen
16:10-16:35	Rodríguez	Morawetz	Barra	González-Férez
16:35-16:50	Molina-Villaplana	Rica	Pérez-Espigares	Boës
16:50-17:20	POSTER SESSION			
17:20-17:35	Diehl	Thiel	Ramsak	Hilfer
17:35-17:50	Mori	Pino	Gallego	Sigal
17:50-18:05	Klich	Perarnau-Llobet	Thingna	
18:05-18:10	Puertas-Centeno	Menczel	Dai	Zueco
18:10-18:15	Takahashi	Shantanav Chakraborty		
18:15-18:20	Aguilera-Fernández	Novo		
18:20-18:25	Morawetz	Prat	Netocny	
18:25-18:30	Ito	Deger	Sindici	
18:30-18:45			Conference Picture	
20:30			Gala Dinner	