QTD2023 Vienna

MONDAY 17 July 2023

09:00-09:40	Registration & Welcome	Monday 17 July 2023

Session 1

Chair: Nicole Yunger Halpern (University of Maryland)

9:40-10:15	Invited Talk	Monday 17 July 2023

Ronnie Kosloff (The Hebrew University of Jerusalem)

Thermodynamically Consistent Quantum control

Abstract:

Control of open quantum systems is essential for the realization of contemporary quantum science and technology. I will demonstrate such control by employing a thermodynamically consistent framework, taking into account the fact that the drive can modify the system's interaction with the environment. Such an effect is incorporated within the dynamical equation, leading to control-dependent dissipation. This relation serves as the key element for open system control. The control paradigm is displayed by analyzing entropy changing state-to-state transformations, such as heating and cooling. The difficult task of controlling quantum gates is achieved for non-unitary reset maps with complete memory loss. In addition, we identify a novel mechanism for controlling unitary gates by actively removing entropy from the system to the environment. We demonstrate a universal set of single and double qubit unitary gates under dissipation. I will address the issue of fighting noise on the controller.

[1] Roie Dann and Ronnie Kosloff, *Quantum signatures in the quantum Carnot cycle*, New J. Phys. **22**, 013055 (2020) [arXiv:1906.06946].
[2] Shimshon Kallush, Roie Dann, and Ronnie Kosloff, *Controlling the uncontrollable: Quantum control of open system dynamics*, Sci. Adv. **8**, eadd0828 (2022) [arXiv:2205.05971].

10:15-11:00	Coffee Break	Monday 17 July 2023

Session 2

Chair: Maximilian P. E. Lock (TU Wien)

11:00-11:35	Invited Talk	Monday 17 July 2023

Aurélia Chenu (University of Luxembourg)

Quantum dynamics in noisy systems: from chaos to control

Abstract:

Quantum experiments are performed in noisy platforms. In NISQ devices, realistic setups can be described by open systems or noisy Hamiltonians. Starting from a generic noisy Hamiltonian, I will first present a scheme to control the thermalization of a harmonic oscillator [1] and generate a squeezed thermal state [2] in arbitrary time.

Then, going beyond the noise-averaged density matrix, I will introduce the concept of stochastic operator variance (SOV) of an observable. The SOV [3] is an operator that characterizes the deviation of any operator from the noise-averaged operator in a stochastic evolution governed by the

Hamiltonian. As such, it is relevant in the quantum simulation of open systems using NISQ devices, e.g., to engineer a given dissipative evolution. Surprisingly, we find that the evolution of the noise-averaged variance relates to an out-of-time-order correlator (OTOC), which connects fluctuations of the system with scrambling. This connection may allow computing the Lyapunov exponent and experimentally access OTOCs without the need to invert the sign of the Hamiltonian. I will illustrate the results in the stochastic LMG model and show how noise changes the phase diagram of the system.

In the last part, I will present how the stochastic model is suited to explain the variance of the density matrix measured in a dissipative qubit.

[1] Léonce Dupays, Íñigo Luis Egusquiza, Adolfo del Campo, and Aurélia Chenu, *Superadiabatic thermalization of a quantum oscillator by engineered dephasing*, Phys. Rev. Res. **2**, 033178 (2020) [arXiv:1910.12088].
[2] Léonce Dupays and Aurélia Chenu, *Dynamical engineering of squeezed thermal state*, Quantum **5**, 449 (2021) [arXiv:2008.03307].
[3] Pablo Martinez-Azcona, Aritra Kundu, Adolfo del Campo, and Aurélia Chenu, *Unveiling out-of-time-order correlators from stochastic operator variance*, arXiv:2302.12845 (2023).

11:35-11:55	Contributed Talk	Monday 17 July 2023

Federico Cerisola (University of Oxford)

Accounting for thermal quantum effects in magnetic materials modelling

Abstract:

Magnetic material modelling is of paramount importance both for a fundamental understanding of ground-breaking experiments, as well as for the development of a wide range of new technologies, such as data storage.

Currently, the most effective tools available for the study of equilibrium magnetic properties and magnetism dynamics accounting for thermal fluctuations are based on atomistic spin dynamics (ASD) simulations, where the atoms in the material are treated as classical magnetic moments which interact through an effective Hamiltonian. Despite proving themselves extremely successful for a variety of applications, ASD simulations have fundamental shortcomings and limitations. In particular, they fail to qualitatively reproduce the low temperature magnetisation of materials and to accurately predict their critical temperatures.

Here, we first show that, within a mean-field approximation, the quantum equilibrium magnetisation can be accurately reproduced by the classical one with an appropriate power-law rescaling of the temperature. Furthermore, we find that the scaling depends exclusively on the magnetic moment of the atoms and is independent of the microscopic details of the system. Combined with the results of [1], this same temperature scaling can be applied to ASD simulations to successfully reproduce the experimentally measured fast magnetisation dynamics and the equilibrium temperature dependence of the magnetisation of a wide range of materials.

Second, we further extend the mean-field approach to an open system strongly coupled to the environment. By treating the environment with the semi-classical method developed in [2], we are able to produce magnetisation curves that do not only match the experimental data qualitatively even at low temperature, but further also agree quantitatively, e.g., begin able predict to good accuracy the critical temperature of the material.

The results here presented are a substantial step forward towards effectively including quantum aspects of the spin dynamics in magnetic calculations. When implemented in a large-scale ASD framework, we believe would provide a far more accurate description of the magnetism dynamics and low temperature behaviour.

[1] Richard F. L. Evans, Unai Atxitia, and Roy W. Chantrell, *Quantitative simulation of temperature-dependent magnetization dynamics and equilibrium properties of elemental ferromagnets*, Phys. Rev. B **91**, 144425 (2015) [arXiv:1409.7397].
[2] Janet Anders, Connor Sait, and Simon A. R. Horsley, *Quantum Brownian motion for magnets*, New J. Phys. **24**, 033020 (2022) [arXiv:2009.00600].

11:55-12:15	Contributed Talk	Monday 17 July 2023

Patrick Potts (University of Basel)

Optical coherent feedback control of a mechanical oscillator

Abstract:

We present the theoretical description and experimental realization of an optical coherent feedback platform to control the motional state of a nanomechanical membrane in an optical cavity. The coherent feedback loop consists of a light field interacting twice with a mechanical oscillator in different cavity modes. Tuning the optical phase and delay of the feedback loop allows us to control the motional state of the mechanical oscillator, its frequency shift and damping rate, which we use to cool the membrane close to the ground state. In the optimal cooling conditions, we derive an expression for the minimal number of phonons and show that this new technique enables ground state cooling. Experimentally, we show that we can cool the membrane to a state with 4.89 ± 0.14 phonons (480 µK) in a 20 K environment. This lies below the theoretical limit of dynamical backaction cooling in the unresolved sideband regime. The described feedback scheme is very versatile and could be implemented in various optomechanical systems.

[1] Maryse Ernzer, Manel Bosch Aguilera, Matteo Brunelli, Gian-Luca Schmid, Thomas M. Karg, Christoph Bruder, Patrick P. Potts, and Philipp Treutlein, *Optical coherent feedback control of a mechanical oscillator*, arXiv:2210.07674 (2022).

12:15-13:45	Lunch Break (self-organized)	Monday 17 July 2023

Session 3 **Chair:** Andrew N. Jordan (Chapman University and the University of Rochester)

13:45-14:20	Invited Talk	Monday 17 July 2023

Ville Maisi (Lund University)

Microwave photodetection and energetics in a double quantum dot absorber

Abstract:

Single-electron devices have become one of the main experimental platforms to perform quantum thermodynamics experiments and sensing. I will give a brief overview of the activities of our group where we study quantum dot devices towards this direction. I will then focus on describing how we use quantum dot absorbers to build microwave photodetectors and discuss when the single photon

energy sets the relevant energy scale and when it rather arises from the voltage amplitude of the microwave signal. Energetics considerations of this photon absorption process allows us to predict a fundamental limit of the characteristic impedance - i.e., the relation between voltage and current - of our microwave absorption picture: The absorption picture ceases to apply when the characteristic impedance reaches the resistance quantum. In this case, the energy absorbed from the voltage amplitude of a single photon would exceed the energy of the photon, which is not energetically allowed.

14:20-14:40	Contributed Talk	Monday 17 July 2023

Iva Březinová (TU Wien)

Thermal reduced density matrices from eigenstates of mixed systems

Abstract:

A key issue in the foundations of statistical mechanics is the emergence of equilibrium ensembles in isolated and closed quantum systems. Recently, it has been predicted that in the thermodynamic limit of large quantum many-body systems canonical density matrices for small subsystems emerge from almost all pure states. This notion of canonical typicality is assumed to arise from the entanglement between subsystem and environment and the resulting intrinsic quantum complexity of the many-body state. For individual eigenstates it has been shown that local observables exhibit thermal properties if the eigenstate thermalization hypothesis holds, which requires that the system be quantum chaotic. Here, we study the emergence of thermal states in the regime of a quantum analog of a mixed phase space. Specifically, we study the emergence of the canonical density matrix of an itinerant impurity upon reduction from isolated energy eigenstates of a large but finite quantum. Our system can be tuned by means of a single parameter from quantum integrability to quantum chaos, and in between corresponds to a system with mixed quantum phase space. We show that the probability of finding a canonical density matrix when reducing the ensemble of energy eigenstates of the finite many-body system can be quantitatively controlled and tuned by the degree of quantum chaos present. For the transition from quantum integrability to quantum chaos we find a continuous and universal (i.e. size independent) relation between the fraction of canonical eigenstates and the degree of chaoticity as measured by the Brody parameter or the Shannon entropy.

[1] Mahdi Kourehpaz, Stefan Donsa, Fabian Lackner, Joachim Burgdörfer, and Iva Březinová, *Canonical density matrices from eigenstates of mixed systems*, Entropy **24**, 1740 (2022) [arXiv: 2103.05974].

14:40-15:00	Contributed Talk	Monday 17 July 2023

Nathan Keenan (Trinity College Dublin)

Evidence of Kardar-Parisi-Zhang scaling on a digital quantum simulator

Abstract:

Understanding how hydrodynamic behaviour emerges from the unitary evolution of the many-particle Schrodinger equation is a central goal of non-equilibrium statistical mechanics. In this work we implement a digital simulation of the discrete time quantum dynamics of a spin half XXZ spin chain on a noisy near-term quantum device, and we extract the high temperature transport exponent at the isotropic point. We simulate the temporal decay of the relevant spin correlation function at high temperature using a pseudo-random state generated by a random circuit that is specifically tailored to the ibmq-montreal 27 qubit device. The resulting output is a spin excitation on a highly inhomogeneous background. From the subsequent discrete time dynamics on the device we are able to extract an anomalous super-diffusive exponent consistent with the conjectured Kardar-Parisi-Zhang (KPZ) scaling at the isotropic point. Furthermore we simulate the restoration of spin diffusion with the application of an integrability breaking potential.

[1] Nathan Keenan, Niall Robertson, Tara Murphy, Sergiy Zhuk, and John Goold, *Evidence of Kardar-Parisi-Zhang scaling on a digital quantum simulator*, arXiv:2208.12243 (2022).

15:00-15:45	Coffee Break	Monday 17 July 2023

Session 4 **Chair:** Paolo Andrea Erdman (The Free University of Berlin)

15:45-16:20	Invited Talk	Monday 17 July 2023

Zala Lenarčič (Jožef Stefan Institute, Ljubljana)

Generalized Gibbs ensembles in dissipative nearly integrable systems

Abstract:

Generalized Gibbs ensembles (GGEs) have been introduced to describe steady states of integrable models locally. Recent advances show that GGEs can also be stabilized in nearly integrable systems when driven by external fields and open. I will show that by engineering openness, one can stabilize Lagrange multipliers at will, and I will present how weakly dissipative dynamics that drive towards a steady-state GGE could be implemented in systems of trapped ions. Furthermore, I will illustrate how a neural network can detect the number of most necessary conserved quantities for an approximate description in terms of a truncated generalized ensemble and how to reconstruct those iteratively.

16:20-16:40	Contributed Talk	Monday 17 July 2023

Alessandro Braggio (NEST Pisa)

Thermoelectricity in particle-hole symmetric systems

Abstract:

Superconductors satisfy strong particle-hole symmetry and show negligible thermoelectricity. However, we have recently reported different examples where instead superconductors show unexpected thermoelectrical performances if appropriately managed.

Nonlinear temperature differences may spontaneously trigger particle-hole breaking generating a fully bipolar thermoelectric effect. This mechanism can generate a Seebeck coefficient that scales with the superconducting gap [1]. We have experimentally demonstrated in Al-based tunnel junctions at subKelvin temperature Seebeck coefficients up to 300 microV/K [2] that can be even flux controlled [3]. This thermoelectrical effect represents huge enhancement (up to five orders of magnitude) with respect to a normal metal opening new opportunities in nanodevices [4,5]. Photon-assisted thermoelectricity has been also first proposed for these systems [6]. Topological Josephson junctions host a nonlocal linear thermoelectrical effect up to a tenth microV/K at subKelvin

temperature controlled by flux and phase differences which is connected to helical properties of the edges [7].

[1] Giampiero Marchegiani, Alessandro Braggio, and Francesco Giazotto, *Nonlinear Thermoelectricity with Electron-Hole Symmetric Systems*, Phys. Rev. Lett. **124**, 106801 (2020) [arXiv:1909.04590].
[2] Gaia Germanese, Federico Paolucci, Giampiero Marchegiani, Alessandro Braggio, and Francesco Giazotto, *Bipolar thermoelectric Josephson engine*, Nat. Nanotechnol. **17**, 1084 (2022) [arXiv:2202.02121].
[3] Gaia Germanese, Federico Paolucci, Giampiero Marchegiani, Alessandro Braggio, and Francesco Giazotto, *Phase Control of Bipolar Thermoelectricity in Josephson Tunnel Junctions*, Phys. Rev. Appl. **19**, 014074 (2023) [arXiv:2207.10595].
[4] Francesco Giazotto, Alessandro Braggio, Federico Paolucci, Giampiero Marchegiani, and Gaia Germanese, *Superconducting bipolar thermoelectric memory*, Patent (Filing number: 102021000032042, 21/12/2021), Francesco Giazotto, Alessandro Braggio, Federico Paolucci, and Giampiero Marchegiani, Patent (Filing number: 102023000001854, 06/02/2023).
[5] Lorenzo Bernazzani, Giampiero Marchegiani, Francesco Giazotto, Stefano Roddaro, and Alessandro Braggio, *Bipolar Thermoelectricity in Bilayer-Graphene--Superconductor Tunnel Junctions*, arXiv:2207.08908 (2022).
[6] Alberto Hijano, F. Sebastián Bergeret, Francesco Giazotto, and Alessandro Braggio, *Microwave-Assisted Thermoelectricity in S-I-S' Tunnel Junctions*, Phys. Rev. Appl. **19**, 044024 (2023) [arXiv:2211.04288].
[7] Gianmichele Blasi, Fabio Taddei, Liliana Arrachea, Matteo Carrega, and Alessandro Braggio, *Nonlocal Thermoelectricity in a Superconductor–Topological-Insulator–Superconductor Junction in Contact with a Normal-Metal Probe: Evidence for Helical Edge States*, Phys. Rev. Lett. **124**, 227701 (2020) [arXiv:1911.04367].

16:40-17:00	Contributed Talk	Monday 17 July 2023

Rishabh Upadhyay (Aalto University)

Flux tunable on-chip microwave diode

Abstract:

Operating at ultra-low temperatures, isolating quantum devices from electrical noise is essential to maintain the quantum nature. Non-reciprocal microwave devices such as circulators and isolators help to isolate the quantum circuits from the environment noise. In this work, by exploiting high non-linearity of superconducting flux qubit we report on an on-chip microwave diode architecture designed to demonstrate transmission rectification. The reported device houses a superconducting flux qubit inductively coupled to two resonators of different frequencies with different coupling schemes. We use one-tone rf-spectroscopy technique to study the system. We experimentally observe a significant transmitted power difference of 5 dB measured at the degeneracy point of the device when the direction of the applied input signal is reversed. We compute transmission rectification ratio (R) reaching over 90% near the qubit-resonator avoided crossing points for a narrow frequency bandwidth of 50 MHz and over 60% for a wide frequency bandwidth of ~250 MHz, at -99 dBm applied input power. Due to the high rectification ratio (R), the reported architecture can potentially be useful in the field of circuit quantum thermodynamics (c-QTD) to control and regulate heat in superconducting quantum circuits. The observations encourage the architecture as a strong candidate for an on-chip quantum heat rectifier.

TUESDAY 18 July 2023

Session 5

Chair: Martí Perarnau-Llobet (University of Geneva)

9:00-9:35	Invited Talk	Tuesday 18 July 2023

Silvia Pappalardi (University of Cologne)

The Eigenstate Thermalization Hypothesis and Free Probability

Abstract:

The Eigenstate-Thermalization-Hypothesis (ETH) has been established as the general framework to understand quantum statistical mechanics. Only recently has the attention been paid to so-called general ETH, which accounts for higher-order correlations among matrix elements. In this talk, I will present the close relation between this perspective on ETH and Free Probability theory, as applied to a thermal ensemble or an energy shell. This mathematical framework allows one to reduce in a straightforward way higher-order correlation functions to a decomposition given by minimal blocks, identified as free cumulants, for which we give an explicit formula. I will illustrate examples on two classes of local non-integrable (chaotic) quantum many-body systems: spin chain Hamiltonians and Floquet brickwork unitary circuits. The results show that the non-trivial frequency dependence of free cumulants encodes the physical properties of local many-body systems and distinguishes them from structureless, rotationally invariant ensembles of random matrices. The present results uncover a direct connection between the Eigenstate Thermalization Hypothesis and the structure of Free Probability, widening considerably the latter's scope and highlighting its relevance to quantum thermalization.

9:35-09:55	Contributed Talk	Tuesday 18 July 2023

Maximilian P. E. Lock (TU Wien)

Quantum measurements and equilibration: the emergence of objective reality via entropy maximisation

Abstract:

Textbook quantum physics features two types of dynamics, reversible unitary dynamics and irreversible measurements. The latter stands in conflict with the laws of thermodynamics and has evoked debate on what actually constitutes a measurement. With the help of modern quantum statistical mechanics, we take the first step in formalising the hypothesis that quantum measurements are instead driven by the natural tendency of closed systems to maximise entropy, a notion that we call the Measurement-Equilibration Hypothesis. In this paradigm, we investigate how objective measurement outcomes can emerge within an purely unitary framework, and find that: (i) the interactions used in standard measurement models fail to spontaneously feature emergent objectivity and (ii) while ideal projective measurements are impossible, we can (for a given form of Hamiltonian) approximate them exponentially well as we collect more physical systems together into an ``observer'' system. We thus lay the groundwork for self-contained models of quantum measurement, proposing improvements to our simple scheme.

[1] Emanuel Schwarzhans, Felix C. Binder, Marcus Huber, and Maximilian P. E. Lock, *Quantum measurements and equilibration: the emergence of objective reality via entropy maximisation*, arXiv:2302.11253 (2023).

9:55-10:15	Contributed Talk	Tuesday 18 July 2023

Ian Ford (University College London)

Stochastic entropy production in quantum measurement using Markovian quantum state diffusion

Abstract:

The reduced density matrix that characterises the state of an open quantum system is a projection from the full density matrix of the quantum system and its environment, and there are many full density matrices consistent with a given reduced version. Without a specification of relevant details of the environment, the evolution of a reduced density matrix is therefore typically unpredictable, even if the dynamics are deterministic. With this in mind, we investigate a two level open quantum system using a framework of quantum state diffusion. We consider the pseudorandom evolution of its reduced density matrix when subjected to an environment-driven process of quantum measurement of a system observable, using dynamics that asymptotically send the system to an eigenstate. The unpredictability is characterised by a stochastic entropy production, the average of which corresponds to an increase in the subjective uncertainty of the quantum state adopted by the system and environment, given the underspecified dynamics. This differs from a change in von Neumann entropy, and can continue indefinitely as the system is guided towards an eigenstate. As one would expect, the simultaneous measurement of two non-commuting observables within the same framework does not send the system to an eigenstate. Instead, the probability density function describing the reduced density matrix of the system becomes stationary over a continuum of pure states, a situation characterised by zero further stochastic entropy production and equivalent to Heisenberg Uncertainty. Transitions between such stationary states, brought about by changes in the relative strengths of the two measurement processes, give rise to finite positive mean stochastic entropy production. The framework investigated can offer useful perspectives on both the dynamics and irreversible thermodynamics of measurement in quantum systems.

[1] Claudia L. Clarke and Ian J. Ford, *Stochastic entropy production associated with quantum measurement in a framework of Markovian quantum state diffusion*, arXiv:2301.08197 (2023).

10:15-11:00	Coffee Break	Tuesday 18 July 2023

Session 6

Chair: Eric Lutz (University of Stuttgart)

11:00-11:35	Invited Talk	Tuesday 18 July 2023

Norbert Linke (Duke University & University of Maryland)

Finite-temperature states on a trapped-ion quantum computer

Abstract:

Our quantum computer consists of a chain of 171Yb+ ions with individual Raman beam addressing and individual readout. This fully connected system can be configured to run any sequence of single- and two-qubit gates, making it in effect an arbitrarily programmable digital quantum computer. The high degree of control can be used for digital, but also for analog and hybrid quantum simulations. We also add a classical optimization layer to our quantum stack to realize variational optimization methods allowing us to make thermofield double states, which provide thermal subsystems at arbitrary temperatures [1]. We use this capability for different studies with finite-temperature states,

such as mapping out partition functions in an XXZ spin-chain [2] and measuring the decay out-of-time-ordered correlators in an Ising model system [3]. Finally, we present a new pairwise-parallel entangling gate that effectively improves many characteristics of trapped ion quantum computers by up to a factor of two, lowering the physical errors for the above applications [4].

[1] Daiwei Zhu, Sonika Johri, Norbert M. Linke, Kevin A. Landsman, Nhung H. Nguyen, Cinthia Huerta Alderete, Anne Y. Matsuura, Timothy H. Hsieh, and Christopher Monroe, *Generation of thermofield double states and critical ground states with a quantum computer*, Proc. Natl. Acad. Sci. **117**, 25402-25406 (2020) [arXiv:1906.02699].
[2] Akhil Francis, Daiwei Zhu, Cinthia Huerta Alderete, Sonika Johri, Xiao Xiao, James K. Freericks, Christopher Monroe, Norbert M. Linke, and Alexander F. Kemper, *Many-body thermodynamics on quantum computers via partition function zeros*, Sci. Adv. **7**, eabf2447 (2021) [arXiv:2009.04648].
[3] Alaina M. Green, Andreas Elben, Cinthia Huerta Alderete, Lata Kh Joshi, Nhung H. Nguyen, Torsten V. Zache, Yingyue Zhu, Bhuvanesh Sundar, and Norbert M. Linke, *Experimental Measurement of Out-of-Time-Ordered Correlators at Finite Temperature*, Phys. Rev. Lett. **128**, 140601 (2022) [arXiv:2112.02068].
[4] Yingyue Zhu, Alaina M. Green, Nhung H. Nguyen, C. Huerta Alderete, Elijah Mossman, and Norbert M. Linke, *Pairwise-parallel entangling gates on orthogonal modes in a trapped-ion chain*, arXiv:2302.09145 (2023).

11:35-11:55	Contributed Talk	Tuesday 18 July 2023

Daniel Pijn (University of Mainz)

Probing Quantum Thermodynamics with Trapped-Ion Qubits

Abstract:

Trapped-ion qubits, offering high-fidelity gates and readout, are an ideal platform to realize conceptual studies in microscopic and quantum thermodynamics. We present two recently performed experiments harnessing the capabilities of such platforms. The concept of passivity has been conceived to set bounds on the evolution of microscopic systems initialized in thermal states. We experimentally demonstrate the utility of two frameworks, global passivity and passivity deformation, for the detection of coupling to a hidden environment. We employ a trapped-ion quantum processor, where system qubits undergoing unitary evolution may optionally be coupled to an unobserved environment qubit, resulting in a heat leak. Evaluating the measurement data from the system qubits only, we show that global passivity can verify the presence of a heat leak, which is not detectable by a microscopic equivalent of the second law of thermodynamics. Passivity deformation allows for even more sensitive detection of heat leaks, as compared to global passivity: we experimentally detect a heat leak with an error margin of 5.3 standard deviations, in a scenario where other tests fail. In another experiment, we implement a coherent work protocol for measuring a genuine quantum correction to the classical work fluctuation-dissipation relation (FDR). The results from a sequence of two-time work measurements display agreement with the recently proven quantum work FDR, violating the classical FDR by more than 10.9 standard deviations, certifying coherence in the protocol with large confidence. We show that the quantum correction vanishes in the high-temperature limit, again in agreement with theoretical predictions.

[1] Daniel Pijn, Oleksiy Onishchenko, Janine Hilder, Ulrich G. Poschinger, Ferdinand Schmidt-Kaler, and Raam Uzdin, *Detecting heat leaks with trapped ion qubits*, arXiv:2110.03277 (2021).
[2] Oleksiy Onishchenko, Giacomo Guarnieri, Pablo Rosillo-Rodes, Daniel Pijn, Janine Hilder, Ulrich G. Poschinger, Martí Perarnau-Llobet, Jens Eisert, and Ferdinand Schmidt-Kaler, *Probing coherent quantum thermodynamics using a trapped ion*, arXiv:2207.14325 (2022).

11:55-12:15	Contributed Talk	Tuesday 18 July 2023

Hiroyasu Tajima (University of Electro-Communications Tokyo)

Universal trade-off structure between symmetry, irreversibility and quantum coherence

Abstract:

Symmetry, irreversibility, and quantum coherence are foundational concepts in physics. Here, we establish a universal trade-off relation that builds a bridge between these three concepts. It reveals (1) under a global symmetry, any attempt to induce local dynamics that change the conserved quantity will cause inevitable irreversibility, and (2) such irreversibility could be mitigated by quantum coherence.

Our trade-off follows only from the unitarity and global symmetry of the total dynamics and restricts many types of irreversibility, including thermodynamic irreversibility. Therefore, this result has many applications. Applying the trade-off to the thermodynamic setup, we obtain a trade-off relation between coherence cost of an arbitrary quantum channel and its entropy production. Applying the trade-off to the Hayden-Preskill black hole model, we rigorously show that the rate of information escape from a black hole varies significantly with and without energy conservation. Our trade-off also unifies and extends various restrictions on quantum information processing imposed by symmetry, including the Wigner-Araki-Yanase theorems and the Eastin-Knill theorems.

[1] Hiroyasu Tajima, Ryuji Takagi, and Yui Kuramochi, *Universal trade-off structure between symmetry, irreversibility, and quantum coherence in quantum processes*, arXiv:2206.11086 (2022).
[2] Hiroyasu Tajima and Keiji Saito, *Universal limitation of quantum information recovery: symmetry versus coherence*, arXiv:2103.01876 (2021).

12:15-13:45	Lunch Break (self-organized)	Tuesday 18 July 2023

Session 7 **Chair:** Janet Anders (University of Exeter & University of Potsdam)

13:45-14:20	Invited Talk	Tuesday 18 July 2023

Iman Marvian (Duke University)

Energy-Conserving Quantum Circuits

Abstract:

Energy-conserving unitary transformations play a central role in quantum thermodynamics and related areas, such as quantum clocks. In this talk, I will explore the problem of implementing general energy-conserving unitaries within the framework of quantum circuits. Specifically, I will present methods for synthesizing quantum circuits that implement general energy-conserving unitary transformations on systems composed of an arbitrary number of non-interacting subsystems. These circuits only contain 2-local energy-conserving unitaries, i.e., unitaries that act on, at most, a pair of subsystems. To realize a general energy-conserving unitary in this way, the subsystems need to interact with an ancilla qubit. Additionally, I will discuss the complexity of implementing a general energy-conserving unitary within this framework. To illustrate these results, I will consider the case of qubit subsystems and 2-local energy-conserving unitaries that can be realized with XY interaction. Lastly, I will briefly discuss the extension of these findings to systems with other conserved charges.

14:20-14:40	Contributed Talk	Tuesday 18 July 2023

Fei Meng (City University of Hong Kong)

The nonequilibrium cost of accurate information processing

Abstract:

Accurate information processing is crucial both in technology and in nature. To achieve it, any information processing system needs an initial supply of resources away from thermal equilibrium. Here we establish a fundamental limit on the accuracy achievable with a given amount of nonequilibrium resources. The limit applies to arbitrary information processing tasks and arbitrary information processing systems subject to the laws of quantum mechanics. It is easily computable and is expressed in terms of an entropic quantity, which we name the reverse entropy, associated to a time reversal of the information processing task under consideration. The limit is achievable for all deterministic classical computations and for all their quantum extensions. As an application, we establish the optimal tradeoff between nonequilibrium and accuracy for the fundamental tasks of storing, transmitting, cloning, and erasing information. Our results set a target for the design of new devices approaching the ultimate efficiency limit and provide a framework for demonstrating thermodynamical advantages of quantum devices over their classical counterparts.

[1] Giulio Chiribella, Fei Meng, Renato Renner, and Man-Hong Yung, *The nonequilibrium cost of accurate information processing*, Nat. Commun. **13**, 7155 (2022) [arXiv:2203.09369].

14:40-15:00	Contributed Talk	Tuesday 18 July 2023

Salambô Dago (University of Vienna)

Thermodynamic of information: benefits and specificities of underdamped micro-systems for experimental demonstrations

Abstract:

The Landauer principle states that at least k_BT *ln*(2) of energy is required to erase a 1-bit memory, with k_BT the thermal energy of the system. Practical erasures implementations require an overhead to the Landauer's bound, observed to scale as k_BT B/τ, with τ the protocol duration and B close to the system relaxation time. Most experiments use overdamped systems, for which minimizing the overhead means minimizing the dissipation. Underdamped systems thus sounds appealing to reduce this energetic cost.

We study the effects of inertia on this bound using as one-bit memory an underdamped micro-mechanical oscillator confined in a double-well potential created by a feedback loop [3]. The potential barrier is precisely tunable in the few k_BT range. We measure, within the stochastic thermodynamic framework, the work and the heat of the erasure protocol. We demonstrate experimentally and theoretically that, in this underdamped system, the Landauer bound is reached with a 1% uncertainty, with protocols as short as 100 ms [2].

Besides, we show experimentally and theoretically that for such underdamped systems, fast erasures induce a heating of the memory: the work influx is not instantaneously compensated by the inefficient heat transfer to the thermostat. This temperature rise results in a kinetic and potential energy contribution superseding the viscous dissipation term. Our model covering all damping regimes paves the way to new optimization strategies in information processing, based on the thorough understanding of the energy exchanges [1].

Encouraged by the success of using an underdamped system to study stochastic thermodynamics, we are now using a FPGA (Field-Programmable Gate Arrays) to implement complex feedback operations. The resulting virtual potential can be shaped arbitrarily with high precision and can follow elaborate procedures. This tool opens a wide panel of possible future experiments (bit flip, optimal shortcuts to adiabaticity, engines, etc.).

[1] Salambô Dago and Ludovic Bellon, *Dynamics of Information Erasure and Extension of Landauer's Bound to Fast Processes*, Phys. Rev. Lett. **128**, 070604 (2022) [arXiv:2105.12023].
[2] Salambô Dago, Jorge Pereda, Nicolas Barros, Sergio Ciliberto, and Ludovic Bellon, *Information and Thermodynamics: Fast and Precise Approach to Landauer's Bound in an Underdamped Micromechanical Oscillator*, Phys. Rev. Lett. **126**, 170601, (2021) [arXiv:2102.09925].
[3] Salambô Dago, Jorge Pereda, Sergio Ciliberto, and Ludovic Bellon, *Virtual double-well potential for an underdamped oscillator created by a feedback loop*, J. Stat. Mech. **2022**, 053209 (2022) [arXiv:2201.09870].

15:00-15:45	Coffee Break	Tuesday 18 July 2023

Session 8

Chair: Karen Hovhannisyan (University of Potsdam)

15:45-16:20	Invited Talk	Tuesday 18 July 2023

Naoto Shiraishi (University of Tokyo)

The problem of thermalization in isolated quantum many-body systems

Abstract:

Understanding the process of thermalization in isolated macroscopic systems is a fundamental pursuit in the field of quantum thermodynamics. While thermalization is commonly observed in most many-body systems, the presence or absence of this phenomenon remains a central subject of investigation, since some systems including integrable systems do not thermalize.

The eigenstate thermalization hypothesis (ETH) has been proposed as a potential explanation for thermalization. According to ETH, all energy eigenstates of the system's Hamiltonian possess thermal properties, i.e., indistinguishable from the equilibrium state. The ETH implies thermalization, and numerical simulations show that various non-integrable thermalizing systems satisfy the ETH. Consequently, it has been widely speculated that the ETH determines the thermalization.

In the first part of our presentation, contrary to these expectations, we present a general method for constructing non-integrable systems that violate the ETH while still exhibiting thermalization [1,2]. This discovery refutes the previously held belief that ETH is the sole determinant of thermalization. Our method constructing such anomalous systems is now understood as a general framework for systems with quantum many-body scars.

In the second part of our presentation, we examine the hardness of the problem of thermalization from the viewpoint of computation theory. Specifically, we investigate the problem whether an initial state thermalizes under a given Hamiltonian with respect to a specific observable. Surprisingly, we establish that this problem is undecidable [3]. Remarkably, even when we restrict Hamiltonians to one-dimensional, shift-invariant, and nearest-neighbor interactions, observables to shift-sums of one-body observables, and initial states to product states, the problem remains undecidable. This

result suggests that we never find a universal criterion for thermalization, at least in its most general form.

[1] Naoto Shiraishi and Takashi Mori, *Systematic Construction of Counterexamples to the Eigenstate Thermalization Hypothesis*, Phys. Rev. Lett. **119**, 030601 (2017) [arXiv:1702.08227].
[2] Takashi Mori and Naoto Shiraishi, *Thermalization without eigenstate thermalization hypothesis after a quantum quench*, Phys. Rev. E **96**, 022153 (2017) [arXiv:1707.05921].
[3] Naoto Shiraishi and Keiji Matsumoto, *Undecidability in quantum thermalization*, Nat. Commun. **12**, 5084 (2021) [arXiv:2012.13889].

16:20-16:40	Contributed Talk	Tuesday 18 July 2023

Irene D'Amico (University of York)

Experimental Correlation-Boosted Quantum Engine

Abstract:

Quantum thermodynamics has rapidly become an arena to test and debate fundamental concepts such as the laws of thermodynamics and the related fluctuation theorems at the quantum scale. In this context, quantum features can be considered as extra resources. Through the design and experimental implementation of a two-qubit thermal machine, here, we demonstrate that the use of quantum correlations as an extra resource can indeed lead to a generalized second law of thermodynamics encompassing regimes with efficiency larger than the standard Carnot limit. The boosted efficiency arises from a trade-off between the entropy production and the consumption of quantum correlations during the full thermodynamic cycle. As an added bonus, quantum correlations increase the amount of extractable work, as well as extend the parameter region corresponding to useful work extraction for the proposed cycle. We experimentally demonstrate the engine efficiency enhancement by tailoring the qubits effective energy gap and temperature, using an IBM quantum processor.

[1] Marcela Herrera, John H. Reina, Irene D'Amico, and Roberto M. Serra, *Experimental Correlation-Boosted Quantum Engine*, arXiv:2211.11449 (2022).

16:40-17:00	Contributed Talk	Tuesday 18 July 2023

Martí Perarnau-Llobet (University of Geneva)

Three different perspectives on Landauer principle with finite resources

Abstract:

Landauer´s principle states that a minimum amount of dissipation is required to erase one bit of information. Reaching this bound in practice requires infinite resources (either infinite time or infinite energy), a fact that is intimately connected to the second and third laws of thermodynamics. In the presence of finite resources, it becomes a challenging problem to identify optimal erasure processes that minimize the generation of dissipation. In this talk, I will present progress in this question based on a geometric approach to finite-time thermodynamics. I will focus on three different but interconnected directions:

(i) A recent experimental implementation of information erasure in a driven single-energy quantum dot where dissipation is minimized by following a geodesic protocol [1].

(ii) A theoretical analysis of optimal finite-time erasure protocols for a qubit strongly coupled to a fermionic bath, where both the qubit-energy and the system-bath coupling can be externally controlled [2].

(iii) A characterization of minimally dissipative erasure protocols for a qubit coupled to a finite-size baths with arbitrary external control, i.e., arbitrary unitary operations on system and bath [3].

These three complementary approaches lead to corrections to Landauer bound in the presence of finite resources, when assuming an increasing level of external control.

[1] Matteo Scandi, David Barker, Sebastian Lehmann, Kimberly A. Dick, Ville F. Maisi, and Martí Perarnau-Llobet, *Minimally Dissipative Information Erasure in a Quantum Dot via Thermodynamic Length*, Phys. Rev. Lett. **129**, 270601 (2022) [arxiv:2209.01852].
[2] Alberto Rolandi and Martí Perarnau-Llobet, *Finite-time Landauer principle beyond weak coupling*, arXiv:2211.02065 (2022).
[3] Martí Perarnau-Llobet and Patryk Lipka-Bartosik, in preparation (2023).

17:00-18:00	Break	Tuesday 18 July 2023

18:00-21:00	Poster Session (TU Wien Festsaal)	Tuesday 18 July 2023

WEDNESDAY 19 July 2023

Session 9 **Chair:** Ralph Silva (ETH Zürich)

9:00-9:35	Invited Talk	Wednesday 19 July 2023

Simone Gasparinetti (Chalmers University of Technology, Gothenburg)

Autonomous, thermally driven reset of a superconducting qubit based on a quantum absorption refrigerator

Abstract:

Absorption refrigerators are autonomous machines that utilize the natural flow of heat across a thermal gradient to cool objects. Here, we implement a quantum absorption refrigerator based on superconducting circuits and demonstrate its use to autonomously reset the state of a transmon qubit below its residual thermal occupation. The refrigerator is fueled by an engineered four-wave-mixing interaction between the target qubit and two auxiliary qubits coupled to thermal baths. The baths are realized as microwave waveguides populated with a synthesized thermal occupation. Our proof-of-concept refrigerator shows that quantum thermal machines can be seamlessly integrated with quantum processing units to perform useful tasks. It also initiates a path to experimental studies of quantum thermodynamics using superconducting quantum circuits coupled to propagating thermal microwave fields.

9:35-09:55	Contributed Talk	Wednesday 19 July 2023

Oisín Culhane (Trinity College Dublin)

Powering an autonomous clock with quantum electromechanics

Abstract:

The miniaturisation of technology and the drive to discover quantum enhancements have prompted the exploration of the fundamental cost of timekeeping. Recent works have demonstrated the use of electromechanical systems to explore the thermodynamic cost of timekeeping. This work addresses the cost of timekeeping by using a nano electromechanical system (NEMS) model as an autonomous clock powered by a chemical bias. The output current is measured to generate ticks on a clock. We solve this model in the quasi-adiabatic limit, which allows us to calculate current trajectories and current correlation functions. We show that self-sustained oscillations seen in this system improve the clock's accuracy via the noise spectrum and the Allan variance.

09:55-10:15	Contributed Talk	Wednesday 19 July 2023

Michael Kewming (Trinity College Dublin)

Quantum clock precision studied with a superconducting circuit

Abstract:

In this talk, I will detail how we both theoretically and experimentally study the precision of a quantum clock near zero temperature, explicitly accounting for the effect of continuous measurement. The clock is created by a superconducting transmon qubit dispersively coupled to an open co-planar resonator. The cavity and qubit are driven by coherent fields, and the cavity output is

monitored with a quantum noise-limited amplifier. When the continuous measurement is weak, it induces persistent coherent oscillations (with fluctuating periods) in the conditional moments of the qubit, which are manifest in the output of the resonator. On the other hand, strong continuous measurement leads to an incoherent cycle of quantum jumps. In each regime, we find an equality for the precision of the clock by deriving approximate equations of motion. Furthermore, using these results, we derive and verify a kinetic uncertainty relation for the precision of the clock, thus making an explicit link between the (kinetic) thermodynamic behaviour of the clock and it's precision. Both theory and experiment show enhanced precision in the oscillatory regime over the jump regime, suggesting that in certain situations, quantum coherence may provide a fundamental advantage for timekeeping.

[1] Xin He, Prasanna Pakkiam, Adil A. Gangat, Michael J. Kewming, Gerard J. Milburn, and Arkady Fedorov, *Quantum clock precision studied with a superconducting circuit*, arXiv:2207.11043 (2022).

10:15-11:00	Coffee Break	Wednesday 19 July 2023

Session 10 **Chair:** Benjamin Yadin (University of Siegen)

11:00-11:35	Invited Talk	Wednesday 19 July 2023

Rosa López (University of the Balearic Islands)

The significance of quantum effects in optimizing engine performances

Abstract:

Optimizing engine performances through quantum effects is a critical aspect of quantum technologies. Achieving high efficiency for specific tasks while maintaining stability and minimizing signal fluctuations is paramount. Quantum systems provide a promising avenue to surpass well-known thermodynamic and kinetic uncertainty relations, enabling the generation of highly precise currents without incurring excessive entropy production.

In this study, we investigate the implications of quantum effects on engine performances, focusing on multiterminal quantum conductors. By deriving the aforementioned relations, we demonstrate their importance in the case of a double quantum dot system. This system exhibits a quantum nature through the emergence of Andreev electron-hole processes due to the coupling with a superconducting contact, representing a purely quantum phenomenon.

Furthermore, we explore the behavior of a single quantum dot in the presence of Andreev processes. Our findings reveal significant deviations from both the thermodynamic and kinetic uncertainty relations. These deviations highlight the unique capabilities of quantum systems in achieving enhanced engine performances beyond classical limits.

Our work highlights the importance of quantum effects in optimizing engine performances within the realm of quantum technologies. By surpassing traditional uncertainty relations, quantum systems offer the potential for precise and efficient current generation, while minimizing entropy production. The investigation of multiterminal quantum conductors and the examination of Andreev processes in quantum dots provide valuable insights into the capabilities of quantum engines.

11:35-11:55	Contributed Talk	Wednesday 19 July 2023

Marek Gluza (Nanyang Technological University)

Mechanisms for the emergence of Gaussian correlations

Abstract:

We comprehensively investigate two distinct mechanisms leading to memory loss of non-Gaussian correlations after switching off the interactions in an isolated quantum system undergoing out-of-equilibrium dynamics. The first mechanism is based on spatial scrambling and results in the emergence of locally Gaussian steady states in large systems evolving over long times. The second mechanism, characterized as `canonical transmutation', is based on the mixing of a pair of canonically conjugate fields, one of which initially exhibits non-Gaussian fluctuations while the other is Gaussian and dominates the dynamics, resulting in the emergence of relative Gaussianity even at finite system sizes and times. We evaluate signatures of the occurrence of the two candidate mechanisms in a recent experiment that has observed Gaussification in an atom-chip controlled ultracold gas and elucidate evidence that it is canonical transmutation rather than spatial scrambling that is responsible for Gaussification in the experiment. Both mechanisms are shown to share the common feature that the Gaussian correlations revealed dynamically by the quench are already present though practically inaccessible at the initial time. On the way, we present novel observations based on the experimental data, demonstrating clustering of equilibrium correlations, analyzing the dynamics of full counting statistics, and utilizing tomographic reconstructions of quantum field states. Our work aims at providing an accessible presentation of the potential of atom-chip experiments to explore fundamental aspects of quantum field theories in quantum simulations.

[1] Marek Gluza, Thomas Schweigler, Mohammadamin Tajik, João Sabino, Federica Cataldini, Frederik S. Møller, Si-Cong Ji, Bernhard Rauer, Jörg Schmiedmayer, Jens Eisert, Spyros Sotiriadis, *Mechanisms for the emergence of Gaussian correlations*, SciPost Phys. **12**, 113 (2022) [arXiv:2108.07829].

11:55-12:15	Contributed Talk	Wednesday 19 July 2023

Yi-Zheng Zhen (University of Science and Technology of China)

Finite-Time Landauer Principle for Bit Reset

Abstract:

We consider how the energy cost of bit reset scales with the time duration of the protocol. Bit reset necessarily takes place in finite time, where there is an extra penalty on top of the quasistatic work cost derived by Landauer. This extra energy is dissipated as heat in the computer, inducing a fundamental limit on the speed of irreversible computers. We formulate a hardware-independent expression for this limit in the framework of stochastic processes. We derive a closed-form lower bound on the work penalty as a function of the time taken for the protocol and bit reset error. It holds for discrete as well as continuous systems, assuming only that the master equation respects detailed balance.

[1] Yi-Zheng Zhen, Dario Egloff, Kavan Modi, and Oscar Dahlsten, *Universal Bound on Energy Cost of Bit Reset in Finite Time*, Phys. Rev. Lett. **127**, 190602 (2021) [arXiv:2106.00580].

12:15	Lunch Break (self-organized)	Wednesday 19 July 2023

Free afternoon self-organized

19:00-22:00	Conference Dinner Heuriger Schübel-Auer Kahlenberger Str. 22, 1190 Wien	Wednesday 19 July 2023

THURSDAY 20 July 2023

Session 11 **Chair:** M. Hamed Mohammady (Université Libre de Bruxelles)

9:00-9:35	Invited Talk	Thursday 20 July 2023

Obinna Abah (Newcastle University)

Energetic cost of controlling multipartite quantum systems

Abstract:

The understanding of energy cost of manipulation of quantum systems is crucial for engineering efficient quantum thermodynamic devices beyond the standard Markovian limit. We study the amount of energy required to control the evolution dynamic of any dissipative quantum cascaded. As a consequence, the amount of work done by the controller is influenced by the back flow of information from the environment. In addition, we discuss the minimum power consumption of controlled quantum devices bound imposed by the quantum speed limit.

9:35-09:55	Contributed Talk	Thursday 20 July 2023

Artur Widera (University of Kaiserslautern)

Indication of a phase transition in time during the relaxation of an open quantum system

Abstract:

Control over individual quantum systems allows studying nonequilibrium dynamics of quantum systems at an unprecedented level. We here investigate the relaxation of individual laser-cooled Cs atoms immersed in an ultracold gas. Inelastic spin-exchange interactions couple the highly-excited impurity to the bath, linking the exchange of angular momentum in a collision to a well-known quantum of thermal energy. This mechanism has enabled the formation of a single-atom quantum probe specifically sensitive during the relaxation dynamics. Furthermore, closely investigating the spin-population dynamics, we find that a large range of initial states comes close to the state of maximum entropy and subsequently follows universal dynamics. Numerically extending the size of the system, we find that the spin population indeed becomes fully delocalized at a critical time, and finite-size scaling yields a critical exponent independent of the details of the initial state. We interpret these observations as an indication of an open-system phase transition in time for sufficiently excited states.

[1] Ling-Na Wu, Jens Nettersheim, Julian Feß, Alexander Schnell, Sabrina Burgardt, Silvia Hiebel, Daniel Adam, André Eckardt, and Artur Widera, *Dynamical phase transition in an open quantum system*, arXiv:2208.05164 (2022).

09:55-10:15	Contributed Talk	Thursday 20 July 2023

Ariane Soret (University of Luxembourg)

Thermodynamic consistency of driven quantum optical master equations

Abstract:

The search for quantum signatures in thermodynamic quantities is a widespread thread in quantum thermodynamics. In quantum optics, coherent energy exchanges occur in the so-called coherent

regime of driving, where a strong, time-dependent field drives near resonant transitions in a quantum system, leading to the Rabi oscillations. In the additional presence of a thermal bath, the evolution of the quantum system is well described by the optical Bloch or Floquet master equations, depending on the strength of the driving. Such coherent energy exchanges play a central role in quantum technologies, which has motivated recent work on the consistency of the Bloch and Floquet master equations at the average level [1] and in the steady state [2].

Here, we study the thermodynamic consistency of quantum optical master equations at the fluctuating level. We consider a two level system, or qubit, coupled to a driving mode and to thermal baths. Studying the statistics of the work performed on the qubit is particularly difficult when the driving is treated semiclassically: in this approach, the number of photons in the driving field is assumed to be constant, but microscopically, the energy changes induced by the bath are associated to a variation of the number of driving photons. We overcome this difficulty by starting from a microscopic description of the driving field.

Using the two-point measurement method with counting fields, we derive a general master equation for the joint qubit and driving mode system. In a previous work [3], we showed that, for a quantum system coupled to thermal baths, a fully thermodynamically consistent master equation (i.e., an equation satisfying the first and second laws of thermodynamics at the fluctuating level) could only be obtained by applying the secular approximation, making it impossible to study coherent energy exchanges in the steady state. Here, we generalize this result to the case where the system is coupled not only to thermals baths, but also to photonic modes in coherent states, which behave like work sources. We derive a new fluctuation theorem, valid at all times, and show that the coupling with coherent states allows to derive fully consistent master equations with coherences in the steady state.

We then focus on the Bloch and Floquet master equations, which are deduced from the general master equation by tracing out the driving field and performing additional approximations. We find that the Floquet master equation is fully consistent, while the Bloch equation is only consistent at the average level. We conclude with a discussion of the thermodynamic signatures in the first law for both these equations.

[1] Cyril Elouard, David Herrera-Martí, Massimiliano Esposito, and Alexia Auffèves, *Thermodynamics of optical Bloch equations*, New J. Phys. **22**, 103039 (2020) [arXiv:2001.08033].
[2] Gregory Bulnes Cuetara, Andreas Engel, and Massimiliano Esposito, *Stochastic thermodynamics of rapidly driven systems*, New J. Phys. **17**, 055002 (2015) [arXiv:1412.0283].
[3] Ariane Soret, Vasco Cavina, and Massimiliano Esposito, *Thermodynamic consistency of quantum master equations*, Phys. Rev. A **106**, 062209 (2022) [arXiv:2207.05719].

10:15-11:00	Coffee Break	Thursday 20 July 2023

Session 12 **Chair:** Patrick Potts (University of Basel)

11:00-11:35	Invited Talk	Thursday 20 July 2023

Olivier Maillet (CEA Paris-Saclay)

Thermodynamic probe of the insulating regime of a Josephson junction

Abstract:

The Josephson junction is a building block of superconducting quantum circuits. Its behavior, well understood when treated as an isolated entity, is strongly affected by coupling to an electromagnetic environment.

In the 80s it was predicted that a Josephson junction shunted by a resistance exceeding the resistance quantum RQ = h/4e2 ≈ 6.45 kΩ for Cooper pairs would become insulating since phase fluctuations would destroy the coherent Josephson coupling. Although charge transport experiments had seemingly supported this prediction, recent microwave measurements have questioned this interpretation.

Here, we insert a small junction in a Johnson-Nyquist type setup, where it is driven by weak current noise arising from thermal fluctuations of the environment. Our heat probe minimally perturbs the junction's equilibrium, shedding light on features not visible in charge transport. In a test DC charge transport measurement, the junction demonstrates dissipative behaviour, in agreement with theory. Unexpectedly, however, thermal transport measurements, which cover a range up to the thermal frequency kT/h, show that the Josephson junction acts as an inductor at high frequencies, unambiguously demonstrating a superconducting character. We discuss possible causes of this discrepancy.

11:35-11:55	Contributed Talk	Thursday 20 July 2023

Ludovico Tesser (Chalmers University of Technology, Gothenburg)

Quantum thermodynamics for future solar cells

Abstract:

Proposals for future solar cells (sometimes called 3rd generation photovoltaics) raise interesting questions in quantum thermodynamics. It is likely that answering these questions will be necessary for them to full achieve their potential.

One long-standing hope has been "hot-carrier solar cells", with recent break-through experiments in the team of Heiner Linke (Lund). There the aim is to extract charge carriers (electrons and holes) that have been excited by solar photons (at about 6000 Kelvin), before they relax to thermal equilibrium with their environment (at about 300 Kelvin). This extracts it with much more kinetic energy, this means more energy should be available to convert to useful work.

The quantum thermodynamics model of this solar cell requires multiple reservoirs at different temperatures (photonic reservoirs at 6000K and 300K, one phonon reservoirs at 300K and two reservoirs of charge carriers at 300K). The result is a highly non-equilibrium steady-state for the carriers in the solar-cell. This can be analysed in terms of non-equilibrium free-energies, which shows that one can extract more work than from an equivalent equilibrium distribution (similar to our earlier work on N-demons). One must also ask how to practically extract the maximum amount of work from this no-equilibrium distribution. For this, I present a simple analysis of such a hot-carrier solar cell, which gives first answers to these questions.

[1] Ludovico Tesser, Robert S. Whitney, and Janine Splettstoesser, *Thermodynamic Performance of Hot-Carrier Solar Cells: A Quantum Transport Model*, Phys. Rev. Applied **19**, 044038 (2023) [arXiv:2209.09524].

11:55-12:15	Contributed Talk	Thursday 20 July 2023

Rafael Sánchez (Universidad Autónoma de Madrid)

Interaction induced nonlocal thermoelectric response with quantum Hall edge states

Abstract:

The multiterminal nature of the quantum Hall effect facilitates the design of nonlocal heat engines [1,2]. Electrons propagating along the edges of the system can be selectively put in contact with various thermal reservoirs and their response be measured as a thermoelectric current between another two terminals. Configurations with two edge channels can be used to separate the thermoelectric effect: one of them is coupled to the heat source and the other one to the thermoelectric device. Only when the two channels are put in contact for a finite distance, a response is expected. This way, the Coulomb interaction serves as the mediator of heat exchange and, reversely, the nonlocal Seebeck response gives a measure of the interaction between channels. We propose a three-terminal setup with a quantum dot that allows for both serving as an efficient heat to current generator and for detecting the nonequilibrium distribution resulting from the interacting region. We furthermore emphasize the effect of cross-correlations in a complementary configuration.

[1] Rafael Sánchez, Björn Sothmann, and Andrew N. Jordan, *Chiral Thermoelectrics with Quantum Hall Edge States*, Phys. Rev. Lett. **114**, 146801 (2015) [arXiv:1410.6639].
[2] Rafael Sánchez, Janine Splettstoesser, and Robert S. Whitney, *Nonequilibrium System as a Demon*, Phys. Rev. Lett. **123**, 216801 (2019) [arXiv:1811.02453].

12:20-12:35	Contributed Talk	Thursday 20 July 2023

Ilia Khomchenko (Skolkovo Institute of Science and Technology)

Voltage-amplified heat rectification in SIS junctions

Abstract:

Thermal diodes, also known as heat rectifiers, can control the magnitude and direction of thermal fluxes in mesoscopic and nanoscopic electronic systems [1-3]. To characterise the performance of these devices, the rectification coefficient R was introduced, defined as the ratio of forward and backward heat currents [4-5]. This metric depends on the design of the diode and the working conditions under which the system operates. There are two desired values for the rectification coefficient: either $R \ll 1$ or $R \gg 1$, which means high rectification performance. Although the current solutions for achieving such ranges are quite cumbersome [6], the given work presents a simple solution to this problem. In a nutshell, a superconductor-insulator-superconductor (SIS) junction under an applied rapid oscillating (THz range) voltage is used to control the heat flow direction and magnitude by tuning the initial value of the superconducting phase. A possible steep increase of the heat rectification coefficient with values up to $R \approx 500$ beyond the adiabatic regime is demonstrated in the developed model, based on the coherent-transport formalism and Green´s function formalism. Coherent effects play an essential role in heat rectification in the SIS junction that is pointed out in the current work [7].

[1] Antonio Fornieri, María José Martínez-Pérez, and Francesco Giazotto, *A normal metal tunnel-junction heat diode*, Appl. Phys. Lett. **104**, 183108 (2014) [arXiv:1404.2834].
[2] Giampiero Marchegiani, Alessandro Braggio, and Francesco Giazotto, *Highly efficient phase-tunable photonic thermal diode*, Appl. Phys. Lett. **118**, 022602 (2021) [arXiv:2011.02777].
[3} Jorden Senior, Azat Gubaydullin, Bayan Karimi, Joonas T. Peltonen, Joachim Ankerhold, and Jukka P. Pekola, *Heat rectification via a superconducting artificial atom*, Commun. Phys. **3**, 40 (2020) [arXiv:1908.05574].
[4] Maria Jose Martínez-Pérez and Francesco Giazotto, *Efficient phase-tunable Josephson thermal rectifier*, Appl. Phys. Lett. **102**, 182602 (2013) [arXiv:1304.3672].

[5] Maria Jose Martínez-Pérez, Paolo Solinas, and Francesco Giazotto, *Coherent Caloritronics in Josephson-Based Nanocircuits*, J. Low Temp. Phys. **175**, 813 (2014) [arXiv:1311.4470].
[6] Maria Jose Martínez-Pérez, Antonio Fornieri, and Francesco Giazotto, *Rectification of electronic heat current by a hybrid thermal diode*, Nat. Nanotechnol. **10**, 303 (2015) [arXiv:1403.3052].
[7] Ilia Khomchenko, Henni Ouerdane, and Giuliano Benenti, *Voltage-amplified heat rectification in SIS junctions*, Phys. Rev. B **106**, 245413 (2022) [arXiv:2206.10600].

12:35-14:05	Lunch Break (self-organized)	Thursday 20 July 2023

Session 13 **Chair:** Mohammad Mehboudi (TU Wien)

14:05-14:25	Contributed Talk	Thursday 20 July 2023

Julia Boeyens (University of Siegen)

Probe thermometry with continuous measurements

Abstract:

Accurate thermometry is essential to the control of quantum systems. A well studied approach is to prepare a probe and allow it to interact with a thermal environment of unknown temperature for a fixed time before being measured. However, in some experimentally relevant settings, it is more practical to allow the probe to interact continuously with the environment. Here, we study such a dynamical thermometer. Our minimal model consists of a two-level probe coupled to the thermal environment under investigation. The rate at which transitions between the levels occur provides information about the temperature. We discuss adaptive and non-adaptive strategies in which the gap of the probe is tuned to improve the sensitivity of the thermometer. In particular, we evaluate the Fisher information for the trajectories of the probe and optimise according to this. We apply the Bayesian approach to estimation as it is particularly suited to adaptive estimation schemes. Finally, we investigate the performance of the thermometer when the measurements made are subject to noise. This lays the foundation for experimentally realised adaptive thermometry in real time.

14:25-14:45	Contributed Talk	Thursday 20 July 2023

Sindre Brattegard (Trinity College Dublin)

Thermometry by correlated dephasing of impurities in a 1D Fermi gas

Abstract:

Accurately measuring the temperature of ultracold gases without obliterating the state of the gas is both a challenging and important task. This holds true, in particular, for fermionic gases where the Pauli principle makes precise temperature measurement using time of flight measurements even more difficult. Motivated by recent advances in experimental techniques in ultracold atoms, in this work we show how we can extract temperature information from the non-equilibrium dynamics of impurity probes embedded in a 1D fermionic gas. In particular, we consider pure dephasing of impurity qubits. This has already proved to be a useful approach for thermometry in the case of a single impurity [1] and has also been studied experimentally [2]. We investigate how bath induced interactions from the impurities shared environment affect the dynamics of the impurities and the precision of our impurity thermometer. We find that bath-induced correlations can boost thermometric precision, especially at low temperatures. However, we also show that modelling these correlations is not crucial for capturing the impurity dynamics in most cases. Our results will help to simplify the implementation of impurity-based thermometry for ultracold fermions.

[1] Mark T. Mitchison, Thomás Fogarty, Giacomo Guarnieri, Steve Campbell, Thomas Busch, and John Goold, *In Situ Thermometry of a Cold Fermi Gas via Dephasing Impurities*, Phys. Rev. Lett. **125**, 080402 (2020) [arXiv:2004.02911].
[2] Daniel Adam, Quentin Bouton, Jens Nettersheim, Sabrina Burgardt, and Artur Widera, *Coherent and Dephasing Spectroscopy for Single-Impurity Probing of an Ultracold Bath*, Phys. Rev. Lett. **129**, 120404 (2022) [arXiv:2105.03331].

14:45-15:05	Contributed Talk	Thursday 20 July 2023

Maximilian Prüfer (TU Wien)

Information extraction from quantum many-body systems

Abstract:

The key ingredient for understanding many-body systems when performing quantum simulations is an efficient readout of the available information. In quantum systems every extraction of information implies a backaction altering the system’s state. Here, we present the first steps towards new quantum-limited probes for many-body quantum systems. For our experimental studies we use one-dimensional Bose-Einstein condensates on an atom chip combined with spatially resolved measurements. To implement weak probes, we employ radiofrequency magnetic fields for outcoupling a controllable number of atoms which we detect with near unit efficiency. We present first experimental results concerning the simultaneous readout of number imbalance and phase in a bosonic Josephson junction to study mean-field dynamics as well as quantum correlations. Our setup allows us to directly measure the measurement backaction and thus potentially enables studying the thermodynamic cost of measurements in many-body systems.

15:05-15:50	Coffee Break	Thursday 20 July 2023

Session 14

Chair: Pharnam Bakhshinezhad (TU Wien)

15:50-16:10	Contributed Talk	Thursday 20 July 2023

Marcin Łobejko (University of Gdansk)

The Second Law in quantum thermodynamics – from symmetry to generic quantum batteries and non-thermal resources

Abstract:

A generalization of the free energy for non-equilibrium quantum states gives rise to plenty of results in the field of quantum thermodynamics. In this context, I will share research on the Second Law with work explicitly defined by an energy-storage device (a battery) published in a series of papers [1-4]. The main results interconnect the free energy and ergotropy with a proper definition of the thermodynamic work. Starting with a battery given by the so-called quantum weight (i.e., obeying a translational symmetry), we generalize the free energy to the ergotropy of the system with explicit corrections coming from quantum coherences [1] and non-classical states of the weight [2]. However, one of the most general principles of physics, i.e., the Second Law, cannot depend on exceptional symmetry. This motivates us to put theoretical grounds for a commonly accepted idea

that a generic quantum battery should be characterized by its ergotropy. We have revealed that the upper limit of ergotropy extraction from a thermal reservoir is again related to free energy, which consequently formulates the general Second Law [3]. Moreover, we rediscovered the same concept by extending the work extraction process to more general protocols given by a sequence of repeated interactions [4]. In this case, we have shown an interesting characterization of processes that lead to an indefinite increase of the battery's ergotropy (a transient process) and the ones that saturate to passive states (a recurrent process). As previously, those different processes are discriminated by the passivity (activity) of the resource used to charge the battery. In particular, this dynamical model with repeated interactions generalizes the idea of a heat reservoir (a thermal Gibbs state) to more general passive states.

[1] Marcin Łobejko, *The tight second law inequality for coherent quantum systems and finite-size heat baths*, Nat. Commun. **12**, 918 (2021) [arXiv:2008.05278].
[2] Marcin Łobejko, *Work and Fluctuations: Coherent vs. Incoherent Ergotropy Extraction*, Quantum **6**, 762 (2022) [arXiv:2111.03116].
[3] Tanmoy Biswas, Marcin Łobejko, Paweł Mazurek, Konrad Jałowiecki, Michał Horodecki, *Extraction of ergotropy: free energy bound and application to open cycle engines*, Quantum **6**, 841 (2022) [arXiv:2205.06455].
[4] Marcin Łobejko, Paweł Mazurek, and Michał Horodecki, *The asymptotic emergence of the Second Law for a repeated charging process*, arXiv:2209.05339 (2022).

16:10-16:30	Contributed Talk	Thursday 20 July 2023

Cyril Elouard (Université de Lorraine)

Extending the laws of thermodynamics for arbitrary autonomous quantum systems

Abstract:

Recent formulations of the law of thermodynamics encompass the case of single quantum systems coupled to macroscopic energy source. The latter are generally treated either as ideal work sources (appearing via a time-dependent Hamiltonian) or assumed to be pure heat sources when starting in equilibrium. In contrast, implementations multiple examples of hybrid non work and heat sources. One can also wonder to which extent one can formulate constraints about the energy exchanges between arbitrary quantum systems, under the form of the laws of thermodynamics. We address these questions by considering any quantum system as a hybrid source of work and heat. Based on the systems' entropy, we identify an effective temperature and the fraction of its energy which is of thermal nature. We show that the variation of this thermal energy plays the same role as heat in a formulation of the second law valid for a set of quantum systems, initially each in an arbitrary quantum state. On the other hand, non-thermal energy is shown to be a resource, which when consumed is equivalent to work, e.g., to decrease entropy or reverse the direction of heat flows. We use these notions to recover known limits of quantum thermodynamics, but also to explore nanoscale quantum machines where even the energy sources can be single quantum systems. Our results open perspectives to understand and optimize the energetic performances of autonomous quantum setups, from quantum batteries to in-situ refrigerators.

[1] Cyril Elouard, Camille Lombard Latune, *Extending the laws of thermodynamics for arbitrary autonomous quantum systems*, arXiv:2207.04850 (2022).

16:30-17:30	Panel Discussion	Thursday 20 July 2023

FRIDAY 21 July 2023

Session 15 **Chair:** Gabriel T. Landi (University of Rochester)

9:00-9:35	Invited Talk	FRIDAY 21 July 2023

Tan Vu (RIKEN, Tokyo)

Geometric characterization for cyclic heat engines far from equilibrium

Abstract:

Novel insights into the performance of microscopic heat engines have been obtained through the lens of information geometry. Despite the importance of geometric characterization for heat engines, previous studies on engine cycles have been limited to the near equilibrium regime. Therefore, it is reasonable to ask whether geometric characterizations exist in the nonequilibrium regime and, if so, how heat engines can be physically characterized.

In this talk, we address this open question by exploring the relationship between the geometric length along the path of cyclic heat engines operating at arbitrary speeds and their power and efficiency. We reveal that the power of a heat engine is always upper bounded by the product of its geometric length and the statistics of energy. This finding implies that increasing both the energy gap and the energy fluctuation is necessary for achieving high power output. Moreover, we establish a trade-off relation between power and efficiency using the geometric length and the timescale of the heat engine. We show that the product of power and the difference between efficiency and Carnot efficiency cannot be arbitrarily small if the geometric length and timescale of heat engines are predetermined. These results provide a comprehensive framework for the performance of cyclic heat engines and are universally applicable to both classical and quantum heat engines driven far from equilibrium.

9:35-09:55	Contributed Talk	Friday 21 July 2023

Parvinder Solanki (IIT Bombay)

Seeding Crystallization in Time

Abstract:

We introduce the concept of seeding of crystallization in time by studying the dynamics of an ensemble of coupled continuous time crystals. We demonstrate that a single subsystem in a broken-symmetry phase acting as a nucleation center may induce time-translation symmetry breaking across the entire ensemble. Seeding is observed for both coherent and dissipative coupling, as well as for a broad range of parameter regimes. In the spirit of mutual synchronization, we investigate the parameter regime where all subsystems are in the broken-symmetry phase. We observe that more broadly detuned time crystals require weaker coupling strength to be synchronized. This is in contrast to basic knowledge from classical as well as quantum synchronization theory. We show that this surprising observation is a direct consequence of the seeding effect.

[1] Michal Hajdušek, Parvinder Solanki, Rosario Fazio, and Sai Vinjanampathy, *Seeding Crystallization in Time*, Phys. Rev. Lett. **128**, 080603 (2022) [arXiv:2111.04395].

09:55-10:15	Contributed Talk	Friday 21 July 2023

Mohammadamin Tajik (TU Wien)

Experimental observation of curved light-cones in a quantum field simulator

Abstract:

We investigate signal propagation in a quantum field simulator of the Klein-Gordon model realized by two strongly coupled parallel one-dimensional quasi-condensates. By measuring local phononic fields after a quench, we observe the propagation of correlations along sharp light-cone fronts. If the local atomic density is inhomogeneous, these propagation fronts are curved. For sharp edges, the propagation fronts are reflected at the system's boundaries. By extracting the space-dependent variation of the front velocity from the data, we find agreement with theoretical predictions based on curved geodesics of an inhomogeneous metric. This work extends the range of quantum simulations of non-equilibrium field dynamics in general spacetime metrics.

[1] Mohammadamin Tajik, Marek Gluza, Nicolas Sebe, Philipp Schüttelkopf, Federica Cataldini, João Sabino, Frederik Møller, Si-Cong Ji, Sebastian Erne, Giacomo Guarnieri, Spyros Sotiriadis, Jens Eisert, and Jörg Schmiedmayer, *Experimental observation of curved light-cones in a quantum field simulator*, Proc. Natl. Acad. Sci. U.S.A. **120**, e2301287120 (2023) [arXiv:2209.0913].

10:15-11:00	Coffee Break	Friday 21 July 2023

Session 16

Chair: Tom Rivlin (TU Wien)

11:00-11:20	Contributed Talk	Friday 21 July 2023

Thomas Hewitt (University of Birmingham)

Quantum Thermodynamics in Ultracold Mixtures - Towards Single Atom Quantum Heat Engines

Abstract:

Our experiment is devoted to the study of quantum thermodynamics and eventually aims to realise a single atom quantum heat engine. We take advantage of low-field interspecies Feshbach resonances to control the interactions between an ultracold atomic bath of rubidium-87 and a single potassium-41 atom which is trapped within a species-selective optical tweezer. Current progress explores the unique properties of the single or few atoms, including their energy transfer with the ultracold bath and uses in thermometry. Following this, engine cycles, including the Carnot, Otto and Diesel engine will be achieved by the implementation of basic quantum thermodynamic transformations using the knowledge gained about the tuneable interactions.

[1] Jonas Glatthard, Jesús Rubio, Rahul Sawant, Thomas Hewitt, Giovanni Barontini, and Luis A. Correa, *Optimal Cold Atom Thermometry Using Adaptive Bayesian Strategies*, PRX Quantum **3**, 040330 (2022) [arXiv:2204.11816].
[2] Rahul Sawant, Anna Maffei, and Giovanni Barontini, *Thermalization of a Trapped Single Atom with an Atomic Thermal Bath*, Appl. Sci. **11**, 2258 (2021) [arXiv:2103.04125].
[3] Giovanni Barontini and Mauro Paternostro, *Ultra-cold single-atom quantum heat engines*, New J. Phys. **21**, 063019 (2019) [arXiv:1812.10929].

11:20-11:40	Contributed Talk	Friday 21 July 2023

Eloisa Cuestas (OIST, Okinawa)

Making statistics work: a quantum engine in the BEC-BCS crossover

Abstract:

We present a new class of many-body quantum engine that we termed Pauli engine. Our engine exploits genuine nonclassical forms of energy different from heat, which have not been used until now for work production in cyclic engines. In the Pauli engine the energy input is not related to the temperature of an external bath, instead, our machine is fueled by the energy associated with the change of the statistical behavior of the working medium from bosonic to fermionic and back. This mechanism is of purely quantum origin and has no correlate in the classical regime. Since the change in quantum statistic does not require the coupling to a hot or cold reservoir, the main advantage of the Pauli engine is that it is free of the dissipation processes of conventional engines. We experimentally realized the Pauli cycle by driving a trapped ultracold two-component Fermi gas of ^{6}Li atoms between a Bose-Einstein condensate of bosonic molecules and a unitary Fermi gas. Such experiments result in a work output of several 10^6 vibrational quanta per cycle with an efficiency of up to 25%. Our findings establish quantum statistics as a useful thermodynamic resource for work production in a new class of emergent quantum engines.

[1] Jennifer Koch, Keerthy Menon, Eloisa Cuestas, Sian Barbosa, Eric Lutz, Thomás Fogarty, Thomas Busch, and Artur Widera, *Making statistics work: a quantum engine in the BEC-BCS crossover*, arXiv:2209.14202 (2022).

11:40-12:00	Contributed Talk	FRIDAY 21 July 2023

Alexssandre de Oliveira Jr. (Jagiellonian University, Kraków)

Geometric structure of thermal cones

Abstract:

Keeping track of memory effects in thermodynamics is essential for optimising thermodynamic processes. Markovian thermal processes (MTPs) and thermal operations (TOs) provide two extreme frameworks in this regard, involving no memory and the ability for total recall, respectively. Such a dichotomy calls for a framework capable of bridging the gap between the two extremes. We address this need by considering memory-assisted MTPs (MeMTPs) with memory initiated in thermal equilibrium. Within this setting, we propose a family of protocols composed of sequences of elementary thermalisations that approximate transitions accessible by TOs. We also provide analytic proofs of convergence with memory size going to infinity for arbitrary operations in the infinite temperature regime and a subset of swaps in the finite temperature regime. Furthermore, we present solid numerical evidence for the convergence of modified protocols to any extreme point for any temperature. The protocols' utility is illustrated by studying the interplay between memory and work extraction, where we show that by using MeMTPs one can interpolate in the regime between MTPs and TOs. Finally, we revisit the theorem by Mazurek et al. [1] concerning states unreachable via sequences of two-level TOs or their convex combinations; in this case, our protocols strongly suggest that the aforementioned inaccessibility can be overcome.

[1] Paweł Mazurek and Michał Horodecki, *Decomposability and Convex Structure of Thermal Processes*, New J. Phys. **20**, 053040 (2018) [arXiv:1707.06869].

12:00-12:20	Contributed Talk	Friday 21 July 2023

Andrea Solfanelli (SISSA Trieste)

Quantum heat engine with long-range advantages

Abstract:

The employment of long-range interactions in quantum devices provides a promising route towards enhancing their performance in quantum technology applications. Here, the presence of long-range interactions is shown to enhance the performances of a quantum heat engine featuring a many-body working substance. We focus on the paradigmatic example of a Kitaev chain undergoing a quantum Otto cycle and show that a substantial thermodynamic advantage may be achieved as the range of the interactions among its constituents increases. Interestingly, such an advantage is most significant for the realistic situation of a finite time cycle: the presence of long-range interactions reduces the non-adiabatic energy losses, by suppressing the detrimental effects of dynamically generated excitations. This effect allows mitigating the trade-off between power and efficiency, paving the way for a wide range of experimental and technological applications.

[1] Andrea Solfanelli, Guido Giachetti, Michele Campisi, Stefano Ruffo, and Nicolò Defenu, *Quantum heat engine with long-range advantages*, New J. Phys. **25**, 033030 (2023) [arXiv:2208.09492].

12:20-12:35	Closing Words	Friday 21 July 2023

12:35	End of Conference & Departure	Friday 21 July 2023

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Organizing Principles

Code of conduct

The following behavior will not be tolerated:

- Harassment, bullying and/or intimidation, false accusations, threats and assault, as well as sexual harassment in public or in private.
- Plagiarism and fabrication of data and results.
- Using the event to promote hate or discriminatory speech, or to infringe on the rights of others.
- Discrimination of any kind, such as on the basis of religion, disability, age, national origin, race, ethnicity, sexual orientation, gender identity, or gender expression. Discrimination includes the use of derogatory comments or slurs.
- Impersonation of other persons or entities, as well as falsely claiming the ownership of scientific titles, professional positions, or affiliations.

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- The display of sexual images.
- Deliberate intimidation, stalking, or following.
- Harassing photography or recording.
- Sustained disruption of talks or other events.
- Inappropriate physical contact.
- Unwelcome sexual attention.
- Advocating for, or encouraging, any of the above behavior.

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QTD2023 Vienna

17 – 21 July 2023

Time	Monday	Tuesday	Wednesday
9:00-9:40	Registration & Welcome	Silvia Pappalardi	Simone Gasparinetti
9:40-10:15	Ronnie Kosloff	Maximilian P. E. Lock Ian Ford	Oisín Culhane Michael Kewming
10:15-11:00	Coffee Break	Coffee Break	Coffee Break
11:00-11:35	Aurélia Chenu	Norbert Linke	Rosa López
11:35-11:55	Federico Cerisola	Daniel Pijn	Marek Gluza
11:55-12:15	Patrick Potts	Hiroyasu Tajima	Yi-Zheng Zhen
12:15-12:35	Lunch Break (self-organized)	Lunch Break (self-organized)	Lunch Break (self-organized)
12:35-13:45			
13:45-14:20	Ville Maisi	Iman Marvian	Free afternoon for discussions, sightseeing, etc. (self-organized)
14:20-14:40	Iva Březinová	Fei Meng	
14:40-15:00	Nathan Keenan	Salambô Dago	
15:00-15:45	Coffee Break	Coffee Break	
15:45-16:20	Zala Lenarčič	Naoto Shiraishi	
16:20-16:40	Alessandro Braggio	Irene D'Amico	
16:40-17:00	Rishabh Upadhyay	Martí Perarnau-Llobet	
17:00-17:30			
18:00-19:00		Poster Session (Festsaal TU Wien)	
19:00-22:00			Conference Dinner (Heuriger Schübel-Auer)

Thursday	Friday	Time
Obinna Abah	Tan Vu	9:00-9:35
Artur Widera	Parvinder Solanki	9:35-09:55
Ariane Soret	Mohammadamin Tajik	09:55-10:15
Coffee Break	Coffee Break	10:15-11:00
Olivier Maillet	Thomas Hewitt	11:00-11:20
Ludovico Tesser	Eloisa Cuestas	11:20-11:40
Rafael Sánchez	Alexssandre de Oliveira Jr.	11:40-12:00
Ilia Khomchenko	Andrea Solfanelli	12:00-12:20
	Closing Words	12:20-12:35
Lunch Break (self-organized)	End of Conference & Departure	12:35-14:05
Julia Boeyens		14:05-14:25
Sindre Brattegard		14:25-14:45
Maximilian Prüfer		14:45-15:05
Coffee Break		15:05-15:50
Marcin Łobejko		15:50-16:10
Cyril Elouard		16:10-16:30
Panel Discussion		16:30-17:30
		18:00-19:00
		19:00-22:00

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