Frontiers of Quantum and Mesoscopic Thermodynamics

31 July - 6 August 2022, Prague, Czech Republic

Under the auspicies of

RNDr. Miloš Vystrčil
President of the Senate of the Parliament of the Czech Republic

Prof. RNDr. Eva Zažímalová, CSc.
President of the Czech Academy of Sciences

Supported by

- Committee on Education, Science, Culture, Human Rights and Petitions of the Senate of the Parliament of the Czech Republic
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- Department of Physics, Texas A&M University, USA
- Institut de Physique Théorique, CEA/CNRS Saclay, France
- Institute for Theoretical Physics, University of Amsterdam, The Netherlands
- College of Engineering and Science, University of Detroit Mercy, USA

Topics

- Non-equilibrium quantum phenomena
- Foundations of quantum physics
- Quantum measurement, entanglement and coherence
- Dissipation, dephasing, noise and decoherence
- Many body physics, quantum field theory
- Quantum statistical physics and thermodynamics
- Quantum optics
- Quantum simulations
- Physics of quantum information and computing
- Topological states of quantum matter, quantum phase transitions
- Macroscopic quantum behavior
- Cold atoms and molecules, Bose-Einstein condensates
- Mesoscopic, nano-electromechanical and nano-optical systems
- Biological systems, molecular motors and quantum biology
- Cosmology, gravitation and astrophysics

Scientific Committee

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Ady Stern (Weizmann Institute, Rehovot)
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Organized by

- Institute of Physics, the Czech Academy of Sciences
- Committee on Education, Science, Culture, Human Rights and Petitions of the Senate of the Parliament of the Czech Republic

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Preface

FQMT'22 is a follow-up to the eight previous, successful Prague conferences "Frontiers of Quantum and Mesoscopic Thermodynamics" (FQMT'04, FQMT'08, FQMT'11, FQMT'13, FQMT'15, FQMT'17, FQMT'19 and FQMT'21). For the details of their programs and the history of the FQMT conferences see the www pages https://fqmt.fzu.cz/. The contributions from the previous conferences have been published in Physica E (vol. 29, issues 1-2, 2005, and vol. 42, issue 3, 2010), Physica Scripta (vol. T151, 2012), Fortschritte der Physik (Progress of Physics, vol. 65, issue 6-8, 2017), and European Physical Journal-Special Topics (vols. 227, issue 15-16, 2019 and 230, issue 4, 2021).

Due to the well known circumstances, the FQMT'21 was the first fully virtual (online) FQMT conference, which, of course, could only partly replace the originally planned in-person conference. It was therefore decided during the FQMT'21 that the following FQMT in-person conference would be held in summer 2022 if circumstances were favorable. It turned out that the best format for the FQMT'22 conference (due to the continued complicated situations in some countries) would be a hybrid one, with most of the talks in-person. And, indeed, most of the FQMT'22 speakers will deliver in-person talks in Prague. We hope that the following FQMT conference, maybe the FQMT'23, will be held in Prague again as, in principle, an all in-person conference.

The present (FQMT'22) conference will be focused on a better understanding of the behavior of quantum systems out of equilibrium. To reach this aim, we seek to improve our understanding of foundations of quantum physics, quantum many body physics, statistical physics, and thermodynamics relying on the theoretical and experimental methods of condensed matter physics and quantum optics. The systems considered will be mainly on the order of mesoscopic (nanoscale) size, and include those of both natural and artificial origin. Special attention will be given to non-equilibrium quantum systems, physics of quantum information and manifestation of quantum effects in biological systems. Subjects from astrophysics, gravitation or cosmology related to the above scope will also be included.

Following the tradition of the FQMT conferences, FQMT'22 will attempt to bring together a unique combination of both young and experienced scientists across a disciplinary spectrum covering the above mentioned topics. The interdisciplinary character of the conference will be supported by the choice of key speakers who, apart from their specializations, are not only able to report specific results within their fields, but are also able to discuss the state of the art of their fields from the standpoint of a broader perspective of overlap with other fields. It is an objective to gather important scientists from overlapping branches of physics who can mutually benefit from the exchange of different views and ideas, experiences from studies of many different systems and various theoretical and experimental approaches to the study of current problems in physics. It is intended that this arrangement of the scientific program of the conference will again significantly contribute to the formulation of challenging questions and problems, as well as their related answers that are nowadays essential to improve the understanding of the foundations of quantum physics, many body physics, quantum statistical physics of systems far from equilibrium, the physics of nanoscale and biological systems, and further, will motivate new collaboration and intensive discussions between experts from differing fields of physics, chemistry, and biology.

As in the foregoing FQMT conferences, the aim of FQMT'22 is to create a bridge between the fields of non-equilibrium statistical physics, quantum many body physics, foundations of quantum physics, quantum thermodynamics, quantum optics, physics of quantum information, astrophysics, condensed matter physics, physics of mesoscopic systems, chemical physics and biophysics. Moreover, the organizers have endeavored to create a program which encompasses all these fields, while simultaneously achieves an "equilibrium" between theoretically and experimentally orientated talks to stimulate discussion between the experimentalists and the theorists as much as possible.

The public lectures will be again the part of the conference program. On Thursday (August 4) evening, there will be two unique lectures: the first by Guy Consolmagno, the astronomer in charge of the Vatican observatory, and the other by Harrison Schmitt, a geophysicist who was a member of the crew of Apollo 17 and who collected rocks from the Moon.

In keeping with the multidisciplinary character of the scientific program, the cultural richness of the City of Prague and the tradition of the previous FQMT conferences, the FQMT'22 program will feature one concert of jazz music and three concerts of classical music performed by world-class musicians; two of them will be held in exceptionally outstanding venues of the city, in the Saint Vitus cathedral of the Prague Castle and in the beautiful Baroque church of the Strahov monastery. Both the scientific program and the musical program are intended as a complement to one another, where scientists and musicians are encouraged to mingle and share their knowledge and experience. We believe that both in-person and online participants will enjoy the scientific as well as cultural program of the conference.

Dear colleagues, we welcome you to the FQMT'22 conference and we hope you will enjoy the conference program.

On behalf of the organizers,

Václav Špička, Peter D. Keefe, and Theo M. Nieuwenhuizen

Contents

Abstracts are sorted alphabetically according to the family names of the presenting author.

Important Information

Contact address

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Emergency phone numbers (free calls):

Police: 158
Ambulance: 155
Fire Department: 150
Unified Emergency Call: 112

Conference sites

The FQMT'22 conference will take place at the following sites:

Regular talks, the poster session, the public lectures with the concert, and the jazz concert will take place at:
Pyramida Hotel
address: Bělohorská 24, Praha 6, phone: +420 233 102 111

Conference welcome party will take place at:
Wallenstein Palace Garden
address: Valdštejnské náměstí 4, Praha 1

Concert will take place at:
St. Vitus Cathedral
address: Prague Castle, Praha 1 - Hradčany

Conference dinner and the concert will take place at:
Strahov Monastery
address: Strahovské nádvoří 1/132, Praha 1

Limitations related to the Wallenstein Palace

There are some limitations related to the Wallenstein Palace due to the two facts:
1. the Wallenstein Palace is the seat of the Senate of the Czech Republic
2. the Wallenstein Palace is a historical building

Please, read carefully the following text to know about these limitations:

The entrance to the Wallenstein Palace: it is controlled because of the security reasons (the Palace is the seat of the Senate of the Czech Republic). There is a possibility that all participants will have to pass the metal detection frame and their things have to be screened by x-rays similarly as at airports.
Important: Participants are, therefore, kindly asked to come to the Wallenstein Palace not at the last moment just before the beginning of guided tours/welcome party.

Very important: When entering and moving inside the Wallenstein Palace, all participants are requested to have with them their **conference badges and passports**; both documents can be asked to be shown by the security guards in the Wallenstein palace. Please note that **forgetting your passport could be an admission problem**.

Limitations related to the Prague Castle (St. Vitus Cathedral)

There are some limitations related to the Prague Castle due to the fact that the Prague Castle is the seat of the President of the Czech Republic.

Please, read carefully the following text to know about these limitations:

All visitors of the Prague Castle area have to pass the security check and possibly metal detection frame and their things have to be screened by x-rays similarly as at airports.
Important: Participants are, therefore, kindly asked to come to the Prague Castle not at the last moment before the beginning of the concert in the St. Vitus Cathedral.

Very important: When entering and moving inside the Prague Castle area, all participants are requested to have with them their **conference badges and passports**; both documents can be asked to be shown by the Prague Castle security guards. Please note that **forgetting your passport could be an admission problem**.

Rooms and facilities available for the participants

Pyramida Hotel

- Lecture Hall A (ground floor): Plenary and some parallel sessions, the jazz concert, and the public lectures with the concert will be there.
- Lecture Hall B (first floor) and Lecture Hall C (first floor) will be used for parallel sessions.
- Lobby of the Lecture Hall (ground floor) will serve as a coffee room; tea and coffee will be available there all the time.
- Several other rooms will be available for the FQMT'22 participants, e.g., study and

computer rooms on the first floor.

Posters

Poster session will be held on Tuesday (August 2, from 5:30 p.m.). Posters can be fixed already from 7:30 a.m. on Tuesday on the first floor (corridors) of the Pyramida Hotel and can be exhibited till Friday 10 a.m.

Social events

- Welcome party: Wallenstein Palace Garden, Monday August 1
- Jazz concert: Pyramida Hotel Lecture Hall A, Tuesday August 2
- Classical concert: St. Vitus Cathedral, Wednesday August 3
- Public lectures: Pyramida Hotel Lecture Hall A, Thursday August 4
  These evening lectures will be given by Guy Consolmagno and Harrison Schmitt.
- Classical concert: Pyramida Hotel Lecture Hall A, Thursday August 4
- Tour of Strahov Monastery: Strahov Monastery, Friday August 5
- Conference dinner: Strahov Monastery, Friday August 5
- Classical music concert: Basilica of the Assumption of the Virgin Mary of the Strahov Monastery, Friday August 5

Exact times of the events can be found in the conference program.

Food

Lunches:

All participants can use either:

- A possibility to buy during their registration on Sunday or Monday tickets for lunches in the restaurant in the Pyramida Hotel.
  The price of one lunch will be 20 EUR.

  or

- To go for lunch to restaurants which are situated in the vicinity of the Pyramida Hotel.

Dinners:

- **Monday:** Welcome party in the **Wallenstein Palace Garden**.
- **Tuesday:** Buffet during the poster session in the **Pyramida Hotel**.
- **Wednesday:** Refreshment will be provided after the last session.
- **Thursday:** Refreshment will be provided after the last session.
- **Friday:** Conference dinner in **Strahov Monastery**.
  Price: 70 EUR per person - tickets for this dinner will be available during the registration.

PROGRAM

Sunday, 31 July 2022

17:00 – 21:00 Registration and welcome refreshment
Location: Pyramida Hotel - lobby

Monday, 1 August 2022

07:50 – 08:20 **Opening address**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Václav Špička)

08:20 – 09:50 **1 session: Nonequilibrum physics and thermodynamics**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Joachim Ankerhold)

08:20 – 08:50	Maciej Andrzej Lewenstein:	*To thermalize or not to thermalize, that is the question*
08:50 – 09:20	Jianshu Cao:	*Symmetry in non-equilibrium quantum processes*
09:20 – 09:50	Stefan Nimmrichter:	*Quantum advantage in the charging of batteries by repeated interactions*

09:50 – 10:10 Coffee break

10:10 – 12:10 **2 session: General physics, gravitation**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Wolfgang Schleich)

10:10 – 10:40	Dirk Bouwmeester:	*Conformal cyclic cosmology signatures and anomalies of the CMB sky*
10:40 – 11:10	Petr Hořava:	*Non-equilibrium string theory and the Schwinger-Keldysh time contour*
11:10 – 11:40	Hartmut Abele:	*Gravity resonance spectroscopy, and a search for Lorentz violation, beyond-Riemann and entropic gravity*
11:40 – 12:10	Ron Folman:	*Realization of a complete Stern-Gerlach interferometer: Towards a test of quantum gravity*

12:10 – 13:00 Lunch

13:00 – 15:10	**3 session - A parallel: Quantum thermodynamics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Stefan Nimmrichter)	
13:00 – 13:30	Vlatko Vedral: online	*Quantum cooling activated by coherently-controlled thermalisation*
13:30 – 14:00	Andreas Wacker: online	*Non-resonant transitions: Insights from quantum-thermodynamics*
14:00 – 14:30	Konstantin Dorfman: online	*Quantum heat engine perspective on controlling optical measurements with quantum light*
14:30 – 14:50	David Edward Bruschi:	*Quantum thermodynamics of localized relativistic quantum systems*
14:50 – 15:10	Saar Rahav:	*Singular optimal solutions of stochastic pumps*

13:00 – 15:10	**3 session - B parallel: Quantum transport**	
	Location: Pyramida Hotel Lecture Hall B	
	(chairperson: Michael Galperin)	
13:00 – 13:30	Jürgen Thomas Stockburger:	*The different guises of hierarchical equations of motion*
13:30 – 14:00	Michael Thoss:	*Simulation of quantum transport using the hierarchical equations of motion method*
14:00 – 14:30	Doron Cohen:	*Breakdown of adiabaticity in the quasi-static limit*
14:30 – 14:50	Andre Erpenbeck:	*Steady state formulation of inchworm Quantum Monte Carlo*
14:50 – 15:10	Michael Knap: online	*Probing finite-temperature observables in quantum simulators with short-time dynamics*

13:00 – 15:10	**3 session - C parallel: Spin dynamics**	
	Location: Pyramida Hotel Lecture Hall C	
	(chairperson: Branislav Nikolic)	
13:00 – 13:30	Gergely Zaránd:	*Dynamics of negative temperature hadron formation in repulsive SU(n) Hubbard models*

13:30 – 14:00	Peter Schmitteckert:	*Automated generation of spin-bath Hamiltonians for a wide range of interacting systems*
14:00 – 14:30	Thore Posske:	*The power of the boundary: Creating quantum spin helices, quantum skyrmions, and measuring one-dimensional topological superconductivity without relying on Majorana modes*
14:30 – 14:50	Aires Ferreira:	*Emergent spin-orbit phenomena in designer 2D van der Waals materials*
14:50 – 15:10	Claudio Verdozzi: online	*Microscopic theory of ultrafast optical skyrmion excitation in magnetic thin films*

15:10 – 15:30 Coffee break

15:30 – 18:00 **4 session: Foundations of quantum physics**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Howard Wiseman)

15:30 – 16:00	Ana María Cetto:	*The quantization of radiation: role of the vacuum field*
16:00 – 16:30	Wolfgang Schleich:	*The Riemann zeta function and quantum mechanics*
16:30 – 17:00	Yuval Gefen:	*Passive vs. active quantum steering*
17:00 – 17:30	Juan Ramón Muñoz de Nova:	*Quantum information with top quarks at the LHC*
17:30 – 18:00	Gregor Weihs:	*Multiparticle Quantum Interferometry*

18:00 – 19:00 Free time and transfer to Wallenstein Palace

19:00 – 22:00 **Welcome party**

Location: Wallenstein Palace and its Garden

19:00 – 19:30 Opening

19:30 – 22:00 Welcome party in the Wallenstein Palace Garden

Tuesday, 2 August 2022

07:50 – 09:50	**1 session: Physics of superfluids**		
	Location: Pyramida Hotel Lecture Hall A		
	(chairperson: Thomas Gasenzer)		
07:50 – 08:20	Vanderlei Salvador Bagnato:	*Production and characterization of a far from equilibrium BEC: turbulence and universality*	
08:20 – 08:50	Fernando Sols:	*Superfluidity from correlations in driven boson systems*	
08:50 – 09:20	Nir Navon:	*Ultracold Fermi gases in a box*	
09:20 – 09:50	Frédéric Chevy:	*Fermi gases in quantum wires*	
09:50 – 10:10	Coffee break		

10:10 – 12:10	**2 session: Thermodynamics, molecular machines**		
	Location: Pyramida Hotel Lecture Hall A		
	(chairperson: Jürgen Stockburger)		
10:10 – 10:40	Andrew N. Jordan:	*Quantum engines based on entanglement and continuous measurement*	
10:40 – 11:10	Jens Eisert:	*Quantum field thermal machines*	
11:10 – 11:40	Jennifer Koch:	*Many-body effects in quantum engines*	
11:40 – 12:10	Liliana Arrachea:	*Energy dynamics, heat production and heat-work conversion with qubits*	
12:10 – 13:00	Lunch		

13:00 – 15:10	**3 session - A parallel: Many body physics, quantum transport**		
	Location: Pyramida Hotel Lecture Hall A		
	(chairperson: Gert-Ludwig Ingold)		
13:00 – 13:30	Sergey N. Shevchenko: online	*Quantum control via Landau-Zener-Stuckelberg-Majorana transitions*	
13:30 – 14:00	Takafumi Kita: online	*Asymmetry of critical exponents above and below second-order transitions with continuous symmetries*	
14:00 – 14:30	Björn Sothmann:	*Quantized phase-coherent heat transport of counterpropagating Majorana modes*	

14:30	–	14:50	Alessandro Romito:	*Measurement-induced topological transition in a free fermion model*
14:50	–	15:10	Llorenç Serra:	*Trivial and topological confinements in bilayer graphene*

13:00 – 15:10

3 session - B parallel: Molecular junctions

Location: Pyramida Hotel Lecture Hall B

(chairperson: Jaroslav Fabian)

13:00	–	13:30	Oren Tal:	*Quantum flicker noise demonstrated in molecular junctions*
13:30	–	14:00	Elisabetta Paladino:	*Supercurrent noise in short ballistic graphene Josephson junctions*
14:00	–	14:30	Alessandro Braggio:	*Nonlocal thermoelectricity in topological Josephson junctions*
14:30	–	14:50	Olivier Maillet:	*Anomalous photonic heat transport across a Josephson junction in a highly dissipative environment*
14:50	–	15:10	Jerome Rech:	*Delta-T noise in quantum Hall junctions*

13:00 – 15:10

3 session - C parallel: Quantum transport, superconductivity

Location: Pyramida Hotel Lecture Hall C

(chairperson: Eugene Sukhorukov)

13:00	–	13:30	Yaroslav M. Blanter:	*Analog quantum control of magnonic cat states on-a-chip by a superconducting qubit*
13:30	–	14:00	Pascal Simon:	*Shot noise in superconducting sub gap states*
14:00	–	14:30	Friedemann Queisser:	*Dynamically assisted tunneling in the impulse regime*
14:30	–	14:50	Ambroise Peugeot:	*Entangled beams and photon multiplets from a dc-biased superconducting circuit*
14:50	–	15:10	Thibaut Jonckheere:	*Anyonic statistics revealed by the Hong-Ou-Mandel dip for fractional excitations*
15:10	–	15:30	Coffee break	

15:30 – 17:30	**4 session - A parallel: Many body physics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Fernando Sols)	
15:30 – 16:00	Stephanie M Reimann: online	*Droplet-superfluid compounds in binary bosonic mixtures*
16:00 – 16:30	Yoram Alhassid: online	*Cold atomic Fermi gases in two dimensions: superfluidity and pseudogap effects in the strongly interacting regime*
16:30 – 17:00	Alexandre Zagoskin: online	*Towards qualitative theory of large quantum coherent structures*
17:00 – 17:30	Radim Filip:	*Quantum non-Gaussian optics and mechanics*

15:30 – 17:30	**4 session - B parallel: Physics of quantum information**	
	Location: Pyramida Hotel Lecture Hall B	
	(chairperson: Giuseppe Falci)	
15:30 – 16:00	Thomas Walther:	*A scalable quantum key distribution network based on time-bin entanglement*
16:00 – 16:30	Yasuhiro Utsumi:	*Computation time and thermodynamic uncertainty relation of Brownian circuits*
16:30 – 17:00	Martin Ringbauer:	*Quantum computing and simulation with high-dimensional systems*
17:00 – 17:30	Wister Wei Huang:	*Quantum information processing with graphene quantum dots*

15:30 – 17:30	**4 session - C parallel: General physics, quantum structures**	
	Location: Pyramida Hotel Lecture Hall C	
	(chairperson: Peter Schmitteckert)	
15:30 – 16:00	Joseph Maciejko: online	*Hyperbolic band theory*
16:00 – 16:30	Grégoire Ithier:	*Many body density of states of a system of spinless fermions*
16:30 – 17:00	Parveen Kumar:	*Optimized steering: Quantum state engineering and exceptional points*

17:30 – 19:20 **Poster session and refreshment**

Location: Pyramida Hotel - first floor

19:20 – 20:00 Free time

20:00 – 22:00 **Jazz concert**

Location: Pyramida Hotel Lecture Hall A

Wednesday, 3 August 2022

07:50	–	09:50	**1 session: Light - matter interactions**	
			Location: Pyramida Hotel Lecture Hall A	
			(chairperson: Yuri Rostovtsev)	
07:50	–	08:20	Franco Nori: online	*Quantum optics with giant atoms: Decoherence-free interaction between giant atoms in waveguide quantum electrodynamics.*
08:20	–	08:50	Ortwin Hess:	*Nanoplasmonics as enabler of room-temperature quantum nanophotonics*
08:50	–	09:20	Walter Pfeiffer:	*Emergent functionality in quantum plasmonics*
09:20	–	09:50	Norbert Kroo:	*Some applications of high field nanoplasmonics*
09:50	–	10:10	Coffee break	
10:10	–	12:10	**2 session: Quantum thermodynamics**	
			Location: Pyramida Hotel Lecture Hall A	
			(chairperson: Andrew Jordan)	
10:10	–	10:40	Tapio Ala-Nissilä:	*Trajectory-based approach to quantum thermodynamics for general quantum systems*
10:40	–	11:10	Amir Ordacgi Caldeira:	*Von Neumann entropy and entropy production of a damped harmonic oscillator*
11:10	–	11:40	J. Miguel Rubi:	*Negative thermophoresis in the strong coupling regime*
11:40	–	12:10	Gershon Kurizki:	*Nonlinear coherent steering of heat and work*
12:10	–	13:00	Lunch	

13:00	–	14:40	**3 session - A parallel: General physics, biophysics**	
			Location: Pyramida Hotel Lecture Hall A	
			(chairperson: Lev Mourokh)	
13:00	–	13:30	Warwick P. Bowen: online	*Absolute quantum advantage in imaging: biological microscopy beyond the quantum limit*
13:30	–	14:00	Suzy Lidström:	*Consciousness as coherent excitation of a hybrid quantum field*
14:00	–	14:20	Václav Špička:	*On physical processes controlling biological neural networks*
14:20	–	14:40	Peter D. Keefe:	*The first order phase transition of Type I superconductors: Bardeen hysteresis explained*

13:00	–	14:40	**3 session - B parallel: Hall effect**	
			Location: Pyramida Hotel Lecture Hall B	
			(chairperson: Branislav Nikolic)	
13:00	–	13:30	Thomas L Schmidt:	*Supercurrent-enabled Andreev reflection in a chiral quantum Hall edge state*
13:30	–	14:00	Pavel Středa:	*Anomalous Hall conductivity and quantum friction*
14:00	–	14:20	David F. Mross:	*The fractional quantum Hall state at nu=5/2: Recent insights from theory and experiment*
14:20	–	14:40	Jiří J. Mareš:	*Hidden momentum and Hall effect*

13:00	–	14:40	**3 session - C parallel: General physics**	
			Location: Pyramida Hotel Lecture Hall C	
			(chairperson: Shmuel Gurvitz)	
13:00	–	13:30	Marco Genovese:	*Emergence of constructor-based irreversibility in quantum systems*
13:30	–	14:00	Ofer Biham:	*The life cycle of random walks on random regular graphs*
14:00	–	14:20	Eytan Katzav:	*Convergence of contracting networks towards an asymptotic maximum-entropy structure*
14:20	–	14:40	Satoshi Ejima:	*Photoinduced pairing states in pumped excitonic insulators*

14:40	–	15:00	Coffee break

15:00 – 17:10	**4 session - A parallel: Quantum optics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Wolfgang Schleich)	
15:00 – 15:30	Yuri Rostovtsev:	*Room-temperature tunable masers based on the weakly aligned molecules*
15:30 – 16:00	Marlan Scully: online	*Of Bose condensates, squeezed light and black holes*
16:00 – 16:30	Olga Kocharovskaya: online	*Nuclear ensembles with controllable inhomogeneous broadening for nuclear quantum memories and spectral intensity enhancement*
16:30 – 16:50	Frank A. Narducci: online	*A T-cubed atom interferometer*
16:50 – 17:10	Anil K Patnaik: online	*Tabletop mixed radiation source from liquid target via extreme light interactions*

15:00 – 17:10	**4 session - B parallel: Quantum transport**	
	Location: Pyramida Hotel Lecture Hall B	
	(chairperson: James Freericks)	
15:00 – 15:30	Riku Tuovinen:	*Time-linear non-equilibrium Green's function approach to correlated quantum transport*
15:30 – 16:00	Michael Ridley:	*Quantum probability from causal structure*
16:00 – 16:30	Pawel Danielewicz:	*Slabs of correlated nucleons with nonequilibrium Green's functions*
16:30 – 16:50	Michael Galperin:	*Green's function methods for single molecule junctions*
16:50 – 17:10	Ivan Rungger:	*Quantum computing algorithms for Green's functions in materials science*

15:00 – 17:10	**4 session - C parallel: Quantum physics and gravitation**	
	Location: Pyramida Hotel Lecture Hall C	
	(chairperson: Dirk Bouwmeester)	
15:00 – 15:30	Michael Kopp:	*Lessons on quantum gravity from gravitationally induced entanglement*

15:30	–	16:00	Roland E Allen:	*Origin of the Bekenstein-Hawking entropy, Einstein-Hilbert action, and a dark matter particle that should be detected in the next 2-5 years*
16:00	–	16:30	Giorgio Torrieri:	*The equivalence principle and inertial-gravitational decoherence*
16:30	–	16:50	Theo M. Nieuwenhuizen:	*Exact solutions for black holes with a smooth quantum core*
16:50	–	17:10	Matthias Zimmermann:	*Hawking radiation, the logarithmic phase singularity, and the inverted harmonic oscillator*

17:10 – 19:00 Free time and transfer to St. Vitus Cathedral

19:00 – 20:30 **Concert of classical music**

Location: Prague Castle - St. Vitus Cathedral and live on internet

Thursday, 4 August 2022

07:50 – 09:50 **1 session: General physics, light - matter interactions**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Elisabetta Paladino)

07:50 – 08:20	Christoph Bruder:	*Quantum synchronization*
08:20 – 08:50	Joachim Ankerhold:	*Bright sources for quantum microwaves by dc-biased superconducting circuits*
08:50 – 09:20	Vincenzo Macrì:	*Virtual and real dynamical Casimir effects in optomechanical systems*
09:20 – 09:50	Eliahu Cohen:	*Quantum clocks: time-energy uncertainty relations and the emergence of non-unitarity*

09:50 – 10:10 Coffee break

10:10 – 12:10 **2 session: Quantum transport, spin systems**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Wolfgang Belzig)

10:10 – 10:40	Christian D Glattli:	*Two-particle time-domain interferometry in the fractional quantum Hall effect regime*
10:40 – 11:10	Jan van Ruitenbeek:	*On the problem of chirality-induced spin selectivity (CISS)*
11:10 – 11:40	E.K.U. Gross:	*Non-linear spin dynamics, the OISTR effect, and the birth of atto-magnetism*
11:40 – 12:10	Shmuel Gurvitz:	*Non-standard Hubbard model and two-electron pairing*

12:10 – 13:00 Lunch

13:00 – 14:30 **3 session: Light - matter interactions**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Christoph Bruder)

13:00 – 13:30	Giuseppe Falci:	*Detection of virtual photons in ultra-strongly coupled quantum systems*
13:30 – 14:00	Omar Di Stefano:	*Gauge principle and gauge invariance issues in the ultrastrong coupling regime*

14:00	–	14:30	Roberto Stassi:	*Unveiling and veiling an entangled light-matter quantum state from the vacuum*
14:30	–	14:50	Coffee break	

14:50 – 16:20

4 session: Quantum optics, General physics

Location: Pyramida Hotel Lecture Hall A

(chairperson: Vincenzo Macrì)

14:50	–	15:20	Alistair James Brash:	*Quantum optics in the solid state*
15:20	–	15:50	Evgenii Narimanov:	*Ghost exchange: Ferromagnetic-antiferromagnetic phase transition in linear optics of non-magnetic dielectrics*
15:50	–	16:20	Tamar Seideman: online	*Insights from high harmonic generation. Toy models*
16:20	–	17:00	Free time	

17:00 – 22:00

Evening session: Public lectures of Guy Consolmagno, Harrison Schmitt and concert

Location: Pyramida Hotel Lecture Hall A

(chairperson: Václav Špička)

17:00	–	17:15	Music introduction and opening address	
17:15	–	18:30	Public lecture	
17:15	–	18:15	**Guy J. Consolmagno:**	***Astronomy, God, and the Search for Elegance***
18:15	–	18:30	Discussion after the lecture of Guy Consolmagno	
18:30	–	18:45	Coffee break	
18:45	–	20:00	Public lecture	
18:45	–	19:45	**Harrison H Schmitt:**	***From Coyotes to Moonbeams***
19:45	–	20:00	Disscusion after the lecture of Harrsion Schmitt	
20:00	–	20:30	Coffee break	
20:30	–	22:00	**Concert of classical music**	

Friday, 5 August 2022

07:50 – 09:50	**1 session: General physics, biophysics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Peter McClintock)	
07:50 – 08:20	Cristiane de Morais Smith:	*Time glasses, imaginary time crystals, and all that*
08:20 – 08:50	Lev Mourokh:	*Physical models of mitochondrial proton-pumping complexes*
08:50 – 09:20	Yutaka Shikano:	*Quantum computer health check via quantum random number generation*
09:20 – 09:50	Karl John Friston: online	*Me and my Markov blanket*
09:50 – 10:10	Coffee break	
10:10 – 12:10	**2 session - A parallel: Quantum transport, spin dynamics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Friedemann Queisser)	
10:10 – 10:40	Sebastian Deffner: online	*Assessing nonequilibrium excitations in quantum annealers*
10:40 – 11:10	Lea F. Santos:	*Experimental detection of the correlation Renyi entropy in the central spin model*
11:10 – 11:40	Jaroslav Fabian:	*Spintronics with van der Waals heterostructures*
11:40 – 12:10	Branislav Nikolic:	*What is quantum spin torque: Spintronics meets nonequilibrium strongly correlated and long-range entangled quantum matter*
10:10 – 12:10	**2 session - B parallel: Foundations of quantum physics**	
	Location: Pyramida Hotel Lecture Hall B	
	(chairperson: Howard Wiseman)	
10:10 – 10:40	Denys I. Bondar: online	*Experimental classical optical analogues of open quantum systems: Quantum discord, violation of the Leggett-Garg inequality, and decoherence enhanced tunneling*

10:40	–	11:10	Georgi Gary Rozenman:	*Emulating black holes using surface gravity waves*
11:10	–	11:40	Fabrizio Piacentini:	*Extracting (anomalous) weak values by detecting a single photon*
11:40	–	12:10	Ehtibar Dzhafarov:	*A general proof that context-independent mapping (or local causality) and free choice are equivalent*

10:10 – 12:10

2 session - C parallel: Foundations of quantum physics, transport theory

Location: Pyramida Hotel Lecture Hall C

(chairperson: Jerome Rech)

10:10	–	10:40	John Goold:	*Taking the temperature of a pure quantum state*
10:40	–	11:10	Jakub Spiechowicz:	*Arcsine law and multistable Brownian dynamics in a tilted periodic potential*
11:10	–	11:40	Eugene Sukhorukov:	*Transmission line approach to transport of heat in chiral and drift-diffusion systems with dissipation*
11:40	–	12:10	Sungguen Ryu:	*Photoassisted chiral transport beyond the Carnot limit*

12:10 – 13:00 Lunch

13:00 – 15:00

3 session: Space exploration

Location: Pyramida Hotel Lecture Hall A

(chairperson: Wolfgang Schleich)

13:00	–	13:30	Harrison H Schmitt:	*50 Years and counting: Major science from Apollo 17 mission to Taurus-Littrow on the Moon*
13:30	–	14:00	Guy J. Consolmagno:	*What's surfacing about Bennu?*
14:00	–	14:30	Hansjörg Dittus:	*Quantum sensors - A necessity on modern spacecraft*
14:30	–	15:00	Ernst M Rasel:	*Twin lattice interferometry - a tool for gyros and gravitational-wave detection*

15:00 – 15:20 Coffee break

15:20 – 16:20	**4 session: Many body physics, magnetism**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Björn Sothmann)	
15:20 – 15:50	Wolfgang Belzig:	*Quantum properties of squeezed magnons in ferro- and antiferromagnets*
15:50 – 16:20	Thomas Vojta:	*Controlling the stripe order in a diluted frustrated magnet*

16:20 – 17:30 Free time and transfer to Strahov monastery

17:30 – 23:00	**Guided tour, conference dinner and concert**
	Location: Strahov Monastery
17:30 – 19:00	Guided tour through Strahov monastery
19:00 – 19:20	Welcome
19:20 – 20:30	First part of the conference dinner
20:30 – 21:30	Concert of classical music in the Basilica of Assumption of Our Lady
21:30 – 23:00	Second part of the conference dinner

Saturday, 6 August 2022

08:20 – 10:20	**1 session: Foundations of quantum physics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Theo Nieuwenhuizen)	
08:20 – 08:50	Howard M. Wiseman:	*Can a qubit be your friend? Why experimental metaphysics needs a quantum computer.*
08:50 – 09:20	James Freericks:	*How do we measure the momentum of a quantum particle*
09:20 – 09:50	Gerard Kennedy:	*Energetics of quantum vacuum friction*
09:50 – 10:20	Federico Cerisola:	*Quantum-classical correspondence in spin-boson equilibrium states at arbitrary coupling*
10:20 – 10:40	Coffee break	
10:40 – 12:10	**2 session: Physics of superfluids**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Joseph Maciejko)	
10:40 – 11:10	Jeff Steinhauer: online	*Analogue cosmological particle creation in an ultracold quantum fluid of light*
11:10 – 11:40	Thomas Gasenzer:	*Instantons in far-from-equilibrium spinor gases*
11:40 – 12:10	Peter V. E. McClintock:	*Quantum turbulence in superfluid He-4: creation, evolution and decay in novel geometries*
12:10 – 13:00	Lunch	
13:00 – 15:00	**3 session: Thermodynamics and statistical physics**	
	Location: Pyramida Hotel Lecture Hall A	
	(chairperson: Jürgen Stockburger)	
13:00 – 13:30	Rudolf Hilfer:	*Foundations of statistical mechanics for unstable interactions*
13:30 – 14:00	Jerzy Łuczka:	*Quantum counterpart of energy equipartition theorem - General case*

14:00	–	14:30	Gert-Ludwig Ingold:	*Casimir interaction in colloidal and biophysical systems*
14:30	–	15:00	Mario Arnolfo Ciampini:	*Spatiotemporal control of levitated nanoparticles for nonequlibrium thermodynamics*

15:00 – 15:30 **Closing remarks**

Location: Pyramida Hotel Lecture Hall A

(chairperson: Václav Špička)

Public Lectures

Astronomy, God, and the Search for Elegance

Guy J. Consolmagno

Specola Vaticana, V-00120, Vatican City State, Holy See (Vatican City State)

Scientific theories must do more than merely satisfy the data; they must do so in a way that is (to use a term much favored by mathematicians) "elegant." Kepler, Maxwell, and Einstein are examples of scientists who found that a sense of esthetic "rightness" helped them to direct their scientific intuition toward theories that could then be expressed rationally and mathematically… theories that could lead to deeper insights about nature. By looking closely at a handful of astronomical images, we'll explore the way that one proceeds from an emotional appreciation of the beauty of the stars and planets, to an understanding that satisfies both reason and emotion. Ultimately, this link between "elegance" and rational truth has profound philosophical and theological implications.

From Coyotes to Moonbeams

Harrison H Schmitt

University of Wisconsin-Madison, P.O. Box 90730, Albuquerque, USA

The last Apollo mission to the Moon, Apollo 17, left Earth on a huge Saturn V rocket on December 7, 1972 to land in the deep Valley of Taurus-Littrow, carved through the magnificent mountain rim of the Serenitatis impact basin. On December 11, 1972, as the Lunar Module Pilot, New Mexican, and geologist Harrison Schmitt became the 12th and last Apollo astronaut to step on the Moon. For 75 hours, he lived and worked in the valley, performing extensive geological studies of volcanic rocks, boulders that had rolled down from the surrounding mountains, and the meteor impact generated soils (regolith) that cover the valley floor and walls. Over 22 hours of successful exploration of Taurus-Littrow capped Apollo's six-mission investigation of the materials and history of the Moon. His synthesis of the observations, samples and photographs from the Apollo missions and subsequent orbital spacecraft continues to this day. At the initial conclusion of these studies, however, science had gained a first order understanding of the evolution of the Moon as a planet and of the earliest history of the Earth during which life began and evolved. Humankind also has gained knowledge of new resources in the soils of the Moon that may provide energy for use on the Earth and help initiate the exploration and settlement of Mars.

Invited Talks

Gravity resonance spectroscopy, and a search for Lorentz violation, beyond-Riemann and entropic gravity

Hartmut Abele

TU Wien, Atominstitut, Stadionallee, Wien, Austria

The qBounce collaboration has been developing gravity resonance spectroscopy (GRS) for ultra-cold neutrons in the gravity potential of the earth. This quantum interference technique allows to test gravity and basic symmetries on different levels. We present recent results on the following topics: First, we analyze the dynamics of ultracold neutrons caused by interactions violating Lorentz invariance within the Standard Model Extension (SME). We use the effective non–relativistic potential for interactions violating Lorentz invariance derived by Kostelecký and Lane (1999) and probe contributions of these interactions to the transition frequencies of transitions between quantum gravitational states of UCNs bouncing in the gravitational field of the Earth. Second, we analyze a possibility to probe beyond-Riemann gravity by GRS. We improve by order of magnitude some constraints obtained by Kostelecký and Li (2021). Third, Erik Verlinde's theory of entropic gravity, postulating that gravity is not a fundamental force but rather emerges thermodynamically, has gathered much attention as a possible resolution to the quantum gravity problem. We address some criticism by modelling linear gravity acting on small objects as an open quantum system and show full compatibility with the qBOUNCE experiment.

Trajectory-based approach to quantum thermodynamics for general quantum systems

Tapio Ala-Nissilä

Aalto (FIN) and Loughborough University (UK), Otakaari 1, FIN-00250 Espoo, Finland

One of the main problems in developing a consistent theory of Quantum Thermodynamics (QT) along the lines of classical thermodynamics lies in the fact that quantities such as work and heat cannot in general be described by Hermitian operators whose eigenvalues would give their expectation values. This has culminated into the “no-go” theorem that states that it is impossible to construct such (super)operators with proper physical properties [1]. The theorem can be circumvented by a Hamilton-Jacobi based approach to work, but in that case the total wave function of the system and the environment must be known [2]. In the simple limit of Markovian quantum evolution, work and heat can be identified from the change of the system Hamiltonian and its density matrix, respectively. This is based on the Gorini-Kossakowski-Sudarshan-Lindblad (GKSL) picture, where unitary and dissipative parts of open-quantum-system evolution can be separated. We have recently shown how any open-system evolution can be written in a generalized GKSL form, where this separation no longer holds [3]. By analysing trajectories given by the time evolution of the density matrix of the system we show how the internal energy change in the system can be unambiguously separated into entropy-generated and isentropic parts, identified as heat and work, respectively [4]. This allows consistent description of the First Law for any time-continuous evolution of an open quantum system.

[1] M. Perarnau-Llobet, E. Bäumer, K. V. Hovhannisyan, M. Huber, and A. Acin, Phys. Rev. Lett. vol. 118, 070601 (2017).

[2] R. Sampaio, S. Suomela, T. Ala-Nissila, J. Anders, and T.G. Philbin, Phys. Rev. A vol. 97, 012131 (2018).

[3] S. Alipour, A.T. Rezakhani, A.P. Babu, K. Mølmer, M. Möttönen, and T. Ala-Nissila, Phys. Rev. X vol. 10, 041024 (2020).

[4] S. Alipour, A.T. Rezakhani, A. Chenu, A. del Campo, and T. Ala-Nissila, Phys. Rev. A Letters (2022).

Cold atomic Fermi gases in two dimensions: superfluidity and pseudogap effects in the strongly interacting regime

Yoram Alhassid[1], Shasta Ramachandran[1], and Scott Jensen[2]

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Cold atomic Fermi gases are of great interest in diverse areas of physics because they provide a well-defined paradigm of strongly interacting Fermi systems. We discuss the strongly interacting regime of the crossover between the Bose-Einstein condensate (BEC) and the Bardeen-Cooper-Schrieffer (BCS) limits of the two-species Fermi gas with attractive contact interaction in two (2D) spatial dimensions [1]. The physics of a 2D system is different than the corresponding 3D system in that a two-particle bound state exists for arbitrarily weak interactions and the superfluid phase transition is of the Berezinskii-Kosterlitz-Thouless (BKT) type, characterized by the algebraic decay of correlations in the superfluid regime.

The 2D BEC to BCS crossover and the BKT transition have been intensively studied in recent experiments and theoretical work. Of particular interest is a pseudogap regime in which pairing correlations persist above the critical temperature. Many of the theories used are based on uncontrolled approximations. We use controlled auxiliary-field quantum Monte Carlo (AFMC) methods in the canonical ensemble on a discrete lattice that are accurate up to statistical errors [2,3]. Systematic errors associated with the discreteness of the lattice are eliminated by extrapolating to the continuum limit [4].

We determined the critical temperature by finite-size scaling of the condensate fraction and observe signatures of pseudogap (or spin gap) in the temperature dependence of the spin susceptibility and of the free energy gap.

Another observable of interest is the contact, a fundamental property of quantum many-body systems with short-range correlations that measures the pair correlation at short distances. We find that the 2D contact increases rapidly as the temperature decreases below the critical temperature for superfluidity, as was found for the 3D unitary Fermi gas [4].

[1] S. Ramachandran, S. Jensen, and Y. Alhassid, to be published (2022).

[2] S. Jensen, C. N. Gilbreth, and Y. Alhassid, Phys. Rev. Lett. 124 (2020) 090604.

[3] For a recent review of AFMC, see Y. Alhassid, in *Emergent Phenomena in Atomic Nuclei from Large-Scale Modeling: a Symmetry-Guided Perspective*, edited by K.D. Launey, (World Scientific, Singapore, 2017), Ch. 9, pp. 267 - 298.

[4] S. Jensen, C. N. Gilbreth, and Y. Alhassid, Phys. Rev. Lett. 125 (2020) 043402.

Origin of the Bekenstein-Hawking entropy, Einstein-Hilbert action, and a dark matter particle that should be detected in the next 2-5 years

Roland E Allen

Texas A&M University, Department of Physics and Astronomy, College Station, TX USA

This talk is based on the 3 papers cited below. The following results are obtained in Ref. [1] and a paper under review.

Starting with the simplest imaginable picture, and interpreting our universe as the product of two spaces with topological singularities, we obtain the following results: 4-dimensional spacetime with one time coordinate; spin 1/2 fermion and spin zero boson fields defined on this spacetime; path-integral quantization of these fields; gauge fields and a fundamental gauge theory which is necessarily SO(N); correct couplings of matter fields to the gauge fields; a gravitational vierbein; correct couplings of matter fields to gravity; Lorentz invariance; supersymmetry at some energy scale; elimination of the usual enormous cosmological constant; the Einstein-Hilbert action for gravity; the Bekenstein-Hawking entropy of black holes; and a new set of particles, including a new dark matter WIMP which should be detectable in the near future.

This dark matter candidate is consistent with all current experiments, and observable in the near or foreseeable future through a wide variety of direct, indirect, and collider detection experiments. To review the conclusions of Refs. [2] and [3]: This particle is unique in that it has (i) precisely defined couplings and (ii) a well-defined mass of about 72 GeV, providing specific cross-sections and other experimental signatures as targets for clean experimental tests – for example, in direct detection experiments which should be fully functional within the next few years, including XENONnT, LZ, and PandaX. The cross-section for collider detection at LHC energies is small – roughly 1 femtobarn – but observation may ultimately be achievable at the high-luminosity LHC, and should certainly be within reach of the even more powerful colliders now being planned. It is possible that the present dark matter candidate has already been observed via indirect detection: Several analyses of gamma rays from the Galactic center, observed by Fermi-LAT, and of antiprotons, observed by AMS-02, have shown consistency with the interpretation that these result from annihilation of dark matter particles having approximately the same mass and annihilation cross-section as the present candidate.

[1] Roland E. Allen, arXiv:1101.0586 [hep-th].

[2] Reagan Thornberry et al., EPL (Europhysics Letters) 134, 49001 (2021).

[3] Caden LaFontaine et al. Universe 7, 270 (2021).

Bright sources for quantum microwaves by dc-biased superconducting circuits

Björn Kubala[1,3], Ciprian Padurariu[1], Ambroise Peugeot[2], Gerbold Menard[2], Denis Vion[2], Daniel Esteve[2], Fabien Portier[2], and Joachim Ankerhold[1]

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[3]*Institute of Quantum Technologies, German Aerospace Center (DLR), 89069 Ulm, Germany*

Creating quantum microwaves is key to several quantum communication technologies. However, in contrast to optical light, they are rather difficult to produce and they are rather difficult to detect. In the last years in extending set-ups of circuit quantum electrodynamics (cQED), devices combining Josephson junctions and microwave cavities have turned out as versatile, remarkably simple, and very bright sources for various sorts of non-classical radiation (Josephson Photonics). This includes anti-bunched [1, 2] and bi-partite entangled microwave photons [3, 4] and, very recently, the emission of photon multiplets with up to six photons [5]. Crucial for this progress is the tailoring of the effective fine structure constant of quantum electrodynamics in the circuits to be of order 1. In this talk, I will provide an overview about the theoretical framework and then discuss specific examples including quantum synchronization [6].

[1] V. Gramich et al., Phys. Rev. Lett. 111, 247002 (2013)
[2] C. Rolland et al., Phys. Rev. Lett. 122, 186804 (2019)
[3] M. Westig et al., Phys. Rev. Lett. 119, 137001 (2017)
[4] A. Peugeot et al., Phys. Rev. X 11, 031008 (2021)
[5] G. Menard et al., Phys. Rev. X 12, 021006 (2022)
[6] L. Danner et al., Phys. Rev. B 104, 054517 (2021)

T6 Tue, 2 August, 11:40 - 12:10, 2 session

Energy dynamics, heat production and heat-work conversion with qubits

Liliana Arrachea

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We adopt a geometric approach to describe the performance of adiabatic quantum machines, operating under slow time-dependent driving and in contact with two reservoirs with a temperature bias during all the cycle [1]. We show that the problem of optimizing the power generation of a heat engine and the efficiency of both the heat engine and refrigerator operational modes is reduced to an isoperimetric problem with nontrivial underlying metrics and curvature. This corresponds to the maximization of the ratio between the area enclosed by a closed curve and its corresponding length. We illustrate this procedure in a qubit coupled to two reservoirs operating as a thermal machine by means of an adiabatic protocol [2].

[1] Geometric properties of adiabatic quantum thermal machines, Bibek Bhandari, Pablo Terrén Alonso, Fabio Taddei, Felix von Oppen, Rosario Fazio, Liliana Arrachea (https://journals.aps.org/prb/abstract/10.1103/PhysRevB.102.155407, arXiv:2002.02225)

[2] Geometric optimization of non-equilibrium adiabatic thermal machines and implementation in a qubit system PT Alonso, P Abiuso, M Perarnau-Llobet, L Arrachea PRX Quantum 3 (1), 010326 - arXiv preprint arXiv:2109.12648, 2021

Production and characterization of a far from equilibrium BEC: turbulence and universality

Vanderlei Salvador Bagnato

IFSC-University of São Paulo, Av. Trabalhador São Carlense, 400, São Carlos, Brazil

In this presentation we will combine many of the experiments performed in Brazil relating to the production and characterization of a Bose Condensate of Rb atoms, driven far from equilibrium. Excitation of the trapped BEC can be done through a combination of fields that promote time distortion of the trapping potential. These excitations can evolve over time, promoting energy migration from the largest to the smallest scales in a process called cascade. We perform temporal excitations that consist of deformation and slight rotation of the potential, causing the system to evolve to a turbulent regime. Simulations demonstrated generation of solitons, vortices and waves in the sample. Using time of flight techniques, we measure the moment distribution, n(k, t) and from it we obtain the energy spectrum E (k, t). This makes it possible to identify the inertial regions, where E (k, t) is clearly dependent on the power law (inertial region) characteristic of turbulent regime, and to measure the energy flow migrating between the scales and their preservation from the absence of dissipation. Finally, the temporal evolution of the moment distribution allows to verify the presence of a space-time scalability, which indicate the presence of a class of universality in the phenomenon. The problem is investigated on the basis of the theory of the existence of non-thermal fixed points in the system and a discussion around these aspects is offered. This work received support from FAPESP- program CEPID, CNPq and CAPES, all Brazilian agencies and had the participation of L. Madeira, A. Garcia-Orosco, P. Castilho, M. Moreno, L. Machado, G. Telles, H A. J. Middleton-Spencer (visiting student) and P.E.S. Tavares.

Quantum properties of squeezed magnons in ferro- and antiferromagnets

Wolfgang Belzig

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Exotic quasiparticles have been observed in complex spin systems exhibiting spin ice rules, skyrmions and so on. Here, we discuss the emergence of novel quasiparticles, mediated by magnetic dipolar interactions or anisotropies, that have been hiding in simpler spin systems with uniformly ordered ground states. These quasiparticles exhibit a spin ranging from zero to above 1 and display a variety of interesting quantum properties [1]. Of particular interest is our finding that the eigenmodes in an easy-axis antiferromagnet are spin-zero quasiparticles instead of the widely believed spin-1 magnons [2]. These unusual properties originate from a competition between quantum mechanical squeezing (increasing the spin) and hybridization (decreasing the spin). In antiferromagnet, the magnons are in highly entangled two-mode-squeezed state that might be a resource for quantum information. We suggest that the quantum properties can be detected by noise correlations of spin transport across a magnet/non-magnetic conductor interface [3]. In the simple case of ferromagnets with non-integer "effective spin" above bar, we show that spin-current noise measurement can reveal this fundamental quantum phenomenon [1] in full analogy to the effective charge known e.g., in the fractional quantum Hall regime, that has been experimentally determined via shot noise measurements. Further details of the spatial coherence are seen in the spin current-cross correlations.

[1] A. Kamra and W. Belzig, Super-Poissonian shot noise of squeezed-magnon mediated spin transport, Phys. Rev. Lett. 116, 146601 (2016).

[2] A. Kamra, U. Agrawal, and W. Belzig, Noninteger-spin magnonic excitations in untextured magnets, Phys. Rev. B 96, 020411(R) (2017).

[3] A. Kamra and W. Belzig, Spin pumping and shot noise in ferrimagnets: bridging ferro- and antiferromagnets, Phys. Rev. Lett. 119, 197201 (2017).

The life cycle of random walks on random regular graphs

Ofer Biham, Ido Tishby, and Eytan Katzav

The Hebrew University, Racah Institute of Physics, Jerusalem, Israel

We present analytical results for the trajectories of random walks (RWs) on random regular graphs (RRGs), which consist of N nodes of degree c. Starting from a random initial node i, at each time step an RW hops into a random neighbor of its previous node. Here we focus on landmark events in the life cycle of RWs on RRGs. In particular, we calculate the distribution of times at which these events take place.

First Hitting (FH) Time: In some of the time steps the RW may hop into a yet-unvisited node while in other time steps it may revisit a node that has already been visited before. The first time at which the RW enters a node that has already been visited before is called the first hitting time. The first hitting event may take place either by backtracking to the previous node or by retracing, namely stepping into a node which has been visited two or more time steps earlier. We calculate the distribution $P(T_{\rm FH} = t)$ of first hitting times, which turns out to be a product of a geometric distribution and a Rayleigh distribution. In the dilute network limit the first hitting process is dominated by backtracking and the mean first hitting time is $\langle T_{\rm FH} \rangle \sim c$. In the dense network limit it is dominated by retracing and the mean first hitting time is $\langle T_{\rm FH} \rangle \sim \sqrt{N}$.

First Return (FR) time: We calculate the distribution $P(T_{\rm FR} = t)$ of first return times of the RW to the initial node i. We distinguish between the first return trajectories in which the RW retrocedes its own steps backwards all the way back to the initial node i and the trajectories in which the RW returns to i via a path that does not retrocede its own steps (and thus must include at least one cycle). In the retroceding scenario the first return time follows an exponential distribution whose mean is of order 1, while in the non-retroceding scenario it follows an exponential distribution whose mean is of order N.

Cover (C) time: The cover time $T_{\rm C}$ is the number of time steps required for the RW to visit every single node in the network at least once. We derive a master equation for the distribution $P_t(S = s)$ of the number of distinct nodes s visited by an RW up to time t and solve it analytically. Inserting $s = N$ we obtain the cumulative distribution of cover times, namely the probability $P(T_{\rm C} \le t) = P_t(S = N)$ that up to time t an RW will visit all the N nodes in the network. Taking the large network limit, we show that $P(T_{\rm C} \le t)$ converges to a Gumbel distribution, whose mean is $\langle T_{\rm C} \rangle \sim N \ln N$.

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[2] I. Tishby, O. Biham and E. Katzav, J. Phys. A: Math. Theor. 54, 325001 (2021).

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Analog quantum control of magnonic cat states on-a-chip by a superconducting qubit

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Interaction of magnons with microwave and optical photons is a recent rapidly developing fields [1]. In particular, it has been extended to quantum domain, and quantum properties of magnons have been demonstrated. All research on quantum magnonics so far has been concentrated on cavity architectures. Here, we propose to directly and quantum-coherently couple a superconducting transmon qubit to magnons — the quanta of the collective spin excitations, in a nearby magnetic particle, via a superconducting interference device (SQUID). We predict a resonant qubit-magnon exchange and a nonlinear radiation-pressure interaction that are both stronger than dissipation rates and tunable by an external flux bias. We additionally demonstrate a quantum control scheme that generates qubit-magnon entanglement and magnonic Schrödinger cat states with high fidelity [2].

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[2] Marios Kounalakis, Gerrit E. W. Bauer, and Yaroslav M. Blanter, arXiv:2203.11893

Experimental classical optical analogues of open quantum systems: Quantum discord, violation of the Leggett-Garg inequality, and decoherence enhanced tunneling

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State of incoherent classical light is described by a coherency matrix. In our research we utilize a known mathematical equivalency between the coherency matrix and the density matrix of a quantum system to import concepts from the theory of open quantum systems to classical optics in order to uncover surprising new physics.

We, for the first time, experimentally realize complete kinematic state controllability of an open single-qubit by Kraus maps and construct all-optical input-agnostic polarization transformer (AI-APT), which transforms all input states of polarization to a particular state that can be polarized or partially polarized [1]. The output state of polarization and intensity depends solely on setup parameters, and not on the input state, thereby the AI-APT functions differently from simple polarizers and polarization rotators.

Quantum discord has been shown to be a resource for quantum advantage in addition to quantum entanglement. We present an experimental realization of an analogue of quantum discord using classical light [2]. Such a classical analogue may provide further insight in understanding and development of quantum information technologies making use of discord.

Evanescent waves are classical optical analogue of quantum tunnelling. Evanescent waves are inhomogeneous electromagnetic waves resulting from the continuity of the electric field under the conditions of total internal reflection. We experimentally and theoretically show that transmittances of the evanescent waves can be control by visibility (i.e., the degree of coherence) of the incident light [3]. This predicts a new quantum tunneling phenomenon, where incoherence of the initial state can be used to enhance the tunneling rate.

Contradicting a widespread expectation, we experimentally demonstrate *the violation of the Leggett-Garg inequality in a classical optical system* using only the polarization degree of freedom of a laser beam [3]. Our results show maximal violations of the Leggett-Garg inequality.

[1] W. Zhang et al. arXiv:2103.05398.

[2] Jacob M. Leamer et al. arXiv:2205.00088.

[3] Nicholas J Savino et al.arXiv:2205.00087.

[4] W. Zhang et al. Phys. Rev. A 104 (2021) 043711.

Conformal cyclic cosmology signatures and anomalies of the CMB sky

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We discuss the Conformal Cyclic Cosmology (CCC) model introduced by R. Penrose and present a high-resolution search for low-variance circles in the Planck and WMAP Cosmic Microwave Background (CMB) data, and introduce a machine-learning algorithm to search for Hawking points in the CMB, which are both predicted signatures of Conformal CCC. We find that CMB anomalies, consisting of a single or a few bright pixels can lead to regions with many low-variance circles when applying the search criteria used in previous works. After removing the anomalies from the data no statistically significant low-variance circles can be found. Concerning Hawking points, also no statistically significant evidence is found when using a Gaussian temperature amplitude model over approximately 1 degree opening angle and after accounting for CMB anomalies. We do observe significant local deviation of the real CMB sky from Gaussian noise. This is a remaining signature of, but not unique to, CCC, and can have consequences for ΛCDM .

Absolute quantum advantage in imaging: biological microscopy beyond the quantum limit

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It has been recognised since the 1980s that quantum light sources have the potential to improve the performance of microscopes, enhancing the information that can be extracted from biological systems at fixed photon budget [1]. Indeed, today state-of-the-art microscopes use intense lasers that can severely disturb biological processes, function and viability. This introduces hard limits on performance that only quantum photon correlations can overcome [2]. As such, the development of photodamage evading microscopes are widely considered as a key milestone in quantum technology roadmaps.

In this talk I will report recent work which demonstrates absolute quantum advantage in biological imaging [3]. We show that quantum correlations enable signal-to-noise beyond the photodamage-free capacity of conventional microscopy. Broadly, this represents the first demonstration that quantum correlations can allow sensing beyond the limits introduced by optical intrusion upon the measurement process. We achieve this in a coherent Raman microscope, which we use to image molecular bonds within a cell with both quantum-enhanced contrast and sub-wavelength resolution. This allows imaging of biological structures that are inaccessible using classical light. Coherent Raman microscopes allow highly selective biomolecular finger-printing in unlabelled specimens, but photodamage is a major roadblock for many applications. By showing that this roadblock can be overcome, our work provides a path towards order-of-magnitude improvements in both sensitivity and imaging speed.

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[3] Casacio, C. A. et al., Quantum-enhanced nonlinear microscopy. 2021. Nature 594 201–206.

Nonlocal thermoelectricity in topological Josephson junctions

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Thermoelectrical effects are expected to be small in hybrid superconducting systems. In this talk, we will discuss how thermoelectricity can be instead developed and manipulated in such systems showing that could be a relevant method to address their physics.

In double quantum dot Cooper pair splitters [1] one recognises that the nonlocal thermoelectricity signals the entanglement induced by the Cooper pair breaking between the two quantum dots, i.e. the nonlocal Andreev reflection [2]. In this presentation, instead, we will demonstrate that linear nonlocal thermoelectrical effects in a three-terminal topological Josephson junction (JJ) can indeed address the helical (topological) nature of the edge states. In particular, we will show how the magnetic flux [3], via Doppler shift, in the topological JJ can trigger and manipulate (even its sign) strong nonlocal thermoelectric effects when the edge states are helical. We report a nonlinear Seebeck coefficient of tens of μV/K at sub-Kelvin temperatures that is 10^4 times bigger than standard metals at similar temperatures. We contrast these physics with the weaker nonlocal thermoelectric effects that can be similarly generated by Josephson phase biases [4] or gap asymmetry of the topological JJ [5]. In the end, we will discuss the thermodynamic and nonlinear performances of these coherent nonlocal thermoelectric generators [5].

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[2] Z.B. Tan et al. "Thermoelectric current in a graphene Cooper pair splitter" Nature Comm. 12, 138 (2021)

[3] G.Blasi, F. Taddei, L. Arrachea, M. Carrega, A. Braggio "Nonlocal Thermoelectricity in a S-TI-S Junction in Contact with a N-Metal Probe: Evidence for Helical Edge States" Phys. Rev. Lett. 124, 227701 (2020)

[4] G.Blasi, F. Taddei, L. Arrachea, M. Carrega, A. Braggio "Nonlocal thermoelectricity in a topological Andreev interferometer" Phys. Rev. B 102, 241302(R) (2020)

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Quantum optics in the solid state

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Due to their favourable properties, quantum dots (QDs) have attracted much recent attention from the broader quantum optics community. In particular, they have demonstrated excellent performance as sources of non-classical light for prospective optical quantum technologies. Whilst these concepts are typically based on an "ideal" quantum optics picture of an isolated two-level emitter (TLE), a QD also exhibits interactions with the local semiconductor environment which are not present in this simple picture. Whilst some problematic interactions such as those associated with fluctuating charges have been dealt with by advances in sample quality, thermal interactions with quantised vibrations of the semiconductor lattice (phonons) cannot readily be eliminated, even at ultra-low cryogenic temperatures.

In this talk I will present an overview of these electron-phonon interactions in QDs, detailing how they influence both the absorption and emission spectra of the QD in weak and strong excitation regimes. I will show how phonon interactions break the symmetry of the absorption spectrum, leading to a surprising regime where the QD TLE can reach population inversion despite the use of incoherent excitation [1]. Moving to the weak excitation regime, I will explore the influence of the phonon coupling on the emission spectrum. In particular, I will demonstrate that the fraction of light emitted into the incoherent "phonon sideband" is completely insensitive to excitation conditions [2]. I will also explain how phonon interactions lead to a strong modification of the balance of coherent and incoherent scattering processes when compared to the ideal TLE picture [2].

Harnessing this understanding of the role of electron-phonon interactions in the quantum optics of QDs, I will discuss the consequences for their applications to quantum technologies such as non-classical light sources [3]. In particular, I will focus on future possibilities for controlling and exploiting the phononic environment of QDs with a view to future applications in optical quantum technologies.

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Quantum synchronization

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Experimental progress in optomechanical systems, in trapped-ion setups, and in superconducting circuit-QED architectures has motivated the study of synchronization in quantum systems. In my talk I would like to describe theoretical approaches to the synchronization problem for quantum oscillators and discuss some of the issues and open questions [1-4].

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Quantum thermodynamics of localized relativistic quantum systems

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Quantum systems are reaching operational regimes where the can be employed to develop novel quantum technologies. In order for this endeavour to succeed, it is paramount to quantify the quality of any new technology in terms of efficiency. While classical thermodynamics has allowed us to well characterize classical systems to date, novel concepts need to be introduced and developed within the realm of quantum mechanics

Quantum thermodynamics extends concepts from its classical counterpart to regimes where very few small constituents interact, and fluctuations around the mean values of relevant quantities are important. We employ techniques and tools from this field to characterize localized realtivistic and quantum systems that as quantum thermal machines. We focus on quantum fields trapped in cavities with moving boundaries, where potentially finite-dimensional probes can located to extract energy from the field. We discuss current work and outlook for future applications.

Von Neumann entropy and entropy production of a damped harmonic oscillator

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In this presentation we analyze the entropy and entropy production of a nonisolated quantum system described within the quantum Brownian motion framework. This is a very general and paradigmatic framework for describing nonisolated quantum systems and can be used in any kind of coupling regime. We start by considering the application of von Neumann entropy to an arbitrarily damped quantum system making use of its reduced density operator. We argue that this application is formally valid and develop a path-integral method to evaluate that quantity analytically. We apply this technique to a harmonic oscillator in contact with a heat bath and obtain an exact form for its entropy. Then we study the entropy production of this system and enlighten important characteristics of its thermodynamical behavior on the pure quantum realm and also address their transition to the classical limit.

Symmetry in non-equilibrium quantum processes

Jianshu Cao

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The talk explores the role of symmetry in quantum transport and in driven systems.

Symmetry in molecular systems such as benzene rings, LH2 complexes, carbon nanotubes, and C60 can result in multiple steady state solutions in non-equilibrium transport measurements [1]. However, dynamic or static disorder in open systems will break the symmetry and thus the degeneracy of multiple steady-states, leading to a unique current. To reveal the symmetry hidden under disorder, we demonstrate the slow relaxation of dynamical currents and uncover hidden signatures of multiple steady states [1,2].

Another type of symmetry is the commutativity of coupling operators, exemplified by non-commutative quantum transport [3]. Further, to study the symmetry in driven systems, we have systematically developed Floquet response theory for open quantum systems driven by a strong but periodic driving field and perturbed by a weak but arbitrary probe field [4,5]. Dynamical symmetries of the Floquet states lead to spectroscopic signatures including symmetry-protected dark states and Floquet-band selection rules [4].

[1] Dynamical signatures of molecular symmetries in nonequilibrium quantum transport. J. Thingna, D. Manzano, and J. Cao, Sci. Rep. 6, 28027 (2016)

[2] Magnetic field induced symmetry breaking in nonequilibrium quantum networks. J. Thingna, D. Manzano, and J. Cao, New J. Phys. 22, 083026 (2020)

[3] Unusual Transport Properties with Noncommutative System-Bath Coupling Operators. C. Duan, C.-Y. Hsieh, J. Liu, J. Wu, and Jianshu Cao, J. Phys. Chem. Lett. 11, 4080 (2020)

[4] Dynamical Symmetries and Symmetry-Protected Selection Rules in Periodically Driven Quantum Systems. G. Engelhardt and J. Cao, Phys. Rev. Lett. 126, 090601 (2021)

[5] Discontinuities in driven spin-boson systems due to coherent destruction of tunneling: breakdown of the Floquet-Gibbs distribution. G. Engelhardt, G. Platero and J. Cao, Phys. Rev. Lett. 123(12), 120602/1-7 (2019)

Quantum-classical correspondence in spin-boson equilibrium states at arbitrary coupling

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It is well known that the equilibrium properties of both quantum and classical nanoscale systems can deviate significantly from standard thermodynamics due to their coupling to an environment. However, insight into the differences between the quantum and classical cases has remained elusive. In this talk, I will present a comprehensive quantitative characterisation of quantum vs classical thermodynamic properties of a spin that is non-negligibly coupled to an environment [1]. First, I will show that for arbitrary coupling strengths, taking the large spin limit of the quantum spin, the quantum mean-force partition function converges to the mean-force partition function of the classical spin. Thus, we demonstrate that the quantum-classical correspondence is maintained at arbitrary coupling strength. This correspondence gives insight into the conditions for a quantum system to be well-approximated by its classical counterpart. Second, I will discuss how, previously identified environment-induced 'coherences' in the equilibrium state of quantum spins, do not disappear in the classical case. Finally, I will show a thorough categorisation of various coupling regimes, from ultra-weak to ultra-strong, for both the quantum and classical spin. We find that the same value of coupling strength can either be 'weak' or 'strong', depending on whether the system is quantum or classical. The presented results shed light on the interplay of quantum and mean force corrections in equilibrium states of the spin-boson model, and will help draw the quantum to classical boundary in a range of fields, such as magnetism and exciton dynamics.

[1] Quantum–classical correspondence in spin–boson equilibrium states at arbitrary coupling. F Cerisola, M Berritta, S Scali, SAR Horsley, JD Cresser, J Anders, arXiv:2204.10874.

The quantization of radiation: role of the vacuum field

Ana María Cetto and Luis de la Peña

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In previous work we have shown that the action of the zero-point radiation field (ZPF) on a bound particle results in the irreversible transition from the initially classical dynamics, towards a stationary regime controlled by the field variables. As a result, the canonical particle variables become expressed in terms of response functions to a set of ZPF modes, which are identified with the matrix elements of x and p, satisfying $[x, p] = i\hbar$. In this work we complete the description by showing that, in reciprocity, also the radiation field becomes expressed in terms of response functions to the relevant set of ZPF modes. The corresponding response coefficients are identified with the matrix elements of the operators a, $a^{\dagger}$, satisfying $\left[a, a^{\dagger}\right] = 1$. These results show that particle and field quantization are intertwined, and point to the meaning of the energy eigenvalues (both for particle and field) as the *free* energies that can be interchanged during the matter-field interaction.

Fermi gases in quantum wires

Frédéric Chevy

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Physics in low dimension is radically different from their three-dimensional counterpart and many paradigms governing standard matter break down in one or two dimensional systems. In this talk, I will present recent results on the realization of quantum wires where ultracold fermions are confined in quasi-dimensional geometries. In our setup, single-tube resolution allows for a quantitative thermometry of the system and a characterization of its 1D nature. I will also discuss how for many-body systems interactions affect one-dimensionality.

[1] De Daniloff et al.. In Situ Thermometry of Fermionic Cold-Atom Quantum Wires. Physical Review Letters, 127(11), 113602 (2021).

Spatiotemporal control of levitated nanoparticles for nonequlibrium thermodynamics

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Today, optical levitation has achieved a few of the early promises in the field: the application in precise force sensing, proof-of-concept demonstrations in stochastic thermodynamics, and preparation of pure states of motion. In this talk, I will review the state of the art of optomechanics applied to stochastic and quantum thermodynamics, with examples from our experiments exploiting spatiotemporal control of levitated nanoparticles. In particular, I will present an instance of a fast optical erasure of a nonequilibrium memory realized with a levitated particle in a double-well potential. I will discuss the potentiality of the platform for optimizing information processing using thermodynamic criteria. I will then present the feedback cooling of a nanoparticle to the ground state, paving the way to a fully quantum thermodynamic-optomechanical experimental platform.

Breakdown of adiabaticity in the quasi-static limit

Doron Cohen

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A semiclassical picture is most appropriate for the analysis of quasi-static protocols for systems that feature a mixed phase-space with both chaos and quasi-regular regions. Specifically we focus on many-body system of atoms that are described by the Bose-Hubbard Hamiltonian. A circuit that consists of bosonic sites is formally equivalent to a set of coupled anharmonic oscillators. We consider a sweep process, specifically, changing slowly the rotation frequency of the device (time dependent Sagnac phase) [1], or changing slowly the couplings (nonlinear STIRAP) [2] or changing slowly the site potential (reversing the bias) [3]. We argue that the parametric variation of phase-space topology implies that the quasi-static limit is not adiabatic. Residual irreversibility for slow sweep is inevitable. Detailed analysis is essential in order to determine the outcome of quasi-static transfer protocols, and their efficiency.

[1] Yehoshua Winsten, Doron Cohen, Sci Rep 11, 3136 (2021).

[2] A. Dey, D. Cohen, A. Vardi, Phys. Rev. Lett. 121, 250405 (2018).

[3] R. Burkle, A. Vardi, D. Cohen, J.R. Anglin, Phys. Rev. Lett. 123, 114101 (2019).

Quantum clocks: time-energy uncertainty relations and the emergence of non-unitarity

Eliahu Cohen and Ismael Lucas de Paiva

Bar-Ilan University, Max VeAnna Webb St, Ramat Gan, Israel

Time is a concept that lies at the heart of the foundations of physics. Recently, much effort has been put towards a broader understanding of time in quantum mechanics within a relational approach. This approach, originally due to Page and Wootters, consists of having one or more quantum systems used as references for time to study the dynamics of other systems of interest. In this talk, we first use this framework to study the von Neumann measurement scheme of the total energy of a system that contains an internal clock. We analyze whether quantum mechanics requires a minimum duration for the measurement from the perspective of this clock or of others external to the system and derive new time-energy uncertainty relations [1]. Moreover, we show that the dynamics from the perspective of the internal clock is non-unitary [1]. Further studying this aspect, we prove that, in general, non-inertial clock frames lead to non-unitary dynamics [1]. Accelerating and gravitating quantum clocks are given as key examples [2]. Finally, we discuss the implications of the above for dynamical nonlocality in space [3] and time [4].

[1] Paiva I.L., Lobo A.C., Cohen E., "Flow of time during energy measurements and the resulting time-energy uncertainty relations", Quantum 6, 683 (2022).

[2] Paiva I.L., Te'eni A., Peled B., Cohen E., Aharonov Y., "Noninertial quantum clock frames lead to non-Hermitian dynamics", arXiv:2204.04177.

[3] Aharonov Y., Cohen E., Colombo F., Landsberger T., Sabadini I., Struppa, D.C., Tollaksen J., "Finally Making Sense of the Double-Slit Experiment", Proc. Natl. Acad. Sci. USA 114, 6480-6485 (2017).

[4] Paiva I.L., Nowakowski M., Cohen E., "Nonlocality in quantum time via modular operators", Phys. Rev. A 105, 042207 (2022).

What's surfacing about Bennu?

Guy J. Consolmagno

Specola Vaticana, V-00120, Vatican City State, Holy See (Vatican City State)

The recent NASA mission to asteroid Bennu, OSIRIS-REx, is bringing back samples gathered on the surface of a dark, water-rich asteroid. In the process of collecting those samples, it discovered that Bennu has a surface that, on the surface, doesn't make sense: it's looks like it is covered with boulders, but it absorbs heat like a powder. What's going on, and how did it get that way? Our measurements of the most likely analog meteorite type, CM carbonaceous chondrites, suggest a surprising answer.

Slabs of correlated nucleons with nonequilibrium Green's functions

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Nonequilibrium Green's Functions (NGF) represent a practical framework for theoretical investigations of many-body systems out of equilibrium. Expanding our past results for nuclear systems with NGF in one dimension, we incorporate into those short-range two-body correlations, in a self-consistent second-order approximation, and we differentiate between neutrons and protons. The specific treatment of the correlations accounts for the scattering of nucleons in the Born approximation. We discuss the preparation of the stationary initial state for the dynamics and examine the impact of correlations there. Next, we excite a finite symmetric nuclear system to oscillate in an isovector dipole mode and explore the dissipation effects in the oscillation. Finally, in preparation for studies of slab collisions, we demonstrate application of a Galilean boost to a slab that yields a stable uniform motion, with correlations included.

T28 Fri, 5 August, 7:50 - 8:20, 1 session

Time glasses, imaginary time crystals, and all that

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One of the foremost objectives of statistical mechanics is the description of the thermodynamic properties of quantum gases. Despite the great importance of this topic, such achievement is still lacking in the case of non-Hermitian quantum gases. Here, we investigate the properties of bosonic and fermionic non-Hermitian systems at finite temperatures. We show that these systems exhibit oscillations both in temperature and imaginary time. As such, they can be a possible platform to realize an imaginary time crystal (iTC) phase. The Hatano-Nelson model is identified as a simple lattice model to reveal this effect. Our realization of an iTC is effectively a way to filter one specific Matsubara mode. Hence, the Matsubara frequency, which usually appears as a mathematical tool to compute correlation functions at finite temperatures, can be measured experimentally [1].

In the second part of this talk, I will discuss a recent study of the fractional Langevin equation with white noise. By varying the value of the derivative in the friction term of the Langevin equation, we show that it is possible to connect different states of matter, namely a liquid, a glass, an anomalous glass, and even a time glass. The latter emerges in the subohmic regime of a system plus bath description and corresponds to a system with a fractal structure in the free energy landscape [2].

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[2] *Time glass: a fractional calculus approach*, R. C. Verstraten, R. F. Ozela, and C. Morais Smith, Phys. Rev. B 103, L180301 (2021).

Assessing nonequilibrium excitations in quantum annealers

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Currently, existing quantum annealers have proven themselves as viable technology for the first practical applications in the noisy-intermediate-scale-quantum era. However, to fully exploit their capabilities, a comprehensive characterization of their finite-time excitations is instrumental. In this talk, we will outline some of our recent efforts in comprehensibly assessing nonequilibrium excitations in existing hardware. As a main result, we will present a phase diagram for driven Ising chains, from which the scaling behavior of the excess work can be read off as a function of process duration and system size. We will elaborate that "fast" processes are well described by the Kibble-Zurek mechanism; "slow" process are governed by effective Landau-Zener dynamics; and "very slow" processes can be approximated with adiabatic perturbation theory.

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Gauge principle and gauge invariance issues in the ultrastrong coupling regime

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The interaction between quantized electromagnetic fields in cavities and natural or artificial atoms has played a crucial role in developing our understanding of light-matter interactions and quantum technologies. New regimes for light-matter coupling of cavity-QED have been explored in several settings, wherein the light-matter coupling rate becomes comparable to (ultrastrong coupling) or even exceeds (deep-strong coupling) the photon frequency. These coupling regimes can give rise to new physical effects and applications, and they challenge our understanding of cavity QED. Fundamental issues like the proper definition of subsystems, their quantum measurements, the structure of light-matter ground states, and the analysis of time-dependent interactions are subject to gauge ambiguities that can lead to even qualitatively distinct predictions. The resolution of these ambiguities is important for understanding and designing next-generation quantum devices that can operate in extreme coupling regimes. In the last few years, solutions to these ambiguities with different procedures and approaches have been presented [1, 2, 3]. In particular it is possible to obtain a modified quantum Rabi model able to provide gauge-invariant physical results (e.g., energy levels, expectation values of observables, quantum probabilities) in any interaction regime. Moreover, it can be shown that this model is analogous on that obtained with the implementation in two-state systems of the gauge principle (the guiding principle in quantum field theory) [2]. Following this approach it is possible to investigate and solve several physical effects that present gauge issues and provide solutions to such a problem. Finally, I will present a theory of pure dephasing in cavity-QED systems which provides correct and gauge-invariant results at any light-matter coupling strength.

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Quantum sensors - A necessity on modern spacecraft

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Inertial measurement in space is based on quantum sensing to an increasing intend. But the utilization of quantum technology is not longer linked to navigation and communication via satellite, even sensing in earth observation will be based on qunatum sensing in the future.

I will report on recent developments and necessities on modern spacecraft.

Quantum heat engine perspective on controlling optical measurements with quantum light

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We present a consistent optimization procedure for the optical measurements in open quantum systems using recently developed incoherent control protocol [1]. Assigning an effective hot bath for the two-entangled-photon pump we recast the transmission of classical probe as a work in a quantum heat engine framework. We demonstrate that maximum work in such a heat engine can exceed that for the classical two-photon and one-photon pumps, while efficiency at maximum power can be attributed to conventional boundaries obtained for three-level maser heat engine [2]. Our results pave the way for incoherent control and optimization of optical measurements in open quantum systems that involve two-photon processes with quantum light.

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A general proof that context-independent mapping (or local causality) and free choice are equivalent

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Free choice assumption in a hidden variable model (HVM) means that the settings chosen by experimenters do not depend on the values of the hidden variable. The assumption of context-independent (CI) mapping in an HVM means that the results of a measurement do not depend on settings for other measurements. If the measurements are spacelike separated, this assumption is known as local causality. Both free choice and CI mapping assumptions are considered necessary for derivation of the Bell-type criteria of contextuality/nonlocality. It is known, however, for a variety of special cases, that the two assumptions are not logically independent. We show here, in complete generality, for any system of random variables with or without disturbance/signaling, that an HVM that postulates CI mapping is equivalent to an HVM that postulates free choice. If one denies the possibility that a given empirical scenario can be described by an HVM in which measurement outcomes depend on other measurements' settings, free choice violations should be denied too, and vice versa.

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Quantum field thermal machines

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Quantum systems undergoing out-of-equilibrium dynamics provide insights into how features of quantum statistical mechanics emerge. At the same time, they are thought to be relevant for notions in quantum thermodynamics, where quantum effects are expected to play a role in the understanding of the functioning of thermal machines operating in the nanoscopic realm. That said, for the latter, steps towards the realization of quantum thermal machines in which quantum many-body systems take center stage are quite painfully lacking. For the former, while the picture of quantum lattice systems has been becoming clearer, important questions are still widely open for quantum field systems. In this talk, we will have a look at a theoretical and experimental study of the dynamical emergence of Gaussian correlations in continuous quantum many-body systems [1,2], witnessed by new tomographic recovery techniques [3]. Building upon these efforts, we will discuss the blueprint for a quantum field thermal machine [4] for which first data are now being taken. In an outlook, we will put the findings into perspectives of witnessing coherence in quantum thermodynamics, probed by making use of single trapped ions, exemplifying how quantum effects may be important in quantum thermodynamics [5].

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Photoinduced pairing states in pumped excitonic insulators

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The study of systems driven out of equilibrium attracts tremendous attention because of the recent rapid developments of ultrafast pump lasers and various time-dependent spectroscopic measurements. In this talk, we numerically prove photoinduced pairing states in the extended Falicov-Kimball model (EFKM) at half filling [1] both with and without the internal SU(2) structure. In the time-dependent photoemission spectra simulated by the time-dependent density-matrix renormalization group technique [2,3], we demonstrate that the extra band appears above Fermi energy after pulse irradiation, indicating an insulator-to-metal transition. Even in the absence of the SU(2) structure, the pair correlations are enhanced during the pump, while they decrease over time. This implies the possible metallization of Ta_2NiSe_5, a strong candidate for an excitonic insulator material for which the EFKM is considered to be minimal theoretical model. Optimizing the pulse parameters and simulating the time-dependent photoemission, we demonstrate the photoinduced quantum phase transition [4], reflecting recent findings in time- and angle-resolved photoemission spectroscopy experiments on Ta_2NiSe_5.

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Steady state formulation of inchworm Quantum Monte Carlo

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We present an inchworm Quantum Monte Carlo method that is directly formulated in the steady-state. Until now, numerically exact real time Monte Carlo methods simulated steady-state dynamics by propagating from a tractable initial condition to long times. The computational cost for accessing nonequilibrium steady-states in these methods is often prohibitive. We overcome this issue by reformulating the inchworm equations such that they can directly be solved for the steady-state. We demonstrate the performance of our steady-state inchworm Quantum Monte Carlo method by comparison with analytical results and other numerically exact techniques and showcase its usage within dynamical mean field simulations. The steady-state inchworm Quantum Monte Carlo method closes the gap between short-time dynamics and the long-time behavior and extends the regime of applicability for nonequilibrium Monte Carlo methods as impurity solvers within quantum embedding schemes.

Spintronics with van der Waals heterostructures

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Van der Waals heterostructures allow an efficient control of the electronic states which comprise valley and spin degrees of freedom. These degrees of freedom can conspire to result in novel topological states, facilitated by spin-orbit coupling and exchange splitting. Recent technological advances have allowed to systematically investigate twisted heterostructures, in which two or more layers are twisted with respect to each other. It turns out that twisting can severely affect the spin-orbit and exchange coupling, providing a new tool to control topological states [1]. I will present our recent results of first-principles calculations and model simulations of twisted heterostructures and show how to modulate topological states into pure spin-current states in graphene flakes by magnetic field.

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Detection of virtual photons in ultrastrongly coupled quantum systems

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Ultrastrong coupling (USC) between light and matter has been achieved in several physical systems [1], including architectures of solid-state artificial atoms (AA) coupled to cavities. This non-perturbative regime is expected to display new phenomena related to the highly entangled nature of the eigenstates. In particular, the ground state of a two-level AA coupled to a mode contains virtual photons [1]. They could be detected by using a third lower-energy level of the AA allowing the entangled (false) vacuum to decay [2,3], which converts virtual photons to real, the emission of photon pairs being a smoking gun of the effect [1].

However, despite many theoretical predictions, experiments at USC are mostly limited to detecting spectral features. In particular, the three-level approach [2,3] is sensitive to a stray coupling between the AA's "uncoupled" level and the mode, possibly yielding the production of photon pairs without USC [3]. The unambiguous detection of virtual photons requires a combination of spectra and matrix elements of the system which is not met in architectures with state-of-the-art superconducting AAs, such as the transmon or the flux qubit.

We address the design of a multilevel superconducting AA, showing that a superinductor-based architecture where a fluxonium AA is coupled galvanically to a resonator may provide the desired solution. The system is driven by two-tone fields implementing Raman oscillations or STIRAP [4] achieving coherent amplification of the conversion rate of virtual photons to real with 100% efficiency. Supplemented by advanced control, our multilevel design can be exploited for further quantum tasks in the USC regime, also providing a viable strategy to demonstrate coherent dynamics in USC structures.

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Emergent spin-orbit phenomena in designer 2D van der Waals materials

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Spin-orbit coupling (SOC)—a relativistic interaction which entangles a particle's motion with its quantum mechanical spin—is fundamental to a wide range of physics phenomena, spanning from the formation of topological insulators to the spin Hall effect of light. Recent years have seen remarkable progress in probing, enhancing and tailoring SOC effects in atomically thin materials and their interfaces. From the electrical control of spin-valley coupling in bilayer graphene [1] to reversible spin-charge conversion in graphene on transition metal dichalcogenides at room temperature [2], these discoveries challenge our previous notions of the possible behaviour of spin-orbit coupled electrons at interfaces. In this talk, I will discuss recent theoretical work aimed to understand the rich interplay of *spin* and *lattice-pseudospin* degrees of freedom afforded by two-dimensional layered materials [3] and report our on-going research on new approaches to control and detect SOC-induced transport phenomena in lateral spin-valve devices [4].

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Quantum non-Gaussian optics and mechanics

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The talk will report recent theoretical and experimental achievements opening the door to highly non-Gaussian quantum optics and mechanics with single atoms and macroscopic mechanical systems. This territory is challenging for investigation, both theoretically and experimentally. We will briefly present recent theoretical and laboratory activities, mainly the experimental tests of the faithful hierarchy of quantum non-Gaussianity beyond the limits of optical methods [1,2], for multiphonon states of a single atom and their sensing capabilities [3]. The talk will conclude with other related results and the following challenges in theory and experiments with atoms, mechanical oscillators and superconducting circuits to stimulate discussion and further development of this field.

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Realization of a complete Stern-Gerlach interferometer: Towards a test of quantum gravity

Ron Folman

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The Stern-Gerlach effect, found a century ago, has become a paradigm of quantum mechanics. Unexpectedly, until recently, there has been little evidence that the original scheme with freely propagating atoms exposed to gradients from macroscopic magnets is a fully coherent quantum process. Several theoretical studies have explained why a Stern-Gerlach interferometer is a formidable challenge. Here, we provide a detailed account of the realization of a full-loop Stern-Gerlach interferometer for single atoms and use the acquired understanding to show how this setup may be used to realize an interferometer for macroscopic objects doped with a single spin. Such a realization would open the door to a new era of fundamental probes, including the realization of previously inaccessible tests at the interface of quantum mechanics and gravity.

How do we measure the momentum of a quantum particle

James Freericks

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In the conventional von Neumann theory of measurement, an experimental device uniquely entangles the eigenstates of the self-adjoint operator with the pointer states of the experimental device. Then, either wavefunction collapse or decoherence due to macroscopic pointer states, selects the measurement value of the experimental device. When von Neumann introduced this theory, which is the cornerstone of both the quantum theory of measurement and of how we teach measurement in quantum mechanics classes, Schroedinger said that the theory was beautiful, but that he did not think it applied to any actual experiment. While there may be some experiments that fit this paradigm (but I am not clear on any myself), most quantum experiments proceed in a different fashion. Most are counting experiments, which then infer the properties of interest from the geometrical set-up of the experiment. Counting experiments lie outside the von Neumann paradigm and do not seem to have any measurement problem associated with them. They simply require a way to amplify the counts, so they can be easily observed, and because they are often destructive, the precise moment of the experiment is also known. In this talk, I will illustrate how many counting experiments really work and how they should be analyzed. For example, most ways to measure momentum use time-of-flight strategies, where we measure position to infer the momentum. While this work is useful for practicing physicists to know, it is most critical that it become part of the pedagogy we teach in the quantum classroom. Especially as we strive to train the next generation of quantum aware scientists for the quantum-enabled workforce and prepare them for work in quantum sensing.

Me and my Markov blanket

Karl John Friston

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How can we understand ourselves as sentient creatures? And what are the principles that underwrite sentient behaviour? This presentation uses the free energy principle to furnish an account in terms of active inference. First, we will try to understand sentience from the point of view of physics; in particular, the properties that self-organising systems—that distinguish themselves from their lived world—must possess. We then rehearse the same story from the point of view of a neurobiologist, trying to understand functional brain architectures. The narrative starts with a heuristic proof (and simulations of a primordial soup) suggesting that life—or biological self-organization—is an inevitable and emergent property of any dynamical system that possesses a Markov blanket. This conclusion is based on the following arguments: if a system can be differentiated from its external milieu, then its internal and external states must be conditionally independent. These independencies induce a Markov blanket that separates internal and external states. Crucially, this equips internal states with an information geometry, pertaining to probabilistic beliefs about something; namely external states. This free energy is the same quantity that is optimized in Bayesian inference and machine learning (where it is known as an evidence lower bound). In short, internal states will appear to infer—and act on—their world to preserve their integrity. This leads to a Bayesian mechanics, which can be neatly summarised as self-evidencing. In the second half of the talk, we will unpack these ideas using simulations of Bayesian belief updating in the brain and relate them to predictive processing and sentient behaviour.

T44 Wed, 3 August, 16:30 - 16:50, 4 session - B parallel

Green's function methods for single molecule junctions

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We discuss theoretical Green's function methods applicable to open quantum systems out of equilibrium, in general, and single molecule junctions, in particular [1].

Two characteristic energy scales governing the physics are many-body interactions within the junctions and molecule–contacts couplings. We, therefore, identify weak interactions and weak coupling as two limits that can be conveniently treated within, respectively, the standard nonequilibrium Green's function (NEGF) method and its many-body flavors: pseudoparticle and Hubbard NEGF [2,3]. In particular, we show that the Hubbard NEGF is convenient in studies of nanoscale optoelectronics [4,5], current induced molecular dynamics [6], and nonequilibrium quantum thermodynamics [7] in junctions.

Finally, the intermediate regime, where the two energy scales are comparable, can in many cases be efficiently treated within the nonequilibrium dual approaches. We discuss recently developed auxiliary quantum master equation - dual fermion (aux-DF) [8,9] and dual-boson (aux-DB) approaches [10]. We combine ideas of exact mapping of non-Markov dynamics onto Lindblad type evolution in an auxiliary system with dual superperturbation expansions. This combination capitalizes on strong sides of both techniques which leads to formulation of relatively numerically inexpensive universal impurity solvers of high accuracy. Viability of the aux-DF and aux-DB approaches is illustrated within generic junction models, where the schemes are benchmarked against numerically exact results.

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Instantons in far-from-equilibrium spinor gases

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Non-linear excitations such as solitons or vortices play a key role in the far-from-equilibrium dynamics of coherent quantum many-body systems after a quench. Here we present an approach to study instanton-type excitations in ultracold spinor gases and characterise their universal signatures in time evolving correlation functions. In general, quenched or continuously driven quantum systems can show universal dynamics such as near non-thermal fixed points, generically in the form of scaling behaviour in space and time [1-3]. We discuss ways to classify instanton ensembles within this scheme using quantum field theoretical methods.

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Passive vs. active quantum steering

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The challenge of preparing a system in a designated state spans diverse facets of quantum mechanics. To complete this task of steering quantum states, one can employ quantum control through a sequence of generalized measurements which direct the system towards the target state. In an active version of this protocol, the obtained measurement readouts are used to adjust the protocol on-the-go, with a possibility for accelerated performance or fidelity increase. We have considered such active measurement-driven steering as applied to the challenging case of many-body quantum systems. The target states of highest interest would be those with multipartite entanglement. Such state preparation in a measurement-based protocol is limited by the natural constraints for system-detector couplings. We developed a framework for finding such physically feasible couplings, based on parent Hamiltonian construction. For helpful decision-making strategies, we offer Hilbert-space-orientation techniques, comparable to those used in navigation. The first one is to tie the active-decision protocol to the fastest accumulation of the cost function, such as the target state fidelity. We have shown the potential of 9.5-fold speedup, employing this approach for generating the ground state of the Affleck-Lieb-Kennedy-Tasaki spin chain. The second path-finding technique is to map out the available measurement actions onto a Quantum State Machine. A decision-making protocol can be based on such a representation, using semiclassical heuristics. This approach has advantages and limitations complementary to the cost function-based method. We give an example of a W-state preparation which is accelerated with this method by a factor of 12.5.

Emergence of constructor-based irreversibility in quantum systems

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The emergence of irreversibility from time symmetric physical laws is a central problem in contemporary physics. Here we present an innovative take on this topic adopting the recently proposed constructor theory framework [1,2], in which irreversibility is expressed as the requirement that a task is possible, while its inverse is not. We prove the compatibility of such constructor-based irreversibility with quantum theory's time-reversal symmetric laws, using a dynamical model based on the universal quantum homogenizer. We also test the physical realizability of this model by means of an experimental demonstration exploiting high-quality single-photon qubits [3].

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Two-particle time-domain interferometry in the fractional quantum Hall effect regime

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Quasi-particles are elementary excitations of the ground state of condensed matter quantum phases. Demonstrating that they keep quantum coherence while propagating is a fundamental issue for their manipulation for quantum information tasks. This is particularly the case for the quasi-particles called anyons of the Fractional Quantum Hall Effect (FQHE). These fractionally charged quasi-particles obey anyonic statistics intermediate between fermionic and bosonic. Their quantum coherence has been observed by their transmission through the localized states of electronic Fabry-Pérot interferometers. Surprisingly, no quantum interference of anyons was observed in electronic Mach-Zehnder interferometers for which the quasi-particle transmission occurs via propagating states. Here, we show that FQHE anyons do keep a finite quantum coherence while propagating by using a different kind of interferometry, namely two-particle time-domain interference [1] using an electronic beam-splitter. By varying the time delay between photo-created electron-hole pairs and measuring cross-correlated noise sensitive to the two-particle Hanbury Brown Twiss (HBT) phase [1], we observe strong quasi-particle interference [2]. Visibilities as high as 53% and 60% are observed for e/5 and e/3 charged propagating anyons, probably limited by co-propagating channel mixing [3]. We extend these measurements to the 2/3 edge channel which also do demonstrate quantum coherence. Our results [2] call for a better understanding of the absence of interference in Mach-Zehnder interferometers

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Taking the temperature of a pure quantum state

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Temperature is a deceptively simple concept that still raises deep questions at the forefront of quantum physics research. The observation of thermalization in completely isolated quantum systems, such as cold-atom quantum simulators, implies that a temperature can be assigned even to individual, pure quantum states. Here, we propose a scheme to measure the temperature of such pure states through quantum interference. Our proposal involves interferometry of an auxiliary qubit probe, which is prepared in a superposition state and subsequently decoheres due to weak coupling with a closed, thermalized many-body system. Using only a few basic assumptions about chaotic quantum systems, namely, the eigenstate thermalization hypothesis and the emergence of hydrodynamics at long times, we show that the qubit undergoes pure exponential decoherence at a rate that depends on the temperature of its surroundings. We verify our predictions by numerical experiments on a quantum spin chain that thermalizes after absorbing energy from a periodic drive. Our Letter provides a general method to measure the temperature of isolated, strongly interacting systems under minimal assumptions.

Non-linear spin dynamics, the OISTR effect, and the birth of atto-magnetism

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This lecture is about the motion of electrons in solids on the femto- and atto-second time scale; how it can be monitored, analyzed and, ultimately, controlled with ultra-short laser pulses. Real-time simulations are performed employing the ab-initio approach of time-dependent density functional theory. We shall visualize the laser-induced formation and breaking of chemical bonds in real time, and we shall highlight non-steady-state features of the electronic (charge and spin) current through nano-scale junctions. With the goal of pushing magnetic storage processes towards faster and faster time scales, we have predicted how the local magnetic moment can be manipulated with ultrashort laser pulses. The underlying mechanism is an optically induced spin transfer (OISTR) from one magnetic sub-lattice to another [1,2]. As an all-optical process, OISTR is temporally limited by the duration of the laser pulse, which may be as short as atto-seconds. OISTR was first predicted by real-time simulations and later confirmed experimentally. On longer time scales, decoherence arises from the non-adiabatic coupling of electronic and nuclear motion. A full ab-initio description of decoherence [3,4] is achieved with an algorithm deduced from the exact factorization [5].

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Non-standard Hubbard model and two-electron pairing

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Consistent derivation of the Tunneling Hamiltonian and related Wannier functions in terms of small-parameter expansion is presented. The results are confirmed by numerical simulations for the exactly solvable model. In the case of many-particle interaction we reproduce the standard Hubbard Hamiltonian together with the additional non-standard terms representing the density-induced single tunneling and pair-tunneling processes. We demonstrate that in the case of repulsive interaction the density-induced tunneling can cancel the single-particle tunneling amplitude. It results in complete inhibition of the single particle hopping between neighboring sites, which might be an 1D analogue of a flat band in the twisted bi-layer graphene systems. Nevertheless the particle transition between different sites can proceed due to the coherent pair-tunneling generated by the non-standard Hubbard Hamiltonian. Such a process can be considered as a “perfect” two-electron pairing, which would be equivalent to an appearance of the two-electron bound-state generated by a repulsive interaction.

Nanoplasmonics as enabler of room-temperature quantum nanophotonics

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Photonic quantum dynamics of strong coupling of single molecules [1] and single quantum dots [2] to ultra-confined light fields in plasmonic resonators has recently been demonstrated at ambient temperatures. The fact that strong-coupling conditions may be reached at room temperature is of immense interest because it represents a clear route to a practical implementation and use of quantum behaviour in nanophotonic systems and its application in biosensing [3]. Here we discuss the principles of room-temperature single-emitter strong coupling in nanoplasmonics and illuminate perspectives for quantum nanophotonics [4]. We will highlight the physics associated with recently demonstrated room-temperature strong coupling of single molecules in a plasmonic nano-cavity [1] and near-field generated strong coupling of single quantum dots [2] and single quantum emitter Dicke enhancement [5] paving the road towards single-photon quantum nonlinearities. The presentation will also explain near-field enhanced single-photon emission in near-zero index materials [6] multipartite dynamic quantum entanglement [7].

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Foundations of statistical mechanics for unstable interactions

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Traditional Boltzmann-Gibbs statistical mechanics does not apply to systems with unstable interactions, because for such systems the conventional thermodynamic limit does not exist. In unstable systems the ground state energy does not have an additive lower bound, i.e. no lower bound linearly proportional to the number N of particles or degrees of freedom. In this article unstable systems are studied whose groundstate energy is bounded below by a regularly varying function of N with index $\sigma \geq 1$. The index $\sigma \geq 1$ of regular variation introduces a classification with respect to stability. Stable interactions correspond to $\sigma = 1$. A simple example for an unstable system with $\sigma = 2$ is an ideal gas with a nonvanishing constant two-body potential. The foundations of statistical physics are revisited, and generalized ensembles are introduced for unstable interactions in such a way, that the thermodynamic limit exists. The extended ensembles are derived by identifying and postulating three basic properties as extended foundations for statistical mechanics: firstly, extensivity of thermodynamic systems, secondly, divisibility of equilibrium states, and thirdly statistical independence of isolated systems. The traditional Boltzmann-Gibbs postulate resp. the hypothesis of equal *a priori* probabilities are identified as special cases of the extended ensembles. Systems with unstable interactions are found to be thermodynamically normal and extensive. The formalism is applied to ideal gases with constant many-body potentials. The results show that, contrary to claims in the literature, stability of the interaction is not a necessary condition for the existence of a thermodynamic limit. As a second example the formalism is applied to the Curie-Weiss-Ising model with strong coupling. This model has index of stability $\sigma = 2$. Its thermodynamic potentials, originally obtained in Physica A, **320**, 429 (2003), are confirmed up to a trivial energy shift. The strong coupling model shows a thermodynamic phase transition of order 1 representing a novel mean-field universality class. The disordered high temperature phase collapses into the groundstate of the system. The metastable extension of the high temperature free energy to low temperatures ends at absolute zero in a phase transition of order 1/2. Between absolute zero and the critical temperature of the first order transition all fluctuations are absent.

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Non-equilibrium string theory and the Schwinger-Keldysh time contour

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Standard arguments using the large-N expansion of quantum systems with matrix degrees of freedom predict a dual description in terms of a genus expansion of a string theory. We extend this picture to the Schwinger-Keldysh formulation of non-equilibrium quantum systems, and identify several universal features of the anticipated dual string theory. We find a rich refinement of the topological genus expansion: The sum over worldsheet topologies is refined into a triple sum; in particular, the future time instant, where the forward and backward branches of the Schwinger-Keldysh time contour meet, is associated with its own worldsheet genus expansion. After the Keldysh rotation, we find that the worldsheets naturally decompose into their "classical" and "quantum" parts. We discuss how these properties anticipated from "non-equilibrium string perturbation theory" can be realized in the worldsheet path integral formulation of the string dynamics.

Quantum information processing with graphene quantum dots

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Spin qubits in semiconductors have the advantage that the operation and fabrication of gate electrodes are similar to classical transistors. High-quality qubits have been demonstrated on multiple semiconductor platforms including traditional bulk MOSFETs as well as on III-V, silicon- and germanium-based heterostructures. Graphene offers several advantages as a host material for spin qubits, namely naturally low nuclear spin concentrations and weak spin-orbit interactions, similar to Si. In addition, the 2D nature of graphene allows for much smaller and more strongly coupled quantum devices . Furthermore, bilayer graphene quantum dots offer the flexibility of bipolar operation. Here we demonstrate recent advancements toward quantum information processing; we study the one- and two-electron excited state spectra in single and double quantum dots and demonstrate that the spin and valley states can be well manipulated by both electric and magnetic fields [1-2]. The high-tunability allows us to switch controllably between Pauli spin-blockade and valley-blockade physics [3], which are the crucial for qubit readout and two-qubit operations. We then perform an Elzerman-style [4] single-shot readout of the excited spin state with a signal-to-noise ratio of about 7 and find relaxation times to the spin ground state of up to 50 ms with a strong magnetic field dependence, promising even higher values for smaller magnetic fields [5]. The spin relaxation time is a few orders of magnitude longer than typical spin-qubit operation times and competes very well with other group IV elements like silicon.

Casimir interaction in colloidal and biophysical systems

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Fluctuations of the electromagnetic field are at the origin of the Casimir interaction between objects at distances in the submicrometer regime up to a few micrometers. While the Casimir interaction is often thought of as a quantum effect, the high-temperature limit still leads to a finite force which is then of entropic origin. Experiments are mostly carried out with metallic objects in a sphere-plane or sphere-sphere geometry. For these geometries and Drude-type metals, analytical high-temperature results are available, including the case of two spheres of different radii [1]. However, the high-temperature limit is only attained for distances larger than typically 7.6 μm where the Casimir force is rather weak.

Recently, optical tweezers have been employed to measure the Casimir force between two dielectric spheres in an electrolyte [2]. There, thermal fluctuations are expected to be dominant at distances as small as 100 nm. The Casimir interaction then corresponds to a significant fraction of the thermal energy at room temperature so that the thermal Casimir force becomes relevant in colloidal as well as biophysical systems [3, 4]. Due to the non-zero dc conductivity of the electrolyte, the thermal Casimir interaction is universal, a property shared with the case of Drude-type spheres mentioned above. For dielectric spheres, new numerical calculations were performed in the plane-wave basis to cover the whole range of distances between the objects involved [5]. Interestingly, a simple interpolation formula bridging between small and large distances was found which is accurate enough for practical applications.

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Many body density of states of a system of spinless fermions

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Densities of states are crucial quantities for studying physical systems in particular many body quantum systems in condensed matter, where they control material properties. By enumerating accessible states around a given conserved quantity (e.g. energy), they allow to quantify equilibrium as well as transport properties.

Regarding fermionic systems, the success of Landau's theory of Fermi liquids and the associated concept of quasi-particle has promoted the use of Single Body Densities of States and focused attention on the low lying energy states around the Fermi surface. It is only recently that the engineering of nearly isolated quantum simulators, undergoing strongly out of equilibrium dynamics, has revived the necessity to consider Many Body Densities of States, quantities originally investigated in the context of nuclear physics [1]. Indeed, understanding phenomena like for instance Many Body Localization [2,3] requires to take into account potential contributions of strongly correlated many body states over the full spectrum of the system.

In this talk, we will focus on the problem of calculating the Many Body Density of States of a system of identical spinless and non interacting fermions. Surprisingly, even without interactions, this enumeration problem proves to be difficult because of the Pauli exclusion principle [1]. We propose a solution involving the spectral decomposition of matrices of filling factors [4]. The many body spectrum can be decomposed as a weighted sum of weakly correlated components, where remarkably the single body energies are only involved in the weighting coefficients. We consider applications of our results to several condensed matter models.

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Anyonic statistics revealed by the Hong-Ou-Mandel dip for fractional excitations

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The fractional Quantum Hall effect (FQHE) is known to host anyons, quasiparticules with a statistics which is intermediate between bosonic and fermionic. We show here that Hong-Ou-Mandel (HOM) interferences between excitations created by narrow voltage pulses on the edge states of a FQHE system at low temperature show a direct signature of anyonic statistics. The width of the HOM dip is universally fixed by the thermal length scale, independently of the intrinsic width of the excited fractional wavepackets. This universal width can be related to braiding of the incoming excitations with thermal fluctuations created at the quantum point contact. We show that this effect could be observed with periodic trains of narrow voltage pulses using current experimental techniques.

Quantum engines based on entanglement and continuous measurement

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Quantum measurement engines are enabled by combining the physics of quantum measurement with feedback and work extraction based on the information obtained. I will present several new designs of this principle. The first uses continuous measurements of the joint momentum and position of a quantum oscillator together with feedback on the origin of the oscillator potential to extract work from the measurements as a continuous stochastic process [1]. The second uses coupled quantum systems and the entanglement between them to run a measurement engine with local measurements to upconvert energy from one system to another [2]. I will present new research adapting the entanglement-fueled engine to work in the deep strong coupling limit, where vacuum fluctuations of ground state entanglement are rectified with local measurements and energy extraction pulses in order to run an engine cycle on a many-body chain of quantum systems. The work scales linearly with the number of sub-systems in the chain [3].

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Convergence of contracting networks towards an asymptotic maximum-entropy structure

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Complex networks encountered in biology, ecology, sociology and technology often contract due to node failures, infections or attacks. The ultimate failure, taking place when the network fragments into disconnected components was studied extensively using percolation theory. We show that long before reaching fragmentation, contracting networks lose their distinctive features. In particular, we identify that a very large class of network structures, which experience a broad class of node deletion processes, exhibit a stable flow towards universal fixed points, representing a maximum-entropy ensemble, which in the pure contraction scenario is the Erdos-Renyi ensemble. Under more general combination of growth and deletion processes of such networks the resulting degree distribution is Poisson-like. This is in sharp contrast to network growth processes that often lead to scale-free networks. It also implies that contracting networks in the late stages of node failure cascades, attacks and epidemics reach a common structure, providing a unifying framework for their analysis.

The first order phase transition of Type I superconductors: Bardeen hysteresis explained

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Macroscopic and mesoscopic-size Type I superconductors exhibit a first order phase transition in H-T space. For specimens undergoing an adiabatic phase transition, the latent heat is supplied or absorbed by the normal regime. This process, the magneto-caloric effect, proceeds isentropically and for macroscopic-size specimens, through an intermediate state of superconductive and normal phase domains. For mesoscopic-size specimens, the intermediate state is precluded in view the specimen dimension and the range of coherence are commensurate. John Bardeen proposed the appearance of magnetic hysteresis prior to phase nucleation in order for the phase transition to proceed isentropically. The talk will explain how Bardeen's magnetic hysteresis is a consequence of positive interphase boundary surface energy. [1]

[1] The European Physical Journal Special Topics, ISSN: 1951-6355: Non-Equilibrium Systems and Foundations of Quantum Physics, a publication of Springer, V. 230, No. 4, 993-1001 (June, 2021);
available online, open access, at DOI: https://doi.org/10.1140/epjs/s11734-021-00099-9.

Energetics of quantum vacuum friction

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Quantum electromagnetic field fluctuations can induce a frictional force on a neutral but polarizable particle that is moving through free space filled with blackbody radiation. We explore the energetics of such a particle undergoing uniform motion. If the particle has purely real intrinsic polarizability, before being dressed by radiation, the only dissipative mechanism is through its interaction with the radiation field fluctuations. In this case, the particle is guaranteed to be in the nonequilibrium steady state (NESS), where it absorbs and emits energy at the same rate. However, if the particle is intrinsically dissipative, the corresponding intrinsic dipole fluctuations provide a further dissipative mechanism. In this case, the particle can be out of NESS, where it gains or loses net internal energy; indeed, it will be in NESS only if its temperature is equal to a special NESS temperature, which is a function of its velocity and the temperature of the blackbody radiation. In NESS, the frictional force is always negative definite, opposing the motion of the particle. However, out of NESS, the frictional force no longer has a definite sign in the rest frame of the blackbody radiation, though it remains negative definite in the rest frame of the particle. Numerical calculations of the NESS temperature and quantum vacuum friction are illustrated for models of a gold nanosphere.

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Asymmetry of critical exponents above and below second-order transitions with continuous symmetries

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It has widely been believed that the critical exponents are symmetric above and below every continuous phase transition. We report our recent study on the critical exponents of the $O(N)$ symmetric ϕ^4 model with continuous symmetry, which clearly exhibit a counterexample to the statement. The Nambu-Goldstone mode and three-point vertices, which emerge in the ordered phase, make the longitudinal susceptibility diverge and the exponent γ' undefinable accordingly, thus suggesting the presence of asymmetry in the exponents of the model. We have calculated the fixed points and critical exponents above and below the transition on an equal footing based on a functional renormalization-group formalism which also satisfies Goldstone's theorem automatically. Despite the divergence of the longitudinal correlation length, one can define a characteristic length $\xi_{\rm J}$ called "Josephson length" in the ordered phase, which separates the critical region $G_{\parallel}(k) \propto k^{-2+\eta}$ from the Goldstone region $G_{\parallel}(k) \propto k^{-4+d}$ well inside the ordered phase. Our renormalization-group analysis reveals that one can define the exponent ν' in terms of the Josephson length as $\xi_{\rm J} \propto (T_c - T)^{-\nu'}$. Moreover, ν' acquires a value different from ν above the transition due to the emergence of three-point vertices in the ordered phase. The N dependence of the exponents will be discussed in detail.

T64 Mon, 1 August, 14:50 - 15:10, 3 session - B parallel

Probing finite-temperature observables in quantum simulators with short-time dynamics

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Preparing low temperature states in quantum simulators is challenging due to their almost perfect isolation from the environment. Here, we show how finite-temperature observables can be obtained with an algorithm that consists of classical importance sampling of initial states and a measurement of the Loschmidt echo with a quantum simulator. We use the method as a quantum-inspired classical algorithm and simulate the protocol with matrix product states to analyze the requirements on a quantum simulator. This way, we show that a finite temperature phase transition in the long-range transverse field Ising model can be characterized in trapped ion quantum simulators. We propose a concrete measurement protocol for the Loschmidt echo and discuss the influence of measurement noise, dephasing, as well as state preparation and measurement errors. We argue that the algorithm is robust against those imperfections under realistic conditions. The algorithm can be readily applied to study low-temperature properties in various quantum simulation platforms.

Many-body effects in quantum engines

Jennifer Koch[1], Keerthy Menon[2], Eloisa Cuestas[2], Thomas Fogarty[2], Sian Barbosa[1], Eric Lutz[3], Thomas Busch[2], and Artur Widera[1]

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Heat engines play a central role in our modern life, converting heat energy to motion. In recent years, the question of quantum contributions to the operation of microscopic heat engines has attracted increasing attention. In my talk, I will report on our combined experimental and theoretical efforts to identify genuine quantum effects in the operation of engines, using an ultracold gas of fermionic Lithium atoms.

Nuclear ensembles with controllable inhomogeneous broadening for nuclear quantum memories and spectral intensity enhancement

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Record high resonance quality factor can be achieved in nuclear ensembles at room temperature solids such as Q 1013 at 14.4keV transition in 57Fe or 1019 at 12.4keV transition in 45Sc. These numbers are unmatchable with optical transitions in room temperature solids. The hard x-ray photons with corresponding 10 keV energies also have some advantages compared to optical photons. For example, 14.4-keV radiation can be focused into a several nanometers diameter spot and resonantly absorbed by just 70 nm-thick 57Fe foil. The efficiency of the single photon detectors is also higher in that range of photon energies. These appealing features stimulate the development of quantum nucleonics/quantum x-ray optics (see for example [1-3] and the references there in). However, interfacing a single photon with a nuclear ensemble is challenging due to the absence of the relatively bright spectrally narrow hard x-ray radiation sources as well as high quality cavities. In this talk we discuss a possibility to use a controllable inhomogeneous broadening in order to store an incident spectrally broad single photon in the nuclear ensemble and at a later time either to retrieve it on demand (similar to an optical quantum memory via gradient echo or atomic frequency comb protocols [4,5]) or to squeeze it in a spectral domain in order to achieve higher spectral intensity [6], required for addressing of the ultra-narrow nuclear resonances. We show that such controllable inhomogeneous broadening at the x-ray nuclear transitions can be realized i) via introducing a transition frequency gradient in a nuclear ensemble along the photon propagation direction, or ii) via a set of the resonant nuclear absorbers moved with different velocities (nuclear frequency comb) [3]. Finally, we will discuss the recent experimental demonstration at DESY of the nuclear quantum memory via nuclear frequency comb [7], as well as our plans for demonstration of the resonant addressing of the ultra-narrow (1.4 femto-eV natural linewidth) nuclear transition at 12.4 keV in 45Sc to be performed this fall at the European XFEL.

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Lessons on quantum gravity from gravitationally induced entanglement

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Observable signatures of the quantum nature of gravity at low energies have recently emerged as a promising new research field. One prominent avenue is to test for gravitationally induced entanglement between two mesoscopic masses prepared in spatial superposition. Here we analyze such proposals and what one can infer from them about the quantum nature of gravity, as well as the electromagnetic analogues of such tests. We show that it is not possible to draw conclusions about mediators: even within relativistic physics, entanglement generation can equally be described in terms of mediators or in terms of non-local processes [1]. Such indirect tests therefore have limited ability to verify that entanglement is mediated by a quantum channel, as their interpretation is inherently ambiguous. We also show that cosmological observations already demonstrate some aspects of quantization that these proposals aim to test. Nevertheless, the proposed experiments would probe how gravity is sourced by spatial superpositions of matter, an untested new regime of quantum physics.

[1] V. Fragkos, M. Kopp and I. Pikovski, arxiv preprint: 2206.00558

Some applications of high field nanoplasmonics

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High intensity femtosecond laser pulses have been used to excite localized (LSPP) and propagating (SPP) surface plasmons. The extremely high electromagnetic field intensity in plasmonic hot spots has been used to study electronic and nuclear processes in some transparent materials [2] and on metallic (gold) surfaces [1]. Both the experimental and the theoretical modelling results are presented. Time-of-flight multiplasmon electron emission analysis, Raman sectroscopy and laser induced breakdown spectroscopy methods have been used to get the experimental data, and different software programmes for modelling the different processes [3]. The results of the analysis of both of our experimental and theoretical findings are briefly presented.

[1] Surface-Plasmon-Assisted Cooper Pair Formation in Ordered Gold Films at Room Temperature. P.Racz and N.Kroo: Phys. Wave Phen. 27(3), 192-196 (2019)

[2] Radiation dominated implosion with flat target. L. P. Csernai, M. Csete, I. N. Mishustin, A. Motornenko, I. Papp, L. M. Satarov, H. Stöcker, and N. Kroó: Phys. Wave Phen. 28(3), 187-199 (2020)

[3] Laser Wake Field Collider. I. Papp, L. Bravina, M. Csete, I. N. Mishustin, D. Molnar, A. Motornenko, L. M. Satarov, H. Stöcker, D. Strottman, A. Szenes, D. Vass, T. S. Biro, L. P. Csernai, N. Kroo (NAPLIFE Collaboration): Phys. Lett. A 396, 127245 (2021)

Optimized steering: Quantum state engineering and exceptional points

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The state of a quantum system may be steered towards a predesignated target state, employing a sequence of weak blind measurements (where the detector's readouts are traced out). I will present the steering of a two-level system using the interplay of a system Hamiltonian and weak measurements and show that any pure or mixed state can be targeted. Furthermore, I will discuss that the optimization of such a steering protocol is underlain by the presence of Liouvillian exceptional points. More specifically, for high-purity target states, optimal steering implies purely relaxational dynamics marked by a second-order exceptional point, whereas for low-purity target states, it implies an oscillatory approach to the target state. The dynamical phase transition between these two regimes is characterized by a third-order exceptional point. I will also present preliminary experimental data from our collaborator's lab that matches our theoretical predictions.

[1] Parveen Kumar, Kyrylo Snizhko, Yuval Gefen, and Bernd Rosenow, Optimized steering: Quantum state engineering and exceptional points, Phys. Rev. A 105, L010203 (2022)

[2] Yotam Shapira, Parveen Kumar, Kyrylo Snizhko, Tom Manovitz, Nitzan Akerman, Yuval Gefen, and Roee Ozeri, Steady state geometry of a steered trapped ion qubit, to be published.

Nonlinear coherent steering of heat and work

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In recent years we have examined a variety of generic quantum mechanical mechanisms that may allegedly boost the performance of heat machines (HM): qubit coupling to thermal or squeezed baths, a quantized oscillator piston and cooperative multi-qubit working media based on extensions of the Dicke model [1-4] and high-efficiency HM via quantum homodyne measurements [5]. Yet, we have found that genuine quantum boost exists only when QED affects the system-bath coupling [6,7]. More importantly, all existing HM, including those that present a quantum boost, are dissipative open systems, which cannot exhibit purely quantum behavior. We have now broken away from the established thermodynamic paradigm, replacing conventional HM by fully coherent nonlinear devices based on few modes whose thermal-state input is autonomously steered to a chosen mode and/or is partly transformed into work [8]. This fundamentally new principle of operation allows the bridging of quantum coherent and thermodynamic descriptions.

[1] A. Ghosh, D. Gelbwaser, W. Niedenzu, A. Lvovsky, M.O. Scully and G. Kurizki, PNAS 115, 9941 (2018)

[2] A. Ghosh, C.L. Latune, L. Davidovich and G.Kurizki, PNAS 114,12156 (2017)

[3] W. Niedenzu, V. Mukherjee, A. Ghosh, A. Kofman and G. Kurizki, Nat. Commun. 9, 1 (2018)

[4] W. Niedenzu and G. Kurizki, NJP 20, 113038 (2018)

[5] T. Opatrny, A. Misra and G. Kurizki, PRL 127, 040602 (2021)

[6] V. Mukherjee, A.G. Kofman and G. Kurizki, Commun. Phys. 3, 1 (2020)

[7] M.T. Naseem, A. Misra, O.E. Muestecaplioglu and G. Kurizki, PRR 2, 033285 (2020)

[8] T.Opatrny, S. Bauer, A. Misra, O. Firstenberg, E. Poem and G. Kurizki, arXiv (2021)

To thermalize or not to thermalize, that is the question

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Classical systems usually tend to thermalize in isolation (micro-canonical ensemble) or in contact with environment (canonical and generalized Gibbs ensembles). But, already in classical physics there are examples of breakdown of ergodicity and thermalization: spin glasses being the most celebrated, but not the only example. Quantum closed systems, when perturbed or quenched, tend to "thermalize" in an ergodic way: the reduced density matrix of a block of the system in well approximated by the Gibbs-Boltzmann canonical ensemble, at least for averages of local observables and their not too high moments. There are several exceptions from this situation: i) Systems with multiple constants of motion are described by generalized Gibbs-Boltzmann ensembles; ii) Many-body localization (MBL) occurs in certain disordered systems; iii) MBL may occur also in non-disordered systems; iv) Local conservation laws, like the Gauss law, may prevent thermalization, for instance in Lattice Gauge Theory (LGT) models; v) Systems may exhibit quantum many-body scars, i.e. low entropy states that cause "weak" ergodicity breaking; vi) The latter occur frequently in confined LGT, but also deconfined ones.

Consciousness as coherent excitation of a hybrid quantum field

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This talk will contain both the original proposal of the title and a broad overview of related basic descriptions of consciousness, with emphasis on the links to fundamental physics, as a complement to the large number of more detailed experimental and theoretical studies. In the spirit of previous ideas in the neuroscience community, but with a more physics-oriented perspective, we begin with the interpretation that consciousness is the collective excitation of a "brainwide web" of neural cells. This picture is inspired by the fact that, in all major areas of physics, a collective excitation has just as much physical reality as a particle or other localized object. The brainwide web extends into those regions (neuronal and glial networks) where processed information is received from the senses, memories, etc. (emerging out of unconscious processes in prior networks). It unifies those regions (plus motor control regions) via the vast complexity of the neural interactions that it spans.

At the most fundamental level, all physical phenomena result from excitation of quantum fields (since, in current physics, these fields are the bedrock of reality). It follows that, in the present picture, quantum physics solves the old combination (or binding) problem of consciousness, since the experience of consciousness requires coherent excitation of only a single hybrid electron-electromagnetic field.

This talk extends the work of our previous publications [1,2,3].

[1] Suzy Lidström and Roland E. Allen, "Consciousness as the collective excitation of a brainwide web—understanding consciousness from below quantum fields to above neuronal networks", J. Phys: Conf. Ser. 1275, 012021 (2019), https://doi.org/10.1088/1742-6596/1275/1/012021.

[2] Suzy Lidström and Roland E. Allen, "What is consciousness, and do we have free will?", in G. Alexander et al., "The sounds of science—a symphony for many instruments and voices", Phys. Scr. 95, 062501 (2020), https://doi.org/10.1088/1402-4896/ab7a35.

[3] Suzy Lidström and Roland E. Allen, "Toward a physics description of consciousness", Eur. Phys. J. Spec. Top. 230, 1081 (2021), https://doi.org/10.1140/epjs/s11734-021-00097-x.

Quantum counterpart of energy equipartition theorem - General case

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In classical statistical physics, the theorem on equipartition of kinetic energy is one of the most universal relation. It states that for a system in thermodynamic equilibrium of temperature T, the mean kinetic energy E_k per one degree of freedom is equal to $E_k = k_B T/2$, where k_B is the Boltzmann constant. On the contrary, for quantum systems, the mean kinetic energy is not equally shared among all degrees of freedom and the theorem fails. The quite natural question arises whether one can formulate a similar and universal relation for the mean kinetic energy of quantum systems at the thermodynamic equilibrium state. Recently [1], the quantum analogue of the classical energy equipartition theorem has been proved in a general case. The proof is based on the fluctuation-dissipation relation of the Callen-Welton type. The quantum analogue is also universal in the sense that it holds true for all quantum systems which are composed of an arbitrary number of non-interacting or interacting particles, subjected to any confining potentials and coupled to thermostat with arbitrary coupling strength (from weak-coupling to strong coupling regimes) as well as for arbitrary temperatures.

[1] J. Łuczka, J. Stat. Phys. 179 (2020) 839.

Hyperbolic band theory

Joseph Maciejko

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Hyperbolic lattices are a new form of synthetic quantum matter in which particles effectively hop on a discrete tiling of two-dimensional hyperbolic space, a non-Euclidean space of negative curvature. Hyperbolic tilings were studied by the geometer H.S.M. Coxeter and popularized through art by M.C. Escher. Recent experiments in circuit quantum electrodynamics and electric circuit networks have demonstrated the coherent propagation of wave-like excitations on hyperbolic lattices. While the familiar band theory of solids adequately describes wave propagation through periodic media in Euclidean space, it is not clear how concepts like crystal momentum and Bloch waves can be extended to hyperbolic space. In this talk, I will discuss a generalization of Bloch band theory for hyperbolic lattices [1-3] and stress the intriguing connections it establishes between condensed matter physics, high-energy physics, number theory, and algebraic geometry.

[1] J. Maciejko and S. Rayan, Sci. Adv. 7, eabe9170 (2021)

[2] J. Maciejko and S. Rayan, Proc. Natl. Acad. Sci. U.S.A. 119, e2116869119 (2022)

[3] I. Boettcher, A. V. Gorshkov, A. J. Kollár, J. Maciejko, S. Rayan, and R. Thomale, Phys. Rev. B 105, 125118 (2022)

Virtual and real dynamical Casimir effects in optomechanical systems

Vincenzo Macrì

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Here we summarize recent theoretical studies on the dynamical Casimir effects (DCEs) in optomechanical systems. We studied the DCE using a fully quantum-mechanical description and without linearizing the dynamics [1]. We have shown that the resonant generation of photons from the vacuum is determined by a ladder of mirror-field vacuum Rabi splitting. We find that vacuum emission can originate from the free evolution of an initial pure mechanical excited state, in analogy with the spontaneous emission from excited atoms. We also show that the DCE can also be driven by incoherent mechanical pumping [2]. We then applied this framework to study the interaction of two mechanical oscillators mediated by the exchange of virtual photon pairs. Specifically, we demonstrated that mechanical quantum excitations can be coherently transferred among spatially separated mechanical oscillators, through a dissipationless quantum bus, due to the exchange of virtual photon pairs [3]. This system can also operate as a mechanical parametric downconverter.

[1] V. Macrì, A. Ridolfo, O. Di Stefano, A. F. Kockum, F. Nori, S. Savasta, "Nonperturbative dynamical casimir effect in optomechanical systems: vacuum casimir-rabi splittings" Phys. Rev. X 8 (1), 011031

[2] A. Settineri, V. Macrì, L. Garziano, O. Di Stefano, F. Nori, S. Savasta, "Conversion of mechanical noise into correlated photon pairs: Dynamical Casimir effect from an incoherent mechanical drive" Phys. Rev. A 100 (2), 022501

[3] O. Di Stefano, A. Settineri, V. Macrì, A. Ridolfo, R. Stassi, A. F. Kockum, S. Savasta, F. Nori, "Interaction of mechanical oscillators mediated by the exchange of virtual photon pairs" Phys. Rev. Lett. 122 (3), 030402

Anomalous photonic heat transport across a Josephson junction in a highly dissipative environment

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A small Josephson junction in a high-impedance Ohmic environment is a good example of a quantum-mechanical degree of freedom (the junction's phase difference) strongly coupled to its thermal reservoir (e.g. resistors emitting/absorbing photons). DC charge transport in such a system has long been understood in the framework of dynamical Coulomb Blockade [1], where the back-action of the environment inhibits the tunneling of charges across the junction. Intuitively, one could foresee that heat transport of photons between two high resistances put on each side of the junction should be suppressed as well, since this transport translates as supercurrent fluctuations flowing across the junction linking the two resistors.

Here, we report on an experiment showing that, on the contrary, heat transport survives in the high-impedance limit where charge transport vanishes, with a strength that remain close to the limit imposed by the quantum of thermal conductance. This survival cannot be accounted for by the standard theory of dynamical Coulomb Blockade. In light of recent theoretical [2] and experimental [3] developments, we conjecture that, because of the junction's phase slips, inelastic scattering of thermal photons emitted by one resistor results in heavily down-converted, low-energy photons that are nonetheless transmitted to the other resistor, preserving the heat flow, which is a broadband signal.

[1] G.-L. Ingold and Yu. V. Nazarov, "Charge Tunneling Rates in Ultrasmall Junctions", in "Single Charge Tunneling", edited by H. Grabert and M. H. Devoret, NATO ASI Series B, Vol. 294, pp. 21-107 (Plenum Press, New York, 1992)

[2] Moshe Goldstein, Michel H. Devoret, Manuel Houzet, and Leonid I. Glazman, "Inelastic Microwave Photon Scattering off a Quantum Impurity in a Josephson-Junction Array" Phys. Rev. Lett. 110, 017002 (2013)

[3] R. V. Kuzmin, N. Grabon, N. Mehta, A. Burshtein, M. Goldstein, M. Houzet, L. I. Glazman, V. E. Manucharyan, "Inelastic scattering of a photon on a quantum phase slip" Physical Review Letters 126, 197701 (2021)

Hidden momentum and Hall effect

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This contribution concerns the problem of momentum balance in electromechanical systems exposed to static electromagnetic field. While the conversion of electromagnetic momentum into mechanical one is satisfactorily solved for quickly oscillating electromagnetic fields, either theoretically or experimentally, the interaction of ponderable systems with static electromagnetic fields is for more than 120 years a persisting challenge without unambiguous solution [1]. The expected effects are very subtle, of order $\sim 1/c^2$, so they have never been investigated experimentally. They are only subject of abstract theoretical studies. Among the concepts involved, a somewhat puzzling entity, "hidden momentum", representing momentum of non-electromagnetic nature completing the momentum balance plays significant role [2]. To resolve uneasy questions connected with this entity, we suggest to use a robust experimentally manageable phenomenon operating in static electromagnetic fields, ordinary Hall effect, which is sensitive enough to track reliably the exchange of momenta between electromagnetic fields and ponderable matter. Interpreting this effect anew in terms of Poynting vector flows, the importance of time factor characterizing the system assembly is shown, even though the effect formally works in static fields (cf. [3]). This aspect may be crucial also for correct interpretation of other effects belonging to the realm of classical theory of electromagnetic fields.

[1] J. J. Thomson: *On Momentum in the Electric Field*. Phil. Mag. **8** (1904) 331-356

[2] K. T. McDonald: *On the Definition of "Hidden" Momentum.* (July 9, 2012, https://physics.princeton.edu/~mcdonald/examples/hiddendef.pdf)

[3] F. Redfern: *Hidden momentum: A misapplication of the center of energy theorem.* ResearchGate Nov. 2016 (http://dx.doi.org/10.13140/RG.2.2.12838.11840)

Quantum turbulence in superfluid He-4: creation, evolution and decay in novel geometries

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Turbulence is ubiquitous in the real world and affects almost every aspect of our daily lives, including transport, energy production, climate, and biological processes. Despite its universal importance, turbulence is hard to understand at a fundamental level because of the complexity of turbulent motion of the fluid over an extremely wide range of length scales. Quantum mechanics often makes complex problems conceptually simpler, and quantum turbulence (QT) in superfluids is a prime example, consisting of a tangle of vortices that are quantised, and identical. As in classical turbulence, QT is a non-equilibrium phenomenon: remove the driving force, and it decays – though perhaps not completely in superfluid 4He, due to residual quantised vortices pinned metastably to the walls. When the superfluid flows fast enough, the production of QT usually can be "seeded" by such remanent vortices.

We describe an experiment [1] to explore fundamental properties of remanent vortices in the low temperature limit of pure superfluid 4He. We investigate QT for superfluid inside a pill-box-shaped cell fixed symmetrically to a torsional oscillator (TO). In this geometry there is no flow over convex surfaces to create turbulent instabilities. However, we expect the cell movements to generate Kelvin waves on any remanent vortices present if they are pinned to the parallel faces, resulting in reconnections above a critical velocity leading to dissipation through the creation of QT, and correspondingly a change in damping of the TO.

As well as seeking evidence of critical velocities, we are also investigating the pinning of remanent vortices. At finite temperature, we might expect that thermal fluctuations will enable a line to de-pin/re-pin sequentially, sliding its end across the surface whereas, at T=0, the lines would become frozen on pinning sites. There are indications, however, that this may not be what happens in reality. We report preliminary experimental results and discuss future plans for the experiments.

[1] A. M. Guénault, P. V. E. McClintock, M. Poole, R. Schanen, V. Tsepelin, D. Zmeev, D. Schmoranzer and W. F. Vinen, arXiv:2201.08503v1 [cond-mat.other] 21 Jan 2022.

Physical models of mitochondrial proton-pumping complexes

Lev Mourokh

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A proton gradient across a lipid membrane is a common intermediate form of energy storage in biological systems, which is subsequently converted into a proton current and, finally, into the most stable energy of chemical compounds. Even in a single physical system, the inner mitochondrion membrane, there is a variety of mechanisms pumping protons across the membrane, therefore converting the energy of high-energetic electrons into the proton gradient. With the molecular structures of the proton-pumping Complexes I, II, and IV being resolved in detail, actual physical mechanisms of the energy conversion often remain elusive. In this presentation, I will discuss our old and very recent results in modeling the proton-pumping complexes. In Complex IV, the energy transfer due to the direct electrostatic interaction occurs when the electrons and protons populate the sites in close proximity. In Complex I, where the electron and proton sites are well separated, it is assisted by conformational changes in the protein environment. In Complex III, the energy is transferred by means of the electron-proton interaction on the quinone shuttle. In our quantitative approach, we wrote the Heisenberg equations of motion for the electron and proton operators in the presence of the protein environment. In the high-temperature limit, they can be rewritten as the rate equations for the electron and proton populations with the transfer matrix elements having a Marcus-like form. For Complex I, the rate equations are coupled with the phenomenological Langevin equation describing the dynamics of the conformational changes. For Complex III, the mechanical motion of quinones is also described by the Langevin equations. The obtained equations were solved numerically, and it was shown that the protons can be effectively pumped across the membrane within the proposed models for all the Complexes. Moreover, we demonstrated that for the actual sets of parameters, the proton pumping is the most efficient for physiological temperatures.

The fractional quantum Hall state at nu=5/2: Recent insights from theory and experiment

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Non-Abelian phases of matter have long inspired quantum physicists across various disciplines. The strongest experimental evidence of such a phase arises in quantum Hall systems at the filling factor 5/2 but conflicts with decades of numerical work. I will briefly introduce the 5/2 plateau and explain some of the key obstacles to identifying its topological order. I will then describe recent experimental and theoretical progress, including a proposal for resolving the 5/2 enigma based on electrical conductance measurements.

Quantum information with top quarks at the LHC

Juan Ramón Muñoz de Nova[1] and Yoav Afik[2]

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Entanglement is a central subject in quantum mechanics. Due to their genuine relativistic behavior, the exotic character of the interactions and symmetries involved, as well as their fundamental nature, high-energy colliders are attractive systems for the experimental study of quantum information. In particular, top quarks represent unique high-energy systems since their spin correlations can be measured. However, so far, no link between top spin correlations and entanglement has been discussed at the literature. We propose the detection of entanglement between the spins of top–antitop–quark pairs at the LHC [1,2], representing the first proposal of entanglement detection in a pair of quarks, and also the entanglement observation at the highest energy scale so far. We show that entanglement can be observed by direct measurement of the angular separation between the leptons arising from the decay of the top–antitop pair. We analyze the entanglement dependence with the energy of the proton collisions, finding that the detection can be already achieved with high statistical significance using the currently data recorded during Run 2 at the LHC. In addition, we develop a simple protocol for the quantum tomography of the top–antitop pair. This experimental technique reconstructs the quantum state of the system, providing a new experimental tool to test theoretical predictions, as for instance those of New Physics beyond the Standard Model. The explicit implementation of canonical experimental techniques in quantum information in a two-qubit high-energy system paves the way to use high-energy colliders to also study quantum information theory.

[1] Yoav Afik, Juan Ramón Muñoz de Nova, The European Physical Journal Plus 136, 907 (2021).

[2] Yoav Afik, Juan Ramón Muñoz de Nova, arXiv:2203.05582.

A T-cubed atom interferometer

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[4]*This research was performed while the author held an NRC Research Associateship award at the NPS.*

We have been working on a novel atom interferometer whose phase scales as T cubed, where T is the time between the light pulses that form the atom optics of the interferometer. Implementation of this interferometer requires that the atoms move in a linear potential. However, different from a standard Kasevich-Chu interferometer, the linear potential must change with the state of the atom in order to see the T-cubed scaling. We use an appropriately tailored magnetic field to generate this linear potential. I will discuss details of the techniques we use to image the magnetic field, using Raman and Ramsey spectroscopy. I will next discuss our techniques to measure Raman and Ramsey spectra in a magnetic field that varies linearly with position, which includes applying a chirp to the laser system providing the Raman fields. The spectra are produced and displayed as 2D images, and the analysis requires a de-skewing algorithm. Our preliminary measurements on a full atom interferometer showed oscillations that indeed scale as T-cubed, but subsequent measurements showed that the oscillations may not be the effect we seek. I will discuss the interplay of the gradient applied in the direction of the atoms' velocity and the gradient in the orthogonal directions, as dictated by Maxwell's equations. The talk will end with a mystery.

Ghost exchange: Ferromagnetic-antiferromagnetic phase transition in linear optics of non-magnetic dielectrics

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While there exist many photonic equivalents for the physics originally associated with electronic systems, from Anderson localization [1] to Berezenskii-Kosterlitz-Thouless transition,[2] none of them operating in the linear regime offers the possibility of sign reversal of the exchange interaction inherent to strongly correlated interacting electronic systems. As a result, many exchange mediated phenomena of the condensed matter physics are currently beyond the reach of a linear photonic platform.

Here we break through this obstacle by mapping the effective Hamiltonian for the electronic exchange interaction to that of coupled optical modes, using the oscillatory properties of the recently discovered ghost coupling.[3] In particular, the propagating waves in a dielectric photonic crystal formed by alternating layers of biaxially anisotropic and high-index isotropic dielectric materials, satisfy the same Hamiltonian dynamics as the spins in the linear Ising models. Here, the effective Ising spin of the photonic system is defined as the corresponding (real) amplitude in the electromagnetic Bloch function, with the effective Ising Hamiltonian arising from the standard tight-binding expansion of the underlying wave equation.

With such mapping to the exchange-interaction mediated Ising spin chain, the lowest-frequency photonic guided mode corresponds to the ground state of strongly correlated spin system – and naturally shows the resulting "ferromagnetic", "anti-ferromagnetic" - and "paramagnetic" states in the system's phase diagram, as well as the corresponding phase transitions.

To conclude, with the recent discovery of the electromagnetic ghost waves, we established an exact correspondence between the linear electromagnetic wave propagating in biaxial dielectric composite materials, and the dynamics of strongly interacting electronic systems and their associated phase transitions. As ghost waves, have already been demonstrated in experiment [8], this brings many phenomena that were so far limited to electronic condensed matter physics, within the reach of practical photonics.

[1] P.W. Anderson, Phys. Rev. 109, 1492 (1958); M. Segev, Y. Silberberg and D.N. Christodoulides, Nature Photonics 7, 197 (2013).

[2] V.I. Berezinskii, Sov. Phys. JETP 32, 493 (1971); J.M. Kosterlitz and D.J. Thouless, J. Phys. C 6, 1181 (1973); G. Situ and J.W. Fleischer, Nat. Phot. 14, 517 (2020).

[3] E.E. Narimanov, Advanced Photonics 1, 046003 (2019).

[4] M.I. Dyakonov, Sov. Phys. JETP 67(4), 714 (1988).

[5] W. Ma et al., Nature 596, 362 (2021).

T84 Tue, 2 August, 8:50 - 9:20, 1 session

Ultracold Fermi gases in a box

Nir Navon

Yale University, Prospect Street, New Haven, USA

The realization of homogeneous quantum gases has marked a milestone in quantum many-body physics with ultracold atoms [1]. These uniform gases have since opened many new research avenues by simplifying the interpretation of experimental measurements and by enabling previously inaccessible experiments. In this talk, I will present recent investigations of fundamental problems of stability in homogeneous Fermi gases: the case of the spin-1/2 Fermi gas with repulsive contact interactions [2], and of the three-component Fermi gas with spin-population imbalance. Both studies lead to surprising results, highlighting how spatial homogeneity not only simplifies the connection between experiments and theory, but can also unveil unexpected outcomes.

[1] N. Navon, R.P. Smith, Z. Hadzibabic, Nat. Phys. 17, 1334 (2021)

[2] Y. Ji et al., arXiv:2204.03644 (2022)

Exact solutions for black holes with a smooth quantum core

Theo M. Nieuwenhuizen

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A class of exact solutions are presented for the interior of black holes of solar mass and beyond. In a core enclosed by the inner horizon, the binding energy released by dissolution of the pre-collapse nuclei is stored in electrostatic and zero point energy. Gravitational collapse is prevented by their negative pressures.

Accounting for the rest masses of the up and down quarks and electrons leads to corrections at the per cent level.

A surface layer with additional mass and charge can be present on the outer side of the inner and event horizons, so that neutral black holes can be extremal in the interior.

Merging of extremal black holes may produce fireworks.

[1] arXiv:2108.01422 The interior of hairy black holes in standard model physics

T86 Fri, 5 August, 11:40 - 12:10, 2 session - A parallel

What is quantum spin torque: Spintronics meets nonequilibrium strongly correlated and long-range entangled quantum matter

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The “standard model” of magnetization dynamics driven by current via conventional (Slonczewski-Berger) spin-transfer (STT) torque is based on [1] single-particle quantum transport treatment of flowing electrons and classical treatment of localized spins within a magnetic material via the Landau-Lifshitz-Gilbert equation. In the “standard model”, the transfer of spin angular momentum between flowing electronic spins and localized spins occurs only if they are noncollinear. However, recent experiments [2] at low temperatures 1 K suggest that fully quantum nonequilibrium many-body framework is required to describe situations where conventional STT is apparently zero, such as collinear but antiparallel electron and localized spins [3], or localized spins whose expectation value is zero [4] in equilibrium due to entanglement as in the case of quantum antiferromagnets, Mott insulators and quantum spin liquids. To solve this long-standing problems, we have recently [3] adapted time-dependent density matrix renormalization (tDMRG) algorithms for “quantum STT,” by which we term any situation where localized spins must be treated quantum-mechanically with their individual expectation values calculated only at the end. This reveals how quantum STT can generate highly entangled nonequilibrium many-body state of all flowing and localized spins with mutual information between localized spins at the FM edges remaining nonzero even at infinite separation as the signature of dynamical buildup of long-range entanglement [3]. Another prediction from tDMRG [4] shows that interaction of spin-polarized current pulses with the surface of antiferromagnetic Mott insulator (AFMI) will transmute zero expectation value of AFMI localized spins into nonzero values.

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Quantum advantage in the charging of batteries by repeated interactions

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We study self-contained collisional models for the charging of a quantum battery by a stream of identical nonequilibrium qubit units, comparing the charging power for coherent and incoherent protocols on an initially empty battery. The battery can be an oscillator, a large spin, or any other linear energy ladder with a ground state, while the qubits are assumed to be resonant with the ladder, which obviates the need for additional work input as they exchange excitations with the battery.

When the qubits are prepared in a population-inverted, incoherent mixture of energy eigenstates, the energy and ergotropy gain in the battery can be described by a generalized classical random walk process with level-dependent rates. We provide an upper bound on the charging power for any incoherent protocol, including adaptive charging strategies. We show that this bound can be broken by non-adaptive protocols with qubits that contain quantum coherence, thus demonstrating a quantum speedup at the level of a single battery. In homogeneous ladder models with level-independent transition rates, the speedup can be attributed to quantum walk-like interference effects. In oscillator and spin batteries, the greatest speedup is reached in the limit when the charging process approximates a coherent Rabi drive.

We show that such a quantum protocol can significantly outperform the most general adaptive classical schemes, leading to 90% and 38% higher charging power for the cavity and large spin batteries respectively. Concerning possible experimental realizations, we characterise the robustness of the quantum advantage to imperfections (noise and decoherence) and consider implementations with state-of-the-art micromasers and hybrid superconducting devices.

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[2] Salvia et al, arXiv:2205.00026 (2022)

Quantum optics with giant atoms: Decoherence-free interaction between giant atoms in waveguide quantum electrodynamics.

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In quantum optics, atoms are usually approximated as point-like compared to the wavelength of the light they interact with. However, recent advances in experiments with artificial atoms built from superconducting circuits have shown that this assumption can be violated. Instead, these artificial atoms can couple to an electromagnetic field in a waveguide at multiple points, which are spaced wavelength distances apart. Such systems are called giant atoms. They have attracted increasing interest in the past few years (e.g., see the review in [1]), in particular because it turns out that the interference effects due to the multiple coupling points allow giant atoms to interact with each other through the waveguide without losing energy into the waveguide (theory in [2] and experiments in [3]). This talk will review some of these developments. Finally, we will also show how a giant atom coupled to a waveguide with varying impedance can give rise to chiral bound states [4].

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Supercurrent noise in short ballistic graphene Josephson junctions

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Short ballistic graphene Josephson junctions sustain superconducting current with a non-sinusoidal current-phase relation up to a critical current threshold. The current-phase relation, arising from proximitized superconductivity, is gate-voltage tunable and exhibits peculiar skewness observed in high quality graphene super-conductors heterostructures with clean interfaces. These properties make graphene Josephson junctions promising sensitive quantum probes of microscopic fluctuations underlying transport in two-dimensions. Understanding material-inherent microscopic noise sources possibly limiting the phase-coherent behavior of GJJ-based quantum circuits represents an essential, still unexplored, prerequisite. In this presentation we first demonstrate that fluctuations with 1/f power spectrum of the critical current of a short ballistic GJJ directly probe carrier density fluctuations of the graphene channel induced by the presence of charge traps in the nearby substrate, modeled by a spatially uniform distribution of independent generation–recombination centers. Secondly, we study the effect of a dilute homogeneous spatial distribution of non-magnetic impurities on the equilibrium supercurrent within the Dirac-Bogoliubov-de Gennes approach and modeling impurities by the Anderson model. The potentialities of the supercurrent power spectrum for accurate spectroscopy of the hybridized Andreev bound states-impurities spectrum are highlighted. In the low temperature limit, the supercurrent zero frequency thermal noise directly probes the spectral function at the Fermi energy. Our results suggest a roadmap for the analysis of decoherence sources in the implementation of coherent devices by hybrid nanostructures.

[1] F. M. D. Pellegrino, G. Falci, E. Paladino arXiv:2203.04017

[2] F. M. D. Pellegrino, G. Falci, E. Paladino Comm. Phys. 3:6 (2020)

Tabletop mixed radiation source from liquid target via extreme light interactions

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Over-dense matter in relativistic laser-plasma interactions (RLPIs) present an exciting and innovative topic in high field physics, which offers significant promise to advance fundamental knowledge of dense plasmas and develop new sources of energetic particles and radiation. In the interaction of an ultra-intense laser pulse with over-dense matter, electrons are rapidly ionized and accelerated to a significant fraction of the speed of light (> MeV energies) in less than a single optical cycle, producing a broadband bremsstrahlung and narrow k-shell X-rays, and creating a bright source of light spanning from optical to gamma rays; They also help MeV-scale ion acceleration. The resulting generation of energetic radiation and particles creates a single, compact, table-top source of electrons, ions, positrons, neutrons, XUV, X-ray, gamma radiation, and even neutron generation, which offer a small footprint and a cost-effective source with ultrashort pulse duration capability.

We will present how our ability to dynamically generate different target shapes enhance our ability to reach high-density plasma regime, leading up to the unique radiation source from kHz-repetition-rate compatible liquid targets via its interaction with ultrashort lasers at our extreme light laboratory.

Entangled beams and photon multiplets from a dc-biased superconducting circuit

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DC-biased superconducting circuits including a Josephson junction in series with microwave resonators have emerged as a versatile platform for the generation of quantum microwave radiation [1,2]. In these devices, the energy needed to create photons is provided by the DC-voltage source upon the tunneling of Cooper pairs across the junction. We first demonstrate the emission of bright entangled microwave beams by a junction coupled to two resonators with different frequencies, in a process similar to parametric down-conversion [3]. Then, we show how a single resonator with a high-enough impedance can reach the regime of strong-coupling to the junction, with an effective fine-structure constant of $\alpha \simeq 1$. This strong coupling allows us to observe the emission of photon mulitplets by the circuit, with up to 6 photons emitted at the same time by a single tunnel event [4].

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[3] A. Peugeot, G.C. Ménard, S. Dambach, M. Westig et al., Phys. Rev. X, 11.3 (2021) 031008

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Emergent functionality in quantum plasmonics

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Enhancing complexity in interacting systems could give rise to emergent behavior with phase transitions and chaos as striking examples. It is interesting to ask on what level of complexity such emergent behavior arises in quantum systems. Here we demonstrate that already for two interacting quantum systems coupled to the environment a new functionality of the system emerges, i.e., single-photon spontaneous down conversion occurs in a plasmon-exciton hybrid system with almost unity efficiency. In strongly coupled quantum systems, pure dephasing mechanisms acting on one constituent of the hybrid system break symmetry and enable optical transitions, which are forbidden in the uncoupled system. Here we employ this concept to a localized plasmon ultrastrongly coupled to an exciton, which is exposed to an ultrafast pure dephasing process, and demonstrate single-photon induced parametric down-conversion. Fast pure dephasing of the exciton enables photon pair generation as the dominating energy relaxation pathway for the excited system. Note that here the pure dephasing via the interaction with the environment, which is in general seen as a detrimental effect, is key to enable the desired functionality.

Extracting (anomalous) weak values by detecting a single photon

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Is it possible, when measuring a spin component of a spin-1/2 particle, to obtain a value of 100? In 1988 Aharonov, Albert and Vaidman argued that, upon pre- and postselection of particular spin states, weakening the coupling between quantum system and measuring device could allow obtaining this paradoxical result, called "weak value". Weak values have been realised in several experiments, but they are still a lively-debated topic, especially in regard of their "quantumness" and "anomalous" nature (i.e., the possibility to exceed the eigenvalue spectrum). We address these questions by presenting the measurement procedure able to obtain anomalous weak values with just a single photon detection, with no need for statistical averaging [1]. Following this line, we also show what happens if, within the same experimental procedure, we explore different directions, e.g., by making pre- and post-selection coincide (obtaining the so-called Protective Measurement, able to determine the quantum expectation value of an observable with a single detection event [2,3]) and by relaxing the constraint on the coupling weakness. Beyond clarifying the weak value meaning, demonstrating its non-statistical, single-particle nature, these results represent not only a real breakthrough in understanding quantum measurement foundations, but also a groundbreaking tool for quantum technologies, showing unprecedented measurement capability and paving the way to a widespread application of weak values in this field.

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The power of the boundary: Creating quantum spin helices, quantum skyrmions, and measuring one-dimensional topological superconductivity without relying on Majorana modes

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Manipulating the boundary of low-dimensional spin systems can grant full control about topological excitations in this kind of quantum matter. I will discuss the creation and the stability of quantum spin helices and quantum magnetic skyrmions in one- and two-dimensional quantum systems, indicate their possible application to quantum information processing, and outline upcoming theoretical and experimental challenges. Boundaries of electronic topological phases play an elemental role as well, yet differently, by accommodating zero-energy boundary modes. I will further describe how to detect one-dimensional topological superconductivity in circular systems, i.e., without the presence of (Majorana) boundary modes, by using multidimensional spectroscopy.

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Dynamically assisted tunneling in the impulse regime

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We study the enhancement of tunneling through a potential barrier $V(x)$ by a time-dependent electric field with special emphasis on pulse-shaped vector potentials such as $A_x(t) = A_0/\cosh^2(\omega t)$. In addition to the known effects of pre-acceleration and potential deformation already present in the adiabatic regime, as well as energy mixing in analogy to the Franz-Keldysh effect in the non-adiabatic (impulse) regime, the pulse $A_x(t)$ can enhance tunneling by "pushing" part of the wave-function out of the rear end of the barrier. Besides the natural applications in condensed matter and atomic physics, these findings could be relevant for nuclear fusion, where pulses $A_x(t)$ with ω = 1 keV and peak field strengths of 10^{16} V/m might enhance tunneling rates significantly.

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Singular optimal solutions of stochastic pumps

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The investigation of optimal processes has a long history in the field of thermodynamics. It is well known that finite-time processes that minimize dissipation often exhibit discontinuities. We use a combination of numerical and analytical approaches to study the driving cycle that maximizes the output in a simple model of a stochastic pump: a system driven out of equilibrium by a cyclic variation of external parameters. We find that this optimal solution is singular, with an infinite rate of switching between sets of parameters. The appearance of such a singular optimal solution in a thermodynamic process is surprising. Nevertheless, we argue that such solutions are expected to be quite common in models whose dynamics exhibit exponential relaxation, as long as the driving period is allowed to be arbitrarily short. Our results have implications to artificial molecular motors that are driven by a cyclic variation of parameters.

Twin lattice interferometry - a tool for gyros and gravitational-wave detection

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Ultra-cold quantum gases promise to boost the sensitivity of inertial matter-wave interferometers. A long-standing application is the high-precision measurement of rotations, where the device sensitivity scales with the area enclosed by the interferometer. Compared to light matter waves show a larger intrinsic sensitivity and hence, these interferometers require to enclose smaller surfaces. However, beam splitters based on ligth-pulses achieved so far rather modest relative velocities in atom interferometers. Here, twin-lattice interferometry exploiting ultra-cold quantum gases opens up a new perspectives for atom-interferometric rotation measurements.

Delta-T noise in quantum Hall junctions

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Noise is a fundamentally inescapable ingredient of any electronic device, that has now been broadly accepted as a key tool to improve our understanding of nanoscale conductors. Electronic noise is typically broken down into two contributions: thermal (or Johnson-Nyquist) noise and shot noise. Using atomic-scale metallic junctions [1], it was recently showed that under a temperature rather than a voltage bias, a finite non-equilibrium noise signal could be measured , which the authors dubbed "delta-T noise". This previously undocumented source of noise actually corresponds to some form of temperature-activated shot noise.

Here, we propose to investigate the fate of delta-T noise in a prototypical strongly correlated state, namely the edge states of the fractional quantum Hall effect (FQHE). We first study the current correlations of fractional quantum Hall edges at the output of a quantum point contact (QPC) subjected to a temperature gradient. We show that the tunneling of Laughlin quasiparticles leads to a negative delta-T noise, in stark contrast with electron tunneling, a result which arises from the interplay of strong correlations and fractional statistics [2].

We then move on to the situation of an inhomogeneous junction involving two coupled edge states belonging to Hall fluids with different filling factors [3]. In the specific case of an hybrid junction (1/3, 1), we are able to solve exactly the problem for all couplings and for any set of temperatures, showing that contributions linear in the temperature gradient are largely dominating. This then motivates us to derive a universal analytical expression connecting the delta-T noise to the equilibrium one up to lowest order in the temperature mismatch, for any junction involving two fluids belonging to the Laughlin sequence.

Beyond the inherent interest in studying delta-T noise in such systems, accessing properties that cannot be addressed by the usual voltage-induced shot noise, our work may help better understanding charge and heat transport in situations where strong electronic correlations are operating. This would, in turn, allow us to move toward a more involved investigation of the statistics and scaling dimension of their emergent excitations.

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Droplet-superfluid compounds in binary bosonic mixtures

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In this talk, I will review how quantum fluctuations in dipolar or binary mixtures of bosonic atoms with short-range interactions can lead to the formation of self-bound droplets. Emphasis will be on persistent currents in ring-trapped dipolar supersolids. For binary condensates with equal intra-component interactions but an unequal number of atoms in the two components, there is an excess part that cannot bind. A droplet then becomes amalgamated with a residual condensate. This results in particular rotational behavior that sheds new light on the coexistence of localization and superfluidity.

Quantum probability from causal structure

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The Born probability measure describes the statistics of measurements in which observers self-locate themselves in some region of reality [1]. In ψ-ontic quantum theories, reality is directly represented by the wavefunction. We show that quantum probabilities may be identified with fractions of a universal multiple-time wavefunction containing both causal and retrocausal temporal parts. This wavefunction is defined in an appropriately generalized history space on the Keldysh time contour [2]. Our deterministic formulation of quantum mechanics replaces the initial condition of standard Schrödinger dynamics with a network of 'fixed points' defining quantum histories on the contour. The Born measure is derived by summing up the wavefunction along these histories. We then apply the same technique to the derivation of the statistics of measurements with pre- and post-selection [3].

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Quantum computing and simulation with high-dimensional systems

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Today's quantum computers are almost exclusively built for binary information processing, inherited from classical computers. Yet, the underlying quantum systems, in particular trapped ions, are inherently multilevel systems. Similarly, a wide range of target applications for quantum computers and simulators are naturally formulated in high-dimensional Hilbert spaces. I will discuss how to construct a universal toolbox for quantum information processing in trapped-ion qudits and how to use it for improved quantum information processing. We demonstrate that the performance of the quantum processor does not degrade with qudit dimension, making this a promising way to scale the computational power of existing quantum hardware.

Measurement-induced topological transition in a free fermion model

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Quantum measurements have been recently exploited as a tool to induce phase transitions between different steady-state phases of many-body systems. Transitions between phases with different entanglement scaling properties have been initially predicted in quantum circuits with unitary and projective gates [1]. Such transitions can be induced by continuous measurement too, for which analytical treatments and large system size numerical implementation are possible in free fermion models. Here we study a free fermion model where two sets of non-commuting continuous measurements induce a transition between area-law entanglement scaling phases of distinct topological order [2].

We find that, in the presence of unitary dynamics, the two topological phases are separated by a region with sub-volume scaling of the entanglement entropy and that the transition universality class of the measurement-only model differs from that in interacting models with stroboscopic dynamics and projective measurements. We further show that the phase diagram is qualitatively captured by an analytically tractable non-Hermitian Hamiltonian model obtained via post-selection. By the introduction of a partial-post-selection continuous mapping, we show that the topological distinct phases of the stochastic measurement-induced dynamics are uniquely associated with the topological indices of the non-Hermitian Hamiltonian. Our results mark a clear distinction between the topological phase transition induced by projective and continuous measurements and open a door to the construction of topological invariants for stochastic quantum dynamics.

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Room-temperature tunable masers based on the weakly aligned molecules

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We have developed and demonstrated a new mechanism of manipulation of population in molecular rotational levels in a weakly aligned molecules. The mechanism is based on an adiabatically changing electric field interacting with the molecules with dipole moments. Treating molecules as simple rotators, we have described their behavior using the density matrix taking into account the relaxation processes. We have considered the interaction of the weakly aligned molecules with a microwave field in a high finesse cavity. We have found that, on one hand, the population inversion can be reached in the ensemble of the weakly aligned molecules to be used for the maser operation at room temperature. On the another hand, we have found that the enhancement of the absorption can reach the theoretical limit and be used for gas sensing with high sensitivity and selectivity. Such sensors can efficiently analyze the multi-gas mixtures and be used for a huge range of applications – stretching from technology, sciences, control of environment, biology and medicine.

Emulating black holes using surface gravity waves

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It is the occurrence of a logarithmic phase singularity in the proximity of a horizon that lies at the heart of Hawking and Unruh radiation. Recently, these effects have been related to a simple quantum system with a parabolic barrier [1]. Here we demonstrate experimentally that freely propagating waves can also display a horizon and a logarithmic phase singularity. While black hole singularities have already been related to various analog systems, such as hydraulic and acoustic black holes, as well as thermal BEC black holes [2]. In contrast to these experiments, our results indicate that a simple physical system is sufficient to provide fundamental insights into a very complex problem. We tackle this problem by utilizing Weber wave packets, which are the eigenstates of the inverted harmonic oscillator system. An interesting observation is that even without a potential, an initial state that is an energy eigenstate of the inverted harmonic oscillator (i.e., a Weber wave packet) would evolve in free space until it reaches an amplitude singularity, accompanied by a logarithmic phase singularity. These experiments predict that similar physics can be observed for optical, acoustic, and matter waves [3]. In my talk, I will review the intriguing analogies between quantum mechanics, surface gravity waves, and optical systems, as well as present our latest results on several topics, and discuss new measurements and directions.

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Negative thermophoresis in the strong coupling regime

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Negative thermophoresis (a particle moving up the temperature gradient) is a somewhat counterintuitive phenomenon that has thus far eluded a simple thermostatistical description. We will show that a thermodynamic framework based on the formulation of a Hamiltonian of mean force has the descriptive ability to capture this interesting and elusive phenomenon in a straightforward fashion. We propose a mechanism that describes the advent of a thermophoretic force acting from cold to hot on systems that are strongly coupled to a nonisothermal heat bath [1]. When a system is strongly coupled to the heat bath, the system's eigenenergies become effectively temperature-dependent. This adjustment of the energy levels allows the system to take heat from the environment, and return it as work. This effect can make the temperature dependence of the effective energy profile nonmonotonic. As a result, particles may experience a force in either direction depending on the temperature.

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Quantum computing algorithms for Green's functions in materials science

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Quantum embedding approaches for materials simulations, such as the dynamical mean-field theory (DMFT), provide corrections to first-principles calculations for strongly correlated electrons, which are poorly described at lower levels of theory. These embedding methods are computationally demanding on classical computing architectures, and hence remain restricted to small systems, limiting the scope of their applicability. Quantum computers have the potential to overcome this limitation. In this talk we present different methods to compute the Green's functions on quantum computers for materials science simulations, which are based either on the Lehman representation (arXiv:1910.04735, Nature Comp. Sci. 1. 410 (2021)), or on a continued fraction representation using the Krylov basis. We consider two methods to construct the Krylov states. The first is based on the Krylov variational quantum algorithm (KVQA, arXiv:2105.13298), while the second method uses the quantum subspace expansion for Green's functions (QSEG, arXiv:2205.00094).

Photoassisted chiral transport beyond the Carnot limit

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Classically, the power generated by an ideal thermal machine cannot be larger than the Carnot limit. This profound result is rooted in the second law of thermodynamics. A hot question is whether this bound is still valid for microengines operating far from equilibrium. We will show [1] that a quantum chiral conductor driven by AC voltage can indeed work with efficiencies much larger than the Carnot bound. The system also extracts work from common temperature baths, violating Kelvin-Planck statement. Nonetheless, with the proper definition, entropy production is always positive and the second law is preserved. To this end, we adopt the Floquet scattering matrix approach for electric and heat currents and also a generalized definition of entropy production based on Shannon formula for the incoming and outgoing electron distributions in each terminal. We find that the engine efficiency exceeds the Carnot limit when the entropy production is deviated from the Clausius relation due to the energy uncertainty induced by the AC driving. The role of the AC driving can be interpreted as a nonequilibrium demon as the driving induces additional entropy production by rearranging the distribution of electrons in energy in a more uncertain way, while injecting no energy. Our results are relevant in view of recent developments that use small conductors to test the fundamental limits of thermodynamic engines.

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Experimental detection of the correlation Renyi entropy in the central spin model

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A major open question in studies of nonequilibrium quantum dynamics is how long it takes for an isolated many-body quantum system to reach equilibrium. We show that there is not a single answer for this question. The equilibration time depends not only on the model and the initial state, but also on the quantity and the dynamical features considered. We discuss a recent NMR experiment, where we measured a new entropy – the correlation Rényi entropy – and showed that it keeps growing even after the evolution of the entanglement entropy has already saturated [1]. We also discuss the case of chaotic models, where the equilibration time can scale either exponentially or polynomially with system size depending on whether dynamical manifestations of spectral correlations in the form of the correlation hole ("ramp") are taken into account or not [2].

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[2] T. Lezama et al, Phys. Rev. B 104, 085117 (2021).

The Riemann zeta function and quantum mechanics

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The Riemann zeta function ζ plays a crucial role in number theory as well as physics. Indeed, the distribution of primes is intimately connected to the non-trivial zeros of this function. We briefly summarize the essential properties of the Riemann zeta function and then present a quantum mechanical system which when measured appropriately yields ζ. We emphasize that for the representation in terms of a Dirichlet series interference [1] suffices to obtain ζ. However, in order to create ζ along the critical line where the non-trivial zeros are located we need two entangled quantum systems [2]. In this way entanglement may be considered the quantum analogue of the analytical continuation of complex analysis. We also analyze the Newton flows [3, 4] of ζ as well as of the closely related function ξ. Both provide additional insight [5] into the Riemann hypothesis.

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Supercurrent-enabled Andreev reflection in a chiral quantum Hall edge state

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A chiral quantum Hall (QH) edge state placed in proximity to an s-wave superconductor experiences induced superconducting correlations. Recent experiments have observed the effect of proximity-coupling in QH edge states through signatures of the mediating process of Andreev reflection. We present the microscopic theory behind this effect by modeling the system with a many-body Hamiltonian, consisting of an s-wave superconductor, subject to spin-orbit coupling and a magnetic field, which is coupled by electron tunneling to a QH edge state. By integrating out the superconductor we obtain an effective pairing Hamiltonian in the QH edge state. We clarify the qualitative appearance of nonlocal superconducting correlations in a chiral edge state and analytically predict the suppression of electron-hole conversion at low energies (Pauli blocking) and negative resistance as experimental signatures of Andreev reflection in this setup. In particular, we show how two surface phenomena of the superconductor, namely Rashba spin-orbit coupling and a supercurrent due to the Meissner effect, are essential for the Andreev reflection. Our work provides a promising pathway to the realization of Majorana zero-modes and their parafermionic generalizations.

50 Years and counting: Major science from Apollo 17 mission to Taurus-Littrow on the Moon

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The Apollo 17 exploration of the valley of Taurus-Littrow on the Moon, December 11-14, 1972, and subsequent analytical and synthesis of sample analyses, geophysical data, and photographic documentation, provides insights into the development of the lunar regolith, the origin of life and the history of the sun relative to the evolution of that life on Earth, and the nature of the lunar interior among many other details about the history of the Moon. ORIGIN OF LIFE: The finely commutated lunar regolith provides insights into the Earth's surface environment in which replicating life first appeared. In the water-rich regolith existing on Earth soon after crust formation, glass and minerals would rapidly alter to complex phylosilicates (smectitic clay) whose sheet-like crystal structures can evolve inorganically to survive in changing environments but also can provide physical and geochemical templates for the organization of complex organic molecules and simple cellular components. HISTORY OF THE SUN: Data on isotopic ratios of nitrogen 15 to nitrogen 14 in regolith zones in the deep drill core strata indicate that $\delta15\text{N}\permil$ increases linearly with zone maturity (Is/FeO) from as solar wind value of $\delta15\text{N}\permil{=}{-113} \pm 9\permil$. A factor of over 2 change in the slope of a plot of $\delta15\text{N}\permil$ vs. Is/FeO at about 0.550 Ga indicates a significant increase in the average energy of the solar wind. This increase may be the proximate cause of the "Cambrian Explosion" in the quantity and diversity of life forms in the Earth's oceans. LUNAR INTERIOR: Lunar samples 72415 (dunite) and 76235 (troctolite) have symplectitic textures that indicate a geologically rapid decrease of pressure. This suggests that the extremely large, ~3200 km diameter, Procellarum basin-forming impact caused an overturn in the warm upper mantle beneath it. This overturn caused dense, late, and ilmenite-rich cumulates from the crystallization of the Moon's magma ocean to move downward and old, relatively less dense, olivine and plagioclase-rich cumulates to move upward from about 500-400 km depth. The latter then were distributed across the lunar surface by later basin-forming impacts such as Imbrium. The partial melting of the mantle caused by the release of pressure from the basin's excavation also generated the Mg-suite magmas that crystallized in the lower lunar crust at ~4.35 Ga. In addition, the volatiles associated with and included in the Apollo 17 pyroclastic ash deposit (74220 and core 74001-2) include both water and elements with primordial isotopic and elemental ratios. These data indicate that the lower lunar mantle retains primordial geochemical characteristics and did not form by fractional crystallization as part of the accretionary magma ocean, and argue against a giant impact origin. GLOBAL MAGNETIC FIELD: Remnant magnetism in basalt samples from the rim of Camelot Crater indicates the existence of a global, rotation axis oriented, dynamo-driven magnetic field early in lunar history.

T112 Mon, 1 August, 13:30 - 14:00, 3 session - C parallel

Automated generation of spin-bath Hamiltonians for a wide range of interacting systems

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In simulating quantum materials one always has to extract the basic ingredients of a system into a model in order to describe the material under investigation. Here we describe an approach that allows us to extract the spin part of an interacting electronic system leading to a spin system coupled to a fermionic bath. To this end we first perform orbital transformations optimizing the separation of spin and fermionic degrees of freedom. We then perform a generalized Schrieffer-Wolff transformation that leads to the desired spin-bath system. Finally we present results starting with the well known single impurity Anderson model. We then discuss the calculation of the band structure of a two band Hubbard model. Finally we comment on the application to molecular systems.

Of Bose condensates, squeezed light and black holes

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The interface between statistical and optical physics is rich and full of surprises. The present perspective is based on the analogy between ordinary (photon) lasers [1] and the BEC atom laser [2], on the one hand, and Unruh radiation emitted by accelerating atoms in the vicinity of a black hole, on the other. The dynamics of interacting superfluid Bose condensates is naturally developed in which atom pairs, k and -k, are studied [3]. New insights into the Unruh-Hawking radiation problem come from similar pairing correlations between photons above and below the black hole horizon [4]. The quantum optical approach to the problem of Unruh-Hawking radiation gives us new insight into rather subtle aspects of causality and entanglement associated with Unruh acceleration radiation [5].

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Insights from high harmonic generation. Toy models

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High harmonic generation (HHG) is well understood in terms of a 3-step process, wherein tunnel ionization takes place close to the maximum of the electric field of an intense light pulse, generating a free-electron wave packet in the continuum that follows the electric field oscillations. If the field is linearly (or close to linearly) polarized, the electron will revisit the core, with the most energetic recollisions taking place near the second zero of the laser electric field after the electron release. One of the possible consequences of such coherent, energetic recollision events is recombination, whereby photons at high harmonics of the incident frequency are generated. In this talk we will discuss two tunneling toy models that combine to explain the beautiful physics that ensues in case the target molecule is prealigned. The first model describes bound-free electron tunneling and the second describes bound-bound rotational tunneling. Together, these models point to the information content of HHG from aligned molecules. In particular, our theory illustrates that harmonic signals map the rotational coherences of the aligned rotational wavepacket and probe the electronic continua of the molecule.

Trivial and topological confinements in bilayer graphene

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We discuss and compare two different types of confinement in bilayer graphene by top and bottom gating with symmetrical microelectrodes. Trivial confinement corresponds to the same potential of all top gates, which is opposed to that of all bottom ones. Topological confinement requires the polarity of part of the top-bottom pairs of gates to be reversed. We show that the main qualitative difference between trivial and topological bound states manifests itself in the magnetic field dependence. We illustrate our finding with an explicit calculation of the energy spectrum for quantum dots and rings. Trivial confinement shows bunching of levels into degenerate Landau bands, with a non-centered gap, while topological confinement shows no field-induced gap and a sequence of state branches always crossing zero-energy [1-3].

The conductance of electrostatic wire junctions in bilayer graphene is calculated next. We report a conductance quench of the trivial-topological junction, with a conductance near quantization to $4e^2/h$, which is only half of the maximum value allowed by the Chern number of a kink-antikink system. The analysis allowed us to uncover the existence of a chiral edge mode in the trivial wire under quite general conditions. A double junction, trivial-topological-trivial, displays periodic Fano-like conductance resonances (dips or peaks) induced by the created topological loop [4].

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[4] S. Ryu, R. Lopez. L. Serra, preprint (2022).

Quantum control via Landau-Zener-Stuckelberg-Majorana transitions

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Since the pioneering works by Landau, Zener, Stuckelberg, and Majorana (LZSM), it has been known that driving a quantum two-level system results in tunneling between its states. Even though the interference between these transitions is known to be important, it is only recently that it became both accessible, controllable, and useful for engineering quantum systems [1]. We study systematically various aspects of LZSM physics and review the relevant literature, significantly expanding the review article in Ref. [2]. In particular, we address such aspects as Majorana's approach, LZSM logic gates, and dynamics of multi-level systems.

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Quantum computer health check via quantum random number generation

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All computing devices, including quantum computers, must exhibit that for a given input, an output is produced in accordance with the program. The outputs generated by quantum computers that fulfill these requirements are not temporally correlated, however. In a quantum-computing device comprising solid-state qubits such as superconducting qubits, any operation to rest the qubits to their initial state faces a practical problem. On the implementation of the scalable quantum computers, the health check (or stability check) algorithms are needed. We propose that the quantum random number generation is one of the candidates of the health check algorithms in any quantum computing devices.

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Shot noise in superconducting sub gap states

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Majorana bound states are promising building blocks of forthcoming technology in quantum computing. Chains and islands of magnetic impurities in superconductors have attracted considerable attention recently as such systems may host Majorana bound states. However, their non-ambiguous identification has remained a difficult issue because of the concomitant competition with other topologically trivial fermionic states, which poison their detection in most spectroscopic probes. I will theoretically show that the Fano factor, which is the ratio between shot noise and the current, turns out to be a very interesting and distinctive tool in that respect. In particular, the Fano factor tomography displays a spatially constant Poissonian value equal to one for Majorana bound states while it is strongly spatially dependent and exceeds one as a direct consequence of the local particle-hole symmetry breaking for other trivial fermionic in-gap states such as Yu-Shiba-Rusinov or Andreev ones [1]. I will also show how shot noise can be used to reveal coherent and incoherent dynamics of an in-gap bound state associated to the presence of a magnetic impurity in a superconductor which sets the stage for a comparison with experimental shot noise data measured by our experimental colleagues [2].

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Superfluidity from correlations in driven boson systems

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We study a one-dimensional Bose-Hubbard gas in a lattice whose hopping energy is made to oscillate with zero time average. At high frequencies, such a driving gives rise to a static effective model where first-order particle hopping is suppressed while processes of even order in the hopping are allowed, which results in a dynamics that is entirely driven by multi-particle correlations [1]. At a critical value of the driving amplitude, the system passes from a Mott insulator to an exotic superfluid phase whose cat-like ground state consists of two branches characterized by the preferential occupation of opposite momentum eigenstates [2]. We discuss how this non-equilibrium superfluid phase, without autonomous single-particle hopping and thus exclusively based on correlations, differs qualitatively from conventional superfluidity. The effect is robust against variations in experimental details [3]. We thus show that driving the tunnelling ("kinetic driving") provides a novel form of Floquet engineering, which enables atypical Hamiltonians and exotic states of matter to be produced and controlled.

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Quantized phase-coherent heat transport of counterpropagating Majorana modes

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We demonstrate that phase-coherent heat transport constitutes a powerful tool to probe Majorana physics in topological Josephson junctions. We predict that the thermal conductance transverse to the direction of the superconducting phase bias is universally quantized by half the thermal conductance quantum at phase difference $\varphi = \pi$. This is a direct consequence of the parity-protected counterpropagating Majorana modes which are hosted at the superconducting interfaces. Away from $\varphi = \pi$, we find a strong suppression of the thermal conductance due to the opening of a gap in the Andreev spectrum. This behavior is very robust with respect to the presence of magnetic fields. It is in direct contrast to the thermal conductance of a trivial Josephson junction which is suppressed at any phase difference φ. Thus, thermal transport can provide strong evidence for the existence of Majorana modes in topological Josephson junctions.

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On physical processes controlling biological neural networks

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A hypothesis of fixation of information processing patterns and of learning in biological neural networks (BNN) is formulated: Short-range communication of neurons due to the ephaptic coupling ("cross-talk") via extracellular tissue (ECT), which is responsible for information processing, is enhanced by directed growth of dendrites controlled by galvanotaxis. This biophysical mechanism together with closed network topology, which are essentially different from those used in artificial neural networks, accounts for appreciable higher performance of BNNs despite they work at about million times lower frequencies. The hypothesis is based on our recent research into the ionic quantum diffusive transport of action potential through nerve fibre [1] and into the effect of ECT for the maintaining of homeostasis of nervous system and into the ephaptic coupling among vicinal neurons [2].

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Arcsine law and multistable Brownian dynamics in a tilted periodic potential

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Multistability is one of the most important phenomena in dynamical systems, e.g., bistability enables the implementation of logic gates and therefore computation. Recently multistability has attracted a greatly renewed interest related to memristors and graphene structures, to name only a few. We investigate tristability in velocity dynamics of a Brownian particle subjected to a tilted periodic potential. It is demonstrated that the origin of this effect is attributed to the arcsine law for the velocity dynamics at the zero temperature limit. We analyze the impact of thermal fluctuations and construct the phase diagram for the stability of the velocity dynamics. It suggests an efficient strategy to control the multistability by changing solely the force acting on the particle or temperature of the system. Our findings for the paradigmatic model of nonequilibrium statistical physics apply to, inter alia, Brownian motors, Josephson junctions, cold atoms dwelling in optical lattices, and colloidal systems.

[1] J. Spiechowicz and J. Łuczka, Phys. Rev. E 104 (2021) 024132

Unveiling and veiling an entangled light-matter quantum state from the vacuum

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The ground state of an atom interacting with the electromagnetic field in the ultrastrong coupling regime is composed of virtual photons entangled with the atom. We propose a method to promote to real the entire photonic state, while preserving the entanglement with the atom. We consider a four-level atom, with two of these levels ultrastrongly coupled to a cavity mode. The process is obtained by making use of either an ultrafast pulse or a multi-tone π-pulse that drives only the atom. An experimental realization of this proposal will enable the investigation of the exotic phenomena of emission of particles from the vacuum. Moreover, it will allow the inspection of the full structure of the ground state in the ultrastrong coupling regime, and to generate on-demand entangled states for quantum information processing.

[1] R Stassi, M Cirio, K Funo, N Lambert, J Puebla, F Nori. arXiv preprint arXiv:2110.02674, 2021. https://doi.org/10.48550/arXiv.2110.02674

Analogue cosmological particle creation in an ultracold quantum fluid of light

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It is thought that the rapid expansion of the early universe resulted in the spontaneous production of cosmological particles [1]. The latter evolved into the patterns in the cosmic microwave background visible today [2]. The analogue of cosmological particle creation in a quantum fluid could provide insight, but an observation was not achieved previously. This talk presents our observation of analogue cosmological particle creation in a 3-dimensional quantum fluid of light [3]. The process is seen to be spontaneous, and in close quantitative agreement with the quantum-field theoretical prediction. We find that the long-wavelength particles provide a window to early times. This work introduces a new quantum fluid, as cold as an atomic Bose-Einstein condensate.

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[2] N. Aghanim, et al., Planck 2018 results. I. Overview and the cosmological legacy of Planck, Astronomy and Astrophysics 641 (2019) A1.

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The different guises of hierarchical equations of motion

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Hierarchical equations of motion (HEOM) are one of the most robust and versatile approaches to the dynamics of open quantum systems, using auxiliary density operators with time-local equations of motion and typically relying on a multi-exponential decomposition of the reservoir correlation function. While HEOM methods were originally introduced as a technical method to wrest time-local dynamics from non-local path integrals, we now understand that they have – even in the deep quantum limmit – intricate links to Fokker-Planck dynamics as well as other extended-state open system methods such as the quasimode approach. Viewing the extended-state space in a unified, abstract way provides a rich structure of transformations which can significantly improve the stability and efficiency of real-world HEOM simulations.

Previous, physically motivated versions of the multi-exponential decomposition led to a proliferation of terms in the low-temperature regime, resulting in exponential computational cost. We point out a strategy which overcomes this obstacle and provides highly accurate results even for zero temperature and long times [1]. As a test case, the asymptotic algebraic decay of a sub-ohmic spin-boson autocorrelation function is numerically recovered.

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Anomalous Hall conductivity and quantum friction

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Anomalous Hall effect observed on ferromagnetic systems in absence of the external magnetic field attracted attention for more than century. Nevertheless, some of theoretical descriptions of its properties are still controversial. Anomalous Hall conductivity as function of the longitudinal conductivity shows quite large region independent on the system disorder. Measured values coincide quite well with Kubo formula results applied to pure crystals. Surprisingly at higher conductivity region the independence is lost and it starts to increase with decreasing scattering events. Using a two-dimensional network model it will be shown that the Hall conductivity comprises two parts: one which reflects the bulk properties as obtained by the Kubo formula and another which is sensitive to boundary conditions imposed on the network. In fully coherent limit the latter scales with the width of the conducting channel while for real-world samples it is controlled by the coherence length. This interpretation of the observed behavior in the clean limit is based on the quantum friction in analogy with classical friction in viscous fluids responsible for Couette flow [1].

[1] https://arxiv.org/abs/2206.03470

Transmission line approach to transport of heat in chiral and drift-diffusion systems with dissipation

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Measurements of the energy relaxation in the integer quantum hall edge at filling factor ν=2 suggest the breakdown of heat current quantization [H. le Sueur et al., Phys. Rev. Lett. 105, 056803]. It was shown, in a hydrodynamic model, that dissipative neutral modes contributing apparently less than a quantum of heat can be an explanation for the missing heat flux [A Goremykina et al., arXiv preprint arXiv:1908.01213]. This hydrodynamic model relies on the introduction of an artificial high-energy cut-off and lacks a way of a priori obtaining the correct definition of the heat flux. In this work we overcome these limitations and present a formalism, effectively modeling dissipation in the quantum hall edge, proving the quantization of heat flux for all modes. We mapped the QHE to a transmission line by analogy and used the Langevin equations and scattering theory to extract the heat current in the presence of dissipation and (chirality breaking) diffusion.

T128 Tue, 2 August, 13:00 - 13:30, 3 session - B parallel

Quantum flicker noise demonstrated in molecular junctions

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We report on a quantum form of electronic flicker noise that contains valuable information on quantum transport [1,2]. This noise is experimentally studied in molecular junctions, and theoretically analyzed considering quantum interference due to fluctuating scatterers. The identified form of flicker noise uniquely depends on the distribution of transmission channels, which are a central characteristic of quantum conductors. This dependence opens the way for the application of flicker noise as a diagnostic probe for fundamental quantum transport properties, a role that to date has been performed by the experimentally less accessible shot noise.

[1] O. Shein-Lumbroso, J. Liu, A. Shastry, D. Segal and O. Tal, Phys. Rev. Lett. 128 (2022) 237701.

[2] M. Rini, Phys. 15 (2022) s78.

Simulation of quantum transport using the hierarchical equations of motion method

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The hierarchical equations of motion (HEOM) formalism is an accurate and efficient approach to simulate the dynamics of open quantum systems [1]. Formulated as a density matrix scheme, it generalizes perturbative quantum master equation methods by including higher-order contributions as well as non-Markovian memory and allows for the systematic convergence of the results. In this talk, recent extensions of the HEOM method are discussed, including open quantum systems with multiple bosonic and fermionic environments [2] and a matrix product state formulation in twin space [3]. While the former is important for applications in the areas of quantum thermodynamics and quantum transport, the latter allows the simulation of significantly larger systems. Applications of the method to quantum transport in molecular junctions are presented [4], focusing on models with electronic-vibrational coupling, nonadiabatic effects, current fluctuations as well as current-induced bond rupture.

[1] Y. Tanimura, J. Chem. Phys. 153 (2020) 020901.

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[4] C. Schinabeck, A. Erpenbeck, R. Härtle, M. Thoss, Phys. Rev. B 94 (2016) 201407(R); C. Schinabeck, M. Thoss, Phys. Rev. B 101 (2020) 075422; Y. Ke, A. Erpenbeck, U. Peskin, M. Thoss, J. Chem. Phys. 154 (2021) 234702; C. Kaspar, M. Thoss, Phys. Rev. B 105 (2022) 195435; Y. Ke, C. Kaspar, A. Erpenbeck, U. Peskin, M. Thoss, arXiv: 2205.04755 (2022).

The equivalence principle and inertial-gravitational decoherence

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Since the earliest paper on the topic by Matvei Bronstein [1] it was clear that the equivalence principle is incompatible with the usual separation between a "quantum system" and a "classical detector", namely the fact that the charge/mass ratio is "small". A modern treatment, based on open quantum systems and path integrals, can however directly address this issue, and systematically calculate corrections both in the case of a light recoiling detector and in the case of a heavy gravitating one. We illustrate this for an interferometric setup of the type of [2,3] and show that for all parameters a "semiclassical limit", where one can measure a phase shift due to gravitational attraction between quantum objects, is unlikely.

[1] M. Bronstein, Gen. Rel. Grav. 44 (2012) 267-283, Original: Matvei Bronstein, Quantentheorie schwacher Gravitationsfelder, Physikalische Zeitschrift der Sowjetunion, Band 9, Heft 2–3, pp. 140–157 (1936).

[2] S. Bose et. al., arXiv:1707.06050 (PRL).

[3] C. Marletto, V. Vedral, arXiv:1707.06036 (PRL).

Time-linear non-equilibrium Green's function approach to correlated quantum transport

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The non-equilibrium Green's function (NEGF) is a powerful approach for describing correlated quantum systems out of equilibrium [1]. High-order diagrams can be systematically included to achieve high accuracy, and a large variety of observables is directly accessible. Open quantum systems, in contact with reservoirs, can be treated non-perturbatively in the system-reservoir coupling. However, for large-scale (ab-initio) calculations, the computational solution of the NEGF equations, either in Dyson or Kadanoff-Baym form, is extremely demanding, scaling cubically with simulation time. The Generalized Kadanoff-Baym Ansatz (GKBA) reduces the computational scaling from cubic to quadratic with simulation time [2]. Recently, it was shown that the integro-differential GKBA equations can be equivalently recast as a set of time-local first-order ordinary differential equations (ODE) [3]. The computational cost of the ODE scheme is linear instead of quadratic, which means that GKBA time evolutions can be performed with the same scaling as the fastest quantum methods available, such as time-dependent density-functional theory. Here, we extend the time-linear GKBA formulation to a correlated quantum-transport setup. This formulation thus enables treating, on the same footing, inter-particle interactions, external drives and/or perturbations, and coupling to reservoirs with a continuum set of degrees of freedom.

[1] G. Stefanucci and R. van Leeuwen, *Nonequilibrium Many-Body Theory of Quantum Systems: A Modern Introduction* (Cambridge University Press, 2013).

[2] P. Lipavský, V. Špička, and B. Velický, Phys. Rev. B 34 (1986) 6933.

[3] N. Schlünzen, J.-P. Joost, and M. Bonitz, Phys. Rev. Lett. 124 (2020) 076601.

Computation time and thermodynamic uncertainty relation of Brownian circuits

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Computers can be regarded as heat engines transforming free energy into waste heat and mathematical work [1]. The fundamental thermodynamic limit of computation has constantly attracted attention for more than four decades since the infancy of present-day computers [2]. A standard theoretical model of the thermodynamics of computation is the Brownian computer [1,3,4]. We discuss a specific class of Brownian computers, the so-called token-based Brownian circuits [4]. In this type of circuit, Brownian particles, i.e., tokens subject to thermal fluctuations, perform a random search in multi-token state space. The computation time is the first-passage time, the duration of time to reach a final state (output state) starting from an initial state (input state). The output state, i.e., the solution, is unique, although the computation time varies for each run. We numerically calculate the probability distribution of computation time of Brownian adders [4] and analyze the thermodynamic uncertainty relation [5] and the stochastic thermodynamics of error-free detections of outputs and resets [6]. The computation can be completed in finite time without environment entropy production, i.e., without wasting heat to the environment, at the cost of system entropy production by detecting outputs and resets. The signal-to-noise ratio of the computation time is below the mixed bound [5] and approximately the square root of the number of unidirectional transitions, i.e., the error-free detections and resets. The entropy production due to detections of outputs and resets is not prominent since the tokens can diffuse over the state space to approach the equilibrium uniform distribution. This contrasts with the logically reversible Brownian Turing machine, in which the entropy production increases logarithmically with the size of the state space.

[1] C. H. Bennett, The thermodynamics of computation-a review, Int. J. Theor. Phys. 21, 905 (1982).

[2] R. Landauer, IBM Journal of Research and Development, 5,183-191, (1961).

[3] P. Strasberg, J. Cerrillo, G. Schaller, and T. Brandes, Phys. Rev. E 92, 042104 (2015).

[4] J. Lee, F. Peper, et. al., Brownian Circuits: Designs, Int. J. Unconventional Computing, 12, 341 (2016).

[5] J. P. Garrahan, Phys. Rev. E 95, 032134 (2017); K. Hiura, S.-I. Sasa, Phys. Rev. E 103, L050103 (2021); A. Pal, R. Reuveni, S. Rahav, Phys. Rev. Research 3, 013273 (2021).

[6] Y. Utsumi, Y. Ito, D. Golubev, F. Peper, arXiv:2205.10735.

On the problem of chirality-induced spin selectivity (CISS)

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[2] *Institute of Theoretical Physics, University of Regensburg, D-93050 Regensburg, Germany*

Chirality-induced spin selectivity (CISS) refers to an effect that was discovered as early as 1999 [1] and that still defies all current theoretical attempts at explanation [2]. Experiments suggest that an electron current traversing a molecule that has chiral symmetry (a property of most biomolecules) becomes spin polarized. This is surprising in view of the fact that none of the components of the problem is magnetic, and organic molecules typically have only a very small spin orbit coupling. We will start by giving a brief overview of the key experiments, list some of the theoretical attempts, and give some constraints that such theories should observe. In search for explanations of the CISS effect we will elaborate two simple model systems. Although they do not produce the wanted effect, they illustrate very clearly where the difficulties lie. Additional elements will need to be added into the model, and we will discuss which options could work.

[1] Ray, Ananthavel, Waldeck, and Naaman, Science 283 (1999) 814-816.

[2] Evers, Aharony, Bar-Gill, Entin-Wohlman, Hedegård, Hod, Jelinek, Kamieniarz, Lemeshko, Michaeli, Mujica, Naaman, Paltiel, Refaely-Abramson, Tal, Thijssen, Thoss, van Ruitenbeek, Venkataraman, Waldeck, Yan, and Kronik, Adv. Mater. (2022) 2106629.

T134 Mon, 1 August, 13:00 - 13:30, 3 session - A parallel

Quantum cooling activated by coherently-controlled thermalisation

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In my talk I intend to discuss the role of coherence and entanglement in quantum thermodynamics. I will make parallels between thermodynamics and computation and emphasize the role of distinguishability in work-extracting cycles. Some comments will be made related to quantum circuits implementing indefinite causal orders and their use in cooling.

Microscopic theory of ultrafast optical skyrmion excitation in magnetic thin films

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Magnetic skyrmions can be excited by irradiating atomically thin magnetic films with femtosecond laser pulses. We here propose a microscopic theory of electronically driven optical skyrmion excitation based on a two-band electronic model coupled to an external electromagnetic field. This allows to couple the electric field of the laser directly to the charge of the electrons thus enhancing the light-matter coupling. In the strong correlation limit we describe the localized magnetic moments of the d-band in terms of an effective spin model, with a local exchange coupling to the itinerant s-band electrons. For strong $s-d$ coupling we find that irradiation by femtosecond laser pulses leads to skyrmion excitation on a 100 fs timescale. Numerical results combined with an analytical treatment of the strong $s-d$ coupling limit identify the coupling between the electronic current and the localized magnetic moments, mediated via the interfacial Rashba spin-orbit interaction, as the mechanism driving ultrafast optical skyrmion excitation.

Controlling the stripe order in a diluted frustrated magnet

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Significant attention has recently been attracted by phases that spontaneously break real-space symmetries in addition to spin, phase, or gauge symmetries. These phases include the charge-density wave or stripe phases in the cuprate superconductors, the Ising-nematic phases in the iron pnictides, and the valence-bond-solids in certain quantum magnets.

We discuss the interplay between the broken real-space symmetries and vacancies, impurities and other types of quenched disorder that are inevitable in real materials. Specifically, we demonstrate that spinless impurities in a frustrated Ising magnet give rise to a random-field mechanism that can destroy the stripe-ordered phase. The strength of the emerging random fields is governed by the spatial impurity distribution. Moreover, the mechanism can be tuned very efficiently by weak exchange anisotropies that explicitly break the real-space symmetry, providing a way of controlling the phase diagram of this many-particle system.

[1] X. Ye, R. Narayanan, and T. Vojta, Phys. Rev. B. 105 (2022), 024201

[2] S.S. Kunwar, A. Sen, T. Vojta, and R. Narayanan, Phys. Rev. B 98 (2018), 024206

Non-resonant transitions: Insights from quantum-thermodynamics

Andreas Wacker

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Discrete energy levels in atoms and optical transitions with photon energies matching their energy differences are the hallmark of quantum theory. However, due to the uncertainty relation, the photon energy can differ from this transition energy if the excited atom has a finite lifetime. Such non-resonant transitions can be enforced by using an optical cavity with a frequency higher than the transition frequency. In this process, energy conservation seems not to be fulfilled, which motivates the detailed thermodynamic study presented here [1]. It is demonstrated that the associated filling and emptying of the levels from/to reservoirs occurs at average energies differing from the bare level energies. Using these new effective energies, the entire process is shown to be consistent with the first and second law of thermodynamics. This allows for a detailed understanding of a variety of physical processes such as frequency pulling in a laser or Bloch gain for intersubband transitions in semiconductor hetero-structures.

[1] A. Wacker, Phys. Rev. A 105 (2022), 012214.

A scalable quantum key distribution network based on time-bin entanglement

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In this talk, we report on our scalable network for pairwise quantum key distribution [1]. The central component is an all fiber photon source. It generates entangled photons via Spontaneous Parametric Downconversion (SPDC) in a type-0 PPLN crystal. The photons are distributed via an arrayed waveguide grating (AWG) or by a wavelength selective switch (WSS) to the respective parties. Currently, there are four parties connected to the source, but it can be easily scaled up to 100 parties.

The actual key distribution is based on time-bin entanglement requiring identically imbalanced interferometers at each party as well as the source. Due to the specific manufacturing process and precise temperature tuning we achieve low quantum bit error rates (QBER) even for larger distances between parties. In fact, the QBER provides feedback to precisely control the phases of our interferometers via temperature tuning.

We have performed a simultaneous quantum key exchange over various distances by placing fiber spools up to a length of 100 km between the source and the four parties. Moreover, one party was separated from the source by a 26-km field deployed fiber operated by the Deutsche Telekom. Raw key rates in excess of 40 bits/s limited by our detectors and QBER as low as 3% were found for a distance between parties of 60.55 km.

[1] Erik Fitzke, Lucas Bialowons, Till Dolejsky, Maximilian Tippmann, Oleg Nikiforov, Felix Wissel, Matthias Gunkel, Thomas Walther, A scalable network for simultaneous pairwise quantum key distribution via entanglement-based time-bin coding, PRX Quantum 3 (2022) 020341.

Multiparticle Quantum Interferometry

Gregor Weihs[1], Julian Münzberg[1], Franz Draxl[1], Yusuf Karli[1], Robert Keil[1], Christoph Dittel[2], Gabriel Dufour[2], Andreas Buchleitner[2], Alexander Szameit[3], Saimon Filipe Covre da Silva[4], and Armando Rastelli[4]

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[4]*Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, 4040 Linz, Austria*

The quantum interference of many particles on the one hand raises many foundational questions and on the other hand it is an active area of quantum technology development. While the latter has gained momentum with the ever-larger demonstrations of boson sampling, the former have not been explored so much. And yet, we believe that answering some of the foundational questions may lead to better understanding of the requirements and characteristics of quantum technologies that exploit multiparticle interference.

In recent and ongoing work, we were able to show theoretically and experimentally that the outputs of a multiparticle interferometer that occur with zero probability (they are suppressed) can be derived from a surprisingly simple law, which is based on the underlying symmetries of the unitary describing the interferometer [1]. In further theoretical work we extended the notion of wave-particle duality to the multiparticle case [2].

To realize these kinds of experiments, the sources of single photons need to be made as good as possible in terms of brightness and photon indistinguishability. Furthermore, we need to efficiently route the single photons to the desired interferometer inputs. In both areas we have been able to achieve significant improvements [3].

[1] Dittel, G. Dufour, M. Walschaers, et al., *Totally Destructive Many-Particle Interference,* Phys. Rev. Lett. **120**, 240404 (2018), https://doi.org/10.1103/PhysRevLett.120.240404; J. Münzberg, C. Dittel, M. Lebugle, et al., *Symmetry Allows for Distinguishability in Totally Destructive Many-Particle Interference,* PRX Quantum **2**, 020326 (2021), https://doi.org/10.1103/PRXQuantum.2.020326

[2] Dittel, G. Dufour, G. Weihs, et al., *Wave-Particle Duality of Many-Body Quantum States,* Phys. Rev. X **11**, 031041 (2021), https://doi.org/10.1103/PhysRevX.11.031041

[3] Münzberg, F. Draxl, S. Filipe Covre da Silva, et al., *Fast and efficient demultiplexing of single photons from a quantum dot with resonantly enhanced electro-optic modulators* (2022), https://arxiv.org/abs/2203.08682

Can a qubit be your friend? Why experimental metaphysics needs a quantum computer.

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A recent paper by two of us and co-workers [1], based on an extended Wigner's friend scenario, demonstrated that certain empirical correlations predicted by quantum theory (QT) violate inequalities derived from a set of metaphysical assumptions we called "Local Friendliness" (LF). These assumptions are strictly weaker than those used for deriving Bell inequalities. Crucial to the theorem was the premise that a quantum system with reversible evolution could be an observer (colloquially, a 'friend'). However, that paper was noncommittal on what would constitute an observer for the purpose of an experiment.

Here, we present a new derivation of the LF inequalities that uses four metaphysical assumptions which, in conjunction, imply LF for a human-level-intelligent friend:

1. Local Agency: In an experiment, an intervention x is uncorrelated with any events which are relevant to the outcome of the experiment and outside x's future light-cone.

2. Physicalism: Any thought supervenes upon a physical process.

3. Ego Absolutism. My communicable thoughts are absolutely real.

4. Friendliness: If a party displays cognitive ability on par with my own, then any thoughts they communicate are *as real as* my own.

In addition to these four metaphysical assumptions, this new no-go theorem requires two assumptions about what is *technologically* feasible: Human-Level Artificial Intelligence, and Universal Quantum Computing. The latter is often motivated by the belief that QT is universal, but this is *not* an assumption of the theorem. Our new theorem is that the six assumptions lead to a contradiction. It is intended to give a clear goal for future experimentalists, and a clear motivation for trying to achieve that goal, by using assumptions that are logically independent, widely held, not reliant on the exact correctness of QT, and relevant to how different approaches to QT respond to the no-go theorem. To establish the final point, we consider a variety of existing interpretations or modifications of QT, showing that for each of our six assumptions there is an approach that violates that, and arguably only that, assumption. The popular stance that "quantum theory needs no interpretation" does not question any of our assumptions and so is ruled out by the theorem.

[1] Kok-Wei Bong et al., "A strong no-go theorem on the Wigner's friend paradox", Nature Physics 16, 1199–1205 (2020).

Towards qualitative theory of large quantum coherent structures

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Design, characterization and optimization of large artificial quantum structures (e.g., practically useful quantum computers) is hindered by the fact that their efficient simulation by classical means is fundamentally impossible. On the other hand, important information about such systems can be obtained from a qualitative analysis of their "general case" behaviour. In particular, finding the universal dimensionless combinations of their parameters (figures-of-merit), which control transitions between qualitatively different regimes of operation, will help establish the desired parameters of the system with the use of scaled experiments and model calculations.

Dynamics of negative temperature hadron formation in repulsive SU(n) Hubbard models

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[4]*Theoretical Solid State Physics Department, Wigner Research Centre for Physics, Konkoly-Thege Miklos str., Budapest, H-1121, Hungary*

Repulsive and attractive SU(n) Hubbard models provide a rich platform to simulate the dynamics of hadronic matter and baryo-genesis [1].

We study post quench dynamics in the repulsive n-color Fermi-Hubbard model, initialized in a pattern of empty and n-times occupied sites. In any dimension and for any finite interaction, $U > 0$, this state is proven to relax to a negative temperature state. However, while for weak interactions, $U/J \leq 1$, a negative temperature Fermi liquid-like state emerges, for $U/J \geq 1$, quench spectroscopy [2,3] as well as the behavior of time dependent correlation functions reveal the dynamical formation of heavy and strongly interacting composite particles [4].

For $n = 3$, in particular, most of the particles are bound to very heavy spinless 'baryons' (trions), strongly interacting with each other, and a dilute background gas of intermediate mass mobile 'mesons' (doublons) and of light SU(3) fermions. Baryons are found to move diffusively, with a motion generated by collisions with the mesonic background. Similarly rich negative temperature states form for any $n \geq 2$.

[1] A. Rapp, G. Zaránd, C. Honerkamp, and W. Hofstetter, Phys. Rev. Lett. 98, 160405 (2007).

[2] M. Kormos, M. Collura, G. Takács, and P. Calabrese, Nature Physics 13, 246 (2017).

[3] M. Collura, M. Kormos, and G. Takács, Phys. Rev. A 98, 053610 (2018).

[4] M. Werner et al., submitted to Nat. Commun.

Hawking radiation, the logarithmic phase singularity, and the inverted harmonic oscillator

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Some of the most intriguing, but unobserved quantum effects are Hawking [1] and Unruh [2] radiation. At the very heart of both phenomena lies a logarithmic phase singularity that manifests itself at a horizon in spacetime. A very similar singularity is present in the elementary quantum system of an inverted harmonic oscillator when viewed in rotated quadratures of phase space [3,4].

In this talk, we establish the astonishing resemblance [5] between these systems on a theoretical level. Moreover, we demonstrate that the Fourier transform of a logarithmic phase is the key element that governs both the Bose-Einstein and the Fermi-Dirac statistics. This feature determines not only the spectrum of the emitted particles at an event horizon in spacetime, but also the transmission and reflection coefficients of the inverted harmonic oscillator.

Finally, we present different possible ways to reveal the logarithmic phase singularity intrinsic to the energy eigenstates of the inverted harmonic oscillator by applying appropriate transformations in phase space.

[1] S. W. Hawking, Nature 248 (1974) 30.

[2] W. G. Unruh, Phys. Rev. D 14 (1976) 870.

[3] N. L. Balazs and A. Voros, Ann. Phys. (N. Y.) 119 (1990) 123.

[4] D. M. Heim, W. P. Schleich, P. M. Alsing, J. P. Dahl, and S. Varro, Phys. Lett. A 377 (2013) 1822.

[5] F. Ullinger, M. Zimmermann, and W. P. Schleich, AVS Quantum Sci. 4 (2022) 024402.

Invited Posters

Predictions of a fundamental statistical picture

Roland E Allen

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The discovery of a Higgs boson at the electroweak scale appears to point toward supersymmetry, as the most likely mechanism for protecting a scalar boson mass from enormous radiative corrections. The earlier discovery of neutrino masses similarly appears to point toward grand unification of nongravitational forces, which permits (for neutrinos) Majorana masses, Dirac masses, and a seesaw mechanism to drive the observed masses down to low values. A third major discovery, cosmic acceleration suggesting a relatively tiny cosmological constant, appears to point toward truly revolutionary new physics. Many other problems and mysteries also indicate a need for fresh ideas at the most fundamental level. Here a picture is proposed in which standard physics and its extensions are obtained (through a nontrivial set of arguments) from statistical counting and the local geography of our universe [1]. The unavoidable predictions include supersymmetry (at some energy scale), SO(N) grand unification, a drastic diminishing of the usual cosmological constant, and a nonsupersymmetric dark matter WIMP which should be detectable within the next several years.

[1] Roland E. Allen, "Predictions of a fundamental statistical picture", arXiv:1101.0586 [hep-th] and a paper under review.

I2

Relativity and vacuum fluctuations in quantum measurement

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[2]*Faculty of Physics, University of Warsaw, PL02-093 Warsaw, Poland*

Vacuum fluctuations can obscure the detection signal of the measurement of elementary quantum objects like single particles seemingly implying a fundamental limit to measurement accuracy. However, as we show relativistic invariance implies the disappearance of fluctuations for the space-like frequency-wavevector spectrum of an observable at zero temperature. This complete absence of noise can be harnessed to perform noiseless measurement of single particles, as we illustrate for electrons or photons. We outline a general scheme to illustrate the noiseless measurement involving the space-like spectrum of observables based on the self-interference of counter-propagating paths of a single particle in a triangular Sagnac interferometer.

[1] Adam Bednorz and Wolfgang Belzig, Effect of relativity and vacuum fluctuations on quantum measurement, Phys. Rev. D 105, 105027 (2022) [arXiv:2203.13187]

Bipolar thermoelectricity by spontaneous particle-hole symmetry breaking

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Thermoelectrical effects in superconductors are usually thought absent. In this poster, we show a relevant exception where the opposite is true. Indeed, superconductors can be very strongly thermoactive materials due to the gap opening at the Fermi surface but it requires some tricks to clearly unveil their thermoelectrical potential.

Here, we will discuss how strong thermoelectricity can be generated by spontaneous breaking of the particle-hole symmetry in an asymmetric SIS' junction where the Josephson coupling is sufficiently suppressed [1]. Intriguingly the thermoelectricity is very strong and can be of the order of 300 μV/K for Aluminium based tunnel junctions at sub-Kelvin temperatures. Further, the thermoelectricity is spontaneously bipolar, i.e. opposite sign of the thermo-voltage for the same thermal gradient, as the spontaneous breaking mechanism would imply [2]. We will discuss the generality of the effects for different operating conditions [2], different setup configurations [3], phase-coherent control [4] and noise effects [5]. Finally, we show possible experimental observations of the effect discussing also applications such as superconducting memory [6].

[1] G. Marchegiani, A. Braggio, F. Giazotto “Nonlinear thermoelectricity with with Electron-Hole Symmetric Systems” Phys. Rev. Lett. 124, 106801 (2020)

[2] G. Marchegiani, A. Braggio, F. Giazotto “Superconducting nonlinear thermoelectric heat engine” Phys. Rev. B 101, 214509 (2020)

[3] G. Germanese, F. Paolucci, G. Marchegiani, A. Braggio, F. Giazotto "Spontaneous symmetry breaking-induced thermospin effect in superconducting tunnel junctions" Phys. Rev. B 104, 184502 (2021)

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I4

Role of the vacuum field in the transition from classical to quantum mechanics

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The nonrelativistic problem of a bound, charged particle subject to the random zero-point radiation field (ZPF) is revisited, with the purpose of disclosing the mechanism that takes the system from the initial classical regime far from equilibrium, to the final quantum regime characterized by stationary states. The combined effect of the ZPF and the radiation reaction force leads, after a characteristic time lapse, to a loss of memory of the initial conditions and the concomitant irreversible transition of the dynamics to a stationary regime controlled by the field. As a result, the canonical particle variables x,p become expressed in terms of the dipolar response functions to a proper set of ZPF modes. An appropriate ordering of the response coefficients leads to the matrix representation, and to the basic quantum commutator [x,p]=ih/2 π. Further, higher-order effects of the ZPF are shown to correspond to the (nonrelativistic) radiative corrections of QED. These results reaffirm the essentially electrodynamic and stochastic nature of the quantum phenomenon, as posited by stochastic electrodynamics.

Nonadiabatic coupled-qubit Otto cycle with bidirectional operation and efficiency gains

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We study a quantum Otto cycle that uses a 2-qubit working substance whose Hamiltonian does not commute with itself at different times during the adiabatic strokes. We show this cycle displays regimes of operation with efficiencies higher than the standard Otto one, counter-rotating cycles operating as heat engines and efficiency that can increase with a decrease in the temperature difference between the baths. We also investigate how the cycle responds to variations in the quantum adiabaticity of its unitary strokes, finding it displays an intense response in its efficiency behavior, and significantly changes the regimes where it operates as an engine

I6

Measurement-based quantum heat engine in a multilevel system

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We compare quantum Otto engines based on two different cycle models: a two-bath model, with a standard heat source and sink, and a measurement-based protocol, where the role of heat source is played by a quantum measurement. We furthermore study these cycles using two different "working substances": a single qutrit (spin- 1 particle) or a pair of qubits (spin-1/2 particles) interacting via the XXZ Heisenberg interaction. Although both cycle models have the same efficiency when applied on a single-qubit working substance, we find that both can reach higher efficiencies using these more complex working substances by exploiting the existence of "idle" levels, i.e., levels that do not shift while the spins are subjected to a variable magnetic field. Furthermore, with an appropriate choice of measurement, the measurement-based protocol becomes more efficient than the two-bath model

Steady state formulation of inchworm Quantum Monte Carlo

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This is the companion poster for the talk with the same title, where we present an inchworm Quantum Monte Carlo method that is directly formulated in the steady-state. Until now, numerically exact real time Monte Carlo methods simulated steady-state dynamics by propagating from a tractable initial condition to long times. The computational cost for accessing nonequilibrium steady-states in these methods is often prohibitive. We overcome this issue by reformulating the inchworm equations such that they can directly be solved for the steady-state. We demonstrate the performance of our steady-state inchworm Quantum Monte Carlo method by comparison with analytical results and other numerically exact techniques and showcase its usage within dynamical mean field simulations. The steady-state inchworm Quantum Monte Carlo method closes the gap between short-time dynamics and the long-time behaviour and extends the regime of applicability for nonequilibrium Monte Carlo methods as impurity solvers within quantum embedding schemes.

I8

Quantum control in ultrastrongly coupled matter and radiation

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Quantum operations with circuit QED hardware in the ultrastrong coupling (USC) are hindered by the dynamical Casimir effect (DCE), multiphoton generation deteriorating the fidelity even in absence of decoherence [1]. We show that a STIRAP-based [2] adiabatic protocol may overcome this limitation [3] since the cavity is never populated, operating as a virtual bus. Indeed we show that high fidelity fast operations can be performed for moderate couplings in the USC regime [3]. Moreover, properly crafted control extends the high fidelity region to even larger couplings//speed. The protocol is extremely robust against DCE, in the absence of decoherence yields almost 100% fidelity for remote population/state transfer. It is also resilient to decay due to leakage from the cavity, which is the main decoherence mechanism [3]. In this more realistic scenario, it is seen that for larger coupling (entering the deep strong coupling regime) the fidelity decreases due to the interplay between decoherence and DCE. Our results suggest that adiabatic manipulations may be a promising tool for quantum state processing in the USC regime.

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Instantons and self-similar scaling in a 1D spin-1 Bose gas far from equilibrium

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A system driven far from equilibrium via a parameter quench can show universal dynamics, characterized by self-similar spatio-temporal scaling, associated with the approach to a non-thermal fixed point [1-4]. The study of such universality classes may assist in a thorough investigation of many systems ranging from the post-inflationary evolution of the universe to low-energy dynamics in cold gases. Topological excitations in the system are considered to be one of the driving mechanisms of coarsening dynamics in the system and are, as such, a point of interest in the study of far from equilibrium physics. We will discuss the infrared scaling phenomena of a one-dimensional spin-1 Bose gas quenched from the polar phase to the easy-plane phase and provide evidence of the existence of instantons and their contribution to the coarsening dynamics of the system. Furthermore the dependency of the scaling exponents and the evidence of two different scaling behaviors driven by two distinct types of excitations will be presented.

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I10

Anyonic relations in circuit QED and beyond

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In this work, we show from quantum electromagnetic grounds that the charge creation operator may satisfy anyonic relations. More generally anyonic relations should be observable in any 1D bosonic system (like phonons, plasmons, etc.). To specify, we consider the physical experiment by A. Anthore et al. [1]. In this experiment, the predicted Tonomaga-Luttinger power law for conductance versus temperature and the DC current versus DC voltage are accurately checked for Tomonaga-Luttinger interaction parameter K=1/2, 2/3, and 4/3 for various transmission τ of the quantum impurity. In the experiment [1], a QPC transmitting a single mode of transmission τ is in series with a highly resistive impedance $R = (K-1)h/e^2$. According to the most physical representation of dissipation for tunneling, the resistor R can be described by a semi-infinite electromagnetic transmission line of characteristic impedance $Z_C = R$ and terminated, at infinity by the resistance R assumed at zero temperature. We show that the operator $C(t)$ creating a charge q at time t obeys an anyonic relation : $C(t)C(t') = C(t')C(t)e^{i\theta}$ where $\theta = \pi(Z_C q^2/h)$, the anyonic phase, is related to the charge q and to the characteristic impedance and can take any real value. Finally, we consider $K = 1/m$ with m =3, 5, ... to make contact with the case of the Fractional Quantum Hall Effect. We particularly concentrate on the weak backscattering limit (WB) for which $1 - \tau << 1$ an compares with the dual, strong back-scattering limit $\tau << 1$. In the WB limit, we question the nature of the fractional charges e/m and $(m-1)e/m$ which excite the environment of the QPC impurity and look for possible anyonic relation in the charge creation operators. Following the circuit representation in [2], we extend the approach to the Jain's hierarchy of filling factors 1/3, 2/5, 3/7, ...

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Thermally generated autonomous coherence of subsystems

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Quantum superposition of energy eigenstates can appear autonomously in a quantum system coupled to a thermal bath, if such coupling is of the composite nature [1]. Here, we discuss an analogous situation where similar type of composite interaction describes the coupling between two subsystems of a total system in turn weakly coupled to a thermal bath at temperature T. We perform a case-study analyzing the properties of thermally induced steady-state coherence on mutually-interacting subsystems of a compound system. We quantify the local coherence [2] of the subsystems in each respective case and specify the system parameters optimal for reaching high coherence. We complement our study by analysis of mutual coherence [3] of the system, describing the local versus global distribution of coherence in the system. One of our findings is the fact that the best regime for coherence generation on subsystems is generally the low temperature region, where the system is close to its ground state. Therefore, we characterize each case from a thermodynamic perspective [4] by the rate of coherence generation, if the system is cooled down towards its ground state. Our analysis can be beneficial for proposing more autonomous Quantum information protocols employing quantum coherence as an important resource.

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I12

Continuous time crystal from a spontaneous many-body Floquet state

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Floquet driven systems represent an extremely interesting arena to study out-of-equilibrium phenomena such as prethermalization, topological insulation, dynamical phase transitions, high-harmonic generation, or protected cat states. An interesting application of Floquet physics arises in the subject of time crystals where they provide realizations of discrete time crystals, in which the discrete time translation symmetry of the periodic Hamiltonian is spontaneously broken by a subharmonic response of the system. However, the continuous presence of an external periodic driving is required within the current Floquet paradigm. We propose here the concept of spontaneous many-body Floquet state [1]. This is a state that, in the absence of external periodic driving, self-oscillates like in the presence of a periodic Hamiltonian, this behavior being spontaneously induced by many-body interactions. In addition, its quantum fluctuations are described by regular Floquet theory. Furthermore, it is also a time crystal, presenting long-range time-periodic order. However, this crystalline behavior is very different to that of conventional Floquet discrete time crystals: here, there is no external periodic driving, energy is conserved, and the nature of the spontaneous symmetry breaking is continuous instead of discrete. We demonstrate that spontaneous many-body Floquet states can emerge in a variety of canonical many-body problems, ranging from interacting fermions to Bose-Hubbard models. We specifically show that a spontaneous many-body Floquet state is a universal intrinsic state of a one-dimensional flowing atom condensate, both subsonic and supersonic, resulting from a dynamical phase transition and robust against external perturbations and quantum fluctuations, proposing also realistic experimental scenarios for its observation. A spontaneous many-body Floquet state not only represents a realization of a continuous time crystal, but also a novel paradigm in Floquet physics.

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Heat rectification through single and coupled quantum dots

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We study heat rectification through quantum dots in the Coulomb blockade regime using a master equation approach. We consider both cases of two-terminal and four-terminal devices. In the two-terminal configuration, we analyze the case of a single quantum dot with either a doubly-degenerate level or two non-degenerate levels. In the sequential tunneling regime we analyze the behaviour of heat currents and rectification as functions of the position of the energy levels and of the temperature bias. In particular, we derive an upper bound for rectification in the closed-circuit setup with the doubly-degenerate level. We also prove the absence of a bound for the case of two non-degenerate levels and identify the ideal system parameters to achieve nearly perfect rectification. The second part of the paper deals with the effect of second-order cotunneling contributions, including both elastic and inelastic processes. In all cases we find that there exists ranges of values of parameters (such as the levels' position) where rectification is enhanced by cotunneling. In particular, in the doubly-degenerate level case we find that cotunneling corrections can enhance rectification when they reduce the magnitude of the heat currents. For the four-terminal configuration, we analyze the non-local situation of two Coulomb-coupled quantum dots, each connected to two terminals: the temperature bias is applied to the two terminals connected to one quantum dot, while the heat currents of interest are the ones flowing in the other quantum dot. Remarkably, in this situation we find that non-local rectification can be perfect as a consequence of the fact that the heat currents vanish for properly tuned parameters.

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I14

Pseudo-density operators: from modeling chronology-violating regions to recovering quantum dynamics via temporal teleportation

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In the recent years, a novel quantum mechanical formalism named pseudo-density operator (PDO) has been introduced [1]. PDOs are Hermitian, trace-one not positive operators, describing spatial and temporal quantum correlations on an equal footing: this makes PDOs particularly suited for modeling, e.g., exotic spacetime scenarios. Here we illustrate the results obtained by applying PDOs to two different frameworks: quantum particles in chronologyviolating spacetime regions, like entangled pairs undergoing time travel or falling into an evaporating black hole, and quantum evolution reformulated as a series of teleportations in time. First, we consider the case of an entangled pair in which one of the qubits enters an open time-like curve (OTC), i.e. a time-travel configuration (predicted by general relativity) where the qubit does not interact with its past copy. We show that, by exploiting the PDO formalism, the causality issues typical of time travel can be solved without asking for a non-linear quantum dynamics, usually required to avoid entanglement monogamy violation . To do this, we simulate the OTC scenario with polarizationentangled photons, providing an OTC pseudo-density operator quantum tomography and showing how entanglement monogamy violation would occur when describing such a scenario with traditional density operators [2]. The same holds also for other chronology violation regions, e.g. the ones involving evaporating black holes [3]. Second, we illustrate how PDOs allow expressing quantum dynamical evolution as a sequence of teleportations in the temporal domain, demonstrating that any completely positive evolution can be formally reconstructed by teleportation with different temporally-correlated states. This stems from the strict correspondence between spatial and temporal entanglement in quantum theory, that we demonstrate by showing a multipartite violation of generalised temporal and spatial inequalities with high-quality photonic qubits [4].

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Propagation of chirped pulses: STIRAP with single photons

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We study the excitation and manipulation of the quantum coherence in a Λ-type molecular media and its influence on chirped pulse propagation. The coherent population trapping (CPT) of the ground states in the Λ-system results in fascinating new dynamics of pulse propagation through it [1]. We have considered the three-level molecules. The dressed state basis approach is employed, which provides deep physical insights showing interaction of "bright" and "dark" states with radiation.

Refractive index of a system is typically considered as the bulk response of a medium to an incoming electromagnetic field. However, the incoming light would experience the same dispersion even with a single atom at the target. We consider propagation of single photon interacting with a single two-level atom to determine the dispersion behavior and also calculate the phase and group velocity of the single photon wave packet to further analyze the dispersion experienced the single photon. Even more, the STIRAP with single and vacuum photons turned out to be possible. The results are of significant importance for long-distance quantum communications as well as to manipulation of quantum states for molecular detection in engineering, chemical, and biological applications.

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I16

Surface gravity waves: Quantum phenomena in classical waves

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The time evolution of a wave function in quantum mechanics is analogous to that of surface gravity water wave pulses. In our studies, we have recently utilized this analogy and have measured the cubic phase of accelerating wave packets in a linear potential for cases of linear and nonlinear propagation, including a case of initial non-zero momenta [1,2].

Inspired by these successful experiments, we extend this analogy to a study of electromagnetic fields around black holes and different types of amplitude and phase singularities, including a logarithmic phase singularity. The analogous system in hydrodynamics is obtained by generating Gaussian wave packets that propagate in a time-dependent potential that has a shape of an inverted harmonic oscillator. Depending on the wave packet energy with respect to the peak energy of the potential, we observe three different cases: i) wave reflection, in the case of low energy waves. ii) wave stopping when the wave energy matches the potential peak energy or iii) wave transmission, for higher energy waves. We also studied this problem using Weber wave packets, which are the eigenstates of the inverted harmonic oscillator system. An interesting observation is that even without a potential, an initial state which is an energy eigenstate of the inverted harmonic oscillator would evolve in free space until it reaches an amplitude singularity, accompanied by a logarithmic phase singularity.

Furthermore, we propose methods to study the propagation of wave packets in an open system, coupled with the vacuum state. In the latter, we have managed to observe phenomena which is analogous to that quantum decoherence.

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Quantum consensus dynamics by entangling Maxwell demon

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We propose a new type of Maxwell demon that is capable of generating many-body entanglement in the working substance [1]. The entangling demon randomly selects a qubit pair among many and performs a quantum feedback control, in continuous repetitions. Such protocol realizes the quantum steady-state engineering [2] as studied in quantum information and optics. Previous studies have identified possible types of entangled states which are stabilizable [2]. However, the quantum dynamics, i.e. how entanglement, coherence, and von Neumann entropy evolve in time, still lacks understanding. The mechanism behind the quantum dynamics is nontrivial due to two simultaneous tasks, the random selection and the continuous quantum measurement.

We study the quantum dynamics and the second law of thermodynamics under the action of such entangling Maxwell demon. We first propose a quantum version of the voter model, an entangling Maxwell demon adopting a protocol inspired by the noisy voter model, motivated by the fact that the classical model generates classical correlation of human opinions among agents. Our first main finding is that Greenberger-Horne-Zeilinger (GHZ) entanglement is generated among the working substance and stabilized against the bit-flip noises. During the entanglement generation, the purity and the entropy of the working substance change non-monotonically in time, which turns out to be due to the competition between the quantum-classical mutual information gain [3] and the absolute irreversibility [4] of the feedback control. Then, as our second main finding, we reformulate the second law of thermodynamics under the action of a generic class of entangling Maxwell demons. The upper bounds for the entropy reduction and the work extraction are determined by the competition between the information gain and the absolute irreversibility. This suggests that a general condition for the operation of a successful entangling demon, one for which many-body entanglement stabilization and work extraction are possible, is that the information gain is larger than the absolute irreversibility. We expect that our findings will be useful for stabilizing many-body entanglement and exploring quantum thermal machines with many-body entangled working substance.

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I18

Fluctuating thermodynamics in the Caldeira Leggett model - from the quantum mechanical to an effective Langevin description

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We compute the statistics of heat for classical and quantum particles in contact with collections of harmonic oscillators acting as thermal sources. The generating functions (GF) can be expressed exactly using the path integral approach, taking also into account the contribution to dynamics and heat statistics due to a time-dependent system-bath coupling. We explicitly verify that in the semiclassical limit there is a perfect matching between the quantum and classical statistics, and in the Ohmic case both models correspond to the counting statistics of a Langevin particle when the coupling contributions to the work are neglected. In the strong coupling regime we prove that the role of the system-bath interactions can be completely assessed by adopting new thermodynamically consistent equations for heat, work and internal energy at the trajectory level, the latter reducing to the usual Sekimoto characterization in the weak-coupling limit. The role of the quantum corrections to the classical limit are discussed and the quantum signatures in the heat distribution are identified using an analytical procedure. As a final result, all the path integrals are computed explicitly and a compact form of the steady-state heat GF for a system coupled to an arbitrary number of baths is given. Thanks to the quantum-classical correspondence proved in the first part, the analytic formula for the GF can be used to compute the exact statistics of the heat in all the cases mentioned above, from the Caldeira-Leggett model to the Zwanzig model (classical harmonic oscillators) and for a Langevin particle.

Time glass: A fractional calculus approach

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Out-of-equilibrium states in glasses and crystals have been a major topic of research in condensed-matter physics for many years, and the idea of time crystals has triggered a flurry of new research. Here, we provide a description for the recently conjectured time glasses using fractional calculus methods. An exactly solvable effective theory is introduced with a continuous parameter describing the transition from liquid through normal glass and time glass into the marginal glass phase. The phenomenological description with a fractional Langevin equation is connected to a microscopic model of a particle in a sub-Ohmic bath in the framework of a generalized Caldeira-Leggett model.

I20

No trade-off between coherence and sub-Poissonianity for Heisenberg-limited lasers

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Quantum optical coherence can be defined as the number of photons in the maximally populated mode–a definition that requires both the particle- and wave-natures of light. For an ideal laser, it can be thought of as the number of photons emitted into the beam with the same phase. For some 60 years, it was believed that for a laser with an ideal output beam (described by a phase-diffusing coherent state), this number, C, was limited by the Schawlow-Townes limit to the linewidth [1]. Specifically, the S-T limit implies that the coherence C is at most of order the square of the mean number μ of excitations (photonic or otherwise) in the laser itself: C = O(μ^2). But in [2] it was shown, assuming nothing about the laser operation except that its inputs are incoherent, and that its output is close to the ideal beam, that the ultimate (Heisenberg) limit is C = O(μ^4). Moreover, this can be achieved, in principle, it could be realised with familiar physical couplings [2]. Here, we generalize the previous proof of this upper bound scaling by dropping the requirement that the beam photon statistics be Poissonian (i.e. that Mandel's Q parameter be equal to zero). We then show that the relation between coherence C and sub-Poissonianity (Q<0) is win-win, not a tradeoff. For both regular (non-Markovian) pumping with semi-unitary gain (which allows Q to approach -1), and Markovian pumping with optimized gain (which is limited to Q approaching -0.5), C is maximized when Q is minimized.

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Reaching the Heisenberg limit with a qubit sensor array

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Using an analytically solvable model, we show that a qubit array-based detector allows to achieve the fundamental Heisenberg limit in detecting single photons. In case of superconducting qubits, this opens new opportunities for quantum sensing and communications in the important microwave range.

I22

Symplectic speed-up of adiabatic quantum computation

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In adiabatic quantum computation, the Hamiltonian is continuously deformed to drive the system from a trivial quantum state to a complex quantum state of interest. The efficiency and speed of adiabatic quantum computation is, however, very sensitive to the structure of avoided level crossings.

Many times, the states of interest are generated as the ground state of a system with time reversal invariance, belonging to the orthogonal class of Hamiltonians. We study how unitary and symplectic deformations of the Hamiltonian change the speed of adiabatic quantum computation. In particular, we show on the example of Ising systems, that the speed of quantum computation can be increased by orders of magnitude using unitary or symplectic deformations.

Posters

Design and manufacturing of a beams splitter in chip to produce different quantum statistics

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The design and manufacturing of a linear waveguide and a Beam splitter (BS) in resine (Ip-Dip) with directly coupled optical fibers are shown. They were manufactured by two photon polimerization (in a Nanoscribe) over a fused silica substrate and cover with Loctite to fix the coupling with multimode optical fiber. Those waveguides were used to process individual photons coming from a SPDC (subpoissonian statistic), waiting for different statistics in every output port when controlling the transmission and reflection coefficients in the BS as shown in the numerical simulation. The statistics we are interested on are the poissonian and the one with noise of the 1/f type to contribute to the understanding of these statistics and, moreover, because its potencial application in quantum cryptography protocols.

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P2

Affleck-Dine leptogenesis from Higgs inflation

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We investigate the possibility of simultaneously explaining inflation, the neutrino masses and the baryon asymmetry through extending the Standard Model by a triplet Higgs. The neutrino masses are generated by the vacuum expectation value of the triplet Higgs, while a combination of the triplet and doublet Higgs' plays the role of the inflaton. Additionally, the dynamics of the triplet, and its inherent lepton number violating interactions, lead to the generation of a lepton asymmetry during inflation. The resultant baryon asymmetry, inflationary predictions and neutrino masses are consistent with current observational and experimental results.

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Continuous measurements for adaptive qubit thermometry

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Bayesian estimation was recently applied to quantum thermometry since it allows for better estimation accuracy when data is limited [1] and admits adaptive estimation schemes [2]. Here, we apply the Bayesian framework to the setting of continuous temperature measurement. We model a qubit probe, subject to continuous monitoring interacting with a bosonic bath of unknown temperature. The Kushner-Stratonovich equation from classical filtering theory is simulated to find the posterior distribution. Bayesian estimation is then used to infer the temperature from this probability distribution. This is compared to the discrete analogue, collisional thermometry [3]. An adaptive strategy for improved accuracy is described where Hamiltonian parameters of the qubit can be changed continuously by measurement feedback.

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P4

Shot noise on chaotic chiral devices

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We investigate both the conductance and the shot-noise power of a confined chiral device that engenders subtle embedded backscattering mechanisms. We present analytical results and the correspondent numerical confirmation of the chiral electronic sublattice signal. Examples of quantum dots generating chiral symmetries include graphene sheets and topological insulators. The analytical results are universal and exhibit a robust and peculiar signal for an arbitrary number of open scattering channels. We also demonstrate a tunable mechanism of the valleytronics shot-noise power signal through perpendicular magnetic fields and/or the device symmetry edges. The results also indicate a "Fano factor" associated with the main quantum interference term with a universal value of 1/4 for a quantum dot with symmetric contacts, regardless of external fields and the number of open channels.

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Quantum trajectories for general time local master equations

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We extend quantum trajectory theory to encompass a large class of open quantum systems interacting with an environment at arbitrary coupling strength [1]. Specifically, we show that general time-local quantum master equations of the form

$$\frac{d}{dt}\rho(t) = -i[H,\rho(t)] + \sum_{l=1} \Gamma_l(t) \left(L_l \rho(t) L_l^\dagger - \frac{1}{2}\{L_l^\dagger L_l, \rho(t)\} \right)$$

with “rates” $\Gamma_l(t)$ that can take negative values, admit an unravelling in quantum trajectories with jumps. The sufficient condition is to weigh Monte Carlo averages E of state vectors by a probability pseudo-measure which we call the "influence martingale" $\mu(t)$. Concretely, the state $\rho(t)$ is reconstructed by the average

$$\rho(t) = \mathrm{E}(\mu(t)\psi(t)\psi^\dagger(t)).$$

The influence martingale satisfies a 1d stochastic differential equation enslaved to the ones governing the evolution of the state vectors $\psi(t)$. At weak coupling, the influence martingale method naturally reduces to the well-known quantum trajectory representation of the Lindblad–Gorini–Kossakowski–Sudarshan master equation. In genuine strong coupling cases, the influence martingale provides an algorithmically straightforward method to compute the evolution of open quantum systems. In contrast, to earlier methods there is no need to take memory effects into account [2] or expensive Hilbert space doubling [3]. The method places no real restrictions on the $\Gamma_l(t)$ and can therefore also simulate non-positive evolutions, for example generated by Redfield equations. Furthermore, we illustrate how our result provides a new avenue to numerically integrate systems with large numbers of degrees of freedom by naturally extending the existing theory.

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P6

Quantum effects in axion dark matter

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Axion-like particles (ALPs) are promising dark matter candidates. A classical field description is typically employed, motivated by large phase space occupation numbers. Here we show that such a description is accompanied by a quantum effect: squeezing due to gravitational self-interactions. For a typical QCD axion today, the onset of squeezing is reached on microsecond-scales and grows over millennia. Thus within the usual models based on the classical Schrödinger-Poisson equation, a type of Gross-Pitaevskii equation, any viable ALP is nonclassical. We also show that squeezing may be relevant on scales of galactic solitonic cores. Conversely, our results highlight the incompleteness and limitations of the typically employed classical single field description of ALPs.

Unique signatures of topological phases in two-dimensional THz spectroscopy

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We address the microscopic theory for the two-dimensional optical spectroscopy of one-dimensional topological superconductors. We consider an archetypal topological superconductor in a ring geometry physically realizing periodic boundary conditions. This allows for bypassing energy-specific differences caused by topologically protected or trivial boundary modes that are hard to distinguish otherwise. In this way, the topological and trivial phase of the chain only differ by their bulk topologies. We present numerical and analytic results showing that the cross-peak structure of the 2D spectra carries unique signatures of the topological phases of the chain. Thus, our work reveals how 2D spectroscopy can identify topological phases in bulk properties.

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P8

Optimal cold atom thermometry using adaptive Bayesian strategies

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Precise temperature measurements on systems of few ultracold atoms is of paramount importance in quantum technology, but can be very resource-intensive. Here, we put forward an adaptive Bayesian framework that substantially boosts the performance of cold atom temperature estimation. Specifically, we process data from release–recapture thermometry experiments on few potassium atoms cooled down to the microkelvin range in an optical tweezer. We demonstrate that adaptively choosing the release–recapture times to maximise information gain does substantially reduce the number of measurements needed for the estimate to converge to a final reading. Unlike conventional methods, our proposal systematically avoids capturing and processing uninformative measurements. Furthermore, we are able to produce much more reliable estimates, especially when the measured data are scarce and noisy. Likewise, the resulting estimates converge faster to the real temperature in the asymptotic limit. Our method can be adapted to enhance the precision and resource-efficiency of many other techniques running on different experimental setups, thus opening new avenues in quantum thermometry.

Bending the rules of low-temperature thermometry with periodic driving

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There exist severe limitations on the accuracy of low-temperature thermometry, which poses a major challenge for future quantum-technological applications. Low-temperature sensitivity might be manipulated by tailoring the interactions between probe and sample. Unfortunately, the tunability of these interactions is usually very restricted. Here, we focus on a more practical solution to boost thermometric precision-driving the probe. Specifically, we solve for the limit cycle of a periodically modulated linear probe in an equilibrium sample. We treat the probe-sample interactions *exactly* and hence, our results are valid for arbitrarily low temperatures T and any spectral density. We find that weak near-resonant modulation strongly enhances the signal-to-noise ratio of low-temperature measurements, while causing minimal back action on the sample. Furthermore, we show that near-resonant driving changes the power law that governs thermal sensitivity over a broad range of temperatures, thus 'bending' the fundamental precision limits and enabling more sensitive low-temperature thermometry. We then focus on a concrete example-impurity thermometry in an atomic condensate. We demonstrate that periodic driving allows for a sensitivity improvement of several orders of magnitude in sub-nanokelvin temperature estimates drawn from the density profile of the impurity atoms. We thus provide a feasible upgrade that can be easily integrated into low- T thermometry experiments.

P10

Application of a quantum action principle to a simple beam splitter experiment

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We have proposed [1] that a time-symmetric, realistic quantum theory can be based on an extension of the principle of stationary action. The action is ordinarily defined as the spacetime integral of the Lagrangian density, involving integration over one spacetime coordinate (four dimensions) for a single particle, or N spacetime coordinates for N particles. Based on the observation that the square of the action is stationary wherever the action is, we required stationarity of the superaction, defined as an integral over 2N spacetime coordinates that resembled the squared action except that the integrand included a factor coupling one set of N coordinates with the other set. The inclusion of the coupling factor made the theory explicitly nonlocal in space and time; it also made the wave equation nonlinear, in general an integrodifferential equation (IDE). We proposed that the IDE should be solved over a region of spacetime subject to boundary conditions imposed over its entire boundary; heuristically, those conditions are initial conditions, boundary conditions in 3-space, and final conditions. The theory is retrocausal because the solution in the interior of the region depends in part on conditions later in time. In an idealized measurement, the initial conditions come from the experimental preparation, and the reading of the outcome provides a "natural boundary condition" as a final condition. We argued that a theory of this type can explain wavefunction collapse under measurement in a natural way while still agreeing with conventional theory for cases corresponding to "no measurement". Such a theory has other advantages, such as explaining EPR correlations and delayed-choice experiments, but parts of the formalism are incomplete.

In order to understand and develop this theory further, we here apply it to a simple beam splitter experiment involving a single photon. Although the theory seems to require the inclusion of the photon source and both detectors in the description, it may be possible to capture the essential features in just two particles–the photon, and an electron in the half-silvered mirror that either oscillates and produces a reflecting surface current, or remains stationary and allows the photon to be transmitted.

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Electron-vibration interactions for AC driven quantum transport

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Molecular junctions, consisting of molecules bonded between macroscopic leads, allow researchers to probe and design charge and energy transport at some of the smallest scales possible, with the promise of device functionalities whose descriptions range from efficient to exotic. Such systems are often manipulated and observed whilst time-dependent lead and gate voltages are applied, with many devices, including pumps and rectifiers, designed with time-dependent, usually alternating, voltages in mind. Given such small scales and the sensitivity of these systems, vibrations can often influence transport properties and contribute significantly to device failure. Naturally, understanding the interplay between time-dependent voltages and vibrations will be an essential part of molecular junction design. Of particular importance is the interplay of periodically driven leads and vibrations of the central region, with research already suggesting the possibility of 'cooling' of vibrations due to the application of driving [1,2], whereas the introduction of phonons within a mean-field approximation saw significant deviations from noninteracting behaviour in a time-scale separation approach [3]. To this end, we make use of nonequilibrium Green's functions in a Floquet setting [4], where electron-phonon coupling is considered within the self-consistent Born approximation. This allows for the calculation of nonequilibrium phonon occupations within the central molecule whilst lead energies are varied periodically. This result extends the of theory used to explain point-contact spectroscopy and inelastic tunnelling spectroscopy to consider alternating drivings, which sees the characteristic signs of inelastic transport gain photon-assisted side-peaks. The presence of photon-assisted transport is also observed within the nonequilibrium phonon occupations. Within a period of driving, phonon occupancy is found to change significantly when driving and vibrational frequencies come into resonance, giving support to the intuition that the system may be more susceptible to failure when driven at resonance.

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P12

Thermal quantum nanomachine with near-field plasmonics for generation of (phonon) lasing

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Recent advances in near-field plasmonics, i.e. metamaterials, have demonstrated the ability to generate localized fields of high intensity to maintain relatively large nanoscale heat gradients. A plasmonic near-field transducer (NFT) can achieve such large gradients, making population inversion achievable within photonic (or phononic) media.

We develop a thermal nanomachine composed of a nanoscale (phononic) laser that uses an NFT as a plasmonic energy source. Our vertically stacked system consists of a central three-level system in ladder-type configuration interacting with a two-level subunit at each side, coupled to a heat bath, i.e. created by the NFT and the cryostat, at the top and bottom, respectively. The different temperatures of the baths impose a heat gradient, which for certain parameters, at the central quantum system, could accompany the flow by the coherent (phonon) lasing.

In this contribution, we present a conceptionally new idea of a thermal nanomachine composed of a nanoscale (phononic) laser with an NFT as a source of plasmonic energy. Our description of the system kinetics is based on the Jaynes-Cummings Model, and the coupling to the external field given via a dipole approximation, with a single mode, quantized radiation field and phonon coupling. Indeed, we show that the positive inversion can be harnessed to generate coherent output having full control of the proposed phonon lasing medium.

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Nonuniform convergence in moment expansions of integral work relations

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Several seminal results concerning out-of-equilibrium process take the form of an exponential average. Examples include the Jarzynski equality [1], its extension to processes with measurement and feedback [2], and more. Mathematically, the results take the form $\left\langle e^{-X}\right\rangle = e^{-B}$.

In this work [3], we highlight the importance of order of mathematical operations in exponential averages. We give physically motivated examples of parameter dependent processes in which naively using a limiting value of the parameter results in an apparent violation of the above equation. The first example is a model of a process with measurement and feedback. The singular limit of this example is that of error-free measurement. The second example is an ideal gas particle inside an infinitely (under the limit) fast expanding piston.

We show that this mathematical behavior of exponential averages is associated with nonuniform convergence of the moment series of X obtained by expanding $\left\langle e^{-X}\right\rangle$. We specify the shared characteristics of the examples. In both, the moments begin to deviate from their limiting value in high enough order, which is pushed higher as we approach the limit. This deviation grows strong in higher and higher moments. We also identify the dominant moments in the convergence of the series of moments.

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P14

Engineering the speedup of quantum tunneling in Josephson systems via dissipation

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We theoretically investigate the escape rate occurring via quantum tunneling in a system affected by tailored dissipation [1]. Specifically, we study the environmental assisted quantum tunneling of the superconducting phase in a current-biased Josephson junction. We consider Ohmic resistors inducing dissipation both in the phase and in the charge of the quantum circuit. We find that the charge dissipation leads to an enhancement of the quantum escape rate. This effect appears already in the low Ohmic regime and also occurs in the presence of phase dissipation that favors localization. Inserting realistic circuit parameters, we address the question of its experimental observability and discuss suitable parameter spaces for the observation of the enhanced rate.

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Coherence-powered energy exchanges between a solid-state qubit and light fields

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Quantum coherence has recently emerged as a key concept to describe the law of quantum thermodynamics, supporting the definition of work and governing the laws of energy exchange. More specifically, recent theory predicts quantum coherence to play a crucial role in the energy transfer from a quantum substance to a quantum battery [1-4]. The coupling of a two-level system to a single mode harmonic oscillator has been proposed as a toy model to explore these energy transfers [2,3]. Such system can be mapped to a two level-system (qubit) coupled to a single mode of the electromagnetic field (battery), with light emission taking place either in the spontaneous (empty battery) or stimulated regime (loaded battery) [2,3]. In the spontaneous emission regime, it was recently predicted that the maximum amount of work extracted from the working substance to the quantum battery is limited to the coherent part of the energy carried by the initial qubit.

We experimentally study the role of coherence in the process of energy transfer both in the charging and discharging of a quantum battery. We investigate the energy transfer from a qubit (a two-level system of a quantum dot) into an initially empty quantum battery (a mode of the electromagnetic field). We observe that the amount of work charged into the quantum battery through spontaneous emission is proportional to the quantum coherence initially carried by the qubit and is altered by temperature. We then show that we can transfer the work from the battery into a classical coherent field using homodyne-type measurements, thereby discharging the battery. The amount of energy transferred to the classical field is controlled by the relative fields' classical optical phase, the overall quantum purity of the charged battery field as well as long term fluctuations in the qubit energy.

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P16

An ideal rapid-cycle Thouless pump

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Thouless pumping is a fundamental instance of quantized transport, which is topologically protected. Although its theoretical importance, the adiabaticity condition is an obstacle for further practical applications. Here, focusing on the Rice-Mele model, we provide a family of finite-frequency examples that ensure both the absence of excitations and the perfect quantization of the pumped charge at the end of each cycle. This family, which contains an adiabatic protocol as a limiting case, is obtained through a mapping onto the zero curvature representation of the Euclidean sinh-Gordon equation.

Ultrastrong coupling of a qubit with a nonlinear optical resonator

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We study the interaction of a two-level atom with a single-mode nonlinear electromagnetic resonator, considering coupling strengths ranging from zero to the so-called deep strong coupling regime. When the qubit-resonator coupling is very strong, the standard Kerr model for the resonator becomes questionable. Moreover, recently, it has been shown that extra care is needed when constructing gauge-independent theories in the presence of approximations as the truncation of the Hilbert space of the matter system. Such a truncation can ruin gauge invariance leading to nonphysical results, especially when the light-matter interactions strength is very high. Here we face and solve these issues to provide a consistent nonlinear-resonator quantum Rabi model satisfying the gauge principle.

P18

Work to heat conversion in atomic springs

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Mechanical work to heat conversion is a familiar phenomenon from everyday life, as well as a central process of energy loss in any mechanical device. However, it is not clear how mechanical work is converted to heat at the atomic scale. Here, we propose to reveal the properties of mechanical work conversion to heat in metallic atomic contacts and atomic chains. Using thermal noise measurements, we will probe local temperature changes under repeated elastic and plastic deformation of atomic-scale contacts between two metal tips. We will use a mechanically controllable break junctions system to fabricate either different contacts of several dozens of atoms in diameter down to a single atom or elongate atomic chains between atomically sharp metal tips. We will study the role of system size, injected energy magnitude, elastic vs. plastic deformation, and metal type. This research is expected to shed light on the interplay between mechanical work and heat dissipation at the atomic scale, which is central for any nano-mechanical system.

Regimes of cavity-QED under incoherent excitation: From weak to deep strong coupling

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The prototypical system constituted by a two-level atom interacting with a quantized single-mode electromagnetic field is described by the quantum Rabi model (QRM). The QRM is potentially valid at any light-matter interaction regime, ranging from the weak (where the decay rates exceeds the coupling rate) to the deep strong coupling (where the interaction rate exceeds the bare transition frequencies of the subsystems). However, when reaching the ultra-strong coupling regime, several theoretical issues may prevent the correct description of the observable dynamics of such a system: (i) the standard quantum optics master equation fails to correctly describe the interaction of this system with the reservoirs; (ii) the correct output photon rate is no longer proportional to the intracavity photon number; and (iii) they appears to violate gauge invariance. Here, we study the photon flux emission rate of this system under the incoherent excitation of the two-level atom for any light-matter interaction strength, and consider different effective temperatures. The dependence of the emission spectra on the coupling strength is the result of the interplay between energy levels, matrix elements of the observables, and the density of states of the reservoirs. Within this approach, we also study the occurence of light-matter decoupling in the deep strong coupling regime, and show how all of the obtained results are gauge invariant.

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Geometric energy transport and refrigeration with driven quantum dots

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Thermal transport in quantum dots has been extensively studied in the context of steady-state heat engines. However, quantum dots are also relevant for cyclic thermal machines as they can be time-dependently driven, e.g., to pump charge. Understanding the characteristics of energy transport in slowly-driven quantum dots is therefore important.

I will present the simple case of a slowly-driven single-level quantum dot weakly coupled to two electronic contacts. The dot has a strong onsite interaction, which can be either repulsive, as typical, or attractive, as realized experimentally. I will show the concrete effects of strong many-body interaction and the impact of the interaction sign on energy transport. Then, I will explain how to use this device as a heat pump or refrigerator and highlight the crucial role of the interaction sign in the performance of these thermal machines.

These results [1] were obtained by analyzing adiabatic charge and energy pumping, i.e., transport across the quantum dot due to the slow periodic modulation of system parameters, which is geometric. Our approach uses a fermionic duality for the evolution operator of the master equation [2], which provides compact and insightful analytic expressions. We identified and explained the pumping mechanisms for any pair of driving parameters. Building on this transport analysis, we studied the driven dot as a thermal machine in the presence of a small temperature difference δT between the two contacts. We derived a simple analytical expression of the efficiency in the limit of a vanishing δT which provides an insightful estimate of the device performance. But, even at finite δT and cooling power, we found a sizable efficiency, around 15% of Carnot efficiency. Finally, an attractive interaction yields a lower efficiency than a repulsive one but makes it possible to operate the device with larger δT due to the suppression of stationary currents.

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Quantum sensing and simulations using NV centres in diamond

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In the last decade, colour defects in diamond, like Nitrogen Vacancy centres (NVs), have been established as a robust platform for quantum sensing and quantum simulations. They allow optical access to the electronic spin and act as a nanoscale quantum sensor of magnetic fields at room temperature [1]. In our newly established lab, we are interested in utilising single NV centres in diamond in combination with nearby nuclear spins towards two main objectives. Firstly, to perform nanoscale sensing experiments on different surface modifiers using nanoscale Nuclear Magnetic Resonance (NMR) [2]. The precession of NMR active nuclei in an external magnetic field is detected by the NV sensors as an additional phase which can be extracted using Dynamical Decoupling (DD) MW pulse sequences applied to the NV spin. Secondly, to perform quantum simulations of thermodynamic [3] and many-body effects [4] in quantum systems. We aim to realise quantum thermal devices to manipulate energy transfer between interacting spins. To realise these devices, we plan to use a small cluster of nuclear spins that are coupled to a nearby single NV by hyperfine interaction.

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P22

A Keldysh-Langevin approach to modelling nuclear dynamics in molecular junctions

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The quintessential system which is used to observe and study the effects of quantum transport is that of the molecular junction: a molecular bridge bonded between two macroscopic conducting leads. Molecules in molecular junctions are subject to current-induced forces that can break chemical bonds, induce reactions, destabilize molecular geometry, and halt the operation of the junction. Additionally, novel phenomena such as telegraphic switching and localised heating have the possibility of being exploited for device functionality. We develop a nonequilibrium Green's function based transport theory in which atoms on the molecular bridge are allowed to move. This is achieved by utilising the inherent separation of timescales between slow nuclear motion and fast electronic dynamics, allowing us to solve for the adiabatic Green's functions along with non-adiabatic dynamical corrections. To make the theoretical approach fully self-consistent, the same time-separation approach is used to develop expressions for the adiabatic, dissipative, and stochastic components of current-induced forces in terms of adiabatic Green's functions. Using these current induced forces, the equation of motion for the nuclear degrees of freedom is cast in the form of a Langevin equation. This model is applied for both static and AC driving in the leads [1] and incorporates the motion of the atoms in the central region along with the atoms on the leads interface [2]. Furthermore, we utilise a Fokker-Planck description for the classical coordinate in order to calculate Kramers' first-passage times and reaction rates [3]. We observe localized heating effects and the formation of bi-stable effective potentials for the classical coordinates which are analysed through the use of the measured noise in the current [2,3]. Negative viscosities are shown to emerge under an applied voltage bias in a variety of systems, which demonstrates the lack of a possible steady-state for certain configurations [2,4]. An applied AC driving is shown to be capable of producing a cooling effect to the molecular bridge, increasing the stability and longevity of the system [1]. We assess the validity of the Langevin approach in different regimes by applying a novel time-stepping algorithm to solve for the classical Ehrenfest dynamics of the molecular bridge and find that the results produced by the Langevin method are accurate provided that the applicable regimes are not abused [4].

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Two-photon optomechanical hopping

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We study the interaction between two electromagnetic resonators separated by a vibrating two-sided perfect mirror. We started from its canonical quantisation generalising the results of Ref. [1]. The vibrating mirror separates both sides of the cavity at the classical level, but not quantum-mechanically. We report about the peculiar two-photon hopping mechanism which is not ascribable to a tunnel effect, but to an effective interaction between the three bosonic sub-systems. We describe this interaction within the effective Hamiltonians James' approach [2], and we use quantum trajectories to single out events otherwise invisible in statistical outcomes [3].

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P24

Work extraction from unknown quantum sources

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Ergotropy is one of the promising definitions of work extracted from a quantum system. Like other definitions, this definition requires full knowledge of the quantum state of the system. However, in real world the only way how to obtain this knowledge either requires creating the state, which costs at least as much as how much can be extracted, or performing a full quantum state tomography on the source, which may be impractical or even fundamentally impossible. In a real world situation, however, one would expect to do just a few measurements on an unknown source, and see how much work can be extracted by having this limited information. We do exactly that: we define a scenario in which we have a completely unknown source, characterize it by a single type of measurement, and then determine how much work can be extracted: this is done by modifying the definition of ergotropy so it applies for this situation. This models real life scenarios and goes much further into practical usefulness of ergotropy as a realistic figure of merit. Interestingly, we find that this notion of ergotropy naturally connects with recently developed notion of Observational entropy.

Chaos assisted many-body tunneling

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We study the interplay of chaos and tunnelling between weakly-coupled Bose-Hubbard dimers. Constructing a double-dimer Bose-Hubbard model, we map the classical mixed phasespace structure and study its manifestaions on the quantum many-body spectrum. The classical phasespace structure exhibits quasi-integrable self-trapping islands for particles and excitations, separated by a chaotic sea. We show that the many-body dynamical tunneling gap between macroscopic Schrödinger cat states supported by these islands is chaos-enhanced. The many-body tunnelling rate fluctuates over several orders of magnitude with small variations of the system parameters or the particle number.

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Casimir interaction between two spheres with perfect electromagnetic boundary conditions

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Vacuum fluctuations of the electromagnetic field in the presence of two scatterers give rise to a force between the objects known as Casimir force or retarded van der Waals force. For finite temperatures, thermal fluctuations contribute to the force as well. Specifically, we consider the Casimir interaction between two bi-isotropic spheres where polarization mixing upon reflection at each sphere occurs. An asymptotic expansion of the Casimir force for large spheres shows that the leading term corresponds to the result obtained when the Casimir force between two plates is integrated over the local distances between the spherical surfaces [1]. This approximation is commonly known as proximity force approximation (PFA).

A special case of bi-isotropic spheres are perfect electromagnetic conductors interpolating between spheres with infinite permittivity and infinite permeability for which we present results for vanishing [2] as well as non-zero temperatures. Apart from the PFA results, we also determine the leading PFA corrections and the results for large distances which reveal that the transition from an attractive force to a repulsive force depends on the temperature and the distance between the spheres.

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Thermodynamic uncertainty relation in degenerate an non degenerate maser heat engine

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In this work, we investigate the thermodynamic uncertainty relation, which represents a trade-off between entropy production rate and relative power fluctuations, for non-degenerate three-level and degenerate four-level maser heat engines. For the non-degenerate case, we study two slightly different configurations of three-level maser engine and compare degree of violation of thermodynamic uncertainty relation in both models. We also show that the thermodynamic uncertainty relation remains invariant when we scale the matter-field coupling constant and system-bath coupling constants by the same factor. Further, for the degenerate four-level engine, we study the effects of noise-induced coherence on the thermodynamic uncertainty relation. We show that depending on the parametric regime of operation, the phenomenon of noise-induced coherence can either enhance or suppress the relative power fluctuations.

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Agent model of Covid 19 disease spreading and its confrontation with excess deaths data explains real effects of governance strategies

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We have examined some of the origins of oscillating behaviour in agent-based models of SARS-CoV-2 infectiousness and immunisation. We discuss only the model that correctly predicts the 11-week oscillation period observed in Czechia and the mechanisms behind the successful 2020 spring virus suppression. Lockdown in the strict sense or its weaker version - oscillation dampening after the first wave - was not achieved in any European country.

The model follows this concept: (1) The agents move for a given step length in a random direction. (2) An infected agent infects all non-immune agents present in the given field. (3) The infected agent is infected for a given time, then becomes immune or dies. (4) We added the long-term attribute immunity to mucosal virus, which makes the agent susceptible to infection but not dying by the infection. (5) Third passage of the disease makes the agent immune until the long-term immunity slowly vanishes. (6) The agents have a finite lifespan and may reproduce. The starting parameters are (1) population density and (2) the initial number of infected agents.

We compared the results to the excess death numbers from the Euromomo database and Czech statistical authorities' data.

The length of the step is a simulation of lockdown. At step 0, the strict lockdown, infected agents infect only agents initially present at a given field, and the virus dies out. Step 1, which was used in all agent-based models before, leads to a heavily dampened first oscillation. Any longer step leads to dampened oscillations with a period determined by the combination of population density, duration of the disease, duration of immunity, and probability of infection. The main conclusion of this work is that we determined the period of oscillations in the Czech Republic, 11 weeks, and parameters satisfying this criterion.

The decrease of population density has a similar effect as lockdown, the heavy dampening. We suggest that the success of the spring 2020 anti-covid measure in Czechia was due to the dilution of the population by the re-location of people into countryside cottages. It is likely to be also the cause of low mortality in Scandinavian countries. In contrast, the so-called lockdown in the autumn 2020 - winter 2021 in Czechia was no real lockdown. People were locked up in high-density towns through travel restrictions and mixed up quickly in public transport. The transfer of infection from working parents to grandparents also likely contributed to excess deaths.

The model also predicted the single autumn 2021 wave that ended in the first week of January 2021. The results are consistent with recent WHO findings.

Density and pseudo-spin rotons in a bilayer of soft-core bosons

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We study the dynamics of a bilayer system of bosons with repulsive soft-core Rydberg-dressed interactions within the mean-field Bogoliubov-de Gennes approximation. We find roton minima in both symmetric and asymmetric collective density modes of the symmetric bilayer. Depending on the density of bosons in each layer and the spacing between two layers, the homogeneous superfluid phase becomes unstable in either (or both) of these two channels, leading to density and pseudospin- density wave instabilities in the system. Breaking the symmetry between two layers, either with a finite counter flow or a density imbalance renormalizes the dispersion of collective modes and makes the system more susceptible to density wave instability.

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Quasiparticle properties of three-dimensional soft-core fermions

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Rydberg-dressed ultracold atoms are characterized by their soft-core interactions. Using the G0W technique along with the random-phase approximation for the dynamically screened particle-particle interactions we study the effects of many-body exchange and correlation on the quasiparticle properties of a three-dimensional system of ultracold Rydberg-dressed fermions with repulsive interactions. In particular, we look at the effective mass and renormalization constant of this system. In the weak coupling regime, the Hartree-Fock (static) term is the dominant term in the self-energy where the renormalization constant remains close to one. Upon increasing the coupling constant and soft-core radius, enhancement of the correlation effects in the system causes the reduction of the renormalization constant. At strong coupling and large soft-core regime, a strong suppression is observed in the renormalization constant, but it never reaches zero. It indicates the validity of the Landau Fermi liquid picture in the Rydberg-dressed Fermi gases up to very strong couplings. Our numerical calculations predict a strong reduction in the many-body effective mass with increasing interaction strength and soft-core radius.

The logarithmic phase singularity in the inverted harmonic oscillator

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Phenomena in quantum field theory, such as Hawking radiation [1] or acceleration radiation [2], or based on a logarithmic phase singularity at an event horizon in spacetime.

In this contribution, we show that related effects emerge in the elementary quantum system of a one-dimensional inverted harmonic oscillator. In fact, the Wigner function corresponding to an energy eigenfunction of this system [3,4] clearly displays a horizon in phase space. Although usually hidden, even a logarithmic phase singularity in combination with an amplitude singularity appears after a suitable coordinate transformation.

Our insights [5] into this simple quantum system lay the foundation for future applications in the field of matter wave optics.

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Observation of quantum phase-synchronization in a nuclear spin-system

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Inspired by the ubiquity and stability of classical synchronization, quantum synchronization has been field of intense study. Studies have shown fundamental implications of quantum synchronization to other fields such as entanglement generation, thermodynamics, etc. To study synchronization, the quantum analogue of phase space is constructed using quasiprobability distributions such as Husimi function and Wigner function, from which measures of synchronization are developed. These measures help establish a valid limit cycle that is robust against external perturbations and possesses a neutral free phase, and exhibits phase-localization upon synchronization. Experimental demonstration of quantum synchronization is in general challenging since measurements typically require the system to settle into a steady state, which necessitates the need for long waiting times. Such long wait times allow for other experimental noise sources to interfere with the signal. Besides this, tomographic reconstruction of the state scales exponentially with the system size, making experimental studies further cumbersome.

Here, we present an experimental study of phase-synchronization in a pair of interacting nuclear spins subjected to an external drive in NMR architecture. A weak transition-selective radio-frequency field applied on one of the spins is observed to cause phase-localization, which is experimentally established by measuring the Husimi distribution function under various drive conditions. We have developed a general interferometric technique to directly extract values of the Husimi function via the transverse magnetization of the undriven nuclear spin, bypassing the need for state tomography. We further verify the robustness of synchronization to detuning in the system by studying the Arnold tongue behaviour. This work opens up avenues for studying the implications of synchronization in areas such as spectroscopy, quantum computing and quantum thermodynamics.

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Experimental studies of dynamical tunneling in nuclear spin systems using NMR

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Tunneling is conventionally defined as the phenomenon in which a quantum system penetrates a potential barrier despite having lesser energy than the barrier height. Dynamical tunneling, on the other hand, describes the mechanism by which a quantum system accesses regions of the phase space that are isolated by its dynamics. This is observed in chaotic systems with mixed phase space comprising disconnected islands of regular regions surrounded by a sea of chaotic region. Classically, a system initialized in a regular region remains localized therein as the dynamics prohibits crossing over the chaotic sea and beyond. Quantum systems, however, can bypass this and exhibit periodic tunneling between the disconnected regular regions.

Here, we study dynamical tunneling of nuclear spins in NMR architecture using the quantum kicked top model, a quintessential model of chaos. We operate in the mixed phase space regime, and use the expectation values of the angular momentum operator as probes to observe tunneling of the quantum system between regular regions. The expectation values of these operators show periodic revival as the system tunnels between regular regions. We also study the dependence of the tunneling period on system size, and show that as the system size increases thereby approaching the classical limit, the period becomes longer, signalling suppression of tunneling behaviour. We further study quantum correlations such as von Neumann entropy and quantum discord during dynamical tunneling. These studies open avenues to explore tunneling in a generic chaotic environment, such as transport in a leaf or biological cell, qubits in a noisy quantum channel, many body quantum chaotic systems, etc.

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P34

Quantum heat transport through a multi-level system coupled to bosonic reservoirs

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Heat transport in nanoscale objects has been a central topic in condensed matter physics from both aspects of fundamental physics and the application for heat devices. Recently, various quantum heat devices, e.g., a quantum heat rectifier and a quantum heat valve, were suggested theoretically, and a part of them has been realized in superconducting circuits, which are the main platform to investigate quantum heat transport. The rapid development of techniques for the fabrication and the measurement in superconducting circuits allows us to observe heat transport with high accuracy and then motivates us to compare the experimental data with the theoretical model in detail.

In this poster, we consider heat transport in the quantum Rabi model, which is one of the most typical multi-level systems in the superconducting circuit [1]. Since the quantum Rabi model is more flexible and complex due to more degrees of freedom compared to a two-level system, it is expected to show characteristic transport properties reflected from multiple levels. In this work, we found that the thermal conductance has two peaks in its temperature dependence when tuning parameters to a specific region. At the poster discussion, we will talk about the reason for the double-peak structure in the thermal conductance and its possibility of application for quantum heat devices.

This work is partly supported by JST's Moonshot RD (Grant No. JP- MJMS2061).

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P35

Can charge measurements identify the nu=5/2 state?

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We propose an experiment to identify the topological order of the ν=5/2 state through a measurement of the electric conductance of a mesoscopic device. Our setup is based on interfacing ν=2, 5/2, and 3 in the same device. Its conductance can unambiguously establish or rule out the particle-hole symmetric Pfaffian topological order, which is supported by recent thermal measurements. Additionally, it distinguishes between the Moore-Read and anti-Pfaffian topological orders, which are favored by numerical calculations.

P36

A statistical approach for the many-body density of states of spinless fermions

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The description of out-of-equilibrium many-body systems requires going beyond the low-energy physics and local densities of states. Many-body localization, presence or lack of thermalization and quantum chaos are examples of phenomena in which states at different energy scales, including the highly excited ones, contribute to the dynamics and therefore affect the system's properties. To quantify these contributions, one has to obtain the many-body density of states (MBDoS), a function whose calculation becomes challenging even for quantum non-interacting identical particles due to the difficulty in enumerating states to account for the exchange symmetry. In the present work, we introduce a statistical approach to evaluate the MBDoS in the case of systems that can be mapped into free fermions. The starting point of our method is the principal component analysis of the filling matrix F describing how M electrons can be configured into K single-particle energy levels. We show that the two principal components of F and corresponding eigenvectors can be analytically calculated and one can treat them statistically to recover the many-body spectrum and the MBDoS. We illustrate our method in two classes of problems that are mapped into spinless fermions: (i) non-interacting electrons in a homogeneous tight-binding model in 1D and 2D, and (ii) interacting spins in a chain under a transverse field.

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Many-body tunnelling in a symmetric double-well potential

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Tunnelling is one of the most fascinating phenomena in quantum physics, whose implications on the dynamics of many-body systems are still unclear. Recently, it has been argued that the presence of inter-particle interactions in quantum many-body systems may lead to cooperative effects, such as the modification of the single-particle tunnelling (density-induced tunnelling) or the simultaneous tunnelling of a few particles as a single object through a potential barrier (cotunnelling). Under certain conditions, these additional non-standard Hubbard terms are considerably more important than previously assumed, due to correct account of the Wannier functions, which tails were neglected in many estimations. In this poster, we will examine some preliminary results about cooperative effects shown by a couple of particles in a double-well potential, under the effect of different types of interaction. Our results show that, under certain conditions, the non-standard cotunnelling process affects the dynamics of the system, which is slightly, but notably modified. Moreover, the non-standard density-induced tunnelling amplitude may suppress the single-particle tunnelling even for repulsive two-particle interactions. This would correspond to a bound state localized in one well, which cannot decay but only propagate between the wells due to the cotunnelling mechanism.

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Conference Site Buildings

Pyramida Hotel

Pyramida Hotel was built in 1980 in the neo-functionalist style with an interesting star-like ground plan and pyramid-like outer shape. Last renovation of the hotel took place in 2021-2022. The hotel offers a wide selection of conference services. The hotel offers a wide selection of conference services.

The Pyramida Hotel is situated in the residential area of Prague called Břevnov near the Prague Castle - see map 'Prague center'. It is in the same time very near the historical center of Prague and Prague international airport - about 20 minutes by car. From the Pyramida Hotel you can reach easily many historical and important places of Prague taking trams No. 22 or No. 23 which have their stops nearly in front of the Pyramida Hotel: Prague Castle within about 5 minutes, Lesser Town is about 10 minutes, Charles Bridge area, too, Old Town and New Town centers (in the vicinity of Old Town Square and Wenceslas Square) within about 20 minutes ride.

Wallenstein Palace

Wallenstein Palace (Valdštejnský palác) is situated in the very center of the Lesser Town in close vicinity of the Lesser Town Square and the Charles Bridge. The origin of the settlement in the Lesser Town is directly linked to Prague Castle, which was founded around 880 AD. The oldest settlement of the future city named Prague was concentrated just to places below the castle. In this area the second town of Prague was later formed: the space between the river of Vltava and Prague Castle was fortified in the 13th century and the Lesser Town was founded in 1257 by the Czech King Přemysl Otakar II.

The Wallenstein Palace was built from 1624 to 1630 as a seat of the Imperial Generalissimo, Admiral of the Atlantic Ocean and the Baltic Sea, Albrecht Eusebius of Valdstein (Wallenstein) who was one of the most important figures of the Thirty Year's War. Apart from being famous as a very influential soldier (Commander-in-Chief of the Imperial Army), Wallenstein is also known for his belief in the influence of the stars. It is a very interesting experience to read personal characterization of Wallenstein in the horoscope written for him personally by Johannes Kepler. This link is not the only one which connects Wallenstein Palace with astronomy and physics: inside the Palace there is the astronomical-astrological corridor with allegories of seven planets, the leading architect who designed the Wallenstein Palace and its Sala Terrena in the huge Baroque garden was Italian Giovanni Battisto Pieronni, a student of Galileo Galilei. When designing the huge palace complex of the Wallenstein Palace, Pieronni (together with two other Italian architects A. Spezza and N. Sebregondi) combined elements of the Late Renaissance with those of the Early Baroque. He also hired the most renowned artists to participate on the art works and decoration of the palace. This resulted in the first Baroque palace complex in Prague which became a really representative and up to date as for fashion seat of Albrecht Wallenstein. By this palace the idea of Wallenstein to express his power and glory by building a magnificent palace whose size and decoration even surpassed those of the Prague Castle, was fulfilled.

To imagine the size of the Wallenstein Palace consider the fact that Wallenstein purchased twenty three houses, three gardens and the municipal brick-kiln to gain the place for his palace. The palace complex has a perimeter of almost 750 meters. It is completely separated from the outside world by walls and concentrated around a landscaped garden and five courtyards. The huge garden is famous for its monumental Baroque Sala Terrena with three open arches as well as for a number of bronze statues of ancient gods by Adriano de Vries. As for the palace rooms, the most famous place there is the Main Hall. This hall reaches to the height of two floors and its dimensions are further enlarged optically by mirror windows.

The Wallenstein Palace is nowadays the seat of the Senate of the Parliament of the Czech Republic.

How to get there:
The entrance to the Wallenstein Palace is from the Wallenstein Square which you can reach within five minutes walk either from tram and underground station Malostranská or from tram station on the Lesser Town Square (Malostranské náměstí) - see map 'Prague Castle and Wallenstein Palace neighborhood'.
Special tram will depart from the Pyramida Hotel to the Malostranská station on Monday afternoon to facilitate FQMT'22 participants transfer. Exact departure time will be announced during the Conference.
Stops Malostranská or Malostranské náměstí can also be reached from the Pyramida Hotel by tram No. 22 (23) - 5th or 6th stop.
Alternatively, you can get to the Wallenstein Palace directly from the Pyramida Hotel within 30-40 minutes of a nice walk - see maps 'Pyramida Hotel - access and nearest neighborhood' and 'Prague Castle and Wallenstein Palace neighborhood'.

Prague Castle, St. Vitus Cathedral

The **Prague Castle**, the ancient seat of Czech sovereigns, now the seat of the president of the Czech Republic, is the most important historical and cultural place of Prague. Its palaces, Saint Vitus Cathedral and churches situated at the hill above the Vltava River represent the symbol of the Czech Lands. These palaces, gardens and churches create the largest castle complex in Europe. You can read more about the Prague Castle in various books on the European and Czech history besides much special literature devoted just to the Prague Castle, its history and architecture.

St. Vitus Cathedral (St. Vitus, St. Wenceslas and St. Adalbert Cathedral in full name) has been always considered to be the most important church of the Czech Lands and intimately related to the history of the Czech state. The coronations of Czech kings took place in it, and many kings are buried there.

How to get there:

From the Pyramida Hotel you can reach the Prague Castle (see maps 'Pyramida Hotel - access and nearest neighborhood' and 'Prague Castle and Wallenstein Palace neighborhood'):

1. either by about 20 minutes walk, starting down along the Bělohorská street (the main street where the Pyramida Hotel is situated)
2. or by tram No. 22 or 23 (1 stop, about 2 minutes) down along Bělohorská street from the stop Malovanka to the stop Pohořelec, from where you can reach the Prague Castle within 15 minutes walk
3. or going by tram No. 22 or 23 (3 stops, 5 minutes) to the Pražský Hrad stop from where you can reach the central part of the Prague Castle by a side entrance within 5 minutes walk.

The St. Vitus Cathedral is situated in the central part of the Prague Castle - see map 'Prague Castle and Wallenstein Palace neighborhood'.

Strahov Monastery

The **Strahov Monastery** (Strahovský klášter) was founded as a Premonstratensian abbey by Jindřich Zdík, Bishop John of Prague, and Vladislaus II, Duke of Bohemia already in 1143. It is located in Strahov in the vicinity of the Prague castle.

The original monastery has been rebuilt many times. The monks began to build their monastery first of wood, with a Romanesque basilica as the center of all spiritual events in Strahov. The building was gradually completed and the construction of the monastery stone buildings continued, in order to replace the provisional wooden living quarters with permanent stone. In 1258, the monastery was heavily damaged by fire and later renewed.

The monastery continued functioning until the period of the Hussites, when it was attacked and plundered in 1420. Consequently, the monastery took a long time to recover. It was not until the arrival of the abbot Jan Lohelius, who became the abbot of Strahov in 1586, that a turn came about. He devoted all his abilities to the renewal of Strahov. He reconstructed the church, renewed the abbey buildings, established workshops, built a new dormitory and refectory, and had the monastery gardens newly laid out. He regained many of the monastery estates in order to build up the material base of the monastery, providing funds for the institution's maintenance and further development.

In 1612, the new abbot, Kašpar Questenberg, continued in the expensive work started by Lohelius, completed the lower cloisters and prelature, and even erected a new building in the form of St. Elizabeth's Hospital, as well as adding out-buildings and a brewery. The financial account of the costs incurred by his building activities was comparable with such builders as his contemporary Albrecht von Wallenstein.

One of the biggest events in the history of the Premonstratensian order was the transfer of the remains of Norbert of Xanten, the founder of the order, from Magdeburg. The reinterring took place under Questenberg's abbacy. This came about in 1627, and since then the remains of the saintly founder have laid at rest in the abbey church.

The abbey was plundered by troops of the Swedish Empire towards the end of the Thirty Years' War. The church and the library were looted. After the departure of the Swedes, the abbot Kryšpin Fuk had the damaged abbey repaired again.

In 1670 Jeroným Hirnheim, a philosopher and theologian, became the abbot of Strahov. His greatest work, which has survived to the present day, was the building of a new library and the so-called Theological Hall which was completed in 1679. During the 17th and early 18th centuries, other abbots continued in the reconstruction of the monastery. In 1779 Václav Mayer became the abbot. His most outstanding work was the building of the new library now in Classical style. Today it is called the Philosophical Hall.

After 1950, the library was incorporated into the Memorial of National Literature. Following events of 1989 the library was, along with the monastery, returned to the Premonstratensians. The Strahov Library contains over 200,000 volumes, including over 3,000 manuscripts and 1,500 first prints stored in a special depository.

The conference dinner will be held in the summer refectory. The refectory dating back to 1691 was designed by Jean Baptiste Mathey, a Burgundy architect. Along the walls there is a portrait gallery with paintings from the end of the 17th century showing significant personalities of the Strahov Monastery. A rood screen is hung on the walls that was used for reading during meals. The vault is decorated with a fresco by Premonstratensian painter Siard Nosecký (1693-1753) and has the theme "Heavenly Feast of the Righteous with the Christ as the Host" dating 1743-1745.

The conference concert will be held in The Basilica of Assumption of Our Lady. The Basilica was constructed as a triple-aisle Romanesque basilica 56 m long and 22 m wide with a transept and two prismatic towers. This design did not last long, because the church was rebuilt in Gothic style after a fire in 1258. The flat wooden ceiling was replaced by a dome and the Chapel of St Ursula was added to the northern transept. After being plundered by the Hussites, the church was reconstructed in Renaissance style. In 17th century, the basilica was extended westwards and the Chapel of Our Lady of Passau was added to the southern transept. In 1742, the Basilica was severely damaged again, this time during the French bombardment of Prague. The building was given a Baroque overhaul under the leadership of Italian architect Anselmo Lurago, and the fruit of this project is today's church. The basilica nave is 63 metres long, 10 metres wide, and 16 metres high. It ends in an apse, which hosts an altar of marble from Slivenec, made by Lauermann in 1768. There are ten side altars located at the pillars which separate the nave from the transepts. The sculptural work on the main altar was made by Ignác Platzer in 1768.

How to get there:

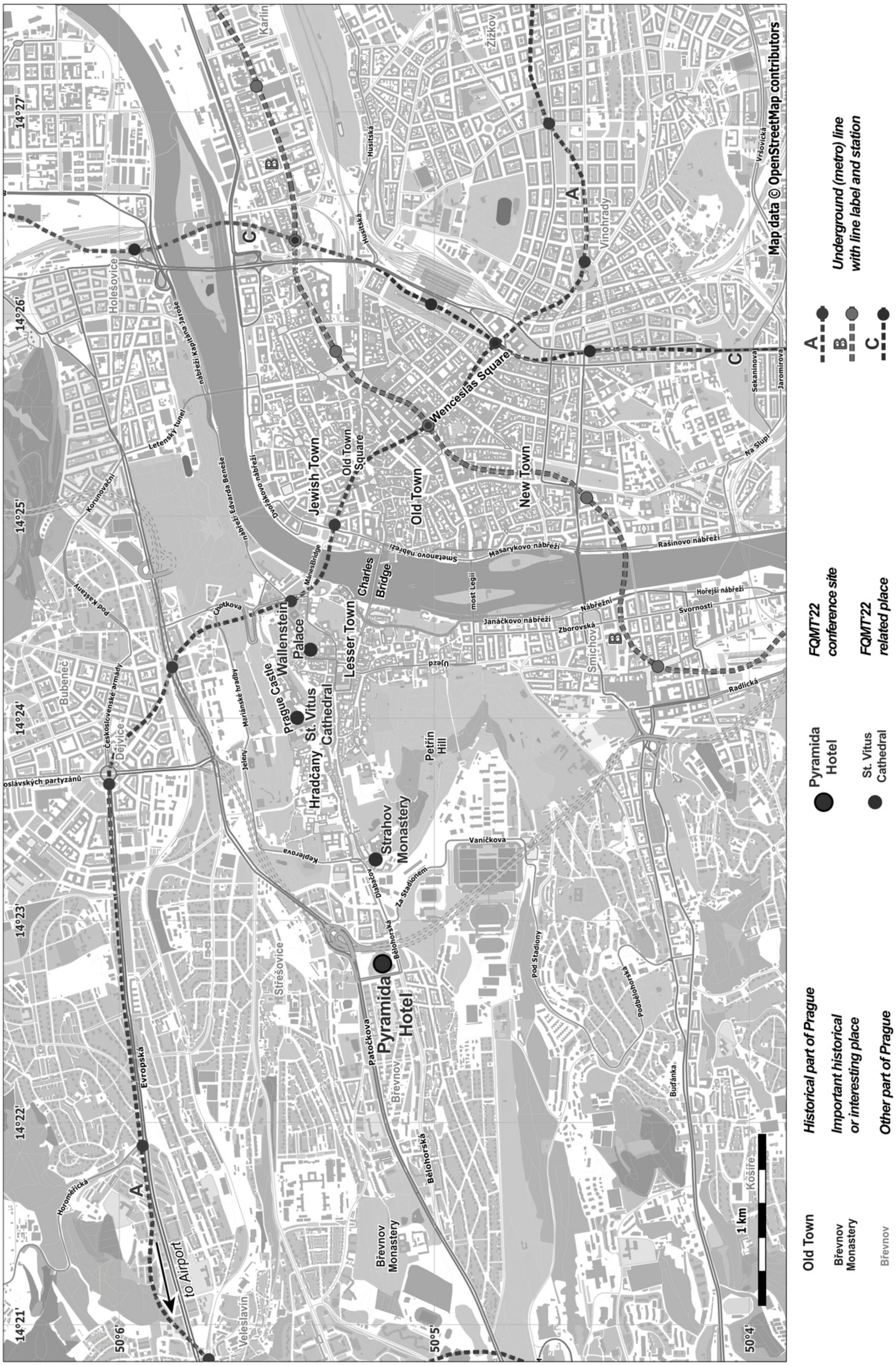
The best way from the Pyramida Hotel is to take a pleasant 10 min walk along the Bělohorská and Dlabačov streets, going left after leaving the hotel. After ca 600 m you will see the narrow road going up to the Strahov Monastery gate.

Alternatively, you can use tram No. 22 or No. 23 (one stop, about 2 minutes) from the stop Malovanka to the stop Pohořelec (towards city center). Then, walk back with respect to the direction in which the tram arrived, cross a wide road and go right using a narrow slightly rising road. After ca 100 m, turn sharply left and you will stand in the front of the Monastery gate.

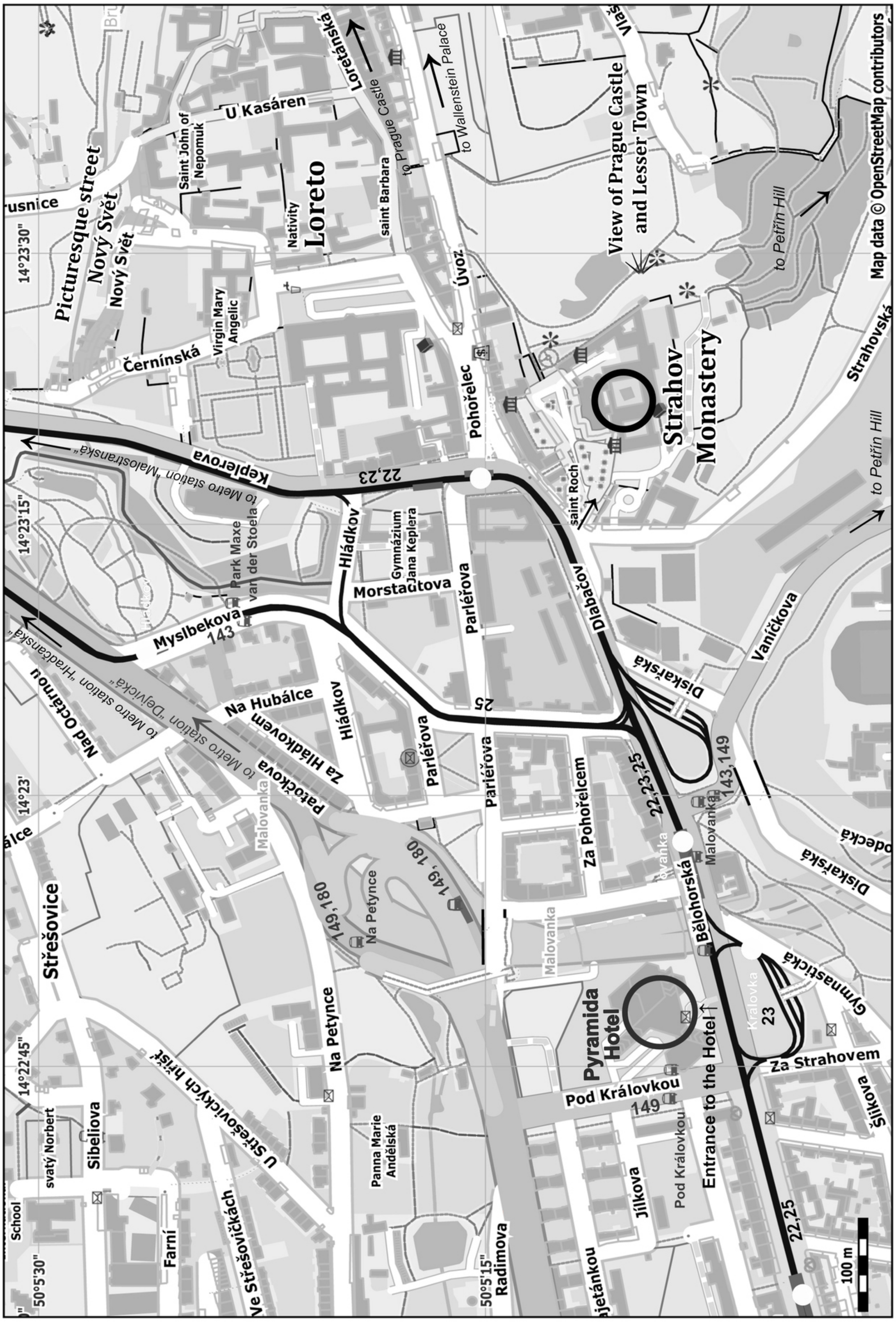
See also map Pyramida Hotel - access and nearest neighborhood

Maps

Prague center



Pyramida Hotel - access and nearest neighborhood



Loreto interesting place near the Pyramida Hotel

○ FQMT'22 relevant place

22,25 Tram lines with line numbers

Tram stop with stop name

149, 180 Na Petynce Bus stop with line numbers and stop name

Prague Castle and Wallenstein Palace neighborhood