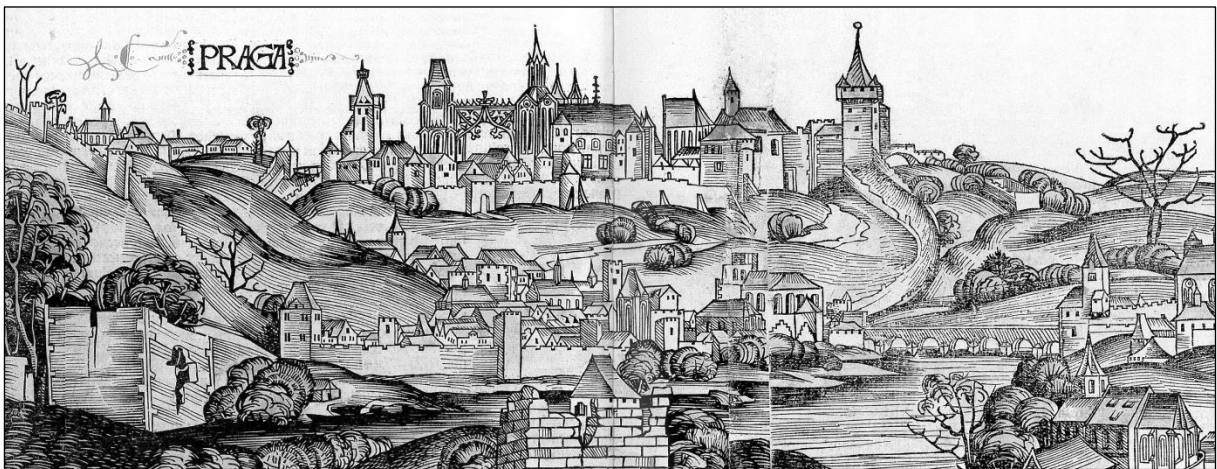


International multidisciplinary conference

# Frontiers of Quantum and Mesoscopic Thermodynamics 2024 (FQMT'24)

**Zero Announcement**



The conference is focused on

Non-equilibrium and Many-body phenomena, Physics of information,  
Foundations of quantum physics,  
Open quantum, Mesoscopic, Biological, and Gravitational systems.

**21 – 27 July 2024, Prague**

<https://fqmt.fzu.cz/24/>

## FQMT Conference Series Overview

FQMT conferences form a series of successful conferences (FQMT'04, FQMT'08, FQMT'11, FQMT'13, FQMT'15, FQMT'17, FQMT'19, FQMT' 21 – online, and FQMT' 22 – hybrid) which are traditionally held in Prague. For the details of the conference 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. 43, issue 3, 2010), Physica Scripta (vol. T151, 2012, and vol. T165, 2015), Fortschritte der Physik (Progress of Physics), vol. 65, 2017, and the European Physical Journal Special Topics (vol. 227, issues 15-16, 2019, vol. 230, issue 4, 2021, and 2023 to appear).

The title of the conferences is traditional and reflects main topics of early FQMT conferences. However, the range of the topics of the recent FQMT conferences, including the FQMT'24, is broader to cover new developments.

## Public Lectures at the FQMT Conferences - Overview

The previous public lectures were presented by the following speakers:

### FQMT'04

Anthony Leggett: Does the everyday world really obey quantum mechanics?

### FQMT'08

Georgiy Shlyapnikov: Novel physics with ultracold fermions

Marlan Scully: The demon and the quantum: From thermodynamics to quantum mechanics and beyond

Raymond Chiao: The Big Bang and the Cosmic Gravitational-wave Background (CGB): Using quantum mechanics to detect the first rumors in the Universe

### FQMT'11

Martin Rees: From Big Bang to Biospheres

Claude Cohen-Tannoudji: Laser manipulation of atoms

### FQMT'13

Serge Haroche: Juggling with photons in a box to explore the quantum world

Pavel Kroupa: How astronomers define our world view

### FQMT'15

Gerard 't Hooft: The quantum deep down

Marlan Scully: The photon sheds light on the quantum

### FQMT'17

John Pendry: Metamaterials and the science of invisibility

Anton Zeilinger: From quantum puzzles to quantum information technology

### FQMT'19

William Phillips: Time, Einstein and the coolest stuff in the universe

Rainer Weiss: The beginnings of gravitational wave astronomy

Wolfgang Ketterle: Cooling close to absolute zero temperature: A recipe for discoveries

FQMT'21

The conference was held online only and no public lectures were included.

FQMT'22

Guy J. Consolmagno: Astronomy, God, and the Search for Elegance

Harrison Schmitt: From Coyotes to Moonbeams

# Frontiers of Quantum and Mesoscopic Thermodynamics (FQMT'24)

21 July (Sunday) – 27 July (Saturday) 2024, Prague, Czech Republic

<https://fqmt.fzu.cz/24/>

## Introduction - 20<sup>th</sup> Anniversary of the FQMT conferences

The FQMT'24 conference will be held at the traditional venue, the Pyramida Hotel, located near the Prague Castle. Its program, both scientific and social, will be, however, somewhat exceptional, to celebrate 20<sup>th</sup> anniversary of the first FQMT conference (FQMT'04). All FQMT conferences have been held in Prague and their welcome parties have been always organized in the Wallenstein Palace, the seat of the Czech Senate.

## Scope of the FQMT'24 conference

The main goal of the conference is traditional: To contribute to a better understanding of the behavior of quantum systems out of equilibrium. To reach this aim we also need to include studies and improve our knowledge of systems in equilibrium and steady state situations. The conference will thus address 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 artificial and natural origin. Special attention will be given to non-equilibrium quantum systems, physics of information and physics of biological systems. Subjects from astrophysics, gravitation or cosmology related to the above scope will also be included.

## Topics

- Non-equilibrium quantum phenomena
- Foundations of quantum physics
- Quantum measurement, vacuum, entanglement, coherence
- Dissipation, dephasing, noise, decoherence
- Many body physics, quantum field theory
- Quantum simulations
- Quantum optics
- Optoelectronics, plasmonics

- Imaging, quantum sensors
- Physics of quantum information and computing
- Statistical physics, thermodynamics, quantum heat engines
- Physics of active matter, molecular motors
- Topological states of quantum matter, quantum phase transitions
- Macroscopic quantum behavior, cold atoms and molecules
- Mesoscopic, nano-electromechanical and nano-optical systems
- Biological systems, organoids, quantum biology
- Neural networks, artificial intelligence
- Cosmology, gravitation, astrophysics

## **Multidisciplinary Character of the Conferences**

The aim of FQMT'24 conference is to create a bridge between researchers from the fields of physics and related disciplines as covered by the above conference topics.

Following the tradition of the FQMT conferences, FQMT'24 will again 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.

## **Public Lectures and Special Talks**

Following the tradition of FQMT conferences, the FQMT'24 program will include several public lectures and special talks which will present interesting topics in a form attractive for both the conference participants and general audience.

The following speakers are, at present, expected (others are anticipated):

- Theodor Hänsch (2005 Nobel Prize in Physics)
- Peter Hänggi (Professor of Physics, Lars Onsager prize recipient)

- Al Hermann (Professor of Physics and Music, Jazz trombone player)

The lectures and talks will be held at special venues and accompanied by concerts.

## Musical, Art and Social Programs

An encompassing social program includes a number of social events and tours enabling participants to enjoy not only physics but also Prague during the conference, in a way hardly available to common visitors of Prague. Hence for accompanying persons, this is an opportunity for a very rare experience of this city.

Participants of FQMT'24 conference and their partners will have an exceptional opportunity to spend some time in the Wallenstein Palace, nowadays the Seat of the Senate of the Czech Republic. They will enjoy the large Baroque Garden of the Wallenstein Palace with its beautiful Sala Terrena for discussions during the evening welcome party. A guided tour will be organized through the huge Baroque complex of the Wallenstein Palace. This will be a unique experience by itself, since it is difficult to see all these places under ordinary circumstances.

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'24 program will feature concerts performed by world-class musicians, held at outstanding venues of the city. The list of these places will likely include e.g. Dvořák's Hall of the Rudolfinum (the seat of the Czech Philharmonic Orchestra and famous by concerts of Prague Spring Festival), the Gothic Cathedral of St. Vitus at Prague Castle (one of the symbols of the Czech Lands), the Baroque St. Margaret Church at the Břevnov Monastery or the Basilica of the Assumption of the Virgin Mary at the Strahov Monastery.

The scientific, the fine arts, and the musical programs are intended as a complement to one another, where scientists, historians of the arts and musicians are encouraged to mingle and share their knowledge and experience.

The encompassing social programs include tours and a number of very special events unavailable to the general tourist.

**Special event:** On the occasion of the 20th anniversary and taking into account of the recently increasing interests in robots and artificial intelligence issues, we intend to organize an exhibition devoted to the brothers Čapek who introduced to the world the word robot. The exhibition of some works of Josef Čapek in the Pyramida hotel (he was the foremost Czech painter as well as a writer and journalist and was very instrumental also for texts of his brother) will be accompanied by the exhibition of some books of Karel Čapek and possible by a special talk related to the work of the brothers Čapek and their followers. Karel Čapek wrote several influential books dealing with important ethical problems which are especially important nowadays. As Arthur Miller pointed out: "It is time to read Čapek again for his insouciant laughter and the anguish of human blindness that lies beneath it". Especially significant is the play Rossum's Universal Robots (known worldwide as R.U.R.), where the word Robot (designed by Čapek brothers during their discussions about the play) appeared

for the first time. As Kurt Vonnegut said about this play: “One of the great plays of the twentieth century by a great writer of the past who speaks to the present in a voice brilliant, clear, honorable, blackly funny and prophetic”.

## **The conference is held under the auspices of**

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

## **The conference is supported by**

- Institute of Physics, the Czech Academy of Sciences
- Institute for Quantum Science and Engineering, Colleges of Science and Engineering, Texas A&M University, USA
- Institute for Theoretical Physics, University of Amsterdam, Netherlands
- College of Engineering and Science, University of Detroit Mercy, USA

## **The conference is organized by**

- Institute of Physics of the Czech Academy of Sciences

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**Conference chair:** Václav Špička (*Institute of Physics, Czech Academy of Sciences, Prague*)

Jiří Bok (*Charles University, Prague*)

Howard Brubaker (*Detroit*)

Pavla Bušová (*Prague*)

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Claudia Pombo (*Amsterdam*)  
Marie Svobodová (*Tacca Agency, Prague*)  
Jarmila Šidáková (*Prague*)

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(not yet complete)

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**Co-Chair:** Theo Nieuwenhuizen (*University of Amsterdam*)

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Karl John Friston (*University College London*)

Steven Mark Girvin (*Yale University, New Haven*)

Peter Hänggi (*University of Augsburg*)

Dudley Herschbach (*Harvard University*)

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Anthony J. Leggett (*University of Illinois at Urbana - Champaign*)



Igor Lerner (*University of Birmingham*)  
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Heiner Linke (*Lund University*)  
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Marlan Scully (*Texas A&M University, Baylor University and Princeton University*)  
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Wolfgang Schleich (*University of Ulm*)  
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Jan van Ruitenbeek (*Leiden University, Kamerlingh Onnes Laboratory*)  
Anton Zeilinger (*University of Vienna*)

## **FQMT'24 Scientific Background**

Recent advances in technologies have led to an enormous boost in the possibility to create new, well-defined structures, including e.g. neural networks or organoids, measurement, simulations, sensors, imaging and observation techniques at microscopic, mesoscopic and macroscopic scales. At the same time, various methods allow us to investigate not only equilibrium features of complex many body systems, but also time evolution of these systems (which are in general far from equilibrium) at different time scales. This increasing ability to study subtle details of the dynamics of systems yields new versions of old questions and creates new challenges in many fields of physics.

The FQMT'24 program will thus be focused on conceptual and experimental challenges of non-equilibrium statistical physics, quantum many body physics, quantum thermodynamics, quantum optics, physics of quantum information, biophysics, foundations of quantum mechanics, and quantum field theory.

Further development of all these fields is needed to deal with an increasing requirement for more detailed understanding and use of such phenomena as quantum correlations, entanglement and their dynamics; decoherence and dissipation; light–matter interactions; behavior of closed and open quantum systems far from equilibrium; equilibration and thermalization of systems; roles of initial and boundary conditions; influences of environment,

reservoirs and external fields on the time evolution of systems; fluctuation and dissipation processes; quantum to classical transitions; dynamics of quantum phase transitions; role of the quantum vacuum, and topological states of systems.

A good understanding of the time evolution of both classical and quantum systems is essential for an explanation of many observations and experiments of contemporary physics. Observed systems must often be treated as non-equilibrium, open systems in which their behavior is influenced not only by their inner parameters, but also by properties of their environment and time dependent external fields. The theory of non-equilibrium behavior of quantum many-body systems is, however, far from complete. Important problems include such questions as irreversible behavior of real systems in comparison with reversible microscopic laws, emergence of classical macroscopic behavior from microscopic quantum behavior, charge (electron), spin and heat transport, limits to “phenomenological” thermodynamic descriptions, and the problem of how to properly describe open quantum systems far from equilibrium, especially in the case of strong interaction between a small system and reservoirs. Various versions of classical as well as quantum fluctuation and fluctuation-dissipation theorems can play important role in these developments.

Non-equilibrium processes and the system’s environment also play a decisive role in living organisms and there are many questions to be answered before we fully understand the laws which govern the performance of the structures essential for life. In this regard, it appears one of the necessary conditions for the proper performance of cells is that their dynamics be based on far from equilibrium states and related nonlinear, non-equilibrium transport. It is thus vital to work on a better understanding of active matter physics.

For quickly developing areas of neurosciences, biology of living cells and immunology the understanding of physics of neural and immunological networks as well as their parts, neural and immunological synapses, is vital. This is complemented by studies of artificial neural networks structures, cerebral organoids and detailed simulations of their behavior. All these interrelated issues are moreover related to the physics of information and the field of artificial intelligence.

There are also questions about the role of quantum physics in the behavior of various systems which are essential for living organisms, i.e., under which circumstances quantum effects, coherence, fluctuations, and noise can influence a cell’s functions.

Another challenging problem is stochastic behavior of such systems caused either by innate features of the systems or by noise related to the studied systems being open. Studies of temperature and quantum fluctuations, as well as quantum noise, dephasing and dissipation are of key importance, since these phenomena are closely related to the performance and the reliability of both artificially created nano-devices and “nano-engines” as well as natural “engines”, as are for example molecular motors and processes in cells in general.

Behavior of molecular motors is associated with more general considerations related to thermodynamics and the use of various mesoscopic structures. Among the central themes of classical thermodynamics are the concepts of “temperature”, “system”, “reservoir”, and “engine”. Due to quantum features of mesoscopic systems, it is necessary to deal with quantum thermodynamics to discuss possible quantum pumps, heat engines or refrigerators

based on features of mesoscopic (molecular) systems. The task of quantum thermodynamics is to provide a good “phenomenological” frame for the “macroscopic” description of open mesoscopic systems coming from more detailed studies of non-equilibrium quantum statistical physics of open systems and the foundations of quantum mechanics.

In general, the above problems arise in dissipation, dephasing and decoherence processes, and, on a very basic level, the foundations of quantum mechanics and related theories of quantum measurement. A better knowledge and insight into the foundations of quantum physics is essential for a proper formulation of the fundamental laws of physics. It is also essential for developing a suitable description of small quantum systems and their applications. This applies particularly to studies of light-matter interactions, cold atoms and molecules, quantum optics and physics of quantum information and computing, where questions of quantum interference, entanglement and decoherence processes, together with knowledge of time scales governing the dynamics of the studied systems, are essential and mutually beneficial. Various quantum (two-states) systems are nowadays intensively studied in a hope that their parameters and related dynamics will be suitable for quantum computers.

Many of the above-mentioned problems are also important for cosmology, gravitation and astrophysics, for the reason that these areas of investigation are strongly related to non-equilibrium statistical physics, many body physics, foundations of quantum physics, physics of quantum measurement, physics of the quantum vacuum, macroscopic quantum phenomena and also, mainly due to measurement methods used for observation and detection, to quantum optics, condensed matter physics, and physics of mesoscopic systems.

Mesoscopic systems are of special importance for several reasons. Various systems, of natural and artificial origin, can exhibit mesoscopic features depending on inherent inner parameters and interactions with their environment. Typical mesoscopic systems are of nanometer size, enabling fast developing nanoscale technologies for the preparation of structures with well-defined inner parameters, providing an enormous diversity of systems subject to interaction with the external environment. Nanoscale structures include not only very small artificially prepared structures, but also structures occurring in living cells, as for example complex molecules, proteins and molecular motors. Such systems lie on the border between different disciplines where the dynamic behavior of these systems and corresponding various methods of their description (individual and statistical, microscopic and macroscopic, classical and quantum) meet. These (often open) systems are commonly dominated by quantum effects, by topology of their structures and states, and by strong interactions with their environment. Due to their position between the macro and micro world, these systems exhibit many surprising phenomena which can lead to a better understanding of quantum mechanics, many-body physics, and the relation between classical and quantum behaviors by sensitive choice of parameters. The development of theoretical concepts for their description and reliable experimental methods is of great importance for investigating these systems, testing theories and designing new nanostructures with well defined, desired behavior. They can be now studied by various methods in such detail that affords a deeper understanding of quantum physics, as represented by quantum interference, entanglement, the uncertainty principle and quantum measurement processes.

In summary, further experimental as well as theoretical studies of short to long time dynamics (via transport as well as optical properties) and the influence of initial and boundary conditions are needed. To understand better dynamics as well as equilibrium properties of classical and quantum systems, both theoretical and experimental experiences from such seemingly different, but in fact strongly correlated, fields as condensed matter physics, quantum optics, plasma physics, nuclear physics, physics of quantum information and computing, chemistry, biophysics and astrophysics, will be discussed during the conference program.