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SWEDISH—UKRAINIAN SEMINAR
in THEORETICAL PHYSICS

May 28, 2026

Mixed on-line/off-line regime*

Programe**

10.00–10.05 – Opening

10.05–11.05 – **Erik Aurell** (KTH, Stockholm University, Sweden)

“A high-temperature limit penalizing high-frequency quantum fluctuations”

11.05–11.35 – **Musfer Adzhymambetov** (BITP of the NASU, Kyiv, Ukraine)

“High Baryon Densities from a Thermodynamically Informed Neural Network”

11.35–12.05 – *Coffee break*

12.05 – 13.05 – **Ari P. Seitsonen** (CNRS/UPMC, Paris, France)

“Dynamical Properties of Liquid Water: The Importance of Long-Range Interactions with Machine Learning Interaction Potentials”

13.05 – 13.30 – **Denys Zhuravel** (BITP of the NASU, Kyiv, Ukraine)

“Thermodynamic properties and BEC phase transitions in the interacting system of boson particles-antiparticles”

*** Join Zoom Meeting**

https://kth-se.zoom.us/j/67595215019

A high-temperature limit penalizing high-frequency quantum fluctuations

Erik Aurell

KTH, Stockholm University, Sweden

Both in condensed matter physics, e.g. Eigenstate Thermalization Hypothesis, and in the physics of black holes a natural problem is how thermal a pure quantum state can appear to be. One can also turn the problem around and assume a pure quantum state with some specified partial thermal properties, such as the reduced states of individual modes, and try to estimate how thermal (or not thermal) are other properties. I will discuss these issues in the framework of Gaussian pure states and typical properties in ensembles of random states.

The talk is based on joint work with Mario Kieburg, Lucas Hackl and others, available as Quantum Science and Technology 10:045068 (2025), and earlier papers.

High Baryon Densities from a Thermodynamically Informed Neural Network

Musfer Adzhymambetov

BITP of the NAS of Ukraine, Kyiv, Ukraine

Understanding the properties of strongly interacting matter is one of the central challenges of modern high-energy physics. In heavy-ion collision experiments, nuclei are smashed together at relativistic speeds to recreate extreme conditions of temperature and density, producing a fleeting state of matter known as the quark-gluon plasma. This hot and dense matter behaves as a nearly perfect liquid that flows with remarkably low viscosity and is best described by relativistic hydrodynamics. The key ingredient in such models is the equation of state that encodes the thermodynamic properties of the matter.

Theoretically, such matter must be described by quantum chromodynamics. However, solving QCD from first principles across the full phase diagram remains out of reach. Lattice QCD calculations are reliable only at low baryon chemical potential. On the other hand, the hadron resonance gas model works well only at low particle densities. This leaves a critical gap in the phase diagram, which lies exactly in the region covered by next-generation collider experiments such as RHIC BES, FAIR, and CBM.

In this talk, I present a new approach to bridging this gap using a deep neural network. The network is trained to reproduce lattice QCD and hadron resonance gas thermodynamics in the regimes where they are reliable, while extrapolating in a thermodynamically consistent way into the uncharted high-baryon-density region, similarly to the strategy used in physics-informed neural networks. The result is a four-dimensional equation of state covering the phase space relevant for heavy-ion collisions. Lastly, I will show how this equation of state is implemented within a full hydrodynamic simulation framework.

This work was partially supported by the National Research Foundation of Ukraine (project № 2025.07/0050).

Dynamical Properties of Liquid water: The Importance of Long-Range Interactions with Machine Learning Interaction Potentials

Ari P. Seitsonen

CNRS/UPMC, Paris, France

The importance of the long-range, in particular the electro-static interactions, is basic knowledge in polar materials. Still many of the recent potential models, used in computer simulations of solids or liquids such as water, are based on local models of the interactions parametrised using machine learning; these kind of Machine Learning Interaction Potentials (MLIPs) have been used in several studies, providing results appearing as satisfactory.

Here we investigate the importance the inclusion of the explicit electro-static interactions in computer simulations employing molecular dynamics on the dielectric properties and the collective dynamics of liquid water, extending our earlier results to the MLIPs, thereby enabling larger systems and longer simulations. Similar to the results reported earlier on the dipole-dipole correlations we find a qualitative error appearing at low wave numbers, or large distances in real space; furthermore we discuss the apparent short-coming in the present implementation of the LES that shows up at the very small wave numbers.

Thermodynamic properties and BEC phase transitions in the interacting system of boson particles-antiparticles

Denys Zhuravel, Dmytro Anchyshkin,

Volodymyr Gnatovskyy, Vladyslav Karpenko

BITP of the NAS of Ukraine, Kyiv, Ukraine

The thermodynamic properties of a relativistic system of interacting bosons and antibosons at high temperatures and densities are investigated. Conditions of the Bose–Einstein condensate formation are studied. Phase diagrams and thermodynamic characteristics are evaluated within the framework of the thermodynamic mean-field model and the scalar field model for different ratios of attractive and repulsive interactions. As an example, a system of interacting charged pions ($\pi^{\pm}$) is considered. It is shown that, depending on the interaction constant, four types of phase transitions to the condensate phase can be observed in such a system. Three are second-order phase transitions, and one is a first-order phase transition.

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