Symposium Quantum Mechanics and Gravity: Current Status (SYDK)

jointly organised by
the Theoretical and Mathematical Physics Division (MP) and
the Gravitation and Relativity Division (GR)

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The symposium is devoted to highlighting the recent status of research on quantum gravity. It combines the view of four experts working on different approaches to quantum gravity, namely string theory, loop quantum gravity, dynamical triangulations and asymptotic safety.

Overview of Invited Talks

(Lecture hall ZHG008)

Invited Talks

SYDK 1.1	Thu	10:45–11:15	ZHG008	**String Theory at the Edges of Relativity** — •Niels Obers
SYDK 1.2	Thu	11:15–11:45	ZHG008	**The Quantum Einstein Equations in Loop Quantum Gravity** — •Kristina Giesel
SYDK 1.3	Thu	11:45–12:15	ZHG008	**Causal Dynamical Triangulations: Lattice quantum gravity reloaded** — •Renate Loll
SYDK 1.4	Thu	12:15–12:45	ZHG008	**Taming Quantum Gravity: insights from Asymptotic Safety** — •Alessia Platania

Sessions

SYDK 1.1–1.4	Thu	10:45–12:45	ZHG008	**Quantum Mechanics and Gravity: Current Status**

SYDK 1: Quantum Mechanics and Gravity: Current Status

Time: Thursday 10:45–12:45 Location: ZHG008

Invited Talk SYDK 1.1 Thu 10:45 ZHG008
String Theory at the Edges of Relativity — •Niels Obers — Niels Bohr Institute

The quest for a consistent theory of quantum gravity is one of the most important challenges in theoretical physics. In the landscape of physical theories, quantum gravity resides at the corner where all fundamental constants*Newton*s constant, the speed of light, and Planck*s constant*are finite. Recently, it has become clear that there is rich physics at the edges of relativity, considering respectively the large (non-relativistic) and small (ultra-local or Carrollian) limits of the speed of light. These limits naturally lead to non-Lorentzian geometries, known as Newton-Cartan and Carrollian geometry, revealing a much richer structure of gravity than previously appreciated.

Such non-Lorentzian limits naturally arise in string theory and holography, offering promising pathways toward more tractable models for studying the quantum structure of space and time. This includes exploring the quantum constituents of black holes and gravity at its extremes. I will first introduce the physics and geometric formulation of these limits in the context of gravity, establishing their foundation. Then, I will discuss their role in string theory and holography, highlighting recent advances.

Invited Talk SYDK 1.2 Thu 11:15 ZHG008
The Quantum Einstein Equations in Loop Quantum Gravity — •Kristina Giesel — FAU Erlangen-Nürnberg, Department of Physics, Erlangen Center for Astroparticle Physics, Germany

Loop quantum gravity is a candidate for a theory of quantum gravity that takes general relativity as its classical starting point. In the canonical approach, the quantum theory is obtained by applying a canonical quantization to general relativity. To this end, the techniques known from quantum field theory, which are used in the standard model of particle physics, need to be generalized in order to apply them to general relativity, in which the geometry of spacetime is a dynamical quantity. The dynamics of the quantum theory is described by the so-called quantum Einstein equations, the quantum analog of the Einstein equations. After a brief introduction to the ideas and concepts of loop quantum gravity, we will discuss recent applications in symmetry reduced models in loop quantum cosmology and the quantum gravitational collapse with a special focus on the physical properties and implications of these models.

Invited Talk SYDK 1.3 Thu 11:45 ZHG008
Causal Dynamical Triangulations: Lattice quantum gravity reloaded — •Renate Loll — Radboud University, Nijmegen, The Netherlands

Lattice methods are a powerful tool to investigate quantum field theories beyond perturbation theory, as demonstrated by the impressive successes of lattice QCD. Due to the dynamical character of spacetime in gravity, putting quantum gravity on the lattice faces formidable obstacles, which for a long time were thought to be insurmountable. Key to overcoming them is to adapt the lattice regularization such that both the dynamical and the Lorentzian character of spacetime are built in from the outset. This is realized by the use of causal dynamical triangulations (CDT), which capture the inherent **compatibility** between the principles of quantum theory and general relativity.

Lattice quantum gravity based on CDT is well-tested and operational, using state-of-the-art Monte Carlo simulations. It has opened a computational window near the Planck scale, where "numerical experiments" can be performed, giving for the first time quantitative information on the spectra of geometric observables characterizing quantum gravity nonperturbatively, with unexpected results. Remarkably, a quantum spacetime has been shown to emerge from this primordial soup of quantum fluctuations, displaying large-scale properties of a de Sitter universe. There is a concrete and promising roadmap, focusing on the properties of these quantum fluctuations, to connect fundamental quantum gravity to early-universe cosmology.

Invited Talk SYDK 1.4 Thu 12:15 ZHG008
Taming Quantum Gravity: insights from Asymptotic Safety — •Alessia Platania — NBI, University of Copenhagen

Asymptotically safe gravity is a candidate for a consistent and predictive quantum theory of gravity that is grounded on quantum field theory and the modern Wilsonian understanding of renormalization. Since its inception, significant efforts have been put in corroborating the 'asymptotic safety conjecture' the existence of an interacting fixed point of the gravitational renormalization group flow, serving as a consistent ultraviolet completion of gravity, and making the theory non-perturbatively renormalizable. This talk will review the current state-of-the-art of the field, highlighting recent advancements in understanding the theoretical structure of the theory and testing its internal consistency. Emphasis will be placed on the role of matter, the infrared structure of the theory, and its connection to other quantum gravity approaches. Phenomenological implications of asymptotically safe gravity for cosmology and black hole physics will also be discussed. Finally, challenges and open questions will be outlined, thus providing a roadmap for future research.