

## Holography (C004516)

**Course size** *(nominal values; actual values may depend on programme)*

**Credits 6.0**

**Study time 180 h**

**Course offerings in academic year 2024-2025**

null

**Lecturers in academic year 2024-2025**

Heller, Michal

WE05

lecturer-in-charge

**Offered in the following programmes in 2024-2025**

null

**crdts**

**offering**

**Teaching languages**

English

**Keywords**

Black holes, string theory, holography, gauge-gravity duality, entanglement, complexity.

**Position of the course**

One of the main unsolved problems in theoretical physics is the unification of the standard model of particle physics with the theory of gravitation by Einstein. Another problem, very much related to this, is the microscopic quantum description of black holes. According to Bekenstein's celebrated formula, the classical entropy of a black hole is equal to the surface area of its horizon in Planck units. Within a quantum description this entropy should be proportional to the logarithm of the number of different quantum states of the black hole. Since the black hole entropy scales like the boundary area, rather than the volume, this suggests a holographic description of black holes. A major breakthrough in that direction was the AdS/CFT conjecture by Maldacena, which relates a classical gravitational system in D dimensions to a strongly coupled gauge theory in D-1 dimensions. This holographic gauge-gravity duality spurred a radical new approach to the unification problem and to the related black hole quantum physics. This course offers a problem-solving based introduction to holography through the lenses of quantum many-body systems, quantum field theory and quantum information science. Its aim is to develop understanding of the basics of one of the most important developments in theoretical physics, as well as to advance research skills.

**Contents**

- 1 Holography: hints from black hole physics
- 2 Holographic dictionary
- 3 Anti-de Sitter black holes
- 4 Holography as a tool to study quantum field theory phenomena
- 5 Entanglement and holography

**Initial competences**

Final competences of Quantum field theory, Quantum mechanics 2 and Relativity.

**Final competences**

- 1 Working knowledge of the present state of the research in holography
- 2 Preparing for independent research.

**Conditions for credit contract**

Access to this course unit via a credit contract is determined after successful competences assessment

**Conditions for exam contract**

This course unit cannot be taken via an exam contract

**Teaching methods**

Group work, Seminar

**Study material**

None

**References**

<https://arxiv.org/abs/0909.0518>

<https://arxiv.org/abs/2108.09188>

**Course content-related study coaching**

The lecturers and assistants can be consulted through direct contact or by e-mail.

**Assessment moments**

continuous assessment

**Examination methods in case of periodic assessment during the first examination period**

Assignment

**Examination methods in case of periodic assessment during the second examination period**

Assignment

**Examination methods in case of permanent assessment**

Assignment

**Possibilities of retake in case of permanent assessment**

examination during the second examination period is not possible

**Calculation of the examination mark**

Final project and its presentation.