GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2025-2026

Holography (C004516)

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

Credits 6.0 **Study time 180 h**

Course offerings in academic year 2025-2026

A (semester 2)	English	Gent

Lecturers in academic year 2025-2026

Heller, Michal	WE05	lecturer-in-charge

Offered in the following programmes in 2025-2026	crdts	offering
Master of Science in Physics and Astronomy	6	A
Exchange Programme in Physics and Astronomy (Master's Level)	6	A

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.
In parallel to holography, the course will introduce Wolfram Mathematica software, so that the students will learn how to do complex symbolic and numerical calculations efficiently. This will be an indespensible part of the course and the exam.

Contents

1 Wolfram Mathematica
2 Holography: hints from black hole physics
3 Holographic dictionary
4 Anti-de Sitter black holes
5 Holography as a tool to study quantum field theory phenomena
6 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.
3 Working knowledge of Wolfram Mathematica

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.