GHENT UNIVERSITY

Course Specifications

From the academic year 2021-2022 up to and including the academic year

Quantum Black Holes and Holography (C003690)

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

Credits 6.0		**Study time 180 h**		**Contact hrs**	52.5h

Course offerings and teaching methods in academic year 2022-2023

null

Lecturers in academic year 2022-2023

Heller, Michal	WE05	lecturer-in-charge
Van Acoleyen, Karel	WE05	co-lecturer

Offered in the following programmes in 2022-2023	**crdts**	**offering**
null		

Teaching languages

English, Dutch

Keywords

Black holes, string theory, holography, gauge-gravity duality, entanglement, tensor network states.

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 an introduction to the recent developments in theoretical physics that have led to a deeper understanding of the unification problem and of the quantum physics of black holes: string theory, quantum field theory on curved space-times and Hawking radiation, the black hole membrane paradigm, the AdS/CFT conjecture, quantum entanglement, tensor network states. In addition to these necessary ingredients, the students will have the chance to study (independently but with some supervision) and present a very recent topic in this exciting area of research , e.g. the firewall problem for black holes, holographic thermalisation of strongly coupled quantum field theories, Multi-scale-entanglement renormalization (MERA) and holography. As such this course offers the possibility to develop some first research skills.

Contents

1 The classical laws of black hole physics.
2 Quantum field theory on black hole space-times and Hawking radiation
3 The membrane paradigm
4 Introduction to string theory
5 Holography and the AdS/CFT conjecture.
6 Black hole entropy

7 Tensor network states and holography.
8 Research topics: e.g. firewall problem, thermalisation and black holes, MERA 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 at the intersection of quantum mechanics and general relativity.
2 With an emphasis on the physical principles and mathematical techniques, 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, Lecture, Project, Seminar: coached exercises

Learning materials and price

A syllabus is available at +- 15 euro

References

Mukhanov, Viatcheslav and Winizki, Sergei,"Introduction to Quantum Effects in Gravity", Cambridge University Press, 2007. ISBN 0521868343
Zwiebach, Barton, "A first course in string theory", Cambridge University Press, 2004.

Course content-related study coaching

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

Assessment moments

end-of-term and continuous assessment

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

Oral examination, Written examination with open questions

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

Oral examination, Written examination with open questions

Examination methods in case of permanent assessment

Oral examination

Possibilities of retake in case of permanent assessment

examination during the second examination period is not possible

Calculation of the examination mark

- End-of-term evaluation 50%,
- Permanent evaluation 50%