GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2024-2025

Quantum Black Holes (C004561)

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

Credits 6.0 **Study time 180 h**

Course offerings in academic year 2024-2025

A (semester 2) English Gent

Lecturers in academic year 2024-2025

Mertens, Thomas WE05 lecturer-in-charge

Offered in the following programmes in 2024-2025	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, Quantum Gravity

Position of the course

Black holes are some of the most mysterious objects in the universe, but are in principle ill-understood. A fundamental understanding of black holes and their horizons requires unifying quantum mechanics with general relativity, which has proven to be a very hard problem. In this course, we develop aspects of the theory of quantum black holes. Starting with a thorough analysis of black holes in classical general relativity, we introduce quantum aspects of matter fields and explore Hawking and Unruh radiation leading to both the Bekenstein-Hawking entropy and the notorious black hole information paradox. Understanding both of these requires going beyond classical gravity. This course provides an overview of approaches to quantum gravity (e.g. string theory) and highlights difficulties. In the final chapter, this course explores the recent topic of lower-dimensional quantum gravitational models that are exactly solvable. In particular, Jackiw-Teitelboim (JT) 2d dilaton gravity describes the near-horizon near-extremal regime of higher-dimensional black hole physics.
In addition, the students will perform a research project (in small groups) and present and explain a topic in this exciting area of research to their fellow students, e.g. gravitational shockwaves, black hole membrane paradigm, generalized second law, quantum JT gravity, Euclidean wormholes in lower-dimensional gravity...
This course is complementary to the “Holography” course offered every other year.

Contents

1. Classical black holes: Schwarzschild, Reissner-Nordström, Kerr black holes, Rindler spacetime, black hole thermodynamics, Bekenstein-Hawking entropy
2. Quantum field theory in curved spacetime: Unruh and Hawking effect, black hole information paradox
3. Introduction to quantum gravity: conceptual issues, introduction to some approaches (covariant approaches, string theory)
4. Lower-dimensional quantum gravity models: near-extremal near-horizon quantum gravity, Jackiw-Teitelboim model of 2d quantum gravity, 3d pure gravity and BTZ black hole
5. Research topics (in small groups)

Initial competences

Final competences of Quantum Field Theory and General Relativity

Final competences

1 Working knowledge of the present state of the research domain at the intersection of quantum mechanics and general relativity.
2 Preparation for independent research in contemporary topics in black hole physics in high-energy theoretical physics.

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, Lecture

Extra information on the teaching methods

Guided exercise classes, 1 group work assignment with report and presentation

Study material

Type: Syllabus

Name: Quantum Black Holes
Indicative price: Free or paid by faculty
Optional: no
Language : English
Number of Pages : 200
Available on Ufora : Yes
Online Available : Yes
Available in the Library : No
Available through Student Association : No

References

Mukhanov, Viatcheslav and Winizki, Sergei, "Introduction to Quantum Effects in Gravity", Cambridge University Press, 2007. ISBN 0521868343
Review on JT gravity: https://arxiv.org/abs/2210.10846

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 assessment, Written assessment with open-ended questions

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

Oral assessment, Written assessment with open-ended questions

Examination methods in case of permanent assessment

Oral assessment, Assignment

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%