| Module title | | | | Abbreviation |
|---|---|---|---|---|
| **Black Holes** | | | | 11-SLQ-Int-241-m01 |
| **Module coordinator** | | | **Module offered by** | |
| Managing Director of the Institute of Theoretical Physics and Astrophysics | | | Faculty of Physics and Astronomy | |
| **ECTS** | **Method of grading** | **Only after succ. compl. of module(s)** | | |
| 6 | numerical grade | -- | | |
| **Duration** | **Module level** | **Other prerequisites** | | |
| 1 semester | graduate | -- | | |

**Contents**

PART 1 - Classical solutions

1. Vacuum solutions of Einstein's equation - the Schwarzschild solution, Birkhoff's theorem, the Eddington-Finkelstein coordinates, Kruskal extension and eternal black holes, the Penrose diagram, conformal compactification and Carter-Penrose diagram
2. Gravitational collapse - the Oppenheimer-Snyder solution
3. Charged and rotating black holes - Cauchy horizons, ergosphere
4. ADM formalism - energy and angular momentum
5. Black hole thermodynamics

PART 2 - Astrophysical observations of black holes

1. Spin and mass measurements of black holes
2. Black hole electromagnetism
3. Gravitational waves and their measurement

PART 3 – Quantum aspects of black hole

1. Introduction to QFT on curved spacetime: Rindler spacetime, Unruh effect
2. Derivation of Hawking radiation
3. Hawking's original formulation of the information paradox
4. The "holography of information" - information paradox in AdS/CFT, the Page curve and Islands
5. Firewall, fuzzball, complementarity - possible resolutions of information paradox
6. Wormholes and the factorization puzzle

**Intended learning outcomes**

This course plays a bridging role joining the basics on GR learnt in the GR I course and the active research directions in the fields of Astronomy, Astrophysics, General Relativity, String Theory and Gauge/Gravity Duality. Through this course, the students will gain sufficient commands over the applications of general relativity in connection with research directions in this area. This in turn will motivate them to pursue careers as a researcher in the aforementioned directions and help them to successful begin their Master and PhD projects.

**Courses** (type, number of weekly contact hours, language — if other than German)

V (3) + R (1)
Module taught in: English

**Method of assessment** (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or
d) project report (approx. 8 to 10 pages) or
e) presentation/talk (approx. 30 minutes).
If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the following semester

**Allocation of places**

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**Additional information**

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**Workload**

180 h

**Teaching cycle**

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**Referred to in LPO I** (examination regulations for teaching-degree programmes)

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**Module appears in**

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)