

# Introduction to holography

Fall 2025

## Basic course information

**Lecturer:** Monica Guica (for *urgent* questions, please use *monica.guica@ipht.fr*)

**TAs:** Adrien Martina *adrien.martina@epfl.ch*

**Location:** BSP 727

**Remote participation:** A zoom session can be organised for students who cannot make it in person; however, it will not be organised by default. Please contact Monica in advance of the session that you cannot come to.

**Assesment method:** Problem sets to be handed in weekly and oral examination during the exam period.

This course will consist of 14 two-hour lectures and as many exercise sessions. Please consult the academic calendar for the precise dates.

## Topics covered

1. Hints of holography in classical GR
  - the GR Hamiltonian and definitions of energy, black hole thermodynamics, 't Hooft's argument for holography
2. The *very* basics of string theory
  - spectrum of the bosonic string, basics of D-branes
3. Deriving the correspondence via the decoupling limit
4. A basic introduction to CFT
  - conformal transformations, conformal algebra, local operators (primaries and descendants), correlation functions, stress tensor, radial quantization (state-operator map), operator product expansion, conformal anomaly
5. The geometry and symmetries of AdS
  - definition, coordinate systems, Penrose diagram, geodesics, Fefferman-Graham expansion, conserved charges in gauge theories and gravity (asymptotic symmetries) holographic conformal anomalies

## 6. Correlation functions

- statement of the holographic dictionary, holographic renormalization, Euclidean versus Lorentzian, general backgrounds

## 7. Holography at finite temperature

- Schwarzschild-AdS solutions, the Hawking-Page transition, the BTZ black hole, microscopic entropy match

## 8. Entanglement and the emergence of gravity

- entanglement concepts and definitions, the eternal AdS - Schwarzschild black hole, the Ryu- Takayanagi formula, emergence of gravity from entanglement

## Literature

This course will not follow any particular book or set of lectures. Some possibly useful literature you may consult is:

- Robert Wald, “General Relativity”
- Matthias Blau, “Lecture Notes on General Relativity”
- Ted Jacobson, “Introductory Lectures on Black Hole Thermodynamics”
- Richard Szabo, “An Introduction to String Theory and D-Brane Dynamics”
- Tom Hartman, “Lectures on Quantum Gravity and Black Holes”
- Aharony, Gubser, Maldacena, Ooguri and Oz, “Large  $N$  Field Theories, String Theory and Gravity,” hep-th/9905111
- Hong Liu, “String theory and holographic duality”
- The Conformal Bootstrap, arXiv:1602.07982 (Simmons-Duffin)
- Conformal field theory (Di Francesco, Mathieu, Senechal)
- Mark van Raamsdonk, “Lectures on Gravity and Entanglement”, 1609.00026 [hep-th]