Introduction to holography

Fall 2024

Basic course information

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

TAs: Adrien Martina adrien.martina@epfl.ch

Mattia Varrone mattia.varrone@epfl.ch

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 - Scwarzschild black hole, the Ryu- Takayanagi formula, emergence of gravity from entanglement

9. Beyond AdS/CFT: non-conformal and other backgrounds (time permitting)

Literature

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

- Aharony, Gubser, Maldacena, Ooguri and Oz, "Large N Field Theories, String Theory and Gravity," hep-th/9905111
- Tom Hartman, "Lectures on Quantum Gravity and Black Holes"
- Mark van Raamsdonk, "Lectures on Gravity and Entanglement", 1609.00026 [hep-th]
- Robert Wald, "General Relativity"
- Richard Szabo, "An Introduction to String Theory and D-Brane Dynamics"
- EPFL Lectures on CFT in $D \geq 3$ Dimensions, arXiv:1601.05000 (Rychkov)
- The Conformal Bootstrap, arXiv:1602.07982 (Simmons-Duffin)
- Conformal field theory (Di Francesco, Mathieu, Senechal)