Black holes and gravitational holography

The main goal of this course is the quantum mechanical description of black holes using holography.

Summary. The *holographic principle* in gravity arose from the fact that the entropy of black holes is given by their surface area. The AdS/CFT correspondence is a realization of the holographic principle within string theory which explains a duality between string theory and a quantum field theory. It provides a gravitational description of theories without gravity. Conversely, quantum gravity (strings) in asymptotically AdS geometries can be studied in terms of quantum field theories without gravity.

Stephen Hawking in 1974 by applying quantum mechanics showed that black holes radiate, and thus eventually evaporate away. This triggered the "black hole information paradox," which asks what happens to all the information that black holes swallow. Obviously for addressing this question we need a quantum theory to understand how things that fall in black holes also get out. Holography guarantees that the information that falls into a black hole is encoded on the boundary and never lost. But how?

In this course we especially aim to learn and investigate the required tools in AdS/CFT correspondence for answering this question about black holes. In our approach we benefit a lot from studying solvable (toy) models on both sides of the duality.

Course objectives. A sketch of major topics which we aim to cover in this course are;

Part I

- **Black holes and wormholes.** Penrose diagram — Bekenstein-Hawking entropy — Thermodynamics — Energy conditions — Entropy bound
- **Black holes and Quantum mechanics.** Hawking radiation and Black hole evaporation — Hartle-Hawking state — Page curve — Information paradox

Part II

- **Basics of the AdS/CFT correspondence.** Correlation functions — Holographic renormalization — Bulk Reconstruction
- **Holographic entanglement entropy.** Rényi entropy — Replica trick — Entanglement wedge
- **Black holes and holography.** Eternal black holes and holography — Quantum Chaos — Quantum extremal surfaces — Generalized entropy — Islands

Target group. Graduate students with some background in quantum (field) theory and gravity can take this course.

References. There are books, review papers and lecture notes that can be used as the reference. Some of them that will be used in this course are; Susskind-Lindesay book, Harlow lecture notes, Hartman lecture notes, ...

Schedule. Saturday (14:00-15:30) and Monday (10:00-11:30) in IPM school of physics.