Gauge-Gravity Duality (E16)

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The gauge/gravity duality relates properties of gravity theories in D dimensions to those of certain quantum field theories in d dimensions, with $D > d$, where gravity is absent. In most known examples, the duality is of the strong-weak type: when the gravitational theory is classical and well-described by a two-derivative action, the dual field theory is strongly coupled and has a large number of degrees of freedom. Conversely, when the gravitational theory is highly quantum, the field theory becomes perturbative. The significance of this duality lies in our limited understanding of both strongly coupled quantum field theories and quantum gravity.

The dictionary between the two sides of the duality is best understood in cases where the field theory is conformal and admits a supersymmetric UV completion. The primary example is the correspondence between four-dimensional $\mathcal{N} = 4$ Super Yang–Mills theory with gauge group $SU(N)$ and type IIB string theory on $\mathrm{AdS}_5 \times S^5$. Although this duality has passed many nontrivial checks, a full mathematical proof remains an open problem.

In these lectures, we aim to discuss the following:

1. Basics of conformal field theory.
2. General relativity in anti-de Sitter spacetime (with emphasis on wave equations).
3. The correspondence: its formulation and dictionary.
4. The duality between black holes and thermal states.
5. The fluid-gravity correspondence.

Prerequisites

Knowledge of the Michaelmas and Lent terms courses General Relativity, Black Holes, and Advanced Quantum Field Theory will be assumed.

Recommended Literature

1. M. Ammon & J. Erdmenger: Gauge/Gravity Duality - Foundations and Applications.
2. G. T. Horowitz & J. Polchinski: Gauge/gravity duality.
3. R. Sundrum: From Fixed Points to the Fifth Dimension.
4. O. Aharony, S. S. Gubser, J. M. Maldacena, H. Ooguri & Y. Oz: Large N Field Theories, String Theory and Gravity.

Original Articles

1. J. M. Maldacena: The Large N Limit of Superconformal Field Theories and Supergravity.
2. E. Witten: Anti De Sitter Space And Holography.
3. S. S. Gubser, I.R. Klebanov, A. M. Polyakov: Gauge Theory Correlators from Non-Critical String Theory.

Two examples sheets will be provided, and two associated examples classes will be given. There will be a one-hour revision class in the Easter Term, subsequent to the lectures.