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The Holographic Correspondence. Probing Bulk Gravitational Physics with Wilson Lines and Geodesic Witten Diagrams

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Summary

This thesis focuses on aspects of the AdS/CFT correspondence which are directly relevant to problems in quantum and classical gravity. Specifically, we use geodesic Witten diagrams, and gravitational Wilson lines in AdS/CFT to explore bulk gravitational physics. Here, we will very briefly summarize our results.

Introduction

In Chapter 1, we start by reviewing the holographic correspondence, focusing on the features that are essential to this thesis. This will establish the context for the novel results that are presented in the rest of the chapters. This introduction, as well as the thesis, has two distinguishable parts. The first one examines some aspects of the duality in general dimensions, and the second one focuses on the peculiarities of AdS_3/CFT_2. A recurrent leitmotiv is higher spin fields. We will use theories containing spinning fields, as a framework to study the AdS/CFT correspondence.

Spinning geodesic Witten diagrams

In conformal field theories, symmetries play a crucial role. The exploitation of the conformal group gives an efficient organizational principle for the observables in the theory. An example of such a principle is the conformal block decomposition of four-point correlation functions, which makes an explicit distinction among portions that are purely determined by symmetries and the theory dependent data. A very natural question arises in holography: can we organize observables in gravity as efficiently as we do in the dual CFTs? This issue has been addressed

since the beginning of holography using, for example, Witten diagrams. However, it was not until very recently that geodesic Witten diagrams were proposed as the dual of the conformal blocks. Geodesic Witten diagrams shed new light in the program of holographic reconstruction: they give a holographic meaning to the conformal block decomposition of four-point Witten diagrams, and they allow us to write the complicated d-dimensional volume integrals of the Witten diagrams in terms of simpler line integrals.

While the original proposal of geodesic Witten diagrams was formulated for only external scalar fields, we extended it to spinning external legs in Chapter 2. We found a systematic way to evaluate geodesic Witten diagrams for external fields of arbitrary spin, and we decomposed the original Witten diagrams in terms of those. Despite the success of geodesic Witten diagrams, we found some problems that remain unsolved. We observed that the same spinning conformal block can be expressed in terms of different geodesic Witten diagram with inequivalent bulk interactions. This shows that geodesic Witten diagrams do not treat bulk interactions as fundamental.

Wilson lines in $\mathbf{AdS_3/CFT_2}$

In Chapter 3 and 4, we focus on gravity in three dimensions. In this case, gravity does not have propagating degrees of freedom, and it can be recasted as a Chern-Simons theory of gauge connections. This is in general much simpler to manipulate that the formalism of Einstein's general relativity. In Chern-Simons formulation, the coupling of matter is done by using gravitational Wilson lines. In the context of AdS/CFT, these objects are considered to properly probe the bulk from the boundary degrees of freedom, since they are related to quantities such as CFT correlation functions, and entanglement entropy.

In this thesis, we will exploit gravitational Wilson lines in $\mathrm{AdS}_3/\mathrm{CFT}_2$ with two different, but related purposes. In Chapter 3, we will show that they can be used to compute the overlap of two local bulk states. This g. In Chapter 4, we use the Wilson line in the context of higher spin theories. We use them to explicitly provide a notion of causality in higher spin gravity, which allows us to associate a Penrose diagram to higher spin black holes.