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Holography Beyond AdS

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Abstract

We continue our study of string theory in a background that interpolates between AdS_3 in the infrared and a linear dilaton spacetime $\mathbb{R}^{1,1} \times \mathbb{R}_\phi$ in the UV. This background corresponds via holography to a CFT_2 deformed by a certain irrelevant operator of dimension $(2, 2)$. We show that for two point functions of local operators in the infrared CFT, conformal perturbation theory in this irrelevant operator has a finite radius of convergence in momentum space, and one can use it to flow up the renormalization group. The spectral density develops an imaginary part above a certain critical value of the spectral parameter; this appears to be related to the non-locality of the theory. In position space, conformal perturbation theory has a vanishing radius of convergence; the leading non-perturbative effect is an imaginary part of the two point function.

1. Introduction

In two recent papers [1,2] we studied a string background that interpolates between a three dimensional linear dilaton background in the ultraviolet (UV) and AdS_3 in the infrared (IR).[1] From the UV point of view, this background can be interpreted as the bulk description of Little String Theory (LST) in a vacuum with N fundamental strings [3,4]. From the IR point of view,

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[1] In both cases times a compact space that is a spectator under the deformation.

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it can be thought of as an irrelevant deformation of the two dimensional conformal field theory (CFT_2) dual to the above AdS_3 background.

A priori, one would expect the second point of view not to be useful for studying the theory, since it corresponds to flowing up the renormalization group (RG), a process that is in general highly ambiguous. However, as pointed out in [1,2], there are reasons to believe that in this case the situation is better:

(1) While from the point of view of the CFT_2, the (irrelevant) deformation in question is not expected to be under control, in the dual string theory on AdS_3 it corresponds to adding to the worldsheet Lagrangian a marginal operator, which moreover has a current-current (null abelian Thirring) form, and thus is expected to be well behaved (in fact the deformed worldsheet theory is exactly solvable).
(2) The deformation in question shares many properties with the $T\bar{T}$ deformation of CFT_2, studied recently in [5,6]. The latter was argued to be well behaved and in fact the deformed theory appears to be exactly solvable.

One of the interesting properties of the theories studied in [1,2] and [5,6] is that their spectrum approaches that of a CFT_2 in the IR (*i.e.* the corresponding entropy goes like $S_{IR} \sim \sqrt{E}$), while in the UV one finds a Hagedorn spectrum $S_{UV} \sim E$. Thus, the short distance behavior of these theories is not governed by a UV fixed point – they are not local QFT's. Hence, if one can study these theories by starting with the infrared CFT_2 and flowing up the RG, they provide an example of non-local theories that can be understood non-perturbatively.

A natural question is how the non-locality of these theories is reflected in the structure of correlation functions of operators that are local in the infrared CFT. In this note we will initiate the study of this problem in the model of [1,2]. Since this model corresponds to a well behaved vacuum of weakly coupled string theory, we can calculate such correlation functions in an expansion in an effective string coupling (a $1/N$ expansion, or equivalently a large central charge expansion in the IR CFT_2), and study their properties. We are primarily interested in the answers to two questions:

(a) To what extent can we understand these correlation functions by flowing up the RG from the infrared fixed point?
(b) How does the non-locality of the deformed theory manifest itself in the structure of these correlation functions?

We will perform the calculations using the bulk description of the theory, but this is likely a technicality. If we understood the CFT_2 dual of the infrared AdS_3 background sufficiently well, we could perform the same calculations directly in the CFT_2, and due to the AdS/CFT correspondence we would expect to get the same results.

A natural question is what properties do we expect the correlation functions of the deformed theory to have. According to [3], the non-locality of the theory is expected to be reflected in the fact that correlation functions in momentum space are well behaved, but their position space counterparts are not. We will discuss to what extent these expectations are realized.

Note added: The correlation functions we study were also considered in a recent paper by G. Giribet [7].