A Supergravity Dual of a (1,0) Field Theory in Six Dimensions

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We suggest a supergravity dual for the (1,0) superconformal field theory in six dimensions which has $E_8$ global symmetry. Compared to the description of the (2,0) field theory, the 4-sphere is replaced by a 4-hemisphere, or by orbifolding the 4-sphere.

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1. Introduction

It was recently conjectured by [1] that certain string theory or M-theory backgrounds are dual to the large N limit of field theories. The supergravity solution has therefore to reflect all the symmetries of the field theory. A particular example is that of superconformal field theories. For a theory in \( d + 1 \) dimensions the conformal symmetry is \( SO(d + 1, 2) \). On the supergravity side one sees this symmetry geometrically, as the background is a product \( AdS_{d+1} \times K \), where \( K \) is a compact manifold, on which other global symmetries of the theory may act.

A particular example of such a solution is that of the \((2, 0)\) field theory in 5+1 dimensions. The supergravity description is given by M-theory compactified on \( AdS_7 \times S^4 \) [1]. The \( AdS_7 \) part realizes the conformal symmetry and the \( S^4 \) realizes the \( SO(5) \) R-symmetry of the theory. Further analysis of this correspondence, in a related model, is carried out in [2,3,4]. Other cases and related work appears in [5,6,7,8,9].

Another way of obtaining global symmetry is described in [2]. If there are gauge fields on the supergravity side then these naturally couple to symmetry currents on the boundary, and hence the field theory will have additional global symmetries. It was shown in [2], that one obtains the correct 2-pt functions for the global symmetry currents.

In the following short note we will discuss a realization of global symmetry in such a way, in the context of a \((1, 0)\) field theory with \( E_8 \) symmetry in 5+1 dimensions.

Related work also appears in [10].

2. The \((1, 0)\) field theory in 5+1 dimensions

One way of realizing this \((1, 0)\) field theory is in M-theory on \( S^1/Z_2 \) [11]. The field theory is then the low-energy limit of the excitations on an M-theory 5-brane that is located at the fixed point of the \( Z_2 \) action [12,13], and is in a superconformal fixed point. This information is sufficient to determine the M-theory background that corresponds to this field theory when the number of 5-branes, \( N \), is taken to infinity.

In the case of \( AdS_7 \times S^4 \), one set of coordinates on the \( AdS_7 \) is \( X^{0..5} \) and \( U \). These are the coordinates that one naturally gets when starting from the 5-brane solution which is asymptotically flat and then performing the scaling procedure in [1]. The \( X \)'s parametrize

\[1\] At least in some cases.
coordinates parallel to the M5-brane and $U$ is a radial coordinate away from it. $S^4$ then parametrizes the angles around the M5-brane.

The same seems roughly also to apply to the case of an M5-brane at the end of the world. Let us denote the coordinates that the 5-brane spans by $X^{0..5}$ and the coordinate of $S^1/Z_2$ by $X^{10}$. Since the theory is still conformal one has to obtain an $AdS_7$ as part of the solution. When we try and obtain the solution from the the solution which is asymptotically flat, the coordinate $U$ then corresponds to a combination of the distance in the $X^{10}$ direction and in the $X^{6..9}$ directions. The internal manifold $K$, which replaces the $S^4$ in the case at hand, parametrizes the directions on the hypersurface $U = Const$. The 9-brane correspond to a boundary of $K$.

We are further restricted by the global symmetries. The theory has an $SO(4)$ symmetry. This implies that the 4-dimensional manifold is made of a bundle of 3-sphere over a 1-dimensional manifold. The boundary is also a 3-sphere. Since we expect this manifold to be compact (we do not want additional low-lying excitations other than the ones on the $AdS_7$) the only candidate in a hemisphere.

Away from the boundary, we can also calculate the metric. The boundary started its life as the boundary in M theory on $S^1/Z_2$. As it is not a source for any field strength, it does not affect the solution away in the bulk. This implies that the metric is also that of a hemisphere.

In short, to obtain the supergravity desription of the $(1,0)$ field theory, one orbifolds the $S^4$. This also teaches us how to treat the fixed points, i.e., the boundary of the hemisphere. As we need to keep all the degrees of freedom that appear in low-energy supergravity, one need to place, as in [11], an $E_8$ worth of vector fields on the boundary. The $E_8$ gauge fields therefore propagate throughout the $AdS_7$. The field theory then has a global $E_8$ symmetry, and the gauge fields in supergravity correctly reproduce at least some aspects of current-current correlators.

To completely specify the background one needs to specify the state of the gauge field degrees of freedom on $AdS_7 \times S^3$. As we are interested in the point where the $E_8$ symmetry is unbroken, the configuration is such that none of the $E_8$ charged fields have an expectation value. This also solves the equations of motion that couple the bulk to the boundary.

\[\text{In this case we can not hope to do more then a low energy analysis.}\]
3. Discussion

One expects that this procedure can be generalized to other cases, in precisely the same way by which brane probes acquire a global symmetry $G$ when approaching a locus in spacetime where there are localized gauge degrees of freedom of $G$ (such as in F-theory \[14\]). In the case of conformal field theories one expects that there will be gauge bosons which will be smeared on the entire $AdS$ and localized at hypersurfaces in $K$.

In particular, the dual supergravity/string theory description is useful in a regime where the curvature is small and when string perturbation theory is reliable. In that case, when we are close to the singularity in the supergravity side, the correct way to treat the singularity is in string perturbation theory (or by a set of non-perturbative techniques). Because the curvature is small, one expects that its qualitative features will not change from those of such a singularity in flat space\[3]. In particular, if we obtain enhanced gauge symmetry from a singularity in flat space, one expects it to persist in the regime where perturbative string theory around a nearly flat space is a useful approximation. These gauge bosons will reflect the global symmetry of the field theory, as we have seen for the case of the $(1,0)$ field theory above.

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\[3\] At least locally. Globally we could have additional effects. These may correspond to effects due to the flow, such as spontaneous symmetry breaking, or to a change of parameters in the field theory.
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