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CFT duals for attractor horizons

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Abstract

In this paper we generalize the results of Guica et al. (2008) [M. Guica, T. Hartman, W. Song, A. Strominger, arXiv:0809.4266 [hep-th]] to 5-dimensional Anti-de Sitter gravity theories with neutral scalars non-minimally coupled to gauge fields. Due to the attractor mechanism, the near horizon geometry of extremal black holes is universal and is determined by only the charge parameters. In particular, we study a class of near horizon geometries that contain an $AdS_2 \times S^2$ factor after Kaluza–Klein reduction. In this way we obtain the microscopic entropy of Gutowski–Reall black hole. We also point out a possible connection with the AdS_2/CFT_1 correspondence.

1. Introduction

Recently, the Kerr/CFT correspondence [1] has been used extensively to understand the statistical entropy of stationary extremal black holes. These studies are based on the universality of the near horizon geometry of extremal black holes. More precisely, the isometry group of the near horizon geometry is enhanced to $SO(2,1) \times U(1)^{d-3}$ in $d = 4, 5$ dimensions [2,3,5]. Thus, the near-horizon states of an extremal black hole could be identified with a certain two-dimensional chiral conformal field theory[1] [1,6–10].

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[1] In fact, the isometry of the near horizon geometry is $SL(2,R)_R \times U(1)_L$ and so the right movers are in the ground state. The zero mode of Virasoro algebra of the Kerr/CFT correspondence generates $U(1)_L$ — since the zero mode of $SL(2,R)_R$ is ∂_t, the right movers are related to the entropy away from extremality.

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The analysis in [1] is similar to the one proposed by Brown and Henneaux for AdS_3 [11]. In the Hamiltonian formalism, the global charges appear as the canonical generators of the asymptotic symmetries of the theory. For each such infinitesimal symmetry, there is an associated phase space function that generates the corresponding transformation of the canonical variables.

The asymptotic conditions in [11] are the most general for AdS_3 Einstein gravity and they respect the following important consistency requirements [12]: they are invariant under the AdS group; they decay sufficiently slowly to the exact AdS so that to contain the spinning black holes; the fall-off is sufficiently fast so that the conserved charges are finite. It is also important to emphasize that the asymptotic behaviour of the metric in the presence of matter fields can be different from that arising from pure gravity. Consequently, the standard asymptotic conditions should be relaxed. However, it was shown (see, e.g., [13]) that the boundary conditions can be relaxed so that the original symmetry is still preserved — though, the charges are modified in order to take into account the presence of the matter fields.

Obviously, if the theory is slightly modified, the boundary conditions should also be modified in order to accommodate the new solutions of physical interest. In [1] the near horizon geometry involves a fibration over AdS_2 and so it is another phase space of extremal horizons with a different set of boundary conditions. That is, some of the deviation metric ($h_{\mu\nu}$) components are of the same order in inverse powers of r as the corresponding components in the background metric itself. However, these boundary conditions still yield finite charges and give rise to a Virasoro algebra. The construction of phase spaces containing arbitrary functions in the leading components of the metric has been done before [1] (see, e.g., [14]).

In this paper we consider extremal stationary black holes in Einstein gravity coupled to Abelian gauge fields and neutral scalars. Due to the enhanced symmetry of the near horizon geometry, the attractor mechanism [15] can be extended to general extremal spinning black holes [16]. Unlike the non-extremal case for which the near horizon geometry (and the entropy) depends on the values of the moduli at infinity, in the extremal case, the near horizon geometry is universal and is determined by only the charge parameters. This is interpreted as a signal that a clear connection to the microscopic theory is possible.

We discuss in detail the attractor mechanism for a class of near horizon geometries that become $AdS_2 \times S^2$ after Kaluza–Klein (KK) reduction. We use the entropy function formalism [16–18] to explicitly show that the entropy is independent of the asymptotic values of the scalars.

Thus, based on these observations, we argue that the Kerr/CFT correspondence can be generalized to a large class of black holes. A particular example of great interest is the Gutowski–Reall (GR) black hole [19] for which an understanding of the statistical entropy is lacking. Our emphasis is mainly on understanding the relationship between Kerr/CFT correspondence and AdS_2/CFT_1 duality.

In five dimensions there are two distinct asymptotic Virasoro algebras [6–8] that can be obtained by imposing appropriate boundary conditions. Even if the corresponding central charges are different, the statistical entropies computed by using the Cardy formula are equal and match the Bekenstein–Hawking entropy. Since these algebras act on the Hilbert states of the CFT, it seems that there exist two distinct holographic duals.

Inspired by the proposal of [20], we compute the central charge in the AdS_2 geometry obtained by KK reduction of GR black hole to two dimensions. Interestingly enough, we found that it is proportional to the entropy and this may be a hint that there is a connection between the Kerr/CFT correspondence and the AdS_2/CFT_1 duality. However, at this point, it is not clear to us if this is indeed the case.