Generalized Hidden Kerr/CFT

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ABSTRACT: We construct a family of vector fields that generate local symmetries in the solution space of low frequency massless field perturbations in the general Kerr geometry. This yields a one-parameter family of sl(2,R) × sl(2,R) algebras. We identify limits in which the sl(2,R) × sl(2,R) algebra contracts to an SL(2,R) symmetry of the Schwarzschild background. We note that for a particular value of the free parameter, the symmetry algebra generates the quasinormal mode spectrum of a Kerr black hole in the large damping limit, suggesting a connection between the hidden conformal symmetry and a fundamental CFT underlying the quantum Kerr black hole.

Introduction

More than 25 years ago **Brown and Henneaux** have shown that the asymptotic symmetry group of a quotient of a 3-dimensional Anti-de Sitter (AdS) space consists of two copies of a 2-dimensional conformal group, whose generators close under a Virasoro algebra, with a central charge $c = 3l_{AdS}/2G_3$.

Even before we knew about black holes in AdS3, we could count their **entropy**! A subsequent discovery of **BTZ** black hole has put this hint of a duality on a firmer footing: the conformal field theory at the AdS boundary exactly reproduces the classical entropy of the black hole.

The details of the duality have since been further explored within the framework of AdS/CFT correspondence, by mapping **scattering amplitudes** in the bulk to **correlation functions** in the CFT. [Birmingham et al.]

Hope is that this lower dimensional cousin of a **Kerr black hole** gives us insight into 4-dimensional gravity.

Kerr/CFT

[Hartman, Guica, Song and Strominger]

Bardeen and Horowitz have realized early on that **extremal Kerr black hole** admits a **near horizon scaling** (NHEK), under which the geometry takes a form of U(1) fiber over AdS3. In these near horizon coordinates Hartman, Guica, Song and Strominger define an asymptotic boundary at the horizon and compute a central extension of asymptotically conserved currents via a Barnich, Brandt, Compere algorithm. The result obtained was not surprising in view of the Brown and Henneaux computation, except for the fact the central extension comes from the enhancement of U(1), not the asymptotic symmetry group of AdS3.

By using **Cardy formula**,

$$S = \frac{\pi^2}{3}(c_L T_L + c_R T_R)$$

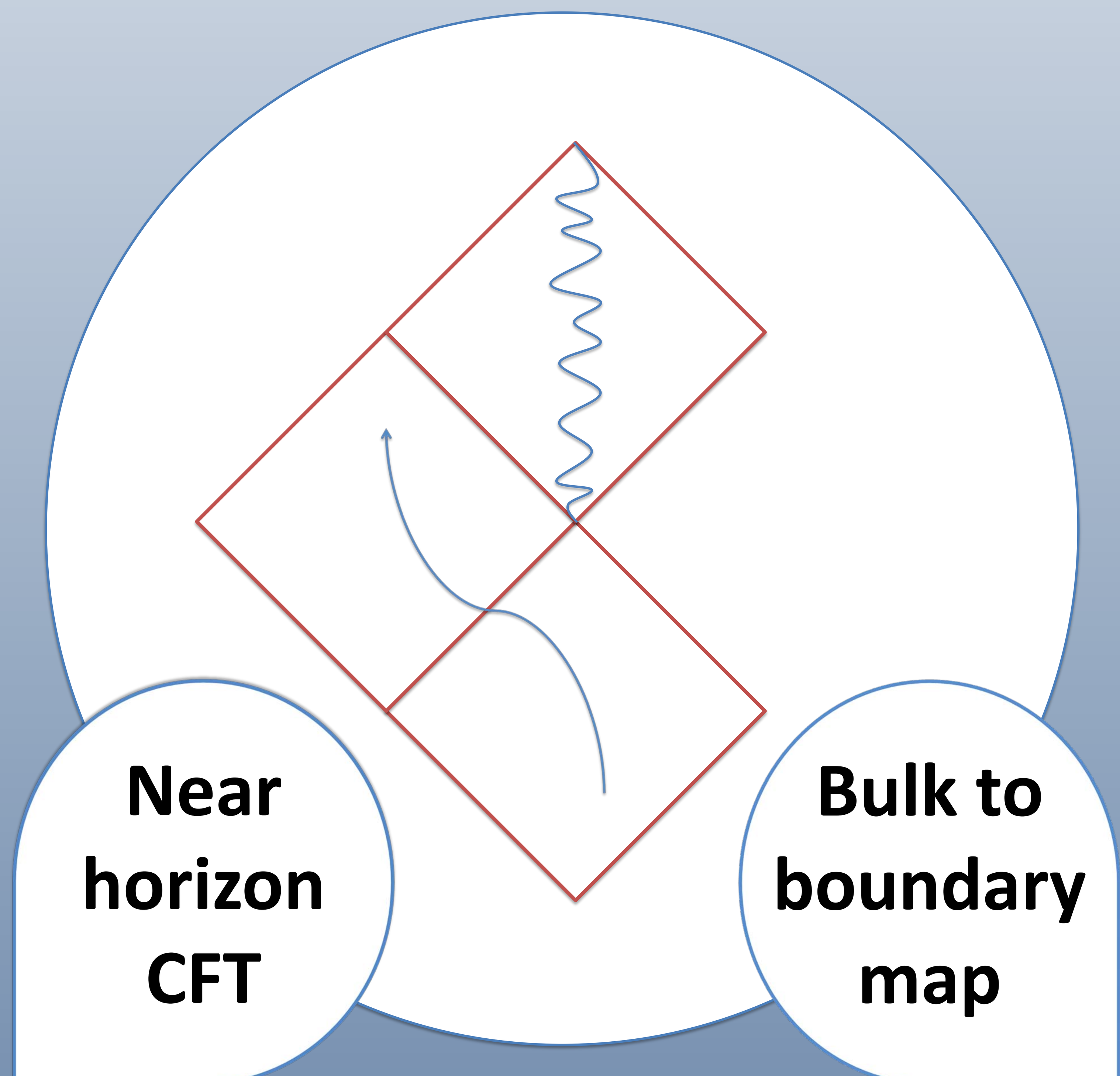
and the computed value of the central charge at extremality

$$c_L = c_R = 12J$$

they can correctly reproduce the Bekenstein-Hawking entropy of the extremal Kerr black hole. The conjecture is these results can be extended away from extremal case.

Kerr/CFT and BTZ

To draw a parallel, similar reasoning can be applied to BTZ black holes. In that case, by performing a near horizon extremal limit, one obtains a selfdual orbifold [de Boer, Sheikh-Jabbari, Simon; Henneaux, Coussaert], and via either Brown-Henneaux or Barnich, Brandt, Compere, procedure one arrives at the central charge that correctly reproduces the black hole entropy. This example teaches us that although the asymptotic symmetry generators at horizon and at infinity might be very much different, they will satisfy the same algebra.



Hidden Kerr/CFT

[Castro, Maloney, Strominger]

If the Kerr/CFT correspondence works outside of the extremal limit, one would expect to find some sort of a **conformal structure to appear in scattering amplitudes**. This ends up being the case: the solutions to low frequency scalar field equation near the Kerr black hole transform under a 2-dimensional conformal group. Interestingly enough, this conformal structure is visible for any value of Kerr angular momentum, not just extremal .

Castro, Maloney and Strominger have constructed local vector fields that generate symmetries of the solution space in the approximation $r\omega \ll 1, \quad M\omega \ll 1,$ whose algebra is of a 2-dimensional conformal group. An interesting observation is that Cardy formula matches the classical entropy of the Kerr black hole, provided the central charge is identified with one obtained from the geometric NHEK computation.

Bulk/boundary map

[Lowe, Messamah, Skanata, arXiv:1105.2035]

In the zero frequency limit the hidden conformal symmetry of the wave equation is exact. The corrections to the wave equation in low frequency limit can be written in an organized **convergent expansion**. These map in a one-to-one manner to an expansion in the CFT in terms of higher dimension operators. We show the exact Kerr background softly breaks the conformal symmetry.

The following observations have been made:

❖ The **weights** of the representations can be read off by looking at falloff at large values of the radial coordinate. To leading order in low frequency expansion these agree with what one gets from quadratic Casimir.

❖ The exact solution to wave equation can be written in terms of an expansion in bulk fields dual to **higher dimension operators**. We expect CFT correlation functions to exactly reproduce bulk scattering amplitudes, to arbitrary order in low frequency expansion.

❖ The conformal symmetry originates from a massless field equation in **flat space**.

❖ The generators of hidden Kerr/CFT symmetries do not smoothly relate to asymptotic symmetry generators of **NHEK**.

Generalizing hidden Kerr/CFT

[Lowe, Skanata, arXiv:1112.1431]

The arguments of the preceding section signal that the hidden Kerr/CFT can in fact source a Kerr/CFT duality on its own, with no relation to NHEK/CFT.

So far it looks promising – correlation functions can be mapped to bulk scattering amplitudes in a one-to-one manner, for any value of Kerr angular momentum, already something NHEK/CFT hasn't been able to provide.

We expect the low energy linearized solution not to become relevant in the full nonlinear equation near the inner horizon, so we explore **deformations** around this point, compatible with low frequency and near region limits:

$$\kappa \frac{M^2\omega}{r - r_-} \ll 1$$

This yields a 1-parameter family of sl(2,R)×sl(2,R) algebras, mapping three independent parameters in the full CFT (two temperatues and central charge) to three parameters in bulk gravity. We expect this low frequency symmetry to open a window towards understanding a more fundamental CFT that correctly describes black hole physics.