Higher-Derivative Corrections to the Asymptotic Virasoro Symmetry of 4d Extremal Black Holes

Noriaki OGAWA

Yukawa Institute for Theoretical Physics, Kyoto University

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Collaboration with:

Tatsuo Azeyanagi (Kyoto Univ), Geoffrey Compére (UCSB),

Yuji Tachikawa (IAS), Seiji Terashima (YITP)

Plan to Talk

1. Overview: The Kerr/CFT Correspondence & Our result
2. Asymptotic symmetry & Kerr/CFT (review)
3. Generalization to higher-derivative gravities
4. Summary & Discussion

Overview: The Kerr/CFT Correspondence & Our result

[Guica-Hartman-Song-Strominger, arXiv:0809.4266]
[Hartman-Murata-Nishioka-Strominger, arXiv:0811.4393], [Compére-Murata-Nishioka, arXiv:0902.1001]

4D Extemal (Kerr) black hole

$\xrightarrow{\text{Near Horizon}}$ **U(1) fibrated AdS_2 geometry (NHEK)**

$$ds^2 = A(\theta)^2\left(-r^2dt^2 + \frac{dr^2}{r^2}\right) + d\theta^2 + B(\theta)^2(d\phi + krdt)^2$$

We can find a dual chiral CFT_2 through asymptotic symmetry
& compute the central charge c (= d.o.f. of the theory).

$\Downarrow$

Reproduce the Bekenstein-Hawking entropy correctly !

We successfully extended this result
to arbitrary higher-derivative action
& reproduced the Iyer-Wald entropy !!

Plan to Talk

Symmetry Correspondences in AdS_3/CFT_2 & AdS_2/CFT_2

- cf) AdS_{d+1}/CFT_d correspondence $(d \geq 3)$
  - d-dim conformal symmetry $= SO(2, d)$

    $\Updownarrow$
  - AdS_{d+1} isometry $= SO(2, d)$
- AdS_3/CFT_2 correspondence
  - 2-dim conformal symmetry = $\text{Virasoro}_L \times \text{Virasoro}_R$

    (enhanced from $SO(2, 2) \simeq SL(2, \mathbb{R})_L \times SL(2, \mathbb{R})_R$)

    $\Updownarrow$
  - something = $\text{Virasoro}_L \times \text{Virasoro}_R$

    (enhanced from AdS_3 isometry $SL(2, \mathbb{R})_L \times SL(2, \mathbb{R})_R$)
- AdS_2/CFT_2 correspondence
  - 2-dim chiral conformal symmetry = Virasoro_L (from $SL(2, \mathbb{R})_L$)

    $\Updownarrow$
  - something = Virasoro_L

    (enhanced from AdS_2 isometry $SL(2, \mathbb{R})_L$??)

[Brown-Henneaux, Comm.Math.Phys(1986)]

What is the symmetry enhancement on the gravity side ?

- **Consider asymptotic ($r \to \infty$) symmetry, not exact isometry.**
- **Asymptotic symmetry**

  = diffeomorphism preserving some boundary condition

$$g_{ab} = \bar{g}_{ab} + h_{ab}, \quad h_{ab} \sim \mathcal{O}(r^{k_{ab}}) \ (r \to \infty)$$

($\bar{g}_{ab}$: background metric)

In fact,

- **Asymptotic symmetry group (ASG) of AdS_3**

  = $\text{Virasoro}_L \times \text{Virasoro}_R$

  (under an appropriate boundary condition)

Asymptotic symmetry of NHEK & entropy reproduction

- asymptotic symmetry = Virasoro (← appropriate b.c. & constraint)

$$\xi_n = -e^{-in\phi}(inr\partial_r + \partial_\phi), \quad i[\xi_m, \xi_n]_{Lie} = (m-n)\xi_{m+n}$$

(enhancement from $\mathrm{U}(1)_\phi$ of S^1, not $\mathrm{SL}(2,\mathbb{R})$ of AdS_2)

- locally no center ⇒ it appears from topology (& boundary)
  - "asymptotic Noether charge" Q_n corresponding to ξ_n
  - construct a symplectic structure on the phase space
  - compute the Dirac bracket

$$i\{Q_m, Q_n\} = (m-n)Q_{m+n} + \frac{c}{12}m(m^2+a)\delta_{m+n}$$

$$c = \frac{3k}{2\pi}\int_{horizon} dA, \quad T_{FT} = \frac{1}{2\pi k}$$

for dual CFT, $[L_m, L_n] = (m-n)L_{m+n} + \frac{c}{12}m(m^2+1)\delta_{m+n}$

by Cardy formula, $S_{CFT} = \frac{\pi^2}{3}c\,T_{FT} = \frac{1}{4}\int_{horizon} dA = S_{BH}$!

Plan to Talk

Kerr/CFT in higer-derivative gravities ?

Motivation:

- LEET of string theory
- universality of gauge/gravity dualities

  in more general gravity theories ?

Setup:

- 4D general higher-derivative pure gravity Lagrangian:

  $$L\left(g_{ab}, R_{abcd}, \nabla_{e_1} R_{abcd}, \nabla_{(e_1}\nabla_{e_2)} R_{abcd}, \ldots, \nabla_{(e_1} \ldots \nabla_{e_k)} R_{abcd}\right)$$

- Near horizon extremal BH geometry:

  $$ds^2 = A(\theta)^2 \left(-r^2 dt^2 + \frac{dr^2}{r^2}\right) + d\theta^2 + B(\theta)^2 (d\phi + krdt)^2$$

Goal:

- reproduce Iyer-Wald formula for BH entropy

  $$S_{IW} = -2\pi \int_{horizon} dA \, \frac{\delta L}{\delta R_{abcd}} \epsilon_{ab} \epsilon_{cd}$$

What is necessary ?

Action-independent properties:

- **b.c. & asymptotic symmetry generators (ξ_n)**
- $T_{FT} = \dfrac{1}{2\pi k}$

Therefore our main task is:

- **find the appropriate definition of the asymptotic charges and symplectic form (= Poisson bracket) on phase space**
- **comptute the central charge c**

Computation of central charge and entropy reproduction

Essence

- **definition of symplectic form and charges:**

  Barnich-Brandt-Compére formalism

  (fix the ambiguity of boundary contribution, which vanishes for Einstein gravity.)

$$\Downarrow$$

$$c = -12k \int_{horizon} dA \, \frac{\delta L}{\delta R_{abcd}} \epsilon_{ab} \epsilon_{cd}, \quad T_{FT} = \frac{1}{2\pi k}$$

$$\therefore \; S_{CFT} = S_{IW} \; !$$

perfectly reproduce Iyer-Wald entropy !!

Summary & Discussion

Main result:

- **We generalized the Kerr/CFT correspondence to arbitrary higer-derivative gravities.**
- **It always reproduces Iyer-Wald entropy.**

Some possible suggestions:

1. **gauge/gravity dualities exist for arbitrary gravity theories, without any relations to string theory or something ?**
2. **extremal BH entropy is a too trivial quantity ? (some underlying mechanism ?)**
3. **or something ?**

Thank you.