

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

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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], [Compère-Murata-Nishioka, arXiv:0902.1001]

4D External (Kerr) black hole

Near Horizon \rightarrow **U(1) fibrated AdS₂ geometry (NHEK)**

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

We can find a **dual chiral CFT₂** through **asymptotic symmetry**
& compute the **central charge c** (= d.o.f. of the theory).



Reproduce the **Bekenstein-Hawking entropy** correctly !

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

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Symmetry Correspondences in $\text{AdS}_3/\text{CFT}_2$ & $\text{AdS}_2/\text{CFT}_2$

- cf) $\text{AdS}_{d+1}/\text{CFT}_d$ correspondence ($d \geq 3$)

- d -dim conformal symmetry = $\text{SO}(2, d)$



- AdS_{d+1} **isometry** = $\text{SO}(2, d)$

- $\text{AdS}_3/\text{CFT}_2$ correspondence

- 2-dim conformal symmetry = $\text{Virasoro}_L \times \text{Virasoro}_R$
(enhanced from $\text{SO}(2, 2) \simeq \text{SL}(2, \mathbb{R})_L \times \text{SL}(2, \mathbb{R})_R$)



- **something** = $\text{Virasoro}_L \times \text{Virasoro}_R$
(enhanced from AdS_3 isometry $\text{SL}(2, \mathbb{R})_L \times \text{SL}(2, \mathbb{R})_R$)

- $\text{AdS}_2/\text{CFT}_2$ correspondence

- 2-dim **chiral** conformal symmetry = Virasoro_L (from $\text{SL}(2, \mathbb{R})_L$)



- **something** = Virasoro_L
(enhanced from AdS_2 isometry $\text{SL}(2, \mathbb{R})_L$??)

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

What is the symmetry enhancement on the gravity side ?

- Consider **asymptotic** ($r \rightarrow \infty$) **symmetry**, not exact isometry.
- Asymptotic symmetry
= diffeomorphism preserving some **boundary condition**

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

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

In fact,

- Asymptotic symmetry group (ASG) of AdS₃
= **Virasoro_L × Virasoro_R**
(under an appropriate boundary condition)

Asymptotic symmetry of NHEK & entropy reproduction

- asymptotic symmetry = **Virasoro** (\leftarrow 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 $U(1)_\phi$ of S^1 , not $SL(2, \mathbb{R})$ of AdS_2)

- locally no center \Rightarrow 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, $S_{CFT} = \frac{\pi^2}{3}cT_{FT} = \frac{1}{4} \int_{horizon} dA = S_{BH} !$

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Kerr/CFT in higher-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:

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

- Near horizon extremal BH geometry:

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

Goal:

- reproduce Iyer-Wald formula for BH entropy

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

Action-independent properties:

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

Therefore our main task is:

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

Essence

- definition of symplectic form and charges:

Barnich-Brandt-Compère formalism

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



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

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

perfectly reproduce Iyer-Wald entropy !!

Main result:

- We generalized the Kerr/CFT correspondence to **arbitrary** higher-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 ?

END

Thank you.