Corrections to AdS_5 black hole thermodynamics from higher-derivative supergravity

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Joint work with:

D. Cassani and E. Turetta

2208.01007 + 2304.06101 [hep-th]

Introduction

- Use AdS/CFT to address the **microstate counting of AdS black holes**

Black hole	$=$	ensemble of states in quantum gravity	$\overset{\text{AdS/CFT}}{=}$	ensemble of states in the dual CFT

$$\log N_{\text{micro}} = \mathcal{S} = \frac{A_{\mathcal{H}}}{4G} + \textbf{corrections}$$

- Field theory prediction for subleading corrections to BPS entropy and match with **higher-derivative corrections** in the gravitational side

- Focus on $\text{AdS}_5/\text{CFT}_4$ and discuss the microstate counting of **supersymmetric AdS_5 black holes of minimal gauged supergravity**

- Dual states should exist in *any* holographic $\mathcal{N} = 1$ SCFT $\rightarrow$ only general properties needed: **superconformal anomalies** play a crucial role

Counting BPS states: the superconformal index

- The relevant quantity is the **superconformal index** ($\equiv$ **supersymmetric partition function** on $S^1_\beta \times S^3$)

Kinney, Maldacena, Minwalla, Raju; Romelsberger

- Black hole contribution can be isolated by taking a **Cardy-like limit**:

$$-\log \mathcal{I} = \frac{8(5a-3c)}{27}\frac{\varphi^3}{\omega_1\omega_2} - \frac{2(a-c)}{3}\frac{\varphi(\omega_1^2+\omega_2^2-4\pi^2)}{\omega_1\omega_2} - \log|\mathcal{G}_{1-\text{form}}| + \text{exp-terms}$$

Cassani, Komargodski; Choi, J. Kim, S. Kim, Nahmgoong + ...

$\omega_1, \omega_2, \varphi \sim$ chemical potentials of the black hole ($\omega_1+\omega_2-2\varphi = 2\pi i$)

a, c are the **superconformal anomaly coefficients**: $\frac{c-a}{a} \sim \mathcal{O}(\frac{1}{N})$

Legendre transform of the superconformal index

- Extremization principle: $(I \equiv -\log \mathcal{I})$

$$\mathcal{S} = \text{ext}_{\{\omega_1, \omega_2, \varphi, \Lambda\}} \left[-I - \omega_1 J_1 - \omega_2 J_2 - \varphi Q_R - \Lambda \left(\omega_1 + \omega_2 - 2\varphi - 2\pi i \right) \right]$$

$$-\frac{\partial I}{\partial \omega_i} = J_i + \Lambda \,, \qquad -\frac{\partial I}{\partial \varphi} = Q_R - 2\Lambda \,, \qquad \omega_1 + \omega_2 - 2\varphi = 2\pi i$$

Hosseini, Hristov, Zaffaroni; Cabo-Bizet, Cassani, Martelli, Murthy

- $I = I(\omega_i, \varphi)$ can be written as an homogeneous function of degree 1

$$\mathcal{S} = 2\pi i \Lambda|_{\text{ext}}$$

- Working at linear order in $\mathbf{a} - \mathbf{c}$, one finds that Λ satisfies:

$$\Lambda^3 + p_2 \Lambda^2 + p_1 \Lambda + p_0 + \frac{p_{-1}}{\Lambda - \frac{Q_R}{2}} = 0$$

with $p_\alpha = p_\alpha(Q_R, J_1, J_2)$ real coefficients

- Reality condition $(\text{Im}\, \mathcal{S} = 0) \quad \Leftrightarrow \quad (\Lambda^2 + X)(\text{rest}) = 0$

Field theory predictions

- Reality condition $(\Lambda^2 + X)(\text{rest}) = 0$ equivalent to a **constraint** on the charges

$$
\begin{aligned}
&\left[3Q_R + 4\,(2\,a - c)\right]\left[3{Q_R}^2 - 8c\,(J_1 + J_2)\right] \\
&= {Q_R}^3 + 16\,(3c - 2a)\,J_1 J_2 + 64a\,(a - c)\,\frac{(Q_R + a)(J_1 - J_2)^2}{{Q_R}^2 - 2a(J_1 + J_2)}
\end{aligned}
$$

- Corrected **BPS entropy**

$$
\mathcal{S} = 2\pi\sqrt{X} = \pi\sqrt{3{Q_R}^2 - 8a(J_1 + J_2) - 16\,a(a - c)\,\frac{(J_1 - J_2)^2}{{Q_R}^2 - 2a(J_1 + J_2)}}
$$

Cassani, AR, Turetta '22

Plan for the rest of the talk

1. Review of previous work: two-derivative match
2. Include relevant higher-derivative corrections in the gravitational effective action
3. Evaluate the on-shell action of the AdS_5 black hole and impose supersymmetry to match the result from the superconformal index
4. Corrections to the BPS entropy and charges and match with field theory

Euclidean approach

Gibbons, Hawking

- We set ourselves in the **grand-canonical ensemble** (fixed β, Ω_i, Φ)

- The **grand-canonical partition function** $\mathcal{Z}(\beta, \Omega_i, \Phi)$ is computed by the Euclidean path integral with (anti-)periodic boundary conditions

$$\mathcal{Z}(\beta, \Omega_i, \Phi) \simeq e^{-I(\beta, \Omega_i, \Phi)}$$

- $I(\beta, \Omega_i, \Phi)$ should then be identified with $\beta\times$(grand-canonical potential), leading to the **quantum statistical relation**

$$I = \beta E - \mathcal{S} - \beta \Omega_i J_i - \beta \Phi\, Q$$

- Because of the master formula of the **AdS/CFT correspondence**:

$$\boxed{I(\beta, \Omega_i, \Phi) = -\log \mathcal{Z}_{\rm CFT}(\beta, \Omega_i, \Phi)}$$

Review of AdS_5 black holes

We work with **minimal gauged supergravity in 5d**

$$\mathcal{L} = R + 12g^2 - \frac{1}{4}F^2 - \frac{1}{12\sqrt{3}}\epsilon^{\mu\nu\rho\sigma\lambda}F_{\mu\nu}F_{\rho\sigma}A_\lambda$$

The **most general AdS_5 black hole** depends on **four parameters**:

$$E, J_1, J_2, Q \qquad \leftrightarrow \qquad \beta, \Omega_1, \Omega_2, \Phi$$

Chong, Cvetic, Lu, Pope

These quantities obey the **first law of black hole mechanics**

$$\mathrm{d}E = T\mathrm{d}\mathcal{S} + \Omega_1 \mathrm{d}J_1 + \Omega_2 \mathrm{d}J_2 + \Phi\, \mathrm{d}Q$$

as well as the **quantum statistical relation**

$$I = \beta E - \mathcal{S} - \beta\Omega_1 J_1 - \beta\Omega_2 J_2 - \beta\Phi\, Q$$

BPS ($\equiv$ supersymmetric and extremal) limit

$$\textbf{supersymmetry} \quad \not\Rightarrow \quad \textbf{extremality}$$

1. Supersymmetric solution if $E - gJ_1 - gJ_2 - \sqrt{3}\,Q = 0$
2. Extremal limit: $\beta \to \infty$

$\Rightarrow$ BPS charges $\{Q, J_1, J_2\}$ must satisfy a constraint, which in field theory units is:

$$(3Q_R + 4a)\left[3{Q_R}^2 - 8a\,(J_1 + J_2)\right] = {Q_R}^3 + 16aJ_1J_2$$

In agreement with the reality condition of the BPS entropy when $\boldsymbol{c} \to \boldsymbol{a}$:

$$\begin{aligned}&[3Q_R + 4\,(2\,a - c)]\left[3{Q_R}^2 - 8c\,(J_1 + J_2)\right]\\ &= {Q_R}^3 + 16\,(3c - 2a)\,J_1J_2 + 64a\,(a - c)\,\frac{(Q_R + a)(J_1 - J_2)^2}{{Q_R}^2 - 2a(J_1 + J_2)}\end{aligned}$$

BPS on-shell action and entropy

- Evaluating the Euclidean **on-shell action** of the black hole, taking the **BPS limit** and expressing the result in terms of

$$\omega_{1,2} = \beta\left(\Omega_{1,2} - g\right), \qquad \varphi = \frac{\sqrt{3}g}{2}\beta\left(\Phi - \sqrt{3}\right)$$

matches expression for the **index** at leading order in large N:

$$I = \frac{16a}{27}\frac{\varphi^3}{\omega_1\omega_2} = -\lim_{c\to a}\log\mathcal{I}$$

$$= \lim_{c\to a}\frac{8(5a-3c)}{27}\frac{\varphi^3}{\omega_1\omega_2} - \frac{2(a-c)}{3}\frac{\varphi(\omega_1^2+\omega_2^2-4\pi^2)}{\omega_1\omega_2}$$

Cabo-Bizet, Cassani, Martelli, Murthy

- The **Legendre transform** of the index reproduces the **Bekenstein-Hawking entropy** Hosseini, Hristov, Zaffaroni; Cabo-Bizet, Cassani, Martelli, Murthy

$$\mathcal{S} = \pi\sqrt{3{Q_R}^2 - 8a(J_1+J_2)}$$

Kim, Lee

The four-derivative effective action

- The **goal** is to go beyond the 2∂ approximation including 4∂ terms

  EFT approach: Add **all** the possible **four-derivative terms** that are consistent with the local symmetries of the two-derivative theory

- **Methodology**

  1. Start from the **off-shell** formulation of 5d **supergravity** where 4∂ supersymmetric invariants have been worked out in the literature

  $$\mathcal{L}_{\rm off-shell} = \mathcal{L}^{(2\partial)}_{\rm off-shell} + \alpha \left(\tilde{\lambda}_1 \, \mathcal{L}_{C^2} + \tilde{\lambda}_2 \, \mathcal{L}_{R^2} + \tilde{\lambda}_3 \, \mathcal{L}_3 \right)$$

  Hanaki, Ohashi, Tachikawa
  Bergshoeff, Rosseel, Sezgin
  Ozkan, Pang

  2. **Integrate out** all the **auxiliary fields** at linear order in α

  3. Use **perturbative field redefinitions** ($g_{\mu\nu} \to g_{\mu\nu} + \alpha \, \Delta_{\mu\nu}$, $A_\mu \to A_\mu + \alpha \, \Delta_\mu$) to **simplify** the resulting action:

  $$S \to S - \alpha \int d^5x \, e \, \left(\mathcal{E}_{\mu\nu} \Delta^{\mu\nu} - \mathcal{E}^{\mu} \Delta_\mu \right) + \mathcal{O}(\alpha^2)$$

$$
\begin{aligned}
e^{-1}\mathcal{L}^S_{C^2} \;=\; & c_I\Big[\tfrac{1}{8}\rho^I C^{\mu\nu\rho\sigma}C_{\mu\nu\rho\sigma} + \tfrac{64}{3}\rho^I D^2 + \tfrac{1024}{9}\rho^I T^2 D - \tfrac{32}{3} D\, T_{\mu\nu}F^{\mu\nu\, I} \\
& -\tfrac{16}{3}\rho^I C_{\mu\nu\rho\sigma}T^{\mu\nu}\, T^{\rho\sigma} + 2C_{\mu\nu\rho\sigma}T^{\mu\nu}F^{\rho\sigma\, I} + \tfrac{1}{16}\epsilon^{\mu\nu\rho\sigma\lambda}A^I_\mu C_{\nu\rho\tau\delta}C_{\sigma\lambda}{}^{\tau\delta} \\
& -\tfrac{1}{12}\epsilon^{\mu\nu\rho\sigma\lambda}A^I_\mu V_{\nu\rho}{}^{ij}V_{\sigma\lambda\, ij} + \tfrac{16}{3}Y^I_{ij}V_{\mu\nu}{}^{ij}T^{\mu\nu} - \tfrac{1}{3}\rho^I V_{\mu\nu}{}^{ij}V^{\mu\nu}{}_{ij} \\
& +\tfrac{64}{3}\rho^I\nabla_\nu T_{\mu\rho}\nabla^\mu T^{\nu\rho} - \tfrac{128}{3}\rho^I T_{\mu\nu}\nabla^\nu\nabla_\rho T^{\mu\rho} - \tfrac{256}{9}\rho^I R^{\nu\rho}T_{\mu\nu}T^\mu{}_\rho \\
& +\tfrac{32}{9}\rho^I R T^2 - \tfrac{64}{3}\rho^I\nabla_\mu T_{\nu\rho}\nabla^\mu T^{\nu\rho} + 1024\rho^I\, T^4 - \tfrac{2816}{27}\rho^I (T^2)^2 \\
& -\tfrac{64}{9}T_{\mu\nu}F^{\mu\nu\, I}T^2 - \tfrac{256}{3}T_{\mu\rho}T^{\rho\lambda}T_{\nu\lambda}F^{\mu\nu\, I} - \tfrac{32}{3}\epsilon_{\mu\nu\rho\sigma\lambda}T^{\rho\tau}\nabla_\tau T^{\sigma\lambda}F^{\mu\nu\, I} \\
& -16\epsilon_{\mu\nu\rho\sigma\lambda}T^\rho{}_\tau\nabla^\sigma T^{\lambda\tau}F^{\mu\nu\, I} - \tfrac{128}{3}\rho^I\epsilon_{\mu\nu\rho\sigma\lambda}T^{\mu\nu}T^{\rho\sigma}\nabla_\tau T^{\lambda\tau}\Big]\,,
\end{aligned}
$$

$$
\begin{aligned}
e^{-1}\mathcal{L}^S_{R^2} \;=\; & a_I\Big(\rho^I \underline{Y}_{ij}\underline{Y}^{ij} + 2\underline{\rho}\,\underline{Y}^{ij}Y^I_{ij} - \tfrac{1}{8}\rho^I\underline{\rho}^2 R - \tfrac{1}{4}\rho^I\underline{F}_{\mu\nu}\underline{F}^{\mu\nu} - \tfrac{1}{2}\underline{\rho}\,\underline{F}^{\mu\nu}F^I_{\mu\nu} \\
& +\tfrac{1}{2}\rho^I\partial_\mu\underline{\rho}\,\partial^\mu\underline{\rho} + \rho^I\underline{\rho}\,\Box\underline{\rho} - 4\rho^I\underline{\rho}^2(D + \tfrac{26}{3}T^2) + 4\underline{\rho}^2F^I_{\mu\nu}T^{\mu\nu} \\
& +8\rho^I\underline{\rho}\,\underline{F}_{\mu\nu}T^{\mu\nu} - \tfrac{1}{8}\epsilon_{\mu\nu\rho\sigma\lambda}A^{\mu I}\underline{F}^{\nu\rho}\underline{F}^{\sigma\lambda}\Big).
\end{aligned}
$$

Ozkan, Pang: JHEP 08 (2013) 042

The four-derivative effective action

- **Four-derivative Lagrangian:** Cassani, AR, Turetta '22

$$\mathcal{L} = \boldsymbol{c_0} R + 12\boldsymbol{c_1} g^2 - \frac{\boldsymbol{c_2}}{4} F^2 - \frac{\boldsymbol{c_3}}{12\sqrt{3}} \epsilon^{\mu\nu\rho\sigma\lambda} F_{\mu\nu} F_{\rho\sigma} A_\lambda + \boldsymbol{\lambda_1 \alpha} \left(\mathcal{X}_{\rm GB} - \frac{1}{2} C_{\mu\nu\rho\sigma} F^{\mu\nu} F^{\rho\sigma} + \frac{1}{8} F^4 - \frac{1}{2\sqrt{3}} \epsilon^{\mu\nu\rho\sigma\lambda} R_{\mu\nu\alpha\beta} R_{\rho\sigma}{}^{\alpha\beta} A_\lambda \right)$$

where $\mathcal{X}_{\rm GB} = R_{\mu\nu\rho\sigma} R^{\mu\nu\rho\sigma} - 4R_{\mu\nu} R^{\mu\nu} + R^2$ and $c_i = 1 + \alpha g^2 \delta c_i$, with:

$$\delta c_0 = 4\boldsymbol{\lambda_2}\,, \qquad \delta c_1 = -10\boldsymbol{\lambda_1} + 4\boldsymbol{\lambda_2}\,, \qquad \delta c_2 = 4\boldsymbol{\lambda_1} + 4\boldsymbol{\lambda_2}\,, \qquad \delta c_3 = -12\boldsymbol{\lambda_1} + 4\boldsymbol{\lambda_2}$$

- **Remarks**
  - Together with 4∂ corrections, there are 2∂ **corrections** controlled by $\lambda_i \alpha g^2$
  - The effect of λ_2 simply reduces to a **renormalization of** G

Holographic dictionary

- The bulk theory is controlled by 2 dimensionless quantities

$$\frac{1}{\boldsymbol{G_{\text{eff}}g^3}} \equiv \frac{1+4\boldsymbol{\lambda_2}\alpha g^2}{Gg^3}\,, \qquad\qquad \boldsymbol{\lambda_1}\alpha g^2$$

- $\mathcal{N}=1$ SCFTs have a **superconformal anomaly** controlled by 2 coefficients:

$$T_i{}^i \;=\; -\frac{\boldsymbol{a}}{16\pi^2}\hat{E}+\frac{\boldsymbol{c}}{16\pi^2}\hat{C}^2 \;-\; \frac{\boldsymbol{c}}{6\pi^2}\,\hat{F}^2\;,$$

$$\nabla_i J^i \;=\; \frac{\boldsymbol{c}-\boldsymbol{a}}{24\pi^2}\,\frac{1}{2}\,\epsilon^{ijkl}\hat{R}_{ijab}\hat{R}_{kl}{}^{ab} \;+\; \frac{5\boldsymbol{a}-3\boldsymbol{c}}{27\pi^2}\,\frac{1}{2}\,\epsilon^{ijkl}\hat{F}_{ij}\hat{F}_{kl}\,,$$

- The **holographic dictionary** tells us that

$$\boxed{\boldsymbol{a}=\frac{\pi}{8Gg^3}\left(1+4\boldsymbol{\lambda_2}\alpha g^2\right) \qquad\qquad \boldsymbol{c}=\frac{\pi}{8Gg^3}\left(1+4\left(2\boldsymbol{\lambda_1}+\boldsymbol{\lambda_2}\right)\alpha g^2\right)}$$

Witten

Henningson, Skenderis

Fukuma, Matsuura, Sakai; Cassani, AR, Turetta ’23

Setting up the computation of the on-shell action at $\mathcal{O}(\alpha)$

A priori we need two ingredients to **evaluate the on-shell action at $\mathcal{O}(\alpha)$**:

1. The corrected solution
2. Boundary terms (Gibbons-Hawking-York terms + counterterms)

However, it is possible to show that **the two-derivative solution is enough** for evaluating the on-shell action

$$I = I^{(0)}|_{\alpha=0} + \alpha \cancel{\partial_\alpha I^{(0)}_{\alpha=0}} + \alpha\, I^{(1)}|_{\alpha=0} + \mathcal{O}(\alpha^2)$$

if one fixes the boundary conditions appropriately, which is automatic if we work in the **grand-canonical ensemble**

Reall, Santos

We just have to identify the appropriate **boundary terms**

Boundary terms

Gibbons-Hawking-York terms

The Dirichlet variational problem is not well posed in higher-derivative gravity. Still, in our case:

- the GHY term associated to the Gauss-Bonnet is known Myers; Teitelboim, Zanelli
- Restricting to **AlAdS$_5$** solutions, it is possible to derive generalized GHY terms for $C_{\mu\nu\rho\sigma}F^{\mu\nu}F^{\rho\sigma}$ and mixed Chern-Simons term but **do not contribute**

Grumiller, Mann, McNees; Landsteiner, Megías, Pena-Benitez

Cassani, AR, Turetta '23

Boundary counterterms

- They can be rigorously derived using the **Hamilton-Jacobi approach** to holographic renormalization de Boer, Verlinde, Verlinde +...
- same as in the 2∂ theory (only the GB term diverges in the 4∂ sector)

Liu, Sabra; Fukuma, Matsuura, Sakai

Cassani, AR, Turetta '23

Matching the superconformal index

- Supersymmetric **on-shell action** of the black hole $(\omega_1 + \omega_2 - 2\varphi = 2\pi i)$

$$I = \frac{2\pi}{27Gg^3}\left(1 - 4(3\lambda_1 - \lambda_2)\alpha g^2\right)\frac{\varphi^3}{\omega_1\omega_2} + \frac{2\pi\alpha\lambda_1}{3Gg}\frac{\varphi\left(\omega_1^2 + \omega_2^2 - 4\pi^2\right)}{\omega_1\omega_2}$$

- This fully **matches the expression for the dual index** in the Cardy-like limit once the holographic dictionary is implemented

$$I = \frac{8\left(5a - 3c\right)}{27}\frac{\varphi^3}{\omega_1\omega_2} + \frac{2\left(c - a\right)}{3}\frac{\varphi(\omega_1^2 + \omega_2^2 - 4\pi^2)}{\omega_1\omega_2}$$

$$= -\log \mathcal{I}$$

Cassani, AR, Turetta '22

Bobev, Dimitrov, Reys, Vekemans '22

- But... what about the **black hole entropy**?

Corrections to the BPS entropy and charges

Cassani, AR, Turetta '22

Fastest method: assume 1st law + qsr and obtain the charges by taking derivatives of the on-shell action with respect to $\beta, \Omega_1, \Omega_2, \Phi$

- BPS entropy

$$\mathcal{S} = \pi \sqrt{3{Q_R}^2 - 8a(J_1 + J_2) - 16\, a(a-c)\frac{(J_1 - J_2)^2}{{Q_R}^2 - 2a(J_1 + J_2)}}$$

(also: Bobev, Dimitrov, Reys, Vekemans '22)

- Non-linear constraint among the charges

$$\left[3Q_R + 4\,(2\,a - c)\right]\left[3{Q_R}^2 - 8c\,(J_1 + J_2)\right]$$
$$= {Q_R}^3 + 16\,(3c - 2a)\,J_1 J_2 + 64a\,(a-c)\frac{(Q_R + a)(J_1 - J_2)^2}{{Q_R}^2 - 2a(J_1 + J_2)}$$

In perfect agreement with field theory predictions!

Charges and entropy from the near-horizon geometry

Goal: Direct method to obtain the charges and entropy

Obstacle: The corrected solution is needed but it is not known and very hard to obtain

How to circumvent this obstacle: (see also Pablo's talk)

- Restrict to the **near-horizon** solution, much easier to obtain
- Derive formulae for **Komar** and **Page charges**, which satisfy **Gauss law**:

$$\mathrm{d}\mathbf{k}_{\xi,\chi} = 0 \qquad \Rightarrow \qquad Q_{\xi,\chi} = \int_{\mathcal{H}} \mathbf{k}_{\xi,\chi} = \int_{\infty} \mathbf{k}_{\xi,\chi}$$

- Use near-horizon solution to compute them

Corrected near-horizon solution

Focus on the $J_1 = J_2 (\equiv J)$ case, aka **Gutowski-Reall (GR) black hole**:

$$
\begin{aligned}
\mathrm{d}s^2 &= v_1 \left(-\varrho^2 \mathrm{d}t^2 + \frac{\mathrm{d}\varrho^2}{\varrho^2} \right) + \frac{v_2}{4} \left[\sigma_1^2 + \sigma_2^2 + v_3 \left(\sigma_3 + w\, \varrho\, \mathrm{d}t \right)^2 \right] \\
A &= e\, \varrho\, \mathrm{d}t + p\, \left(\sigma_3 + w\, \varrho\, \mathrm{d}t \right)
\end{aligned}
$$

where

$$
v_i = v_i^{\mathrm{GR}} + \alpha\, \delta v_i\,, \quad w = w^{\mathrm{GR}} + \alpha\, \delta w\,, \quad e = e^{\mathrm{GR}} + \alpha\, \delta e\,, \quad p = p^{\mathrm{GR}} + \alpha\, \delta p
$$

Solving the corrected EOMs boils down to a linear system of **algebraic eqs**

$$
\mathcal{M} \mathcal{X} = \mathcal{N}\,, \qquad \mathcal{X} = \mathcal{X}^H + \mathcal{X}^P
$$

- $\mathcal{X}^H$ is the **homogeneous solution**, fixed by **boundary conditions**
- $\mathcal{X}^P$ is a **particular solution**, it contains the **"new physics"**

Formulae for charges and entropy

- Page electric charge:

$$Q = -\int_{\mathcal{H}} \left(\star\mathcal{F} - \frac{c_3}{\sqrt{3}} F \wedge A - \frac{2\lambda_1 \alpha}{\sqrt{3}} \Omega_{\rm CS} \right)$$

- Angular momentum:

$$J = \int_{\mathcal{H}} \boldsymbol{\epsilon}_{\mu\nu} \left[-2\nabla_\sigma \mathcal{P}^{\mu\nu\sigma\rho} \eta_\rho + \mathcal{P}^{\mu\nu\sigma\rho} \nabla_\sigma \eta_\rho + \frac{1}{2} \iota_\eta A \left(\mathcal{F}^{\mu\nu} + \frac{c_3}{3\sqrt{3}} \epsilon^{\mu\nu\rho\sigma\lambda} A_\rho F_{\sigma\lambda} \right) \right]$$

- Wald's entropy:

$$\mathcal{S} = -2\pi \int_{\mathcal{H}} \mathrm{d}^3x \sqrt{\gamma}\, \mathcal{P}^{\mu\nu\rho\sigma} n_{\mu\nu} n_{\rho\sigma}$$

Cassani, AR, Turetta '23

Corrections to the BPS charges and entropy

- Corrected near-horizon solution & previous formulae → corrected charges of supersymmetric black hole in AdS_5

- Perfect agreement with BPS charges and entropy found through the on-shell action (modulo a constant shift in the electric charge)

- Microcanonical form of the entropy relying entirely on the near-horizon geometry

$$\boldsymbol{\mathcal{S} = \pi\sqrt{3{Q_R}^2 - 16\,a J}}$$

Cassani, AR, Turetta '23

Conclusions

- **Summary of results**

  - We have constructed a **four-derivative extension** of 5d minimal gauged supergravity and used it to compute **corrections to the thermodynamics of $\mathbf{AdS_5}$ black holes**

  - Restricting to the BPS case: we have reproduced field theory predictions for subleading corrections to the **entropy, charges and on-shell action**

- **General lessons**

  - There are a number of strategies that render the study of higher-derivative corrections much more tractable

  - In the holographic context: they allow us to extract valuable information beyond the strict large N limit and to perform precision tests of holography

Thanks for your attention!