Discrete and higher-form symmetries from wrapped M5-branes

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Introduction

- The landscape of QFTs is vast and uncharted
  - Explore the space of QFTs to understand better strong-coupling regimes
  - New formulation of QFT?
- **Geometric engineering** in string/M-/F-theory:
  - Vast classes of strongly coupled fixed points in various dimensions
  - Includes higher-dimensional SCFTs (5d and 6d) that would be very challenging to study with traditional field theory techniques
  - Compactification of higher-dimensional SCFTs yields large families of 4d SCFTs that are strongly coupled (no known Lagrangian)
  - Topology and geometry give a new organizing principle
- Example: class S program and generalizations
  - 4d SCFTs from 6d SCFTs on punctured Riemann surface
  - Many setups in this class are realized with wrapped M5-branes

Introduction

- How can we extract physical data of geometrically engineered QFTs *directly* from their *geometric* definition?

- A great deal of information about the dynamics is encoded in **global symmetries** and their 't Hooft anomalies

- The concept of global symmetry in QFT has been recently revisited:
  - **generalized global symmetries** [Gaiotto, Kapustin, Seiberg, Willett 14]
  - new implications for the dynamics (e.g. new 't Hooft anomalies to match) [Gaiotto, Kapustin, Komargodski, Seiberg, 17]

- Useful viewpoint on QFTs in geometric engineering for all global symmetries

Regard QFTs in geometric engineering as "edge modes" in supergravity

Introduction

Regard QFTs in geometric engineering as "edge modes" in supergravity

- The QFT is realized by degrees of freedom localized on a "defect" inside a larger ambient space in 10d or 11d
- The "defect" can be a stack of branes or a singularity in the geometry
- At low energies, the ambient space dynamics is described by 10d/11d SUGRA
- The *gauge* symmetries of SUGRA induce *global* symmetries in the QFT
- The pullback of the SUGRA fields onto the defect gives *non-dynamical background gauge fields* for the global symmetries
- In the presence of the "defect", the ambient SUGRA action can acquire a non-zero gauge variation
- This is exactly cancelled by the anomalies of the QFT d.o.f.'s: *anomaly inflow*

NB: This applies to *all* global symmetries

<u>In this talk</u>: Apply this viewpoint to generalized global symmetries of QFTs engineered with wrapped M5-branes

Reminder on generalized symmetries

[Gaiotto, Kapustin, Seiberg, Willett 14]

p-form global symmetry with group G

- Charged operators are p-dimensional $\mathcal{O}(\mathcal{C}^{(p)})$
- If G is continuous:
  - conserved Noether $(p+1)$-form current $d * J_{p+1}$
  - couple to backgr. gauge field: $(p+1)$-form $\delta A_{p+1} = d\Lambda_p$
- NB: G is necessarily Abelian for $p > 0$
- Many aspects of 0-form global symmetries extend to higher-form symmetries
  - organize the spectrum of operators and give Ward identities
  - spontaneous symmetry breaking and Goldstone modes
  - ‘t Hooft anomalies

Reminder on generalized symmetries

- **'t Hooft anomalies** for global symmetries
  - obstruction to gauging (not inconsistency)
  - invariant under RG flow
  - can constrain phases of the QFT

- More familiar situation: perturbative anomalies for ordinary continuous symmetries, computed by triangle diagrams in 4d

- The concept applies to all global symmetries, including discrete and/or generalized symmetries

- To analyze 't Hooft anomalies of discrete and/or generalized symmetries we will use the topological terms in the SUGRA effective action

Outline

Discrete higher-form symmetries from BF terms

Setup and strategy

- Consider a 4d SCFT with a smooth holographic dual in 11d supergravity
- BPS conditions for $AdS_5 \times_w M_6$ solutions are analyzed in

  [Gauntlett, Martelli, Sparks, Waldram 04]

- Reduction of M-theory on M_6 gives a 5d low-energy effective action
  - p-form gauge fields in 5d bulk correspond to global symmetries on the boundary field theory
  - ‘t Hooft anomalies are encoded in topological terms in the 5d action

- Input data about the setup
  - topology of the internal space M_6 (cohomology groups)
  - isometries of the internal space M_6
  - G_4-flux configuration on M_6

p-form gauge fields in 5d

- p-form gauge fields in the 5d effective action have two sources:

  1) 1-form gauge fields from isometries of M_6

  → (possibly non-Abelian) 0-form global symmetry

  2) p-form gauge fields from expansion of C_3 onto cohomology classes of M_6

$$\delta C_3 = c_3 + B_2^u \wedge \lambda_{1u} + A_1^\alpha \wedge \omega_{2\alpha} + a_0^x \wedge \Lambda_{3x}$$

$\lambda_{1u}, \omega_{2\alpha}, \Lambda_{3x}$: closed forms on M_6 with integral periods;
their cohomology classes are a basis of $H_p(M_6, \mathbb{Z})_{\text{free}}$ for p=1,2,3

$$u = 1, \ldots, b_1(M_6) \qquad \alpha = 1, \ldots, b_2(M_6) \qquad x = 1, \ldots, b_3(M_6)$$

$c_3, B_2^u, A_1^\alpha, a_0^x$: external gauge fields in 5d;
their field strengths have periods quantized in units of 2π

- NB: 0-form gauge field a_0^x = compact scalar with period 2π

p-form gauge fields in 5d

$$\delta C_3 = c_3 + B_2^u \wedge \lambda_{1u} + A_1^\alpha \wedge \omega_{2\alpha} + a_0^x \wedge \Lambda_{3x}$$

- Naïve expectation for global symmetries of the boundary QFT:

$U(1)$	2-form symmetry	
$U(1)^{b_1(M_6)}$	1-form symmetry	?
$U(1)^{b_2(M_6)}$	0-form symmetry	

- Some 5d p-form gauge fields enter **topological mass couplings**

$$S_{\rm top} = -\frac{1}{2\pi}\int_{\mathcal{M}_5}\left[N_\alpha\, c_3 \wedge dA_1^\alpha + \frac{1}{2}\, k_{uv}\, B_2^u \wedge dB_2^v\right]$$

$$N_\alpha = \int_{M_6} \frac{G_4}{2\pi} \wedge \omega_{2\alpha} \qquad\qquad k_{uv} = \int_{M_6} \frac{G_4}{2\pi} \wedge \lambda_{1u} \wedge \lambda_{1v}$$

- Some 5d U(1) p-form gauge symmetries are Higgsed to a cyclic subgroup
- The global symmetries on the field theory side depend on a choice of boundary conditions for the topological couplings

BF-like terms in five dimensions

- In the deep IR the topological mass couplings dominate
- We consider a topological 5d theory with action

$$S = \frac{k}{2\pi}\int_{\mathcal{M}_5} c_3 \wedge d\mathcal{A}_1 + \frac{M}{2\pi}\int_{\mathcal{M}_5} \widetilde{B}_2 \wedge dB_2$$

analog of 4d BF theory
see e.g. the review
[Banks, Seiberg 10]

- Let us first take 5d (Euclidean) spacetime $\mathcal{M}_5$ to be a closed manifold
  - Invariance under large gauge transformations requires $k, M \in \mathbb{Z}$
  - On shell: $dc_3 = d\mathcal{A}_1 = d\widetilde{B}_2 = dB_2 = 0$ (no local operators)
  - Natural observables: holonomies ("Wilson lines")

$$W_c(\mathcal{C}_3, n) = e^{in\int_{\mathcal{C}_3} c_3} \qquad W_{\mathcal{A}}(\mathcal{C}_1, n) = e^{in\int_{\mathcal{C}_1} \mathcal{A}_1}$$

$$W_{B,\widetilde{B}}(\mathcal{C}_2, n, \widetilde{n}) = e^{i\int_{\mathcal{C}_2}(\widetilde{n}\, B_2 - n\,\widetilde{B}_2)}$$

BF-like terms in five dimensions

- Correlators of Wilson lines

$$\langle W_c(\mathcal{C}_3, n)\, W_{\mathcal{A}}(\mathcal{C}_1, n')\rangle = \exp\left[2\pi i \frac{nn'}{k}\, L(\mathcal{C}_3, \mathcal{C}_1)\right] \qquad (L = \text{linking number})$$

$$\langle W_{B,\widetilde{B}}(\mathcal{C}_2, n, \widetilde{n})\, W_{B,\widetilde{B}}(\mathcal{C}_2', n', \widetilde{n}')\rangle = \exp\left[2\pi i \frac{n\widetilde{n}' - \widetilde{n}n'}{M}\, L(\mathcal{C}_2, \mathcal{C}_2')\right]$$

- The 5d action describes p-form gauge fields with **discrete** gauge group
  - $c_3, \mathcal{A}_1$ are flat gauge fields with holonomies in $\mathbb{Z}_k \subset U(1)$
  - $\widetilde{B}_2, B_2$ are flat gauge fields with holonomies in $\mathbb{Z}_M \subset U(1)$

- Equivalent viewpoint: **Stückelberg** action

$$S = -\frac{1}{2}\int_{\mathcal{M}_5} g_{\phi\phi}\, (d\phi - k\,\mathcal{A}_1) \wedge *(d\phi - k\,\mathcal{A}_1)$$

$d\phi = *dc_3$

ϕ: compact scalar of period 2π

in the IR: $\mathcal{A}_1 = \frac{1}{k} d\phi$

Spacetimes with a boundary

- For holographic applications we have to consider 5d spacetimes with boundary
- Choice of **topological boundary conditions** for the pairs $(c_3, \mathcal{A}_1)$, $(\widetilde{B}_2, B_2)$

case	boundary conditions	global symm. of boundary theory
(a)	c_3 : free $\mathcal{A}_1$: Dirichlet	$\mathbb{Z}_k$ 0-form symm.
(b)	c_3 : Dirichlet $\mathcal{A}_1$: free	$\mathbb{Z}_k$ 2-form symm.
(c) $k = mm'$ $(m \neq 1, k)$	c_3 : free modulo $\mathbb{Z}_m$ $\mathcal{A}_1$: free modulo $\mathbb{Z}_{m'}$	$\mathbb{Z}_{m'}$ 0-form symm. $\mathbb{Z}_m$ 2-form symm.

"free modulo $\mathbb{Z}_m$": for $\mathcal{C}_3 \subset \partial\mathcal{M}_5$ consider the holonomy $e^{i\int_{\mathcal{C}_3} c_3} = (e^{2\pi i/k})^x$
x must satisfy $x = p \bmod m$ for a fixed p, but is otherwise free

[Witten 98; Gaiotto, Kapustin, Seiberg, Willett 14; Bergman, Tachikawa, Zafrir 20]

Spacetimes with a boundary

- Depending on b.c. different bulk Wilson lines are or are not allowed to end on the boundary

case	boundary conditions	can end on boundary?		
(a)	c_3 : free $\mathcal{A}_1$: Dirichlet	$e^{i\int_{C_3} c_3}$ no $e^{i\int_{C_1} \mathcal{A}_1}$ yes	→	local op. charged under 0-form glob. symm.
(b)	c_3 : Dirichlet $\mathcal{A}_1$: free	$e^{i\int_{C_3} c_3}$ yes $e^{i\int_{C_1} \mathcal{A}_1}$ no	→	surface op. charged under 2-form glob. symm.
(c)	c_3 : free modulo $\mathbb{Z}_m$ $\mathcal{A}_1$: free modulo $\mathbb{Z}_{m'}$	$e^{i\int_{C_3} c_3}$ m' at a time $e^{i\int_{C_1} \mathcal{A}_1}$ m at a time		both local op. and surface op.

[Witten 98; Gaiotto, Kapustin, Seiberg, Willett 14; Bergman, Tachikawa, Zafrir 20]

Spacetimes with a boundary

Remarks:

- In case (a), specifying the b.c. for $\mathcal{A}_1$ is the same as fixing a **background** 1-form gauge field for the global $\mathbb{Z}_k$ 0-form symmetry of the theory on $\mathcal{M}_4 = \partial\mathcal{M}_5$

  if there is no torsion in homology, $\mathrm{Hom}(\pi_1(\mathcal{M}_4), \mathbb{Z}_k) \cong H^1(\mathcal{M}_4, \mathbb{Z}_k)$

- **Gauging** the global $\mathbb{Z}_k$ 0-form symmetry of case (a) gives case (b); gauging subgroups gives case (c)

- In case (c) there is a **mixed 't Hooft anomaly** between the $\mathbb{Z}_{m'}$ 0-form symm. and the $\mathbb{Z}_m$ 2-form symm.

- Formally we detect it from the 6-form that encodes the 5d top. mass terms

$$\frac{S}{2\pi} = \int_{\mathcal{M}_5} I_5^{(0)} \qquad I_6 = dI_5^{(0)} \qquad I_6 = k\,\frac{dc_3}{2\pi} \wedge \frac{d\mathcal{A}_1}{2\pi} + M\,\frac{d\widetilde{B}_2}{2\pi} \wedge \frac{dB_2}{2\pi}$$

- Analogous remarks hold for the $(\widetilde{B}_2, B_2)$ pair

‘t Hooft anomalies from inflow

Embedding in the full gravity theory

- The BF-like terms embed in the full gravity theory obtained from reduction of M-theory on M_6

- The 5d effective action includes kinetic terms for all p-form fields

- The system admits **singleton** modes

    - Pure gauge in the bulk, dynamical on the conformal boundary
    - Hamiltonian determined combining kinetic terms and BF terms

[Maldacena, Moore, Seiberg 01; Belov, Moore 04]

    - Singleton 0-form gauge field from $(c_3, \mathcal{A}_1)$
    - Singleton 1-form gauge field from $(\widetilde{B}_2, B_2)$

- Singleton modes **do not gravitate**

    - They are holographically dual to **decoupled** sectors

(terminology "singleton" from representation theory of superconformal algebra)

Singletons and decoupling

- Decoupling singleton: sum over topological sectors

$$Z = \sum_\beta Z_\beta Z^\beta_{\text{singleton}}$$

$Z^\beta_{\text{singleton}}$: conformal blocks of singleton sector

Z_β: partition function of gravitating modes

β: label for topological sectors

- On field theory side: $Z^\beta_{\text{singleton}}$ → free modes; Z_β → interacting SCFT
- E.g.: $(c_3, \mathcal{A}_1)$ system

start from case (a):
- Dirichlet b.c. for $\mathcal{A}_1$
- Interacting SCFT with $\mathbb{Z}_k$ 0-form glob. symm.
- Choice of b.c. = choice of backgr. gauge field $\beta \in H^1(\mathcal{M}_4, \mathbb{Z}_k)$
- $Z_\beta =$ partition function of SCFT with β backgr. gauge field

to get case (b):
- Gauge 0-form symm.
- $\widehat{Z} \propto \sum_\beta Z_\beta$

- Analogous remarks for $(\widetilde{B}_2, B_2)$

cfr. AdS_5 x S^5 type IIB analysis of [Witten 98; Belov, Moore 04; Gaiotto, Kapustin, Seiberg, Willett 14; Hofman, Iqbal 17]

't Hooft anomalies and inflow

- In the full gravity theory (gravitating + singletons)
  - Kinetic terms & BF terms in the 5d action
  - **2nd order action**: impose Dirichlet b.c. for c_3, $\mathcal{A}_1$, $\widetilde{B}_2$, B_2

cfr. [Hofman, Iqbal 17] and 3d Abelian CS analysis of [Gukov, Martinec, Moore, Strominger 04]

  - The full boundary theory has continuous $U(1)$ p-form symmetries

- Expectation: the anomalies of the full boundary theory (interacting + decoupling) are balanced by anomaly inflow from M-theory bulk

- Since we deal with continuous p-form symmetries, we can describe anomalies using a 6-form anomaly polynomial I_6

- A single 6-form I_6 contains information about 't Hooft anomalies of different SCFTs (corresponding to different top. b.c. in 5d)

Tools for anomaly inflow

- Systematic tools for anomaly inflow based on [Freed, Harvey, Minasian, Moore 98] developed in [Bah, FB, Minasian, Nardoni 19,20]

- Input: (1) topology and isometries of M_6
  (2) G_4-flux quantum numbers

- Auxiliary geometry $M_6 \hookrightarrow M_{12} \to \mathcal{M}_6$ ← external spacetime (Euclidean; descent formalism)

  fibration includes **connections for isometries** of M_6

- Cohomology classes of M_6 are represented by closed forms: $\Omega_4^\alpha, \Lambda_{3x}, \omega_{2\alpha}, \lambda_{1u}$

- Upgrade to globally-def. closed forms on M_{12} : $(\Omega_4^\alpha)', (\Lambda_{3x})', (\omega_{2\alpha})', (\lambda_{1u})'$

  they contain connections for isometries of M_6

Tools for anomaly inflow

- Construct:

$$E_4 = N_\alpha \, (\Omega_4^\alpha)' + \frac{da_0^x}{2\pi} \, (\Lambda_{3x})' + \frac{dA_1^\alpha}{2\pi} \, (\omega_{2\alpha})' + \frac{dB_2^u}{2\pi} (\lambda_{1u})' + \frac{dc_3}{2\pi}$$

input flux quanta

$U(1)$ backgr. p-form gauge fields (forms on $\mathcal{M}_6$ pulled back to M_{12})

- Interpretation: E_4 encodes the 11d **boundary condition** for G_4 **near M5-branes**

- Compute

$$I_6^{\text{inflow}} = \int_{M_6} \left[-\frac{1}{6} \, E_4^3 - E_4 \wedge X_8 \right]$$

$\int_{M_6}$ = fiber integration in $M_6 \hookrightarrow M_{12} \to \mathcal{M}_6$

$X_8 \propto p_1^2 - 4\,p_2$ (Pontryagin classes of TM_{12})

Example I: BBBW

- We consider a stack of N M5-branes wrapped on a Riemann surface without punctures, preserving 4d $\mathcal{N}=1$ supersymmetry

[Bah, Beem, Bobev, Wecht 12]

- 11d background: $\mathbb{R}^{1,3} \times \mathbb{R} \times Y_3$ where Y_3 : total space of $\mathcal{L}_1 \oplus \mathcal{L}_2 \to \Sigma_g$

$$c_1(\mathcal{L}_1) = p \qquad c_1(\mathcal{L}_2) = q \qquad \text{CY condition:} \quad p + q = -\chi(\Sigma_g) = 2g - 2$$

- M5-brane stack sits at a point on $\mathbb{R}$, at the zero section of Y_3, and is extended along $\mathbb{R}^{1,3}$ and the Riemann surface

- For suitable values of p, q, g the system flows to an interacting SCFT which has a **smooth** gravity dual solution in 11d supergravity

$$AdS_5 \times_w M_6 \qquad S^4 \hookrightarrow M_6 \to \Sigma_g$$

$$\text{struct. group: } U(1) \times U(1) \subset SO(5)$$

Caveat: p=q=0 gives 4d $\mathcal{N}=4$ SYM, which does not have a smooth gravity dual in 11d supergravity (dualize to standard type IIB frame)

Example I: BBBW

- Isometries of M_6: $U(1)_{\phi_1} \times U(1)_{\phi_2}$
- (Co)homology of M_6:

one 4-cycle	→	one flux quantum N
one 2-cycle	→	one 1-form gauge field A_1
$2g$ 1-cycles	→	g pairs of 2-form gauge fields $(\widetilde{B}_2^i, B_{2i})$
one 0-cycle	→	one 3-form gauge field c_3
no 3-cycles	→	no 0-form gauge fields (axions)

- Inflow result:

$$I_6^{\text{inflow}} = -\frac{2}{3}\left(N^3 - \frac{1}{4}N\right)\left[p\, c_1^{\phi_1}\,(c_1^{\phi_2})^2 + q\, c_1^{\phi_2}\,(c_1^{\phi_1})^2\right] - \frac{1}{6}N\left[p\,(c_1^{\phi_1})^3 + q\,(c_1^{\phi_2})^3\right] + \frac{1}{24}N\left[p\, c_1^{\phi_1} + q\, c_1^{\phi_2}\right]p_1(T) + \frac{1}{(2\pi)^2}\left[-N\, dc_3\, dA_1 - N\, d\widetilde{B}_2^i\, dB_{2i}\right]$$

- ➢ no interplay between isometries and c_3, A_1, $\widetilde{B}_2^i$, B_{2i}
- ➢ BF terms $dc_3\, dA_1$, $d\widetilde{B}_2^i\, dB_{2i}$:
  - choice of b.c. gives various SCFTs with different global symm.
  - they encode mixed ‘t Hooft anomalies if we select b.c. of type (c)

Example II: GMSW

- Smooth supersymmetric AdS_5 solutions first discovered in
  [Gauntlett, Martelli, Sparks, Waldram 04]

- Internal space M_6: $\mathbb{CP}^1$ bundle over product of two Riemann surfaces

- If one of the Riemann surfaces is a torus it is best to dualize to type IIB
  cfr. $Y^{p,q}$ [Gauntlett, Martelli, Sparks, Waldram 04] and [Gauntlett, O Colgain, Varela 06]

- We consider one 2-sphere and a genus-g surface Σ_g with g=0 or g>2

- Interpretation: near-horizon limit of M5-branes probing a *flux background*
  - Resolved $\mathbb{C}^2/\mathbb{Z}_2$ fibered over Σ_g and stabilized by G_4-flux [Bah, FB 19]

- Strategy here: read off symmetries and anomalies from holographic data

Example II: GMSW

- Isometries of M_6: $U(1)_\psi \times SU(2)_\varphi$
- (Co)homology of M_6:

three 4-cycles	→	three flux quanta N, N_+, N_-
three 2-cycles	→	three 1-form gauge fields A_1, A_1^+, A_1^-
$2g$ 1-cycles	→	g pairs of 2-form gauge fields B_{2i}, $\widetilde{B}_2^i$
one 0-cycle	→	one 3-form gauge field c_3
$4g$ 3-cycles	→	$4g$ 0-form gauge fields $a_{0i}^{\pm}$, $\widetilde{a}_0^{i\pm}$

- BF terms: $\frac{1}{2\pi} c_3 \wedge \left(N\, dA_1 + N_+\, dA_1^+ + N_-\, dA_1^- \right) + \frac{N}{2\pi} \widetilde{B}_2^i \wedge dB_{2i}$
  - ➢ One linear comb. of A's gives a $\mathbb{Z}_k$ 5d gauge field, $k = \gcd(N, N_+, N_-)$

$$N\, A_1 + N_+\, A_1^+ + N_-\, A_1^- \equiv k\, \mathcal{A}_1$$

  - ➢ The other two vectors remain standard U(1) fields
  - ➢ Discrete 2-forms gauge fields in 5d

Example II: GMSW

This system has a rich variety of terms in the inflow anomaly polynomial:

- Mixed terms between isometries/gravity and discrete symmetries, e.g.

$$c_2(SU(2)_\varphi)\,\frac{d\mathcal{A}_1}{2\pi} \qquad\qquad p_1(T)\,\frac{d\mathcal{A}_1}{2\pi}$$

- Mixed terms between discrete symmetries and axions, e.g.

$$\frac{d\mathcal{A}_1}{2\pi}\left(\frac{da_0}{2\pi}\,\frac{d\widetilde{a}_0}{2\pi}\right)^2 \qquad\qquad \left(\frac{d\widetilde{a}_0}{2\pi}\,\frac{dB_2}{2\pi}\right)\left(\frac{da_0}{2\pi}\,\frac{d\widetilde{a}_0}{2\pi}\right)$$

(indices are suppressed)

- All three kinds of symmetries at once, e.g.

$$c_1(U(1)_\psi)\,\frac{d\mathcal{A}_1}{2\pi}\left(\frac{da_0}{2\pi}\,\frac{d\widetilde{a}_0}{2\pi}\right) \qquad\qquad c_1(U(1)_\psi)\left(\frac{d\widetilde{a}_0}{2\pi}\,\frac{dB_2}{2\pi}\right)$$

Example II: GMSW

- Terms with the 0-form gauge fields $a_{0i}^{\pm}$, $\widetilde{a}_0^{i\pm}$ are interpreted as anomalies in the **space of coupling constants**

[Cordova, Freed, Ho Tat Lam, Seiberg 19]

- Exactly marginal couplings associated to 4d operators

$$\Delta(\mathcal{O}) = 4 \qquad \Delta\mathcal{L} \sim a_0\,\mathcal{O} \qquad a_0 \text{ has period } 2\pi \quad \Rightarrow \quad \int_{\mathcal{M}_4} \mathcal{O} *_4 1 \in \mathbb{Z}$$

(analogous to $\Delta\mathcal{L} \sim \theta\,\epsilon_{\mu\nu\rho\sigma}\mathrm{tr}\,(F^{\mu\nu}\,F^{\rho\sigma})$ in gauge theory)

- We expect that this rich structure of ‘t Hooft anomalies has interesting implications for the dynamics of the theory

Conclusions and outlook

Conclusions

- Topological mass terms in 5d AdS supergravity encode discrete global symmetries of the dual field theory
  - ➢ The same bulk theory with different topological boundary conditions gives field theories with different discrete global symmetries

- We can capture ‘t Hooft anomalies with a 6-form inflow anomaly polynomial
  - ➢ Systematic geometric tools using data from holographic solution

- Rich interplay between all p-forms fields from expansion of C_3 (p=0,1,2,3)
  - ➢ Higher-form symmetries
  - ➢ Discrete symmetries
  - ➢ Anomalies in the space of coupling constants, or "(–1)-form" symmetries

Outlook

- Dynamical implications of anomalies
- Analysis of singleton sector and decoupling modes
  - potential avenue for exact anomalies, including $\mathcal{O}(N^0)$ terms
- Complement the holographic/inflow approach with field theory analysis
  - e.g. theories engineered with N=2 M5-branes
- Use topological mass terms in 5d to organize/classify extended operators
  - line operators in class S from $(\widetilde{B}_2^i, B_{2i})$ system?
- Explore other sources of discrete symmetries
  - torsion cycles in the internal geometry
  - discrete isometries
  - …

[Camara, Ibanez, Marchesano 11; Bersaluce-Gonzales, Camara, Marchesano, Regalado, Uranga 12]

Thank you!