Title: Anomalies, 2-groups, 6d susy

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Abstract: <p>Part 1 is about anomalies and how they can deform generalized global symmetry into 2-group global symmetry. This is illustrated with simple QFT examples in 4d. Part 2 is about 6d.</p>

<p>6d theories with 2-group symmetry exist, but cannot be conformal. 6d superconformal theories (SCFTs) cannot have 2-group or higher-form, generalized global symmetries. This requires cancellation of mixed gauge and global terms in the anomaly polynomial.   SCFT relations between conformal and â€™t Hooft anomalies will also be discussed.   Based on papers with Cordova and Dumitrescu.</p>

Anomalies, 2-groups, 6d susy

Ken Intriligator (UCSD)

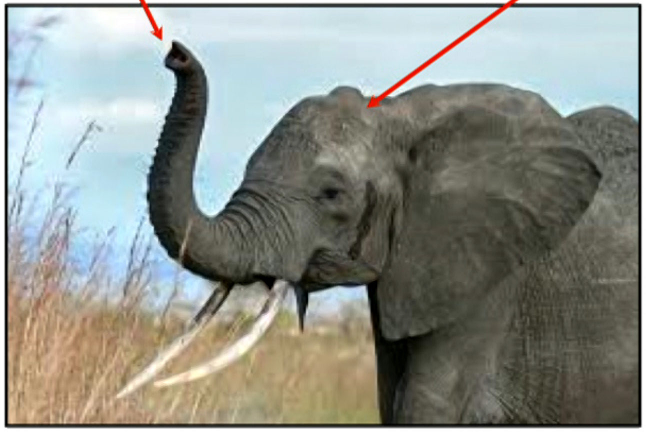
Based on work with **Clay Cordova** (IAS / U. Chicago) and **Thomas Dumitrescu** (UCLA).

“What is QFT?”

(See N. Seiberg’s website for a talk with this title.)

Perturbation theory around free field Lagrangian theories

5d & 6d* SCFTs, + deformations, compactifications



Explore parts of the space of QFTs via CFTs + perturbations

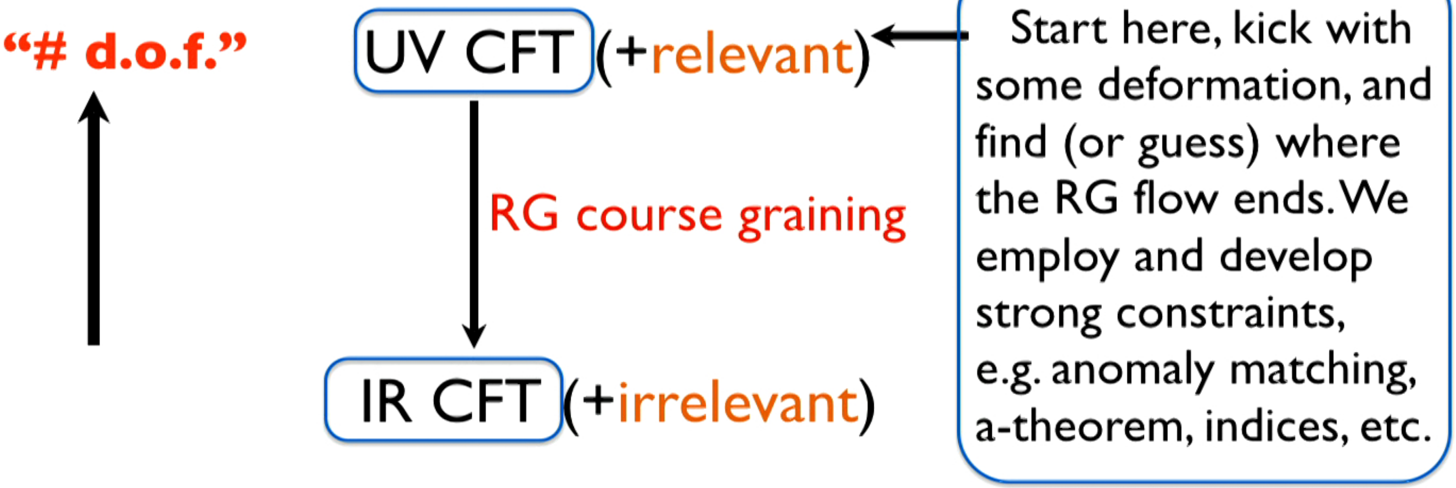
(?unexplored…something crucial for the future?)

* **d=6** is largest d of SCFTs.

RG flows, universality

In extreme UV or IR, masses become unimportant or decoupled. Enhanced, conformal symmetry in these limits. E.g. QCD: UV-free quarks and gluons in UV, and IR-free pions or mass gap in IR. Now many examples of non-trivial, interacting CFTs and especially with SUSY. Can deform them to find new QFTs.

RG flow cartoon:



"# d.o.f."

UV CFT (+relevant)

RG course graining

IR CFT (+irrelevant)

Start here, kick with some deformation, and find (or guess) where the RG flow ends. We employ and develop strong constraints, e.g. anomaly matching, a-theorem, indices, etc.

RG flow constraints

- ’t Hooft **anomaly** matching for global symmetries + gravity. They must be constant on RG flows; match at endpoints.

- Reducing # of d.o.f. intuition. For d=2,4 **(& d=6 susy)** : a-theorem

$$a_{\rm UV} \geq a_{\rm IR} \qquad a \geq 0$$ For unitary thys

conformal **anomaly**: $\langle T^\mu_\mu \rangle \sim aE_d + \sum_i c_i I_i$ ★

a-theorem proof of Komargodski + Schwimmer via **conf’l anomaly matching.**

(d=odd: via sphere partition function / entanglement entropy.)

- Additional power from supersymmetry. Supermultiplets and supermultiplets of **anomalies**.

q-form global currents

- Conserved flavor current: $\partial^\mu J_\mu^a = 0$. Source: A_μ^a bkgd.

  = "q=0-form" global symmetry. (a = g Lie alg. index) $\delta A_\mu^a = (D_\mu \lambda)^a$

- Conserved **higher q-form global symmms:**

  Gaiotto, Kapustin, Seiberg, Willett and refs therein.

$j^{(q+1)}_{[\mu_1 \cdots \mu_{q+1}]}$ with $\partial^{\mu_1} j^{(q+1)}_{[\mu_1 \cdots \mu_{q+1}]} = 0.$ I.e. $d * j^{(q+1)} = 0$

$Q(\Sigma_{d-q-1}) = \int_{\Sigma_{d-q-1}} * j^{(q+1)}$ $\Delta_{\text{exact}}(j^{q+1}) = d - q - 1$

q>0: only abelian, $U(1)^{(q)}$ (or discrete subgroup).

E.g. 4d u(1) gauge theory with charged matter has $U(1)^{(1)}$ global symmetry with $*j^{(2)} = F_{u(1)}$

Couple all currents to background fields

- Poincare': Source = bkgd metric $g_{\mu\nu} = \delta_{ab} e^a_\mu e^b_\nu$
  $\delta e^{(1)a} = -\theta_b^{(0)a} e^{(1)b}$
- Conserved flavor current: $\partial^\mu J^a_\mu = 0$. Source: A^a_μ bkgd.
  Invariance: $\delta A^a_\mu = (D_\mu \lambda)^a$
- Conserved q>0 current:

$$S \supset \int B^{\mu_1 \dots \mu_{q+1}} j_{[\mu_1 \dots \mu_{q+1}]} dV = \int B^{(q+1)} \wedge \star j^{(q+1)}$$

$\delta B^{(q+1)} = d\Lambda^q$ invariance since $d \star j^{(q+1)} = 0$

E.g. for 4d u(1) gauge theory: $\int B^{(2)} \wedge F^{(2)}_{u(1)}$

Background gauge invariance encodes conservation laws.

Recall anomalies

Effective action as fn of background fields:

$$W[\mathcal{B}] = -\log(\int [d\psi][dA]e^{-S[\mathcal{B},\psi,A]/\hbar})$$

$$W[\mathcal{B}+\delta\mathcal{B}] - W[\mathcal{B}] = \mathcal{A}[\mathcal{B}] = 2\pi i \int \mathcal{I}^{(d)}[\mathcal{B},\delta\mathcal{B}]$$

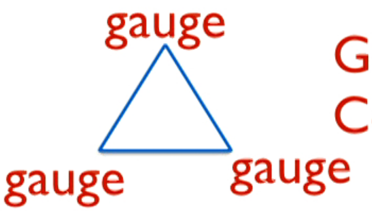
$\nwarrow$ (descent procedure)

$$d\mathcal{I}^{(d)}[\mathcal{B},\delta\mathcal{B}] = \delta\mathcal{I}^{(d+1)}[\mathcal{B}],\ d\mathcal{I}^{(d+1)}[\mathcal{B}] = \mathcal{I}^{(d+2)}[\mathcal{B}]$$

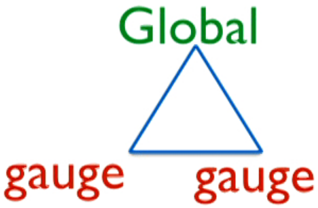
For d=2n, the matter content must be gauge anomaly free. Anomalies encoded in a topological d+2 form in gauge and global background field strength Chern classes, and Pontryagin classes for the background metric curvature. Compute via (n+1)-gon diagram, or inflow, etc. Calculable via various methods.

We discuss mixed gauge+ global anomalies. They quantum-deform the global symmetry group into a``2-group.''

Anomalies (4d case)



Gauge anomalies must vanish for a healthy theory. Constrains chiral matter content.



ABJ anomaly, only for global U(1)s. If non-zero, global U(1) is just not a symm (explicitly broken by instantons, perhaps to a discrete subgroup).

’t Hooft anomalies. **Useful** if non-zero: must be constant along RG flow, match at ends.

Does not violate either symmetry! Deforms global symmetry to a 2-group symmetry.

$$d * j^{(1)}_{\rm global} = \frac{\kappa}{(2\pi)^2} F_{\rm global} \wedge F_{\rm gauge} = \frac{\kappa}{2\pi} F_{\rm global} \wedge * J^{(2)}_B$$

“2-group” global symmetry

Non-trivial structure function interplay between conserved q=2-form current and ordinary currents. Like the Green-Schwarz mechanism for the background fields. We find simple examples, use to explore and clarify many aspects.

(See e.g. Kapustin and Thorngren papers, and refs therein.)

Global symmetry:
bkgd gauge transfs

$$G^{(0)} \times_{\hat{\kappa}} U(1)^{(1)}$$

$$\delta A^a_\mu = (D_\mu \lambda)^a \qquad \delta B^{(2)} = d\Lambda^{(1)} + \frac{\hat{\kappa}}{2\pi}\lambda^{(0)} dA^{(1)}$$

+ analog for Poincare’ SO(4) frame rotation of spin connection: $+\frac{\hat{\kappa}_{\mathcal{P}}}{16\pi}\mathrm{tr}(\theta^{(0)} d\omega^{(1)})$

$$H^{(3)} = dB^{(2)} - \frac{\hat{\kappa}_A}{2\pi} CS(A) - \frac{\hat{\kappa}_{\mathcal{P}}}{16\pi} CS(\omega),$$

dH sourced by background gauge & gravity instanton.

4d QED example

Consider a 4d (non-susy) QED, i.e. u(1) gauge theory, with N flavors of massless Dirac Fermion (IR free, needs a UV cutoff).

Global symmetry: $SU(N)_L^{(0)} \times SU(N)_R^{(0)} \times U(1)_B^{(1)}$

$U(1)_A^{(0)}$ broken by ABJ anomaly.

$U(1)_V^{(0)} \to u(1)_{\text{gauge}}$

$$j_B^{\mu\nu} \propto \epsilon^{\mu\nu\rho\sigma} f_{\rho\sigma}$$

global current	dyn. u(1) gauge field.

Non-zero mixed anomaly. No broken symmetry. Deforms the global symmetry to a 2-group symm.:

$$\left(SU(N)_{L-R}^{(0)} \times_{\kappa=1} U(1)_B^{(1)}\right) \times SU(N)_{L+R}^{(0)}$$

Chiral toy model examples

Consider a 4d (non-susy) theory with two 0-form flavor symms $U(1)_A$ and $U(1)_C$ and matter chiral Fermions with charges (q_A , q_C).

	q_A	q_C
ψ_1	1	3
ψ_2	1	4
ψ_3	-1	5
ψ_4	0	-6

$\kappa_{A^3} = \mathrm{Tr} U(1)_A^3 = 1$ 't Hooft

$\kappa_{A^2C} = \mathrm{Tr} U(1)_A^2 U(1)_C = 12$ mixed

$\kappa_{AC^2} = \mathrm{Tr} U(1)_A U(1)_C^2 = 0$ ABJ=0

$\kappa_{C^3} = \mathrm{Tr} U(1)_C^3 = 0$ gauge=0

Take A=global and C=gauge symmetry. Non-zero 't Hooft and mixed anomaly. $\mathcal{I}_6^{\mathrm{mixed}} = (\kappa_{A^2C} c_2(F_A) + q_{C,tot} p_1(T)) \wedge c_1(f_c)$

global gauge

2-group structure constants

Global 0-form and 1-form symmetries: $G^{(0)} \quad G^{(1)}$

$\beta \in H^3(G^{(0)}, G^{(1)})$ we call them $\hat{\kappa}_{G^{(0)}}, \quad \hat{\kappa}_{\mathcal{P}}.$

Kapustin & Thorngren: Postnikov class. We also call them 2-group structure constants.

Coefficients of CS terms in invariant field strength $H^{(3)}$. For quantized charges, compact global groups, these coefficients must be integers: $\hat{\kappa}_{G^{(0)}}, \quad \hat{\kappa}_{\mathcal{P}} \in \mathbf{Z}$ They are scheme indep physical properties of the QFT. Can only arise at tree-level level or one-loop. Mixed anomaly terms give this symmetry.

E.g.: $U(1)_A^{(0)} u(1)_C^{(0)} \longrightarrow U(1)_A^{(0)} \times_{\hat{\kappa}_A, \hat{\kappa}_{\mathcal{P}}} U(1)_B^{(1)}$

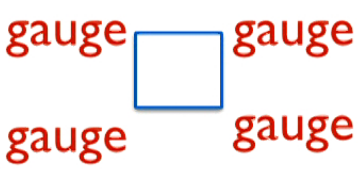
GLOBAL ↗ gauge ↑

$$\hat{\kappa}_A = -\frac{1}{2}\kappa_{A^2C} \in \mathbf{Z}$$

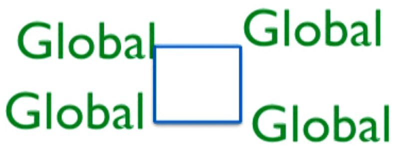
$$\hat{\kappa}_{\mathcal{P}} = -\frac{1}{6}\kappa_{\mathcal{P}^2C} \in \mathbf{Z}$$

"Mixed anomaly" coeffs. give 2-group with no anomaly.

Likewise 6d anomalies



Gauge anomalies must vanish. Can use a dyn GSWS mechanism to cancel reducible parts.



’t Hooft anomalies. Useful if non-zero. Must be constant along RG flow, match at ends.

Does not violate any symmetry. Deforms global symmetry to a 2-group symmetry. Here the gauge group can be non-Abelian. (In 4d, there is only one gauge vertex, so it must be u(1).)

Example: small SO(32) instanton theory (Witten ’95)

$$\mathcal{I}_8^{\text{mixed}} = c_2(F_{sp(N)})\left(c_2(F_{SO(32)}) + (16+N)p_1(T)\right)$$

Mixed gauge/global anomalies and 2-groups

$U(1)^{(1)}_B$ 4d: $\star j^{(2)} = c_1(f_{\rm gauge}) = \frac{f_{gauge}}{2\pi}, \quad q_J = \int_{\Sigma_2} \star j^{(2)} \in \mathbf{Z}$

$U(1)^{(1)}_B$ 6d: $\star j^{(2)} = c_2(f_{\rm gauge}) = \frac{1}{8\pi^2} {\rm Tr}\ {\rm f}_{\rm gauge} \wedge {\rm f}_{\rm gauge}, \quad {\rm q_J} = \int_{\Sigma_2} \star {\rm j}^{(2)} \in \mathbf{Z}$

Conserved since $d \star j^{(2)} = 0$, charged objects = e.g. ANO vortex strings (4d), instanton strings (6d).

Couple the 1-form global symmetries to 2-form background gauge fields B. $S_{4d,6d} \supset \int B \wedge \star j$

The mixed "anomaly" means that B shifts under a bkgd flavor or metric gauge transformation $A' = A + d\lambda_A,$

$$B' = B + d\Lambda + \frac{\kappa}{2\pi} \lambda_A F_A$$

2-group affects reducible 't Hooft anomaly matching

E.g. $U(1)_A^{(0)} \times_{\hat{\kappa}_A} U(1)_B^{(1)}$ only has $\mathrm{Tr}U(1)_A^3$ 't Hooft anomaly matching mod $6\hat{\kappa}_A$, because of a possible counterterm: $S_{SG} = \frac{in}{2\pi}\int B^{(2)} \wedge F_A^{(2)}$, $U(1)_B^{(1)}: \ n \in \mathbf{Z}$

$\kappa_{A^3} \to \kappa_{A^3} + 6n\hat{\kappa}_A$ E.g. can gap if $\mathrm{Tr}U(1)_A^3 = 0 \bmod 6\hat{\kappa}_A$

TQFTs can give similar, but physical (non-counterterm) terms with fractional n. They can be used to match 't Hooft anomalies via a gapped TQFT. E.g. u(1)$_C$ gauge thy broken to Z_{q_C} TQFT by Higgs mechanism of field with charge $q_C > 1$. Allows $\mathrm{Tr}U(1)_A^3 \neq 0$ to be matched by gapped TQFT if $\mathrm{Tr}U(1)_A^3 = 0 \bmod 6n\hat{\kappa}_A, \quad q_C n \in \mathbf{Z}$

2-group symmetry can be IR emergent, accidental.

E.g. embed 4d QED model, with 2-group symmetry, into an su(2) gauge group UV completion, where su(2) is broken to u(1) by the vev of an adjoint Higgs scalar Georgi-Glashow model. The global U(1)$^{(1)}$ of QED theory is an accidental symmetry, explicitly broken in the UV completion by monopole operators. Note subgroups:

$G^{(0)} \times_{\hat{\kappa}} U(1)^{(1)} \supset U(1)^{(1)}$ but $G^{(0)} \times_{\hat{\kappa}} U(1)^{(1)} \not\supset G^{(0)}$

$$\delta A_\mu^a = (D_\mu \lambda)^a \qquad \delta B^{(2)} = d\Lambda^{(1)} + \frac{\hat{\kappa}}{2\pi}\lambda^{(0)} dA^{(1)} + \frac{\hat{\kappa}_{\mathcal{P}}}{16\pi}\mathrm{tr}(\theta^{(0)} d\omega^{(1)})$$

Affects breaking / emerging patterns: the 1-form symmetry must emerge before the 0-form symmetry if $\hat{\kappa} \neq 0$

2-group vs CFT

With background gauge field $d * j_G^{(1)A} = \frac{\hat{\kappa}_A}{2\pi} F_G^{(2)A} \wedge * J_B^{(2)}$

W/o backgrounds, Ward identity contact terms e.g.:

$$\frac{\partial}{\partial x_\mu}\langle j_\mu^A(x) j_\nu^A(y) J_{\rho\sigma}^B(x)\rangle = \frac{\hat{\kappa}_A}{2\pi}\partial^\lambda \delta^{(4)}(x-y)\langle J_{\nu\lambda}^B(y) J_{\rho\sigma}^B(z)\rangle$$

Derivative of delta function: does not alter the charge algebra. Implies non-zero 3-point function also at separated points. Incompatible with additional constraints of CFT (modulo caveats for special cases that we discuss in detail). Tension between 2-group vs CFT. Indeed the examples with 2-group symmetry are IR free. CFT in IR or UV only if 2-group symmetry is IR spontaneously broken or UV emergent.

2-group vs CFT in d>4

1-form symmetry has conserved 2-form current, $\Delta[j_{\mu\nu}] = d-2$

Exists as a short rep of the conf'l gp, and for d>4 it is not necessarily free (it is co-closed, but not also closed as in 4d). Using conservation laws we show that, as in 4d

$\langle T^{\mu\nu}(x) T^{\kappa\lambda}(y) j^{\rho\sigma}(0)\rangle = 0$ So no 2-group with metric diffs.

But there were not enough constraints to rule out

$\langle J^{\mu}(x) J^{\nu}(y) j^{\rho\sigma}(z)\rangle \neq 0$ Possibly 2-group with global symms. But only w/o susy and we don't now know about non-susy 6d QFTs.

No 6d SCFT 2-group

Not even global $U(1)^{(1)}$(CDI): **no** unitary 6d SCFT reps contain global, conserved 2-form currents. So no 2-group symmetry nor mixed gauge, global anomalies can occur for 6d SCFTs. If it is a SCFT, any apparent such mixed anomalies must be cancelled by the GSWS mechanism, along with the reducible gauge anomalies. Justifies prescription of **Ohmori, Shimizu, Tachikawa, and Yonekura.**

$$\mathcal{I}_8^{\text{total}} = \mathcal{I}_8^{\text{"1-loop"}} \underbrace{+\mathcal{I}_8^{GSWS}}_{\substack{\text{Only if } \textbf{dynamical} \\ \text{2-form B gauge field(s).}}} = \underbrace{\mathcal{I}_8^{\text{gauge}}}_{!=0} + \underbrace{\mathcal{I}_8^{\text{mixed}}}_{\substack{=0; \textbf{ if} \\ \text{SCFT}}} + \underbrace{\mathcal{I}_8^{\text{global}}}_{}$$

This affects 't Hooft anomaly coefficients for e.g. $SU(2)_R$ in SCFT examples with gauge multiplets. Turns out to be crucial for ensuring positivity of the conf'l anomaly $\mathbf{a}_{\text{SCFT}}$ computed via 't Hooft anomalies.

6d susy gauge theories

Example: N small SO(32) instantons theory (Witten '95) sp(N) gauge group, with matter s.t. both irreducible and reducible sp gauge anomalies = zero. No tensor multiplet. Exists with little string UV completion. Has a conserved 2-form current from $\star c_2(F_{sp(N)})$ so cannot be conformal.

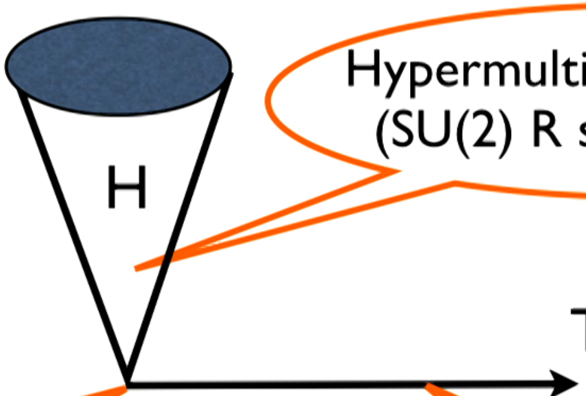
$$\mathcal{I}_8^{\text{mixed}} = c_2(F_{sp(N)})\left(c_2(F_{SO(32)}) + (16+N)p_1(T)\right)$$

so 2-group symmetry.

Example: gauge group and matter s.t. 0 irred gauge anomaly, with non-0 reducible gauge anomaly, cancelled by GSWS mechanism via a dynamical 2-form gauge field. Eliminates 2-form current & mixed anomalies. SCFT.

Part 2: 6d (1,0) SCFTs

Deform SCFT by moving on its vacuum manifold:



Hypermultiplet "Higgs branch" (SU(2) R symmetry broken)

Interacting 6d SCFT at origin

Tensor multiplet branch SU(2) R symmetry unbroken*

* Easier case. Just dilaton, no NG bosons. Dilaton = tensor multiplet. Study anomaly matching in EFT.

6d anomalies & susy

$$\langle T^\mu_\mu \rangle = a\text{Euler} + \sum_{i=1}^{3} c_i I_i(C) + \kappa(\nabla F)^2 + \hat{\kappa} CFF + f f_{abc} \text{Tr}(F^a F^b F^c)$$

Conformal anomaly in presence of background metric and gauge fields coupling to all global conserved currents (flavor and SU(2)$_R$). Equivalent to contact terms in energy momentum tensor and current correlation functions. Determined by operator correlation functions at separated points, e.g. the 3 c anomalies encode 3 independent structures of energy momentum tensor 2-point and 3-point functions. We study susy relations between these anomaly coefficients and 't Hooft anomaly coefficients (= exactly calculable). $\mathcal{I}_8^{\text{gravity+global}} \supset \alpha c_2(R)^2 + \beta c_2(R) p_1(T) + \gamma p_1^2(T) + \delta p_2(T)$

E.g. for the (1,0) SCFT of N small E8 instantons, via M-theory inflow

(N M5s @ M9 Horava-Witten wall.)

Ohmori, Shimizu, Tachikawa

$$\mathcal{E}_N: \ (\alpha, \beta, \gamma, \delta) = (N(N^2 + 6N + 3), -\frac{N}{2}(6N + 5), \frac{7}{8}N, -\frac{N}{2})$$

6d (1,0) tensor LEEFT

$$\mathcal{L}_{\text{dilaton}} = \frac{1}{2}(\partial\varphi)^2 - b\frac{(\partial\varphi)^4}{\varphi^3} + \Delta a\frac{(\partial\varphi)^6}{\varphi^6}$$ **Elvang, Myers, et. al.**

Our deformation classification implies that b=D-term and we argue

$\Delta a = \frac{98304\pi^3}{7}b^2 > 0$ **Proves 6d a-theorem** for susy tensor branch flows.

b-term susy-completes to terms in $X_4 = \sqrt{\Delta I_8}$

b=(y-x)/2 $X_4 \equiv 16\pi^2(xc_2(R) + yp_1(T))$

By recycling a 6d SUGRA analysis from Bergshoeff, Salam, Sezgin '86

Upshot:
CDI'15

$$\boxed{a^{\text{origin}} = \frac{16}{7}(\alpha - \beta + \gamma) + \frac{6}{7}\delta}$$

So exact 't Hooft anomaly coefficients give the exact conformal anomaly. E.g. using this and **OST** for the anomalies get:

$$a(\mathcal{E}_N) = \frac{64}{7}N^3 + \frac{144}{7}N^2 + \frac{99}{7}N$$

a, for 6d SCFTs with gauge flds:

E.g. SU(N) gauge group, 2N flavors, 1 tensor + anomaly cancellation for reducible gauge + mixed gauge + R-symmetry anomalies. Use $a^{\text{origin}} = \frac{16}{7}(\alpha - \beta + \gamma) + \frac{6}{7}\delta$

=0*(via GSWS)

V H T *AC **:GSWS**

$$a_{SCFT} = (N^2-1)(-\frac{251}{210}) + 2N^2(\frac{11}{210}) + \frac{199}{210} + \frac{96}{7}N^2 > 0.$$

Again, cannot be a conserved 2-form current in SCFT at the origin, despite apparent $c_2(f_{\text{gauge}})$: it sources dH and is believed to become part of a (poorly understood) non-Abelian version so not gauge invariant current at the origin.

Other conformal anomalies via ’t Hooft anomalies

$$\langle T^{\mu}_{\mu}\rangle = a\mathrm{Euler} + \sum_{i=1}^{3} c_i I_i(C) + \kappa(\nabla F)^2 + \hat{\kappa}CFF + f f_{abc}\mathrm{Tr}(F^a F^b F^c)$$

✓

On tensor branch: $\mathcal{L}_{\mathrm{dilaton}} = \frac{1}{2}(\partial\varphi)^2 - b\frac{(\partial\varphi)^4}{\varphi^3} + \Delta a\frac{(\partial\varphi)^6}{\varphi^6}$

Δc_i likewise = 6 derivative terms involving Weyl curvature (we assume a linear relation to ’t Hooft anomalies). Unitarity implies that $b \geq 0$ with b=0 iff the dilaton theory is free. Then all anomaly matching terms must be prop’l to b=(y-x)/2, which susy-completes to terms in $\mathcal{L}_{GSWS} \sim B\wedge X_4$

$$X_4 \equiv 16\pi^2(xc_2(R) + yp_1(T)) \qquad X_4 = \sqrt{\Delta I_8}$$

Find: $\Delta c_1 \propto (y-x)(\frac{4}{3}y - x), \quad \Delta c_2 \propto (y-x)(\frac{2}{3}y - x), \quad \Delta c_3 \propto (y-x)(2y-x)$

Used free hyper, free tensor, and (2,0) results to get coeffs, not yet directly derived from higher R (1,0) SUGRA at 6-derivative order (gives predictions).

Susy relations for SCFT

$$\langle T^\mu_\mu \rangle = a\text{Euler} + \sum_{i=1}^{3} c_i I_i(C) + \kappa(\nabla F)^2 + \hat{\kappa} CFF + f f_{abc}\text{Tr}(F^a F^b F^c)$$

$$\left.\begin{aligned} c_1 &= 4\alpha - \frac{14}{3}\beta + \frac{16}{3}\gamma + \frac{8}{3}\delta \\ c_2 &= 4\alpha - \frac{10}{3}\beta + \frac{8}{3}\gamma + \frac{10}{3}\delta \\ c_3 &= 4\alpha - 6\beta + 8\gamma + 2\delta \end{aligned}\right\}$$

Agrees with results already found in literature **Beccaria, Tseytlin; Yankielowicz, Zhou** (via fitting to known examples + non-unitary SCFT of a free gauge field with higher derivative couplings. We instead used $\Delta c_i \propto b \sim (y - x)$

$$c_1 = \frac{1}{2}(c_2 + c_3)$$

As claimed by **de Boer, Kulaxizi, Parnachev.** We prove it via SCFT constraints on <TTT>: 2 indep. structures.

We also use SCFT constraints on 3-point functions + tensor branch EFT to get $\kappa_{\text{flavor}} = \hat{\kappa}_{\text{flavor}} = \tau_{FF} = 2\alpha_{F^2T^2} - 2\alpha_{F^2R^2}, \quad f_{\text{flavor}} = 0.$

Current 2-point coefficient $\quad \mathcal{I}_8 \supset \alpha_{F^2T^2} c_2(F) p_1(T) + \alpha_{F^2R^2} c_2(F) c_2(R)$

SCFT 2 & 3-point functions

$$\langle \mathcal{O}^{R_1}_{1,L_1}(z_1)\mathcal{O}^{R_2}_{2,L_2}(z_2)\mathcal{O}^{R_3}_{3,L_3}(z_3)\rangle = F_{\text{fixed}}(\Delta, L, R, \chi_{13}, \chi_{23}, u_{13}, u_{23}) \cdot H_{\Delta,L,R}(X,\Theta)$$

Supermultiplets of ops
in superspace $z = (x_{[\alpha\beta]}, \theta^r_\alpha)$

Coordinate built from 3 points
in superspace

E.g. 3-point function of energy momentum tensor supermultiplets

$$\langle \mathcal{T}(x_1,\theta_1)\mathcal{T}(x_2,\theta_2)\mathcal{T}(x_3,\theta_3)\rangle \sim H^{\mathcal{TTT}}(Z) = C_1^{\mathcal{TTT}} + C_2^{\mathcal{TTT}}\frac{(X\Theta)^2}{X^6} + C_3^{\mathcal{TTT}}\frac{\Theta^8}{X^4}$$

Shortening conditions on ops on LHS constrain C_i constants on RHS. For energy momentum tensor 3-point function this gives 1 constraint, so 2 indep. C_i on the RHS, corresponding to 2 independent c_i anomalies. Likewise, we consider 3-point functions involving conserved currents. Find all 3-point functions have one additional constraint from SUSY, one fewer independent structure. Constrains the conformal anomalies.

E.g. small E8 instanton SCFT

Global flavor symmetry $SU(2)_L \times SU(2)_R \times E_8$

Exact $\mathcal{I}_8$ and the susy relations give the 2-point and 3-point correlation functions of the energy momentum tensor and conserved currents. Find e.g.

$$\tau^2_{SU(2)_L} = 16N^3 + 6N^2 - 21N$$

$$\tau^2_{SU(2)_R} = c_3 = 16N^3 + 42N^2 + 22N$$

$$\tau^2_{E_8} = 12(2N^2 + 3N)$$

On the tensor branch, pull 1M5 away from other (N-1)M5s+M9. Then

$b \sim (y - x) \sim N + \frac{1}{4}$ The change in all anomaly coefficients, including the above, is proportional to this factor, since the dilaton EFT must trivialize if x=y.

Summary, Conclude

- Explore space of QFTs via enhanced symmetry lamp posts and RG flows.
- 2-group symmetry in simple QFTs in d=4, 6 via mixed anomalies. 2-group vs CFT.
- Exact results for SQFTs and SCFTs in 6d.
- Thank you!