

A Chern-Simons Pandemic

M. Montero

ITF, Utrecht University

Stringpheno 2017

Virginia Tech, Jul 6th 2017

Based on:

A Chern-Simons Pandemic, MM, A. Uranga, I. Valenzuela, 1702.06147



Utrecht University



Introduction

Swampland idea

Not every EFT is consistent with quantum gravity/ string theory
[Vafa '05]

Some examples:

- No global symmetries in QG [Banks-Dixon '88]
- The Swampland conjectures [Ooguri-Vafa '06]
- The WGC [Arkani-Hamed-Nicolis-Motl-Vafa '06,
Rudelius, Heidenreich, Reece, MM, Ibanez, Uranga, Valenzuela, Brown,
Cottrell, Shiu, Soler, Bachlechner, Long, McAllister, Hebecker, Mangat,
Rompineve, Witowski, Junghans, Palti, Saraswat. . . Ooguri-Vafa '16]
- Six-dimensional F-theory Swampland [Vafa, Heckman,
Rudelius, Del Zotto, Park, Mekareeya, Tomasiello, Klevers, Morrison,
Raghuram, Johnson, Taylor, Grimm, Cvetic, Ling Lin. . .]

This talk is about **generalized** global symmetries.

A brief review of GGS

- p -form global symmetry: **Nonlocal** Charged local operators \mathcal{O}_q , and p -form symmetry parameter λ_p , such that

$$\mathcal{O}_q \rightarrow \exp(iq \int_{C_p} \lambda_p) \mathcal{O}_q.$$

is a symmetry – leaves correlators invariant.

- Noether's theorem: Conserved current $d * j_{p+1} = 0$.
- Example: 4d $U(1)$ gauge theory w/o matter:

$$A \rightarrow A + \lambda_1, \quad d\lambda_1 = 0, \quad \mathcal{O}_q = \exp(iq \int A), \quad j_e = F.$$

We will focus on this kind of GGS, arising from periods of gauge potentials. Often broken by charged objects.

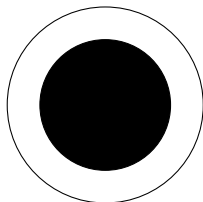
The BGHS black hole

- GGS must be broken in QG:
Otherwise trouble w. remnants.
- Example [Bowick et al. '88]:
Schwarzschild BH with

$$b = \int_{S^2} B_2$$

- Degenerate charged states

$$|n\rangle \equiv \int db e^{inb} |b\rangle$$



Two options

- Gauging
- Breaking

The BGHS black hole

- Gauging: Coupling to C_3 via Stuckelberg lagrangian [Dvali '05]

$$\frac{1}{2}|dB - mC_3|^2$$

The BGHHS black hole

- Gauging: Coupling to C_3 via Stuckelberg lagrangian [Dvali '05]

$$\frac{1}{2}|dB - mC_3|^2$$

- Breaking: Euclidean Schw. has $\mathbb{R}^2 \times S^2$ topology. Effective action for b as a field on \mathbb{R}^2

$$\int \frac{4\pi}{(fr)^2} |db|^2$$

Instantons: Strings on S^2 [Hebecker, Soler '17] Instanton contribution absent from partition function [Coleman, Preskill '92]

A field theory solution

Can we break shift symmetry of b w/o using instantons directly?

- Add coupling

$$N \int bF_2$$

Uplifts to 4d BF.

A field theory solution

Can we break shift symmetry of b w/o using instantons directly?

- Add coupling

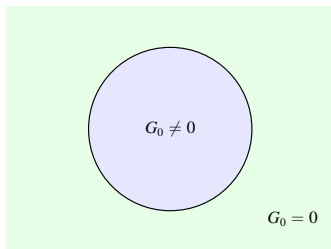
$$N \int bF_2$$

Uplifts to 4d BF.

- Take N to be dynamical:
 $N = \langle G_0 \rangle$.

$$\int G_0 bF_2$$

Current divergence is nonvanishing: $d * d\phi = G_0 F_2$.



Even if $\langle G_0 \rangle = 0$, we can nucleate **bubbles** with $G_0 \neq 0$.

CS pandemic

No need to break the shift symmetry within the EFT realm.

CS pandemic

No need to break the shift symmetry within the EFT realm.

- In fact, precise holographic embedding of 5d BGHHS BH breaks sym. also via stringy/grav. effects

CS pandemic

No need to break the shift symmetry within the EFT realm.

- In fact, precise holographic embedding of 5d BGHHS BH breaks sym. also via stringy/grav. effects

However

CS pandemic

No need to break the shift symmetry within the EFT realm.

- In fact, precise holographic embedding of 5d BGHHS BH breaks sym. also via stringy/grav. effects

However

In every ST example we have found, symmetry-breaking CS-terms are present.

which motivates us to conjecture that there is a

CS pandemic

No need to break the shift symmetry within the EFT realm.

- In fact, precise holographic embedding of 5d BGHHS BH breaks sym. also via stringy/grav. effects

However

In every ST example we have found, symmetry-breaking CS-terms are present.

which motivates us to conjecture that there is a

Chern-Simons pandemic

Every consistent theory w. gravity + p -form syms. with $d - p < 3$ must have the appropriate Chern-Simons term when compactified to 2d.

Discussion

- It is an “almost Swampland” condition: Constraints the theory, but we do not know at which scale.
- Only expected to hold if gravity is weakly coupled.
- The CS terms can have various origins: parity anomaly, 10d CS terms, D-brane couplings.
- Recast in a more general way, independent of action: Symmetry-breaking phases must be present in the theory.
- Rationale: CS terms break the symmetry in a generic way.

Applications

The CS pandemic puts in the Swampland:

- Pure gravity in $d \geq 4$; reduction on T^2 yields a 2d axion w/o CS term.
- Einstein-Maxwell+WGC-compliant matter in 4d: Again, 2d axion w/o CS.
- $\mathcal{N} = 8$ SUGRA in 4d (easily solved: stringy CS terms).

These problems can be easily fixed e.g. with axions or chiral matter.

Examples

- KK photons in ST: Reduction from T-dual

$$B \wedge F_q \wedge F_{8-q}$$

- RR axions: SUGRA CS terms. IIA on CY w. dual 3-cycles A, B

$$\int_A H_3 = p, \quad \int_A C_5 = b'_2, \quad \int_A C_3 = \phi,$$

$$\int_B H_3 = p', \quad \int_B C_5 = b_2, \quad \int_B C_3 = \phi'.$$

4d Lagrangian:

$$\mathcal{L} \sim (p\phi' - p'\phi)F_4 + (p'b_2 - pb'_2)F_2$$

W. orientifold: $p', b_2 = 0$, and $D6$ for tadpole cancellation.
For $p = 0$, they can have worldvolume $b'_2 \text{Tr} F_2$ in 4d.

Examples

- IIA on T^6 : BGHHS with B_2 -hair which can be embedded in M-theory. Romans mass CS

$$\int B_2 F_0 F_8$$

- Nongeometric fluxes: IIB on T^6 : BHGGS with $C'_2 = \int_{T^6} C_8$ gets a CS term with F_2 and a R-type nongeometric flux. Same for $AdS_5 \times S^5$.
- Heterotic: From GS coupling $B_2 \wedge \text{Tr} F^4$ we get

$$\int B_2 F_2 \text{Tr}(F_{SU(3)}^3).$$

(d-1)-form version

A version of the pandemic for $(d - 1)$ -form symmetries would demand e.g. 4d couplings for each 3-form [Dvali '05]:

$$\int G_0 C_3 \wedge d\phi$$

- More speculative, but some evidence [Bielleman, Ibañez, Valenzuela '15].
- Provides hints as to why Bousso-Polchinski is so hard to get: 3-forms always coupled to other stuff.

Summary

- GGS must be broken in PF to avoid remnant trouble;
Charged objects not enough when $d - p \leq 3$.
- A **pandemic of Chern-Simons** terms solves the problem generically.
- This is an almost-Swampland constraint for EFT's, killing $d \geq 4$ pure gravity, $d = 4$ EM+WGC, $\mathcal{N} = 8$ SUGRA.
- 3-form version relevant to Bousso Polchinski mechanism.

Outlook:

- Understand rationale better: AdS/CFT?
- Continue looking for (counter)examples.
- Explore 3-form version.

Summary

- GGS must be broken in PF to avoid remnant trouble;
Charged objects not enough when $d - p \leq 3$.
- A **pandemic of Chern-Simons** terms solves the problem generically.
- This is an almost-Swampland constraint for EFT's, killing $d \geq 4$ pure gravity, $d = 4$ EM+WGC, $\mathcal{N} = 8$ SUGRA.
- 3-form version relevant to Bousso Polchinski mechanism.

Outlook:

- Understand rationale better: AdS/CFT?
- Continue looking for (counter)examples.
- Explore 3-form version.

Thank you!