

# A Chern-Simons Pandemic

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



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# 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 Swampland [Vafa, Heckman, Rudelius, Del Zotto, Park, Mekareeya, Tomasiello. . . '15,16]

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  $\lambda_p$ , 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.

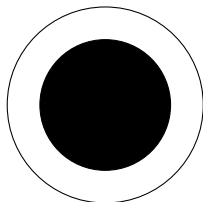
# The BGHS black hole

- 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

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- 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?

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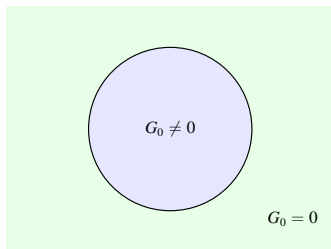
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- Take  $N$  to be dynamical:

$$N = \langle G_0 \rangle.$$

$$\int G_0 bF_2$$

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



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



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### 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.

## (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 [Biellemann, Ibañez, Valenzuela '15].
- Puts  $d = 3$  gravity in the (almost) Swampland. Aligns with recent  $CFT_2$  results.
- 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.
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- Understand rationale better: AdS/CFT?
- Continue looking for (counter)examples.
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Thank you!