On the finiteness of topological gravity Landscape

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Plan

• 1-Problem Identification:

Following the rules of quantum field theory does not guarantee the construction of a consistent effective quantum gravity theory.

• 2-Problem Statement:

There must be a set of additional criteria that quantum gravitational models must verify to insure their consistency.

• 3-Course of action:

Determine such criteria

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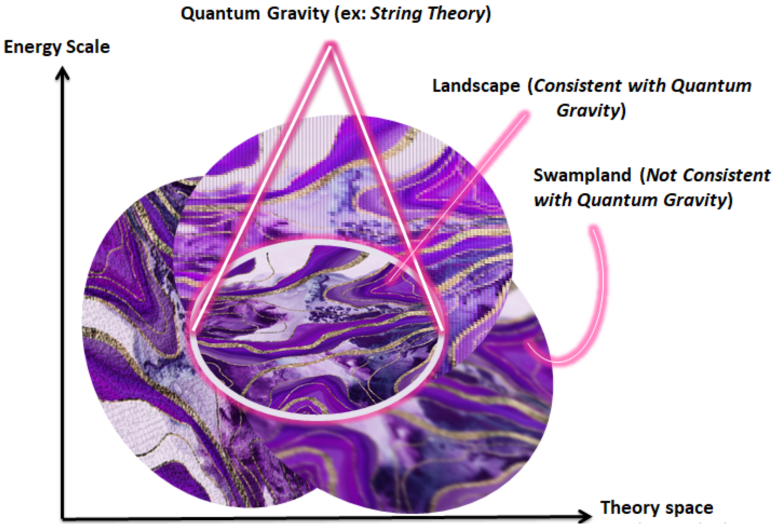
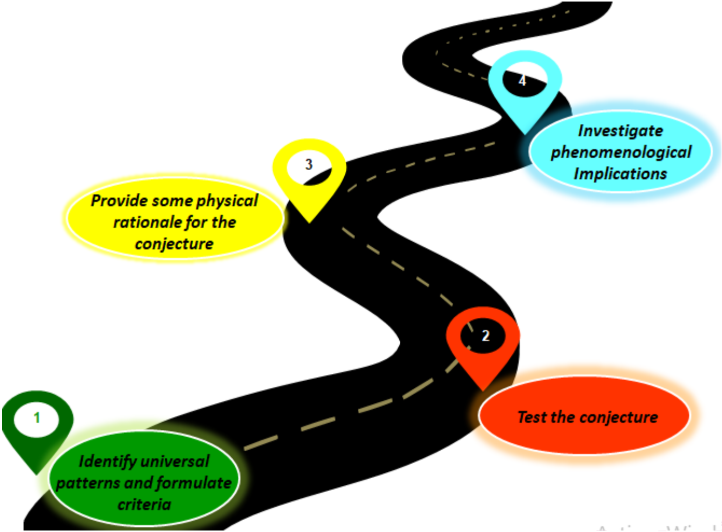
SWAMPLAND PROGRAM

Plan

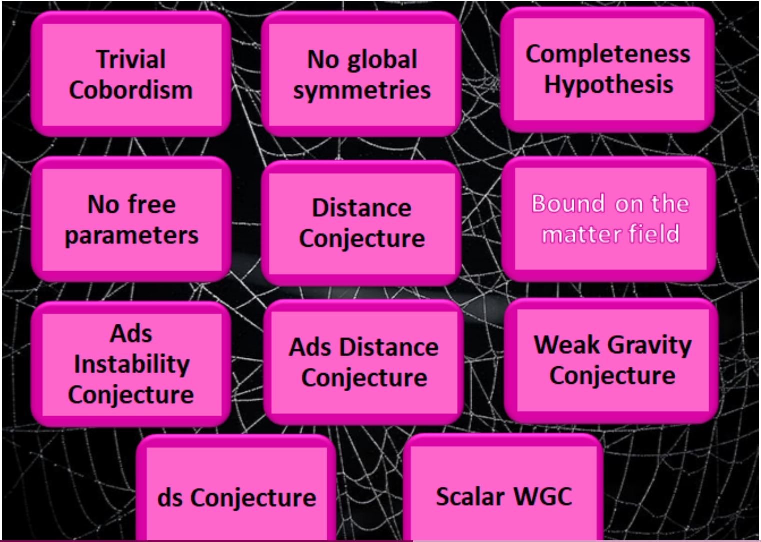
Swampland Vs Landscape



Swampland Algorithm



Swampland Conjectures



Plan

The BNMM Swampland Program: Step 1

The BNMM Swampland Program: Step 1

Criteria Formulation

A d – dimensional EFT coupled to Einstein gravity must have a finite number of massless fields. Moreover, the number of massless fields is bounded from above by a certain number N_{max} which depends only on the number of spacetime dimensions d.

Other than the gravity multiplet, the massless fields of a compactified theory are related to a cohomology class of the manifold. What is noticed is that no known series of CalabiYau manifolds have an infinite dimensional cohomology class.
Could this bound on the number of massless modes be a consequence of consistency of quantum gravity theories? Could the bound on the matter fields be a Swampland conjecture verified by all Landscape theories?

Pattern Identification

The BNMM Swampland Program: Step 2

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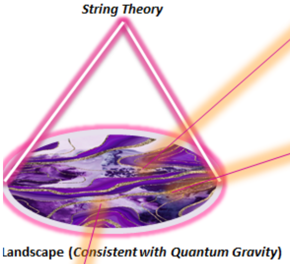

On The Finiteness of 6d Supergravity Landscape

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Swampland constraints on 5d $\mathcal{N} = 1$ supergravity

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Branes and the swampland

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Four-dimensional $\mathcal{N} = 4$ SYM theory and the swampland

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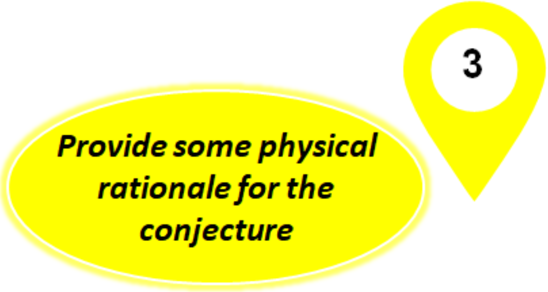
The BNMM Swampland Program: Step 3



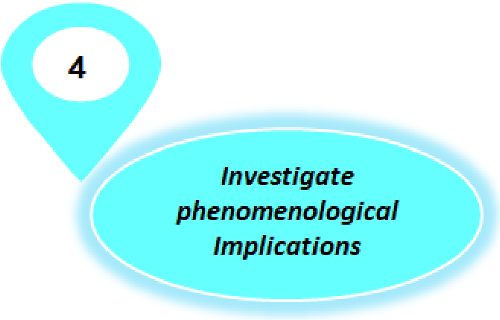
The BNMM Swampland Program: Step 3

In an effective field theory, the entropy of a black hole verify: $S_{BH} > N$ where N is the number of light species, massless modes. Thus, our conjecture is already verified by black hole requirement.

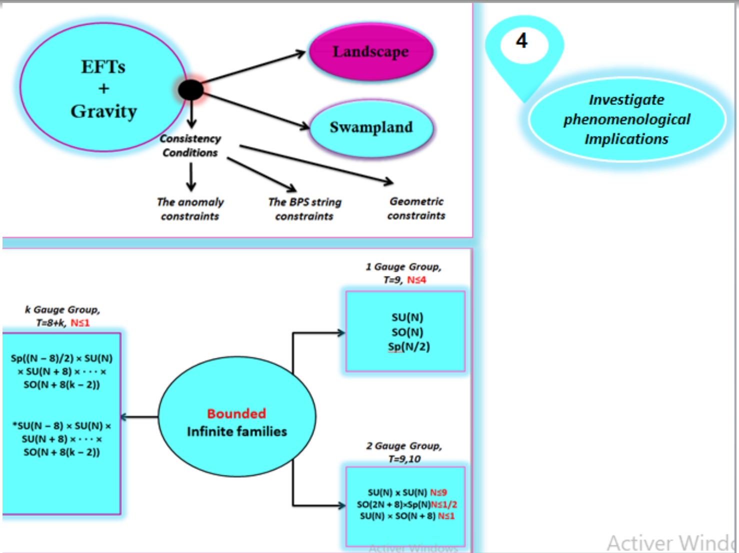
A new evaluation of the cutoff resolution has been found: $\Lambda \leq \frac{M_p}{N^{\frac{1}{d-2}}}$ Providing therefore a tighter bound.

Provide some physical rationale for the conjecture

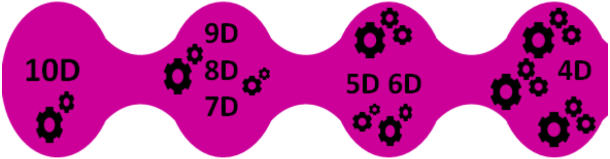
The BNMM Swampland Program: Step 4



The BNMM Swampland Program: Step 4

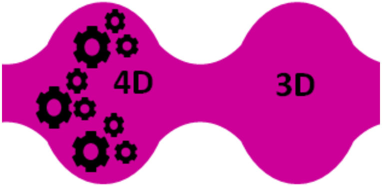


The BNMM Swampland Program



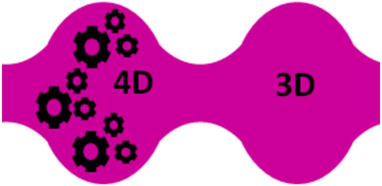
The BNMM Swampland Program

Lower dimensions?



The BNMM Swampland Program

Lower dimensions?



Topological gravity?

Plan

1. Identifying the problem
2. The Swampland Program
3. The BNMM conjecture
4. BNMM in 3D
   - AdS_3 Landscape
   - Boundary anomalies
5. Comments

Here is 3D action

$$I = \frac{1}{16\pi G}\int d^3x\sqrt{g}R$$

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$$I = \frac{1}{16\pi G} \int d^3x \sqrt{g} (R - 2\Lambda)$$

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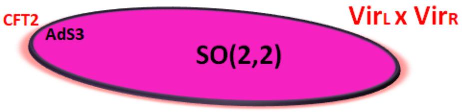
Generous symmetries



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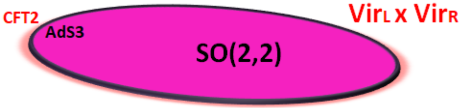
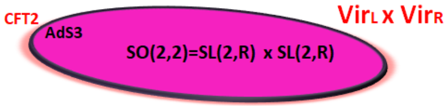


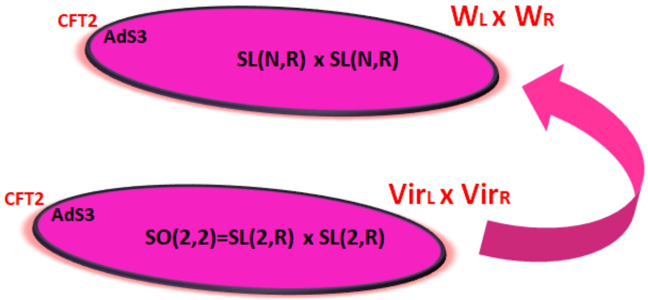
Gravity as a gauge theory



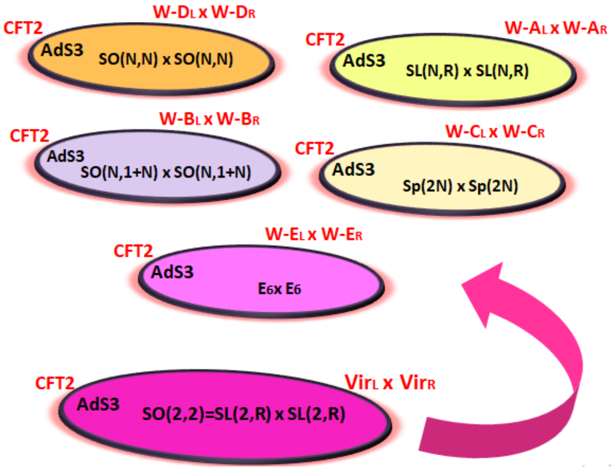
$$I = \frac{1}{16\pi G}\int d^3x\sqrt{g}(R-2\Lambda) = S_{CS}(A_L) - S_{CS}(A_R)$$

Generous symmetries

Higher spin fields



AdS_3 Landscape



$$I = \frac{1}{16\pi G} \int d^3x \sqrt{g}(R - 2\Lambda) = S_{CS}(A_L) - S_{CS}(A_R)$$

where,

$$S_{CS}(A) = \frac{k}{4\pi} \int_{M_{3D}} tr(AdA + \frac{2}{3}A^3)$$

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Gauge anomaly

With the gauge transformation

$$A \longrightarrow A + \delta A$$
$$\delta S_{CS}(A) = \frac{k}{4\pi}\int_{\partial M_{3D}} tr(\delta A A)$$

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Gauge anomaly

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Gravitational anomaly

Choosing $c_R \neq c_L$ accounted for with

$$S_{CS}(\Gamma) = \frac{c_R - c_L}{96\pi}\int_{\partial M_{3D}} tr(\Gamma d\Gamma + \frac{2}{3}\Gamma^3)$$

With an infintesimal diffeomorphism

$$\Gamma \longrightarrow \Gamma + \delta\Gamma$$
$$\partial_\mu T^{\mu\nu} = \frac{c_R - c_L}{96\pi} g^{\nu\alpha}\epsilon^{\mu\rho}\partial_\beta\partial_\mu\Gamma^\beta_{\alpha\rho}$$

Anomaly cancellation

Strings at the boundary

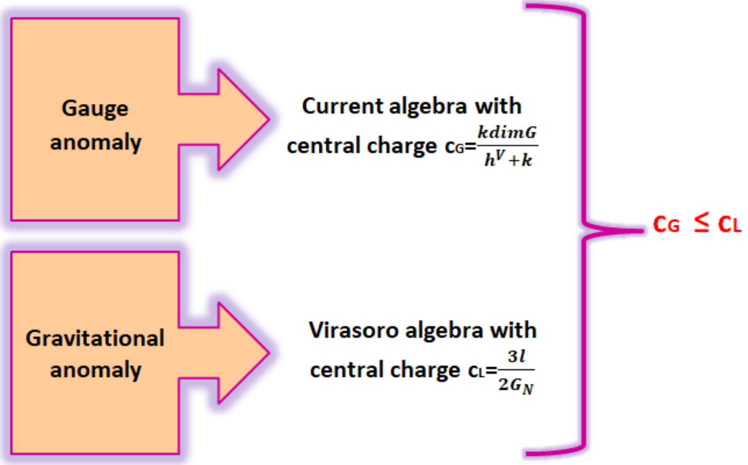
Similarly to polyakov action

$$\begin{aligned}\mathcal{S}_{PL} = &\int_{\partial AdS_3} d^2\xi\sqrt{|-h|}h^{\alpha\beta}\mathrm{G}_{\mathrm{AB}}\partial_\alpha X^{\mathrm{A}}\partial_\beta X^{\mathrm{B}} + \\ &\int_{\partial AdS_3} i\mathrm{B}_{\mathrm{AB}}\varepsilon^{\alpha\beta}\partial_\alpha X^{\mathrm{A}}\partial_\beta X^{\mathrm{B}} + \\ &\int_{\partial AdS_3} d^2\xi\sqrt{|-h|}h^{\alpha\beta}\partial_\alpha\Phi\partial_\beta\Phi + \sqrt{-|h|}\Phi R\end{aligned} \tag{1}$$

One can define

$$\mathcal{S}_{string} = \mathcal{S}^{L}_{wzw}\left(g_L\right) + \mathcal{S}^{R}_{wzw}\left(g_R\right) + \mathcal{S}^{grav}_{wzw}\left(\beta\right) \tag{2}$$

Constraint computation



Constraint computation

For the SL(N,R) case,

$$\frac{k(N^2-1)}{h^V+k} \leq c_L \implies N \leq c_L + 1$$

For the rest of the Landscape theories:

$$SO(N,1+N)_L : \quad \frac{N(2N+1)}{1+2N-1} \leq c_L$$

$$SO(N,N)_L : \quad \frac{N(2N-1)}{1+2N-2} \leq c_L$$

$$Sp(2N,\mathbb{R})_L : \quad \frac{N(2N+1)}{1+N+1} \leq c_L$$

Giving therefore

$$SO(N,1+N)_L : \quad N \leq c_L - \frac{1}{2}$$

$$SO(N,N)_L : \quad N \leq c_L$$

$$Sp(2N,\mathbb{R})_L : \quad N \leq \frac{1}{4}(c_L - 1) + \frac{1}{4}\sqrt{c_L^2 + 14c_L + 1}$$

Plan

- The conjecture provide a bound not only on the number of massless fields but also on the highest spin allowed
$$s \leq N \leq f(c_L)$$
- The conjecture is equivalent to the gravitational exclusion principle (GEP) derived from a BTZ black hole consideration $\Longrightarrow$ A 4D version of GEP might be the key to test the conjecture in 4D.


Thank You!
Any questions?