# Swampland conjectures for higher spin AdS3 gravity

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Orator: Rajae Sammani , Oct 17, 2024

# 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:**

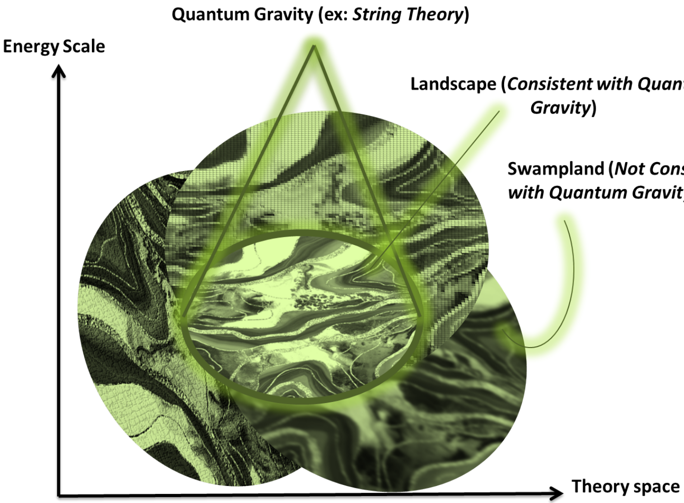
**There must be a set of additional criteria that quantum gravitational models must verify to insure their consistency.**

- **3-Course of action:**

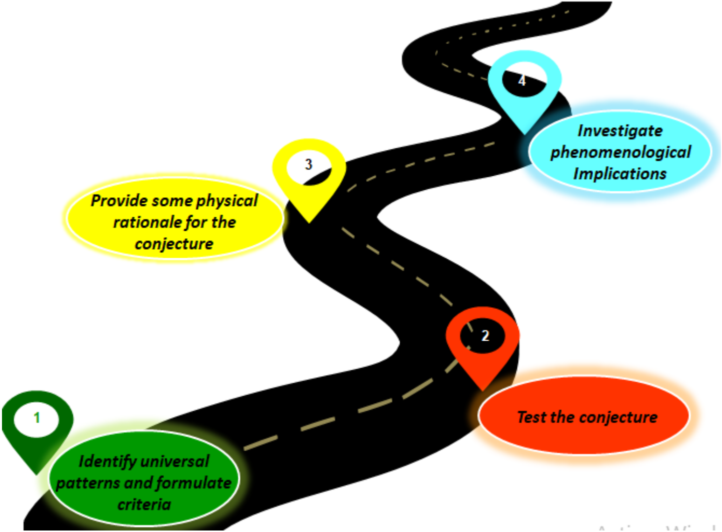
**SWAMPLAND PROGRAM**

# Plan

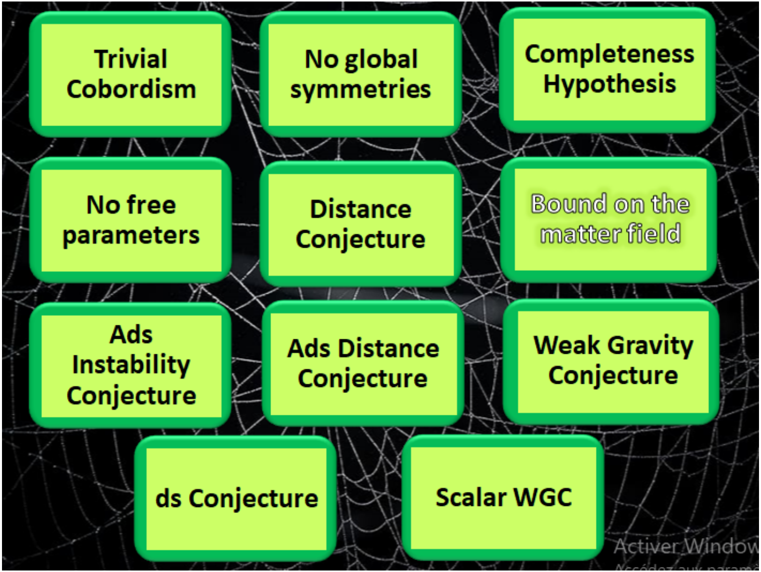
# Swampland vs Landscape



# Swampland Algorithm



# Swampland Conjectures



# Plan

# The BNMM Swampland Program: Step 1

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***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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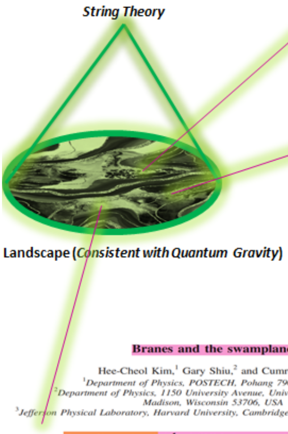



**On The Finiteness of 6d Supergravity Landscape**

**Houri-Christina Tarazi,**[a] **Cumrun Vafa**[a]
[a]*Department of Physics, Harvard University, Cambridge, MA 02138, USA*

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

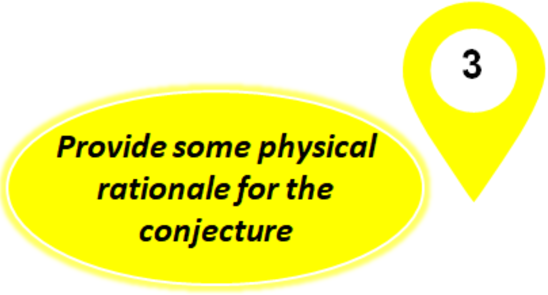
**Sheldon Katz,**[a] **Hee-Cheol Kim,**[b,c] **Houri-Christina Tarazi**[d] **and Cumrun Vafa**[d]
[a]*Department of Mathematics, MC-382, University of Illinois at Urbana-Champaign, Urbana, IL 61801, U.S.A.*
[b]*Department of Physics, Postech, Pohang 790-784, Korea*
[c]*Asia Pacific Center for Theoretical Physics, Postech, Pohang 37673, Korea*
[d]*Department of Physics, Harvard University, Cambridge, MA 02138, U.S.A.*

**Branes and the swampland**

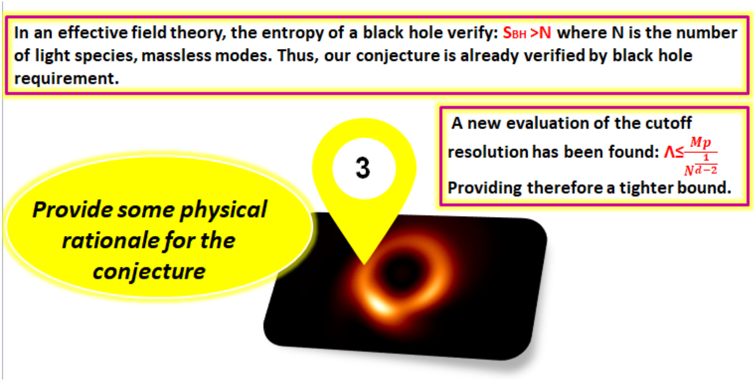
Hee-Cheol Kim,[1] Gary Shiu,[2] and Cumrun Vafa[3]
[1]*Department of Physics, POSTECH, Pohang 790-784, Korea*
[2]*Department of Physics, 1150 University Avenue, University of Wisconsin, Madison, Wisconsin 53706, USA*
[3]*Jefferson Physical Laboratory, Harvard University, Cambridge, Massachusetts 02138, USA*

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

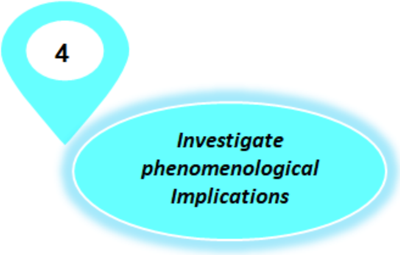
Hee-Cheol Kim,[1] Houri-Christina Tarazi,[2] and Cumrun Vafa[2]
[1]*Department of Physics, POSTECH, Pohang 790-784, Korea*
[2]*Jefferson Physical Laboratory, Harvard University, Cambridge, Massachusetts 02138, USA*


3
Provide some physical rationale for the conjecture

# The BNMM Swampland Program: Step 3

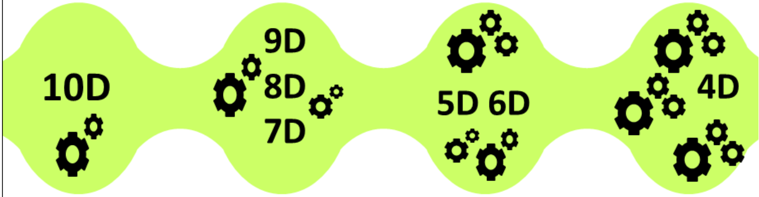


# The BNMM Swampland Program: Step 4



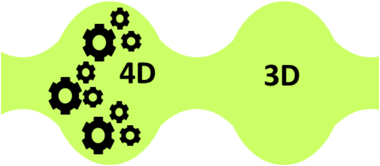

Orator: Rajae Sammani , Oct 17, 2024

# The BNMM Swampland Program: Step 4



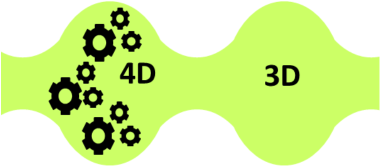
# The BNMM Swampland Program

Lower dimensions?



# The BNMM Swampland Program

Lower dimensions?




Topological gravity?

# Plan

Here is 3D action

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

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Too trivial?

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What about?

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

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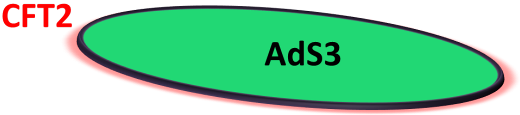
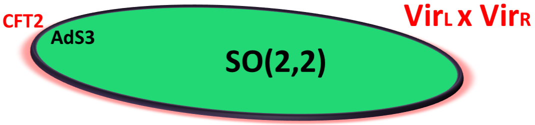
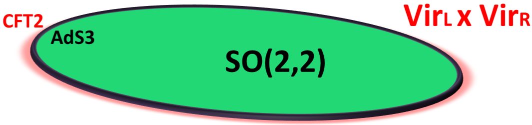


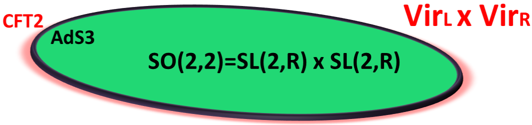
# Generous symmetries



# Generous symmetries



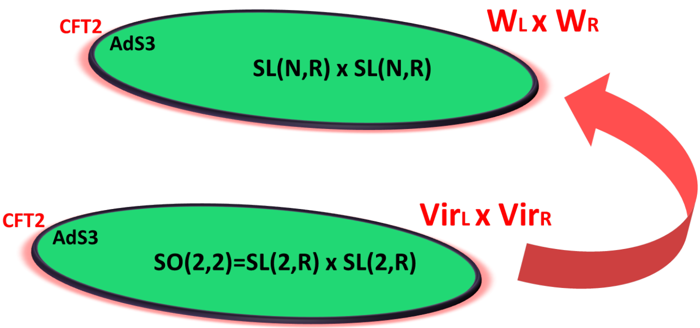

Gravity as a gauge theory



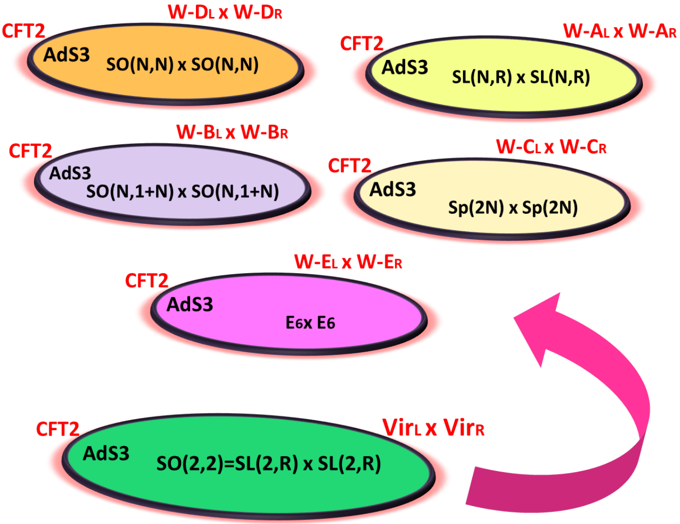

$$I = \frac{1}{16\pi G}\int d^3x\sqrt{g}(R-2\Lambda) = S_{CS}(A_L) - S_{CS}(A_R)$$

# Generous symmetries

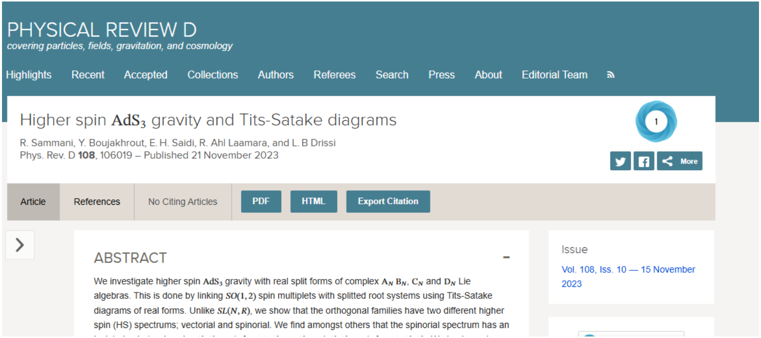
Higher spin fields



# $AdS_3$ Landscape



# $AdS_3$ Landscape



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## Higher spin $\mathbf{AdS_3}$ gravity and Tits-Satake diagrams

R. Sammani, Y. Boujakhrout, E. H. Saidi, R. Ahl Laamara, and L. B Drissi
Phys. Rev. D **108**, 106019 – Published 21 November 2023

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### ABSTRACT

We investigate higher spin $\mathbf{AdS_3}$ gravity with real split forms of complex $\mathbf{A}_N$ $\mathbf{B}_N$, $\mathbf{C}_N$ and $\mathbf{D}_N$ Lie algebras. This is done by linking $SO(1,2)$ spin multiplets with splitted root systems using Tits-Satake diagrams of real forms. Unlike $SL(N,R)$, we show that the orthogonal families have two different higher spin (HS) spectrums; vectorial and spinorial. We find amongst others that the spinorial spectrum has an

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# Landscape of BTZ black holes

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## Black flowers and real forms of higher spin symmetries

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R. Sammani & E. H. Saidi

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

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

$$A \longrightarrow A + \delta A$$

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

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

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Gauge anomaly

With the gauge transformation

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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

$$\Gamma \longrightarrow \Gamma + \delta\Gamma$$

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

Strings at the boundary

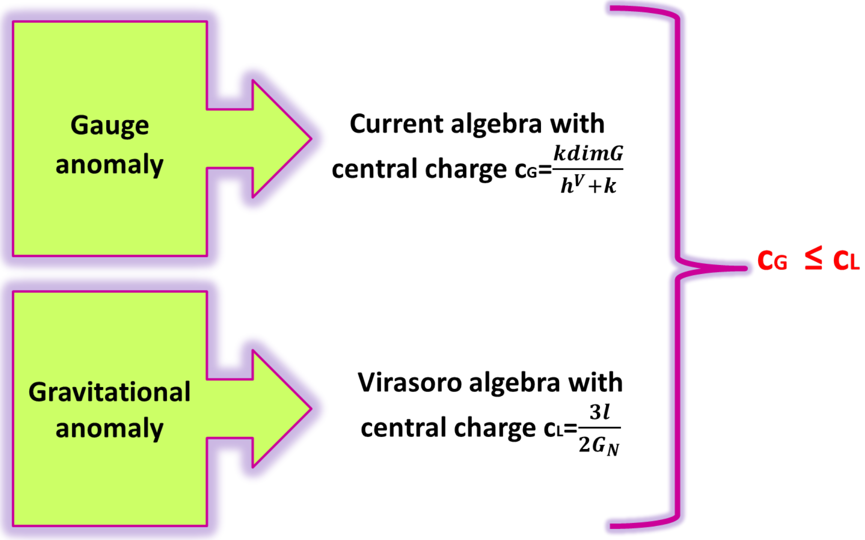
Similarly to polyakov action

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

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:

$$\begin{aligned} SO(N,1+N)_L : & \quad \frac{N(2N+1)}{1+2N-1} \leq c_L \\ SO(N,N)_L : & \quad \frac{N(2N-1)}{1+2N-2} \leq c_L \\ Sp\,(2N,\mathbb{R})_L : & \quad \frac{N(2N+1)}{1+N+1} \leq c_L \end{aligned}$$

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

Giving therefore

# Finiteness conjecture

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## Finiteness of 3D higher spin gravity Landscape

Rajae Sammani[1], Youssra Boujakhrout[1], E H Saidi[2], Rachid Ahl Laamara[3] and Lalla btissam Drissi[4]

Accepted Manuscript online 18 September 2024 • 

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**DOI** 10.1088/1361-6382/ad7cba

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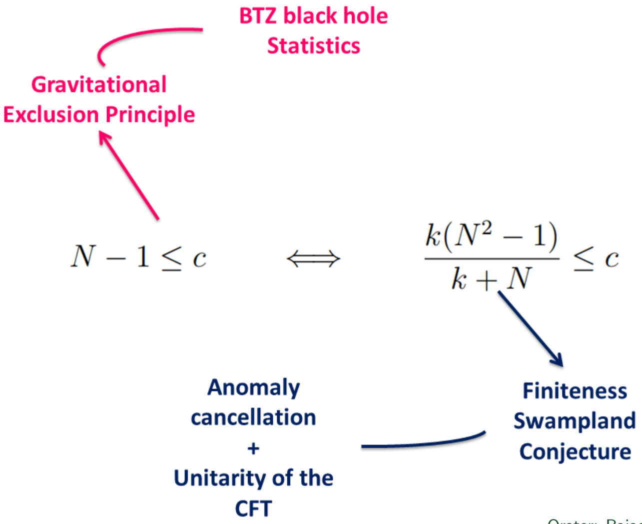
# Finiteness conjecture versus gravitational exclusion principle



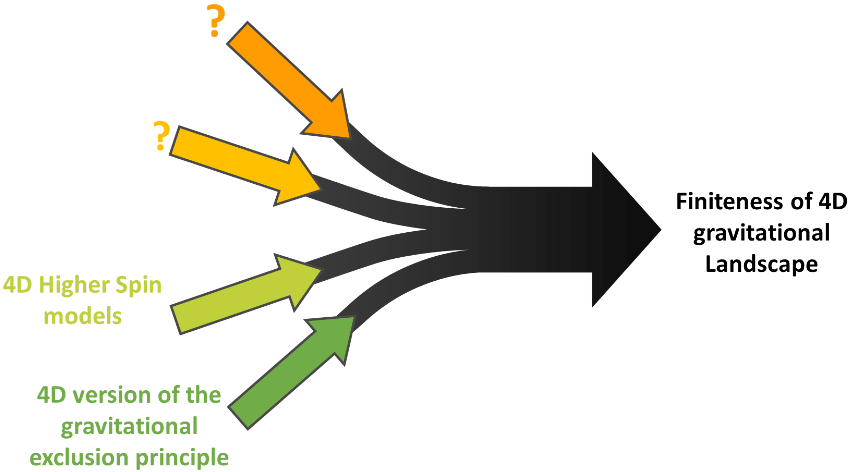
# Highest possible spin

The conjecture provide a bound not only on the number of massless fields but also on the highest spin allowed

$$s \leq N \leq f(c_L)$$

# Plan

# Future Directions




THANK
YOU!