(Higher-)spinning at the Edge of the Swampland

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Based on 2011.03583 and 2305.05693 w/ J. Calderón Infante (CERN)

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UHH Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

The Swampland

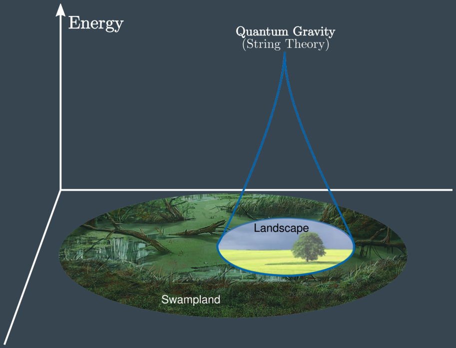
[Vafa '06]

Can all EFTs be completed to Quantum Gravity?

$\longrightarrow$ NO!

Swampland Programme:

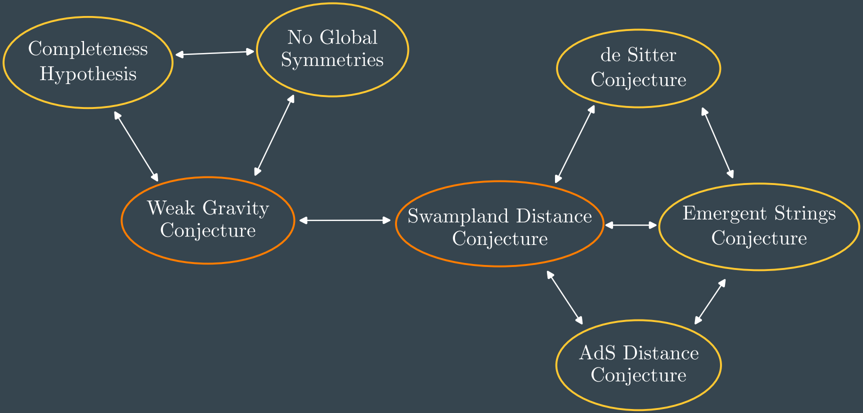
Find constraints EFTs must satisfy



[van Beest, Calderón Infante, Mirfendereski, Valenzuela '21]

Conjecturology

Motivated by string theory, but also by bottom-up approaches



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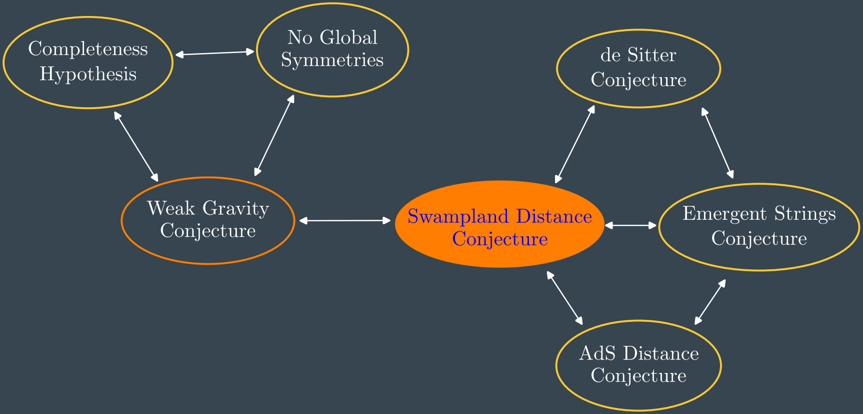
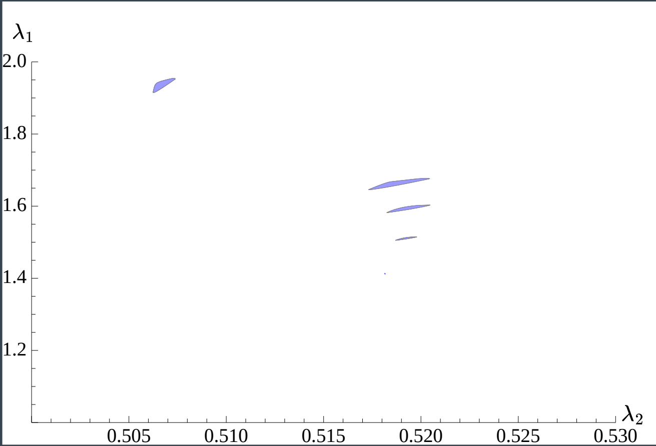


Ultimate Goal: understand the rules of QG



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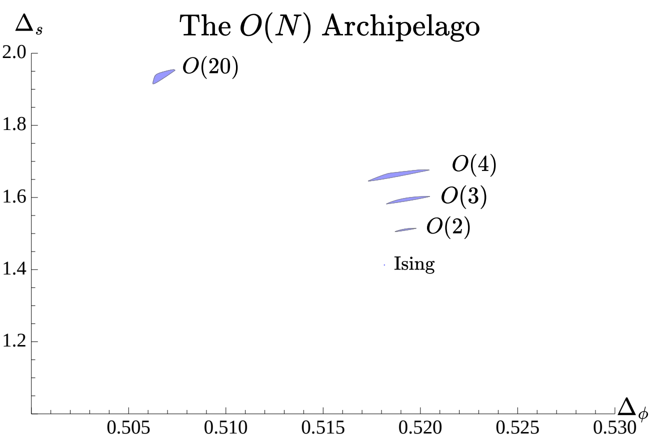

[Kos, Poland, Simmons-Duffin,Vichi'15]

In spirit, similar to the conformal bootstrap !

Holographic Swampland: take the comparison seriously

$$\text{QG in AdS} \quad \overset{\text{holography}}{\longleftrightarrow} \quad \text{Conformal Field theory}$$

Holographic Swampland: take the comparison seriously

$$\underbrace{\text{QG in AdS}}_{\text{HARD!}} \quad \overset{\text{holography}}{\longleftrightarrow} \quad \underbrace{\text{Conformal Field theory}}_{\text{well-defined framework}}$$

Holographic Swampland: take the comparison seriously

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Reformulate Swampland Conjectures, purely in terms of CFT data

Learn new things about CFTs

Backreact results, discover QG features !

The Swampland Distance Conjecture

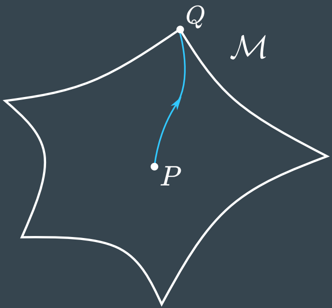
[Ooguri, Vafa '06]

Given a moduli space $\mathcal{M}$ param by $\langle \phi^i \rangle$

1) $\exists$ infinite tower of massless states at infinite-distance points

2) As dist$(P, Q) \to \infty$,

$$\frac{M_{\text{tower}}}{M_{\text{Pl}}} \sim e^{-\alpha_G \cdot \text{dist}}$$



ϕ^i massless

In flat space, well tested. What should it be holographically?

Holographic version of SDC

[FB, Calderón Infante'21]

see also [Perlmutter, Rastelli, Vafa, Valenzuela '21]

Via AdS/CFT

$$\Phi \text{ with } M \qquad \longleftrightarrow \qquad \mathcal{O} \text{ with } \Delta$$

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Via AdS/CFT

$$\Phi \text{ with } M \quad \longleftrightarrow \quad \mathcal{O} \text{ with } \Delta$$

$$m_\phi = 0 \quad \text{(moduli)} \quad \longleftrightarrow \quad \Delta_{\mathcal{O}} = d \quad \text{(marginal operator)}$$

$$(\mathcal{M}_{\text{mod}}\,, G_{ij}(\phi)) \quad \longleftrightarrow \quad (\mathcal{M}_{\text{CFT}}\,, \chi_{ij}(t))$$

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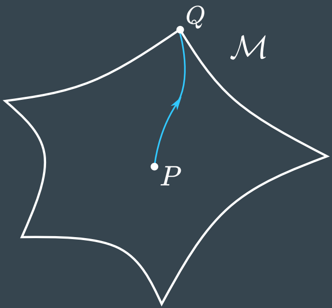

As $\text{dist}(P, Q) \to \infty$,

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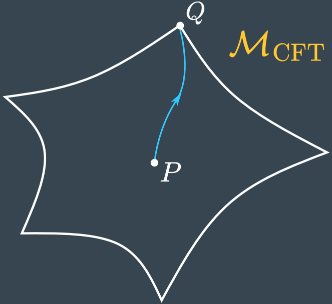
The CFT Distance Conjecture

Given a conformal manifold with marginal coupling t^i



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$d > 2$ $\quad \exists\, T_{\mu\nu}$

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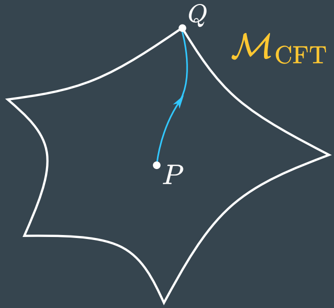

As dist$(P, Q) \to \infty$,

$$\gamma_{\text{tower}} = \Delta - \Delta_{\text{unitarity}} \sim e^{-\alpha \cdot \text{dist}}$$

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The CFT Distance Conjecture

Given a conformal manifold with marginal coupling t^i

1) HS point $\Rightarrow$ ∞ dist.

2) ∞ dist. $\Rightarrow$ HS point

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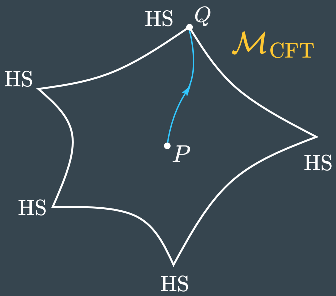

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(HS = higher spin)

Higher-spin Symmetry

higher-spin operators in the spectrum:

$$J_{\mu_1 \ldots \mu_\ell} \sim \bar{\phi}\, \partial_{\mu_1} \ldots \partial_{\mu_\ell} \phi - \text{(traces)}$$

NB: $J_{\mu\nu} = T_{\mu\nu}$

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Physically:

HS symmetry $\Leftrightarrow$ (partially-)free theory

$d = 3$: [Maldacena, Zhiboedov '11]

$d > 3$: [Boulanger, Ponomarev, Skvortsov, Taronna '13] [Alba, Diab '14]

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CFT Distance Conjecture:

$$\text{Infinite Distance} \quad \Leftrightarrow \quad \mathfrak{so}(d,2) \longrightarrow \mathfrak{hs}(d)$$

Status of the Conjecture

Note: Inspired by Swampland, but stands on its own

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CFTs are nice, so we can prove part of it!

$$\text{HS point} \quad \Rightarrow \quad \text{infinite distance}$$

[FB, Calderón Infante '23]

Lightning-speed sketch of the proof

[FB, Calderón Infante '23]

Technical, many details swept under the rug…

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Conformal Perturbation Theory

$$\frac{d\gamma}{dt} = -C_{JJO}(t)$$

t: Zamolodchikov dist.

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Broken HS identity

$$\partial \cdot J_\ell = g K_{\ell-1}$$

Small-parameter exp:

$$\gamma \sim g^2$$

$$C_{JJ\mathcal{O}}(g) = C^{\text{HS}}_{JJ\mathcal{O}} + g\, C^{\text{HS}}_{JK\mathcal{O}} + g^2\, C^{\text{HS}}_{KK\mathcal{O}} + \ldots$$

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At minimum:

$$\gamma \sim C_{JJO}$$

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Lightning-speed sketch of the proof

$$\frac{d\gamma}{dt} \sim -\gamma \qquad\qquad \gamma \sim e^{-t}$$

$$\gamma = 0 \quad \Rightarrow \quad t = \infty$$

HS points are at infinite Zamolodchikov distance!

Lightning-speed sketch of the proof

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HS points are at infinite Zamolodchikov distance!

note: only assumes $T_{\mu\nu}$ + unitarity

NO SUSY required!

Conclusions

CFT Distance Conjecture

1) HS points $\Rightarrow$ ∞-distance points
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2) HS points $\Leftarrow$ ∞-distance points ?
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Join us as we leave the Swampland behind to explore greener (conformal) pastures. . .

Thank you for your attention!