

# A Gravitino Distance Conjecture

Alvaro Herraiez

IPhT CEA/Saclay

Based on:

A. Castellano, A. Font, AH, L.E. Ibáñez [arXiv: 2104.10181]



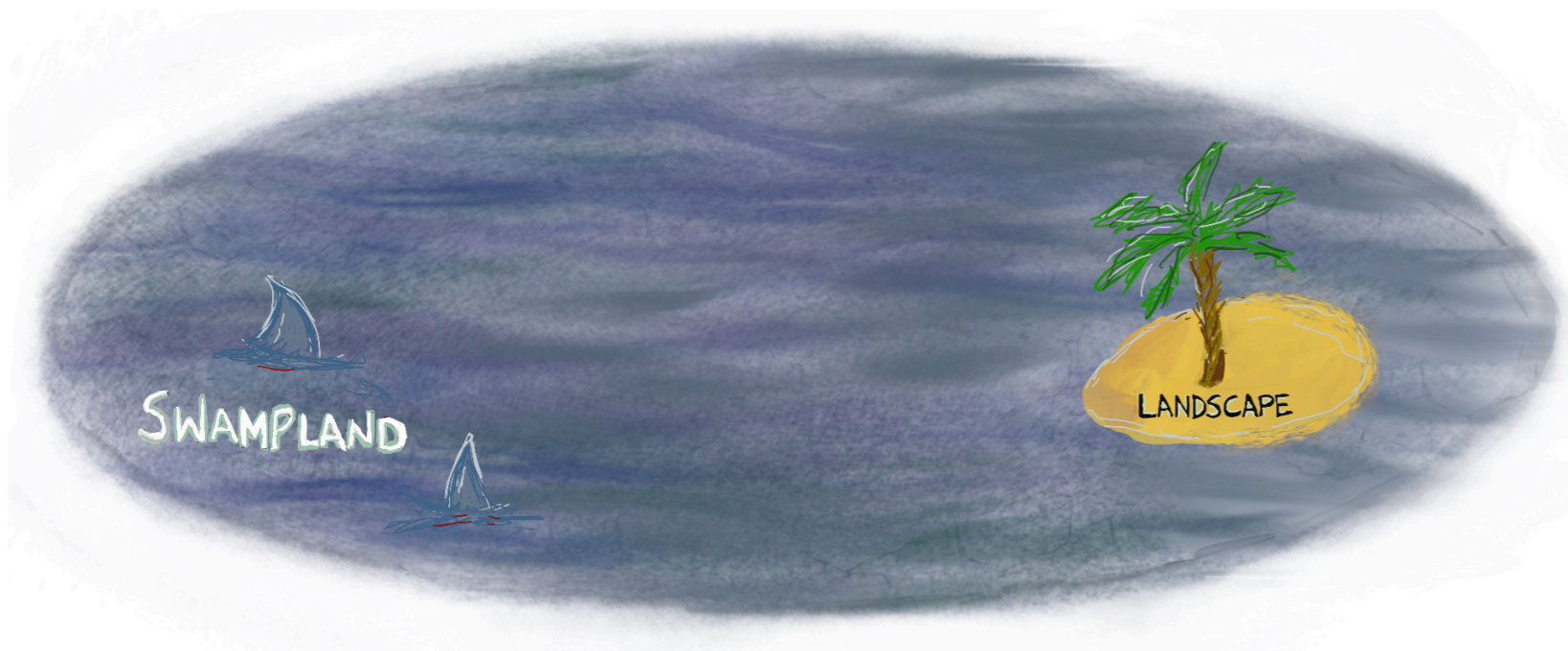
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# The Landscape vs the Swampland

- **String Landscape**  $\longrightarrow$  Naive expectation: Every EFT can be obtained from ST
- **Swampland**  $\longrightarrow$  Set of EFT that look consistent BUT cannot be consistently coupled to QG  
[Vafa '05]

Reviews: [Brennan, Carta, Vafa '17] [Palti '19]  
[van Beest, Calderón-Infante, Mirfendereski, Valenzuela '21]



## QUESTION:

What are the **general features** of all QG EFT?



**Quantum Gravity Conjectures**

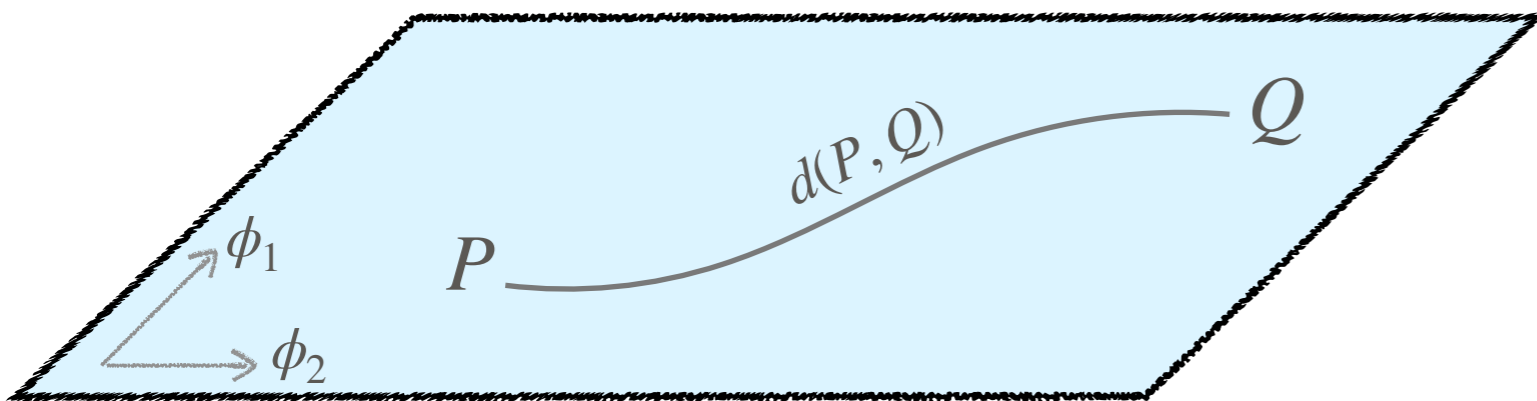
# The Swampland Distance Conjecture

[Ooguri, Vafa '06]

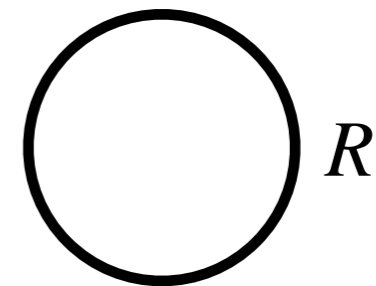
Starting from a point  $P$  in moduli space, and moving to a point  $Q$  an infinite distance away, there appears a tower of states which becomes exponentially massless according to

$$\frac{m(Q)}{M_p} \sim \frac{m(P)}{M_p} e^{-\alpha d(P,Q)}$$

Scalar manifold with metric  $g_{ij}(\phi_i)$  from kinetic terms



- Example: Compactification on a circle of radius



$R \rightarrow \infty$  Kaluza-Klein tower

$R \rightarrow 0$  Winding tower

# The AdS Distance Conjecture

[Lüst, Palti, Vafa '19]

- Generalize distance in moduli space to distance between arbitrary (tensor) field configurations  $\longrightarrow$  Generalized Distance Conjecture
- Apply it to AdS vacua with varying cosmological constant

Anti de-Sitter Distance Conjecture: In a theory of quantum gravity with cosmological constant  $\Lambda$  there exist a tower of states that becomes light in the limit  $\Lambda \rightarrow 0$ , whose masses behave as

$$\frac{m}{M_p} \sim \left| \frac{\Lambda}{M_p^2} \right|^\gamma$$

# Towers everywhere?

- There are many different directions in moduli space with associated towers.
- More generically, towers in many field configuration directions
- QUESTION: Is there any particular direction which particularly interesting to explore?
- Universal ingredient of low-energy (off-shell) supersymmetric effective actions  $\longrightarrow$  GRAVITINO(s)

# The Gravitino Distance Conjecture

[Cribiori, Lüst, Scalisi '21] [Castellano, Font, A.H., Ibáñez '21]

In a supersymmetric theory with a non-vanishing gravitino mass  $m_{3/2}$ , in the limit  $m_{3/2} \rightarrow 0$ , a tower of states becomes light according to

$$\frac{m_{\text{tower}}}{M_p} \sim \left( \frac{m_{3/2}}{M_p} \right)^\delta, \quad 0 < \delta \leq 1$$

[Focus on  $\mathcal{N} = 1$  supersymmetric theories here]

## DISCLAIMER:

- NO contradiction with exactly massless graviton mass (e.g. SUSY Minkowski vacua)
- Claim: massless case is NOT smoothly connected with massive case  $\longrightarrow$   
Infinite towers appear

# Evidence from relation to other conjectures

- Relation with AdS Distance Conjecture:

SUSY vacua:

$$\text{ADC} \longleftrightarrow \text{GDC}$$

$$\left. \begin{aligned} m_{3/2} &= e^{K/2} |W| \\ \Lambda &= -3e^K |W|^2 \end{aligned} \right\} \longrightarrow m_{\text{tower}} \sim m_{3/2}^\delta \sim |\Lambda|^{\delta/2} \longrightarrow \gamma = \frac{\delta}{2}$$

- Relation with Absence of (generalised) global symmetries:

$$T_{\text{mem}}^2 = 2e^K |W|^2 \sim e^2 Q_{\text{mem}}^2$$

$$m_{3/2} \rightarrow 0 \longrightarrow T_{\text{mem}} \rightarrow 0 \longrightarrow e \rightarrow 0 \longrightarrow \text{Symmetry becomes global}$$

$$\text{Magnetic WGC: } \Lambda_{UV} \lesssim e M_p \longrightarrow \text{Tower of states}$$

# Evidence from IIA toroidal compactifications

- $$m_{KK} \simeq m_{3/2}^{2/3}$$

# Evidence from IIA toroidal compactifications

- Type IIA Toroidal orientifold with fluxes

- Moduli  $\rightarrow$  S, T, U

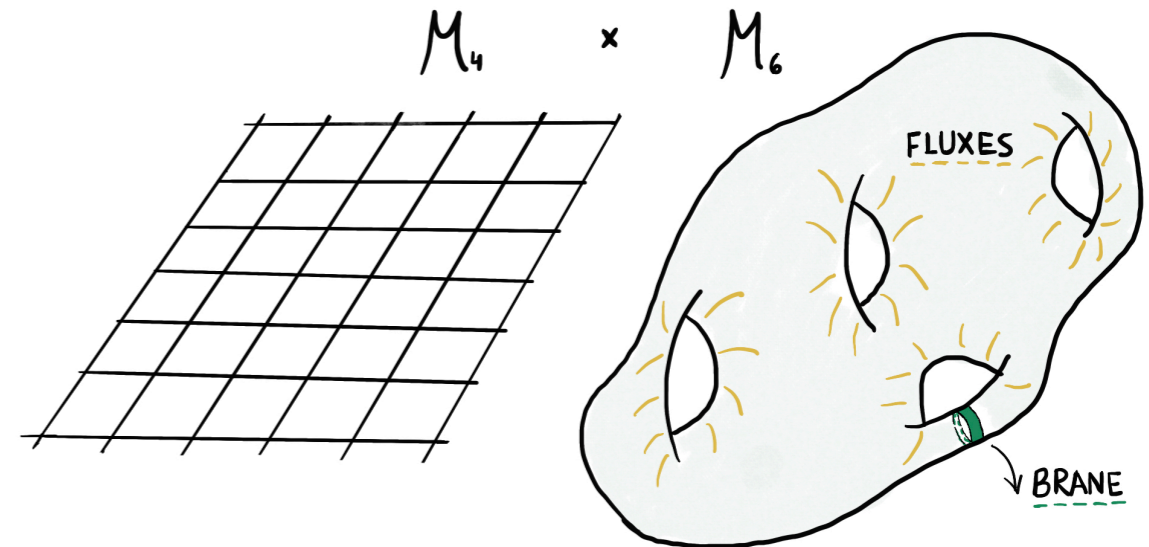
- Fluxes:      RR                      NSNS

$$F_0, F_2, F_4, F_6$$

$$H_3$$

$$(m, c, e, e_0)$$

$$(h_0, h)$$



- More generally:  $m_{3/2}^2 \sim \frac{(\text{tadpole})}{u^3} \rightarrow 1 \geq \delta \geq \frac{1}{3}$

- Relation with SDC ( $m_{3/2}^2 \rightarrow 0$  along flat directions)

$$m_{\text{tower}} = cm_{3/2}^\delta = c'e^{-\alpha d} \rightarrow \frac{\alpha}{\delta} = -\frac{\log(m_{3/2})}{d} \rightarrow \alpha = \sqrt{\frac{3}{2}}\delta$$

$$\rightarrow \alpha \geq \sqrt{\frac{1}{6}} \text{ for CY}_3$$

[Andriot, Cribiori, Erkiner '20]

[Gendler, Valenzuela '20]

[Bastian, Grimm,  
van de Heisteeg '20]

# Evidence at the limits of moduli space

- Asymptotic Hodge Theory  $\longrightarrow$  Limiting Mixed Hodge Structures

[Cattani, Deligne, Griffiths, Schmid, Kaplan...]  
[Grimm et al. '18-'21]

Introducing a growth sector (an ordering of divergent moduli):

$$\mathcal{R}_{1,2,\dots,\hat{n}} = \left\{ T^j = t^j + ib^j \mid \frac{t^1}{t^2} > \gamma, \frac{t^2}{t^3} > \gamma, \dots, \frac{t^{\hat{n}-1}}{t^{\hat{n}}} > \gamma, t^{\hat{n}} > \gamma, b^j < \delta \right\}_{\gamma \gg 1, \delta > 1}$$

Allows us to extract the leading behaviour of some quantities such as W and K

$$\frac{m_{3/2}}{M_P} = \frac{T_{\text{mem}}}{M_P^3} \simeq \frac{T_0}{M_P^3} \rho_{\mathbf{r}}(\mathbf{q}_{\mathbf{r}}, b^i) \underbrace{(t^1)^{\frac{r_1}{2}}}_{\text{Axions, charges (fluxes) FINITE}} \underbrace{(t^2)^{\frac{r_2-r_1}{2}} \dots (t^{\hat{n}})^{\frac{r_{\hat{n}}-r_{\hat{n}-1}}{2}}}_{\text{Saxions DIVERGENT}}$$

BOUNDED INTEGERS  
(Bound depends on singularity type)

$$\frac{m_{3/2}}{M_P} \geq \frac{T_{\text{mem}}}{M_P^3} \geq \frac{T_0 \rho_{\mathbf{r}}}{M_P^3} (t^1)^{\frac{r_{\min}}{2}} \xrightarrow{T_{\text{string}}^1 \simeq \frac{d_1}{2t^1}} \left( \frac{m_{3/2}}{M_P} \right)^{\frac{1}{|r_{\min}|}} \gtrsim \frac{(T_{\text{string}}^1)^{1/2}}{M_P} \simeq \frac{m_{\text{tower}}}{M_P}$$

A string becomes tensionless in the limit  $\longrightarrow$  stringy tower

[Lee, Lerche, Weigand '19] [Lanza, Marchesano, Martucci, Valenzuela '20 '21]

# Evidence at the limits of moduli space

$$\frac{m_{3/2}}{M_p} \geq \frac{T_{\text{mem}}}{M_p^3} \geq \frac{T_0 \rho_{\mathbf{r}}}{M_p^3} (t^1)^{\frac{r_{\min}}{2}} \xrightarrow{T_{\text{string}}^1 \simeq \frac{d_1}{2t^1}} \left( \frac{m_{3/2}}{M_p} \right)^{\frac{1}{|r_{\min}|}} \gtrsim \frac{(T_{\text{string}}^1)^{1/2}}{M_p} \simeq \frac{m_{\text{tower}}}{M_p}$$

- General bounds on  $\delta$ :

$$1 \geq \delta \geq \frac{1}{|r_{\min}|} \quad \left\{ \begin{array}{l} \delta \geq \frac{1}{3} \quad \text{for CY}_3 \\ \delta \geq \frac{1}{4} \quad \text{for CY}_4 \end{array} \right.$$

- Generalize relation between SDC and GDC parameters

$$\frac{\alpha}{\delta} = -\frac{\log(m_{3/2})}{d} \longrightarrow \frac{|r_{\min}|}{\sqrt{2d_1}} \geq \frac{\alpha}{\delta} \geq \frac{|r_{\min}|}{\sqrt{2d_{\hat{n}}}} \longrightarrow \alpha \geq \sqrt{\frac{1}{6}} \quad \text{for CY}_3$$

[Andriot, Cribiori, Erkiner '20]

[Gendler, Valenzuela '20]

[Bastian, Grimm, van de Heisteeg '20]

# Conclusions and Outlook

- Lots of towers in the Swampland  $\longrightarrow$  Focus on the limit  $m_{3/2}^2 \rightarrow 0 \longrightarrow$  GDC
- Evidence from:
  - Relation to AdS Distance Conjecture, Weak Gravity Conjecture and Swampland Distance Conjecture
  - Toroidal orientifold models
  - Asymptotic limits of moduli space: relation to tensionless strings / membranes
- Bounds for  $\delta \geq \frac{1}{n}$  for  $CY_n$
- Things to do:
  - Study more models (see e.g. [Antoniadis, Bachas, Lewellen, Tomaras '88] , [Coudarchet, Dudas, Partouche '21])
  - Phenomenological implications: Towers at SUSY breaking scale

**MERCI BEAUCOUP!**