HermannFest
The sound of symmetry
Potsdam 13/09/2022

Supergravity and the Swampland

Gianguido Dall'Agata

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Supergravity and the Swampland

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together with
N. Cribiori, M. Emelin, F. Farakos and M. Morittu

Hermann (& me)

- *No paper together, but*

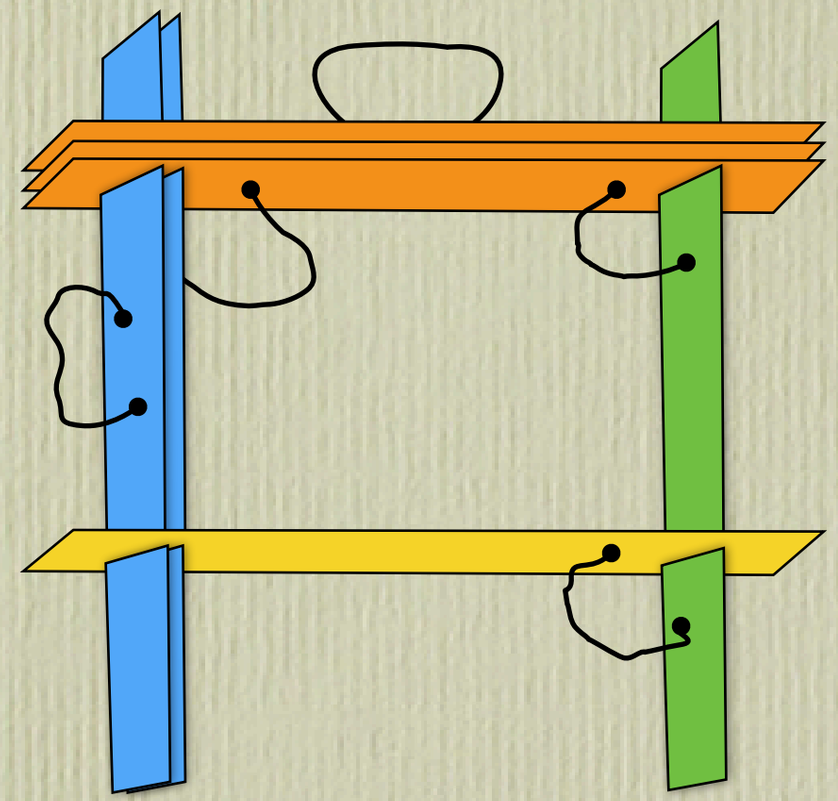
  1/4 of my work based on his

- ***Galileo*** *"Io stimo più il trovar un vero, benché di cosa leggiera, che 'l disputar lungamente delle massime questioni senza conseguir verità nissuna"*

- *I'll focus on a tool and a theory Hermann pioneered extracting some simple physical truths:*

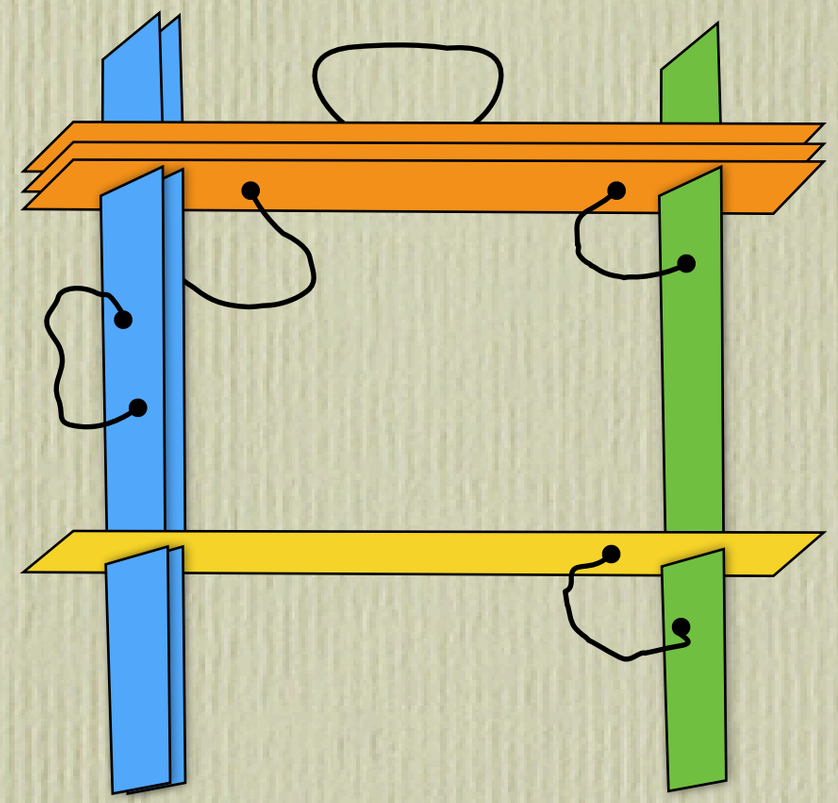
the embedding tensor, supergravity *& the Swampland*

String Phenomenology



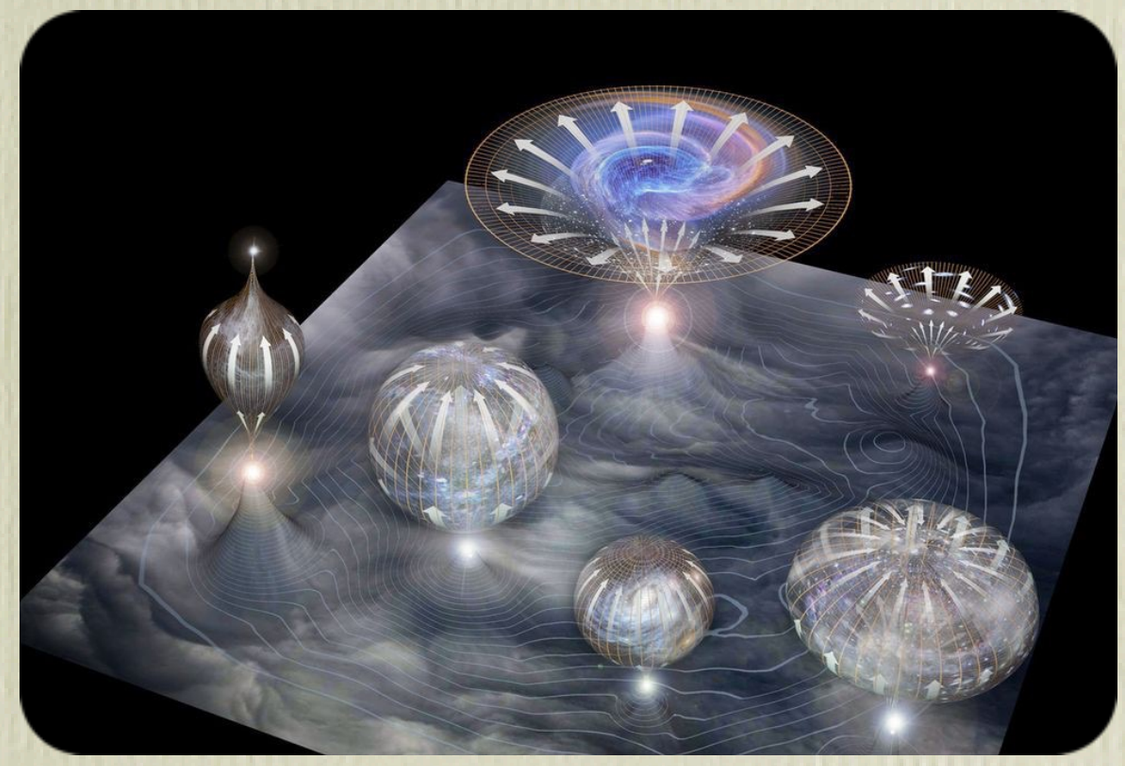
From constructive scenarios...

String Phenomenology

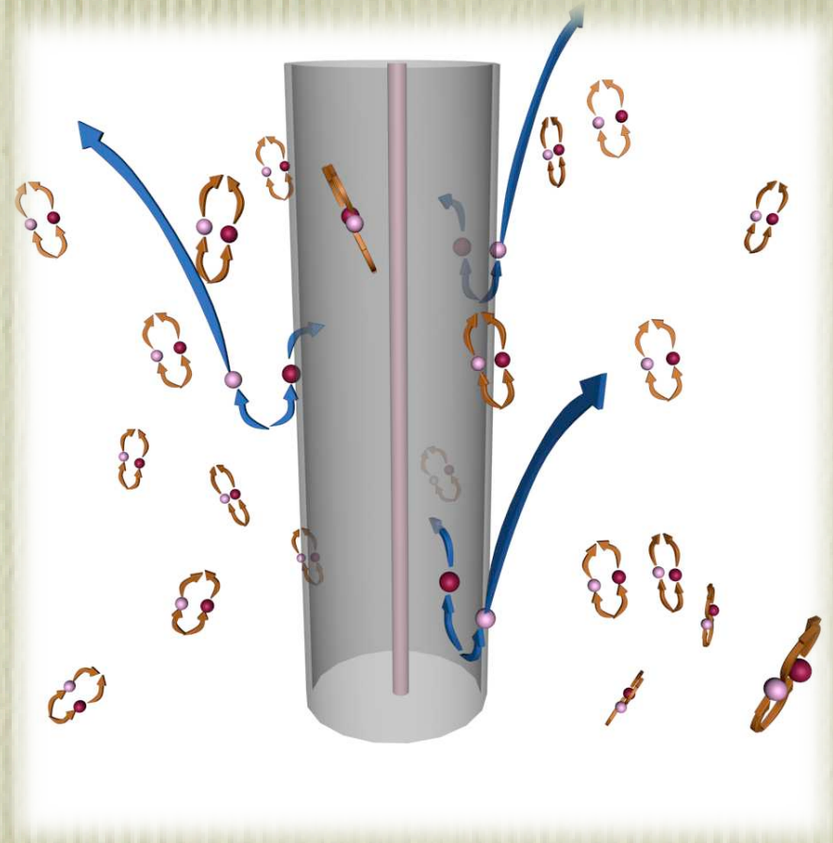


From constructive scenarios...

... to the swampland program



The Weak Gravity Conjecture

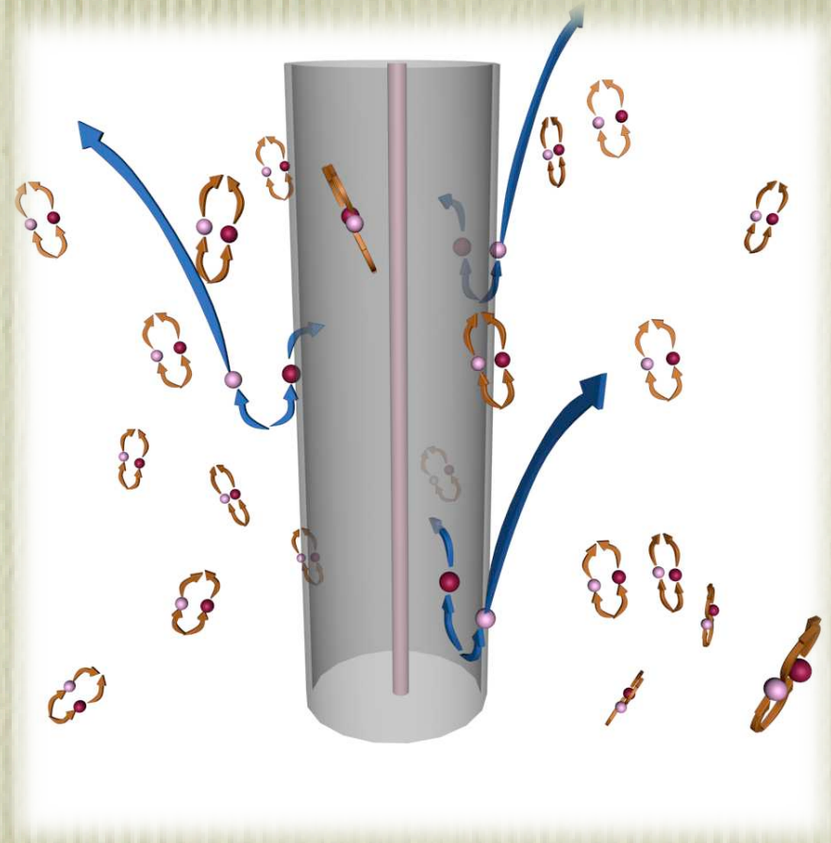


Consistency of the black hole discharge process

$$M_{BH} = Q_{BH}$$

$$M_{BH} - m \geq Q_{BH} - q \qquad m \leq q$$

The Weak Gravity Conjecture



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Electric: there exists a particle satisfying $m \leq g\, q\, M_P$

The Weak Gravity Conjecture

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For the magnetic dual, we get a constraint on the magnetic monopole mass

$$\frac{\Lambda}{g^2} \leq m_m \leq \frac{M_P}{g}$$

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$$\frac{\Lambda}{g^2} \leq m_m \leq \frac{M_P}{g}$$

Magnetic: the cutoff scale Λ *of the EFT is bounded as*

$$\Lambda \leq g\, M_P$$

.

Our progress:

Swampland constraints on dS and scale separation

Cribiori,GD, Emelin, Farakos, Morittu

Magnetic-WGC constraints

Charact.: Gravitino mass,

gauge group,...

Use only ***supergravity***

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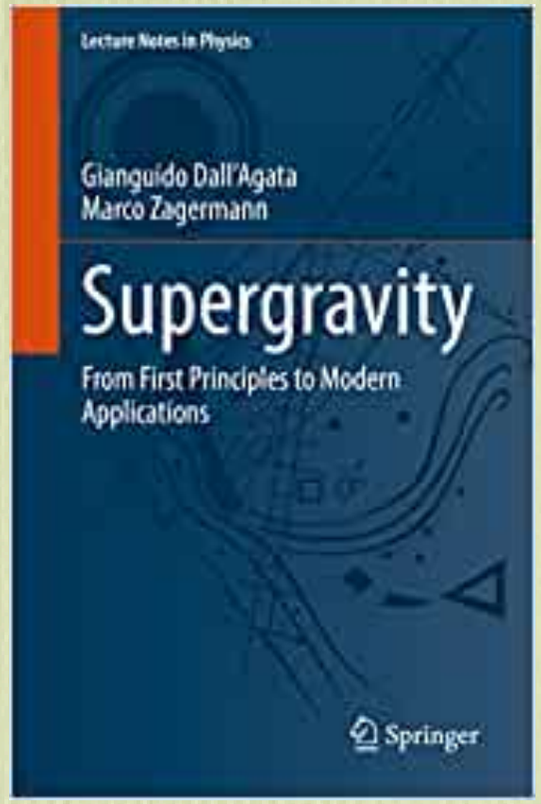
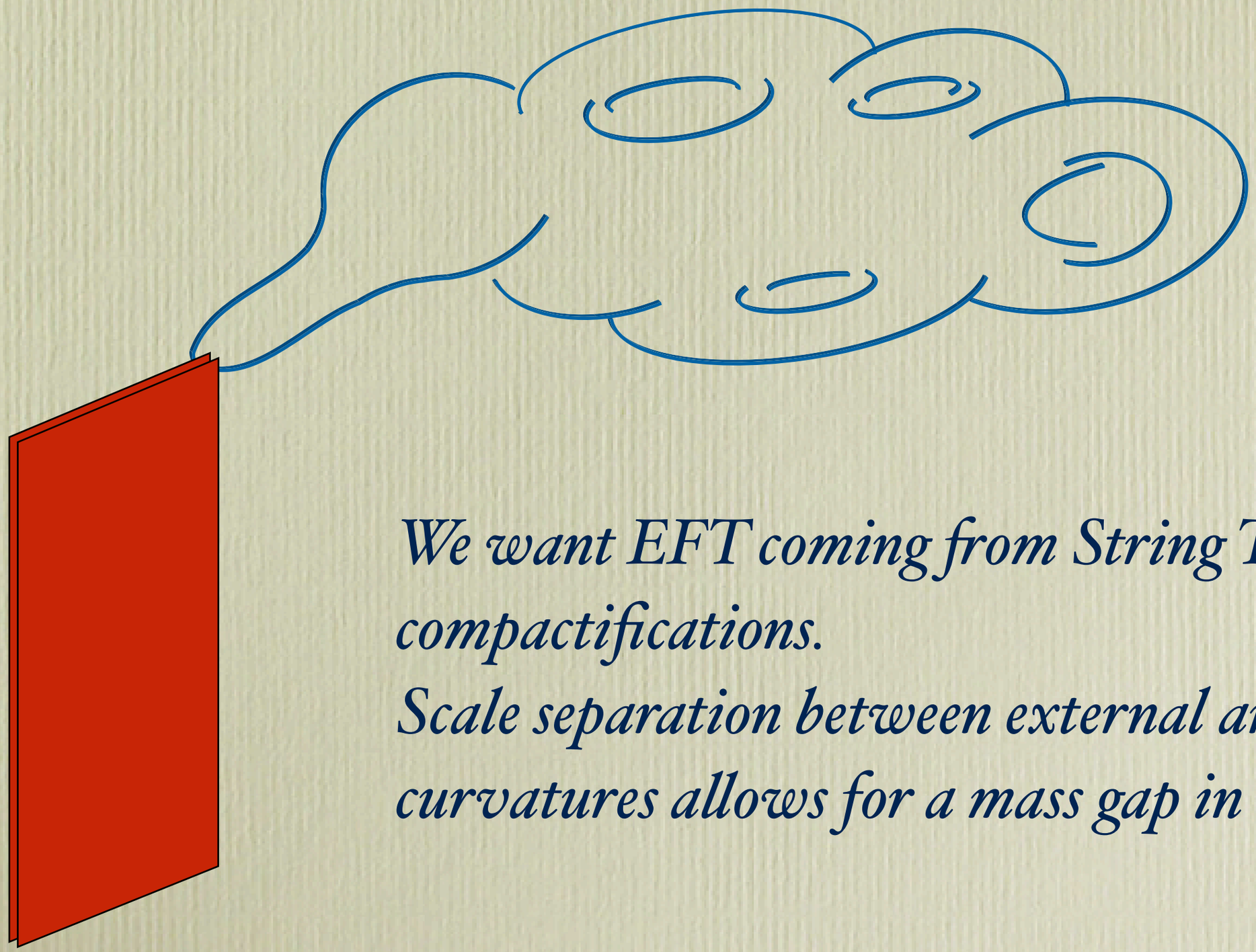


Weak Gravity vs. Scale Separation

Scale Separation: EFT vs truncations



We want EFT coming from String Theory compactifications.

Scale separation between external and internal curvatures allows for a mass gap in the spectrum

Magnetic WGC: The cutoff scale Λ_{UV} of the effective theory is bounded by the gauge coupling

$$\Lambda_{UV} \lesssim g\, M_P$$

Arkani-Hamed, Motl, Nicolis, Vafa; Huang, Li, Song; Antoniadis, Benakli

If we look for AdS Kaluza–Klein reductions

$$\Lambda_{UV} \sim \Lambda_{KK}$$

Scale separation requires

$$R_{AdS} \gg R_{KK} \quad \Rightarrow \quad \frac{1}{R_{AdS}^2} \sim |V_{crit}| \ll \Lambda_{KK}^2 \sim \frac{1}{R_{KK}^2}$$

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Scale separation requires

$$|V_{crit}| \ll \Lambda_{UV}^2 \leq g^2 M_P^2$$

We find that generic AdS vacua of gauged sugra have

$$|V_{crit}|^{1/2} \sim g\, q_{3/2} M_P$$

GD,Cribiori

- *Work in N=2 general matter coupled sugra*
  - Scalar geometry = ***Special–Kähler*** (vectors) + ***Quaternionic–Kähler*** (hypers)
  - Encoded in

- *Sections* $V = \left(L^\Lambda, M_\Lambda\right) \equiv e^{K/2}\ \left(X^\Lambda, F_\Lambda\right)$
- Kähler potential: $K = -\log\, i\left(\bar{X}^\Lambda F_\Lambda - X^\Lambda \bar{F}_\Lambda\right)$

- *Vector* and ***hyper*** *isometries*: $k^I_\Lambda(z)$ $k^u_\Lambda(q)$
- and ***prepotentials***: $P^0_\Lambda(z,\bar{z})$, $P^x_\Lambda(z,\bar{z})$, $x = 1,2,3.$

GD,Cribiori

- *Work in N=2 general matter coupled sugra*
  - Potential from (*electric*) gauging:

$$\mathscr{V} = \mathscr{V}_{D_1} + \mathscr{V}_{D_2} + \mathscr{V}_F$$

$$\mathscr{V}_{D_1} = |\bar{L}^\Lambda k^I_\Lambda|^2 = |D_I L^\Lambda P^0_\Lambda|^2$$

Non. Abelian vector gauging

$$\mathscr{V}_{D_2} = 4\,|\bar{L}^\Lambda k^u_\Lambda|^2$$

Hyper gauging

$$\mathscr{V}_F = \left(g^{I\bar{J}} D_I L^\Lambda \overline{D}_{\bar{J}} \bar{L}^\Sigma - 3\, L^\Lambda \bar{L}^\Sigma \right) P^x_\Lambda P^x_\Sigma$$

Hyper gauging + Fayet–Iliopoulos terms

- **Gravitino mass matrix**: $m_{3/2\,ij} = i\, L^\Lambda P^x_\Lambda\, (\sigma^x)_{ij}$

- *Fully supersymmetric AdS vacua:*

$$\mathscr{V}\,|_* = 3\mathscr{J}^{\Lambda\Sigma}\,Tr\,\left(\mathcal{Q}_\Lambda\mathcal{Q}_\Sigma\right) < 0$$

- *where, introducing the U(1) Gauge vector* $v_m = A_m^{\parallel}$

$$D_m\psi_{nA} = \ldots + i\,g\,v_m\,q_A{}^B\,\psi_{nB} + i\,A_m^{\perp}\,\mathcal{Q}_{\perp\,A}{}^B\,\psi_{nB}$$

$$e^{-1}\mathscr{L}_{kin.} = \frac{1}{4}\;F_{mn}(v)F^{mn}(v) + \frac{1}{4}\;\mathscr{J}_\perp F^{\perp}_{mn}F^{\perp mn}$$

- *Fully supersymmetric AdS vacua:*

$$\mathscr{V}\,|_* = 3\mathscr{F}^{\Lambda\Sigma}\,Tr\left(\mathcal{Q}^{\parallel}_{\Lambda}\mathcal{Q}^{\parallel}_{\Sigma} + \mathcal{Q}^{\perp}_{\Lambda}\mathcal{Q}^{\perp}_{\Sigma}\right) \leq -\,3\,g^2\,Tr(q^2)$$

- *Hence*

- *Fully supersymmetric AdS vacua:*

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- *Hence*

$$|\mathscr{V}\,| \geq 3\,g^2\,Tr(q^2) \geq Tr(q^2)\;\Lambda^2_{UV}$$

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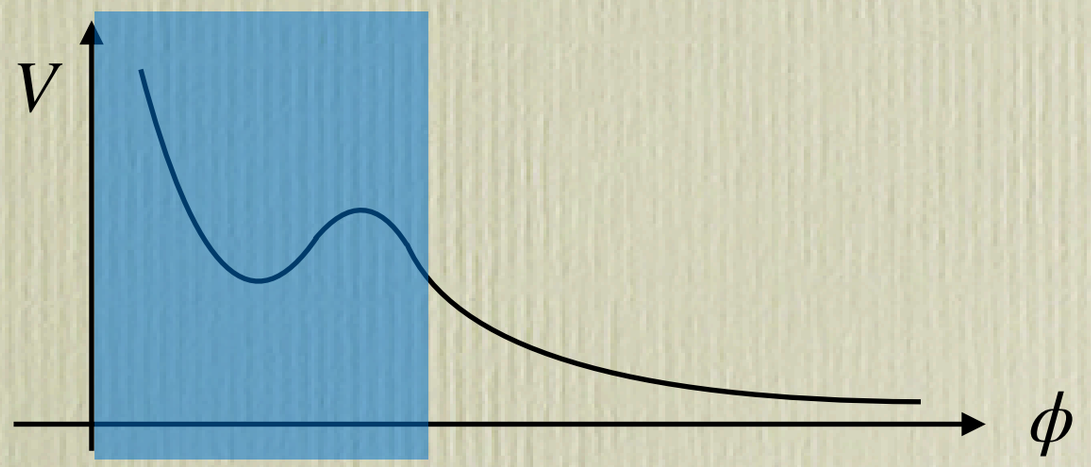
In the Swampland!

Weak Gravity vs. De Sitter

dS Landscape in Supergravity

- ***dS** critical points of extended supergravities are **sparse at best*** Fre, Trigiante, Van Proeyen
- ***Uplifts** to String Theory only for models **without scale separation***
- ***Generic Dine–Seiberg problem***



- ***Swampland criteria** (de Sitter, Transplanckian Censorship,...)*

- **Swampland** conjectures **challenge** the survival of supergravity de Sitter vacua

- *dS conjecture* Ooguri, Palti, Shiu, Vafa

$$|\nabla V| \geq \frac{c}{M_P} V \qquad \text{or} \qquad \min\left(\nabla_i \nabla_j V\right) \leq -\frac{c'}{M_P^2} V$$

- Surviving critical points challenged by other swampland conjectures
(TPCC, SSWGC, Festina-Lente, ***Magnetic-WGC***)

Gravity + U(1)

Cribiori,GD,Farakos

$$e^{-1}\mathscr{L} = \frac{1}{2} M_P^2 R - \frac{1}{4g^2} F_{mn}F^{mn} - 3H^2M_P^2 + \dots \,,$$

+ charged matter $\partial_m\chi + i\,q\,A_m\,\chi\,, \qquad q \in \mathbb{Z}$

as **effective theory**

$$e^{-1}\mathscr{L}_{grav.} = M_P^2\left(\frac{1}{2}R + \frac{\alpha}{\Lambda_{\rm UV}^2}R^2 + \cdots\right)$$

On de Sitter $R = 12H^2 \gg R^2/\Lambda_{UV}^2$

Consistency: $H \ll \Lambda_{UV}$

Magnetic WGC: The cutoff scale Λ_{UV} of the effective theory is bounded by the gauge coupling

$$\Lambda_{UV} \lesssim g\, M_P$$

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Consistency bound:

$$H \ll g\, M_P$$

Cribiori,GD,Farakos

What we find:

- ***large classes have*** $H \sim g\, q_{3/2}\, M_P$
- ***Parametrically light gravitini in the Swampland***

GD, EMELIN, FARAKOS, MORITTU

- *Example: de Sitter in N=2 general matter coupled sugra*

  - When $m_{3/2\,ij} = i\,L^{\Lambda} P^{x}_{\Lambda} (\sigma^{x})_{ij} = 0$ and ψ^{i}_{m} are ***charged*** under a U(1) with charge q:

$$\mathscr{V} = \mathrm{Tr}\left(Q^2\right) + 4\left|\bar{L}^{\Lambda} k^{u}_{\Lambda}\right|^2 \geq q^2$$

$$H = \sqrt{\frac{\mathscr{V}}{3}} \quad \geq \quad \frac{q}{\sqrt{3}} \simeq \frac{\Lambda_{UV}}{\sqrt{3}}$$

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In the swampland!

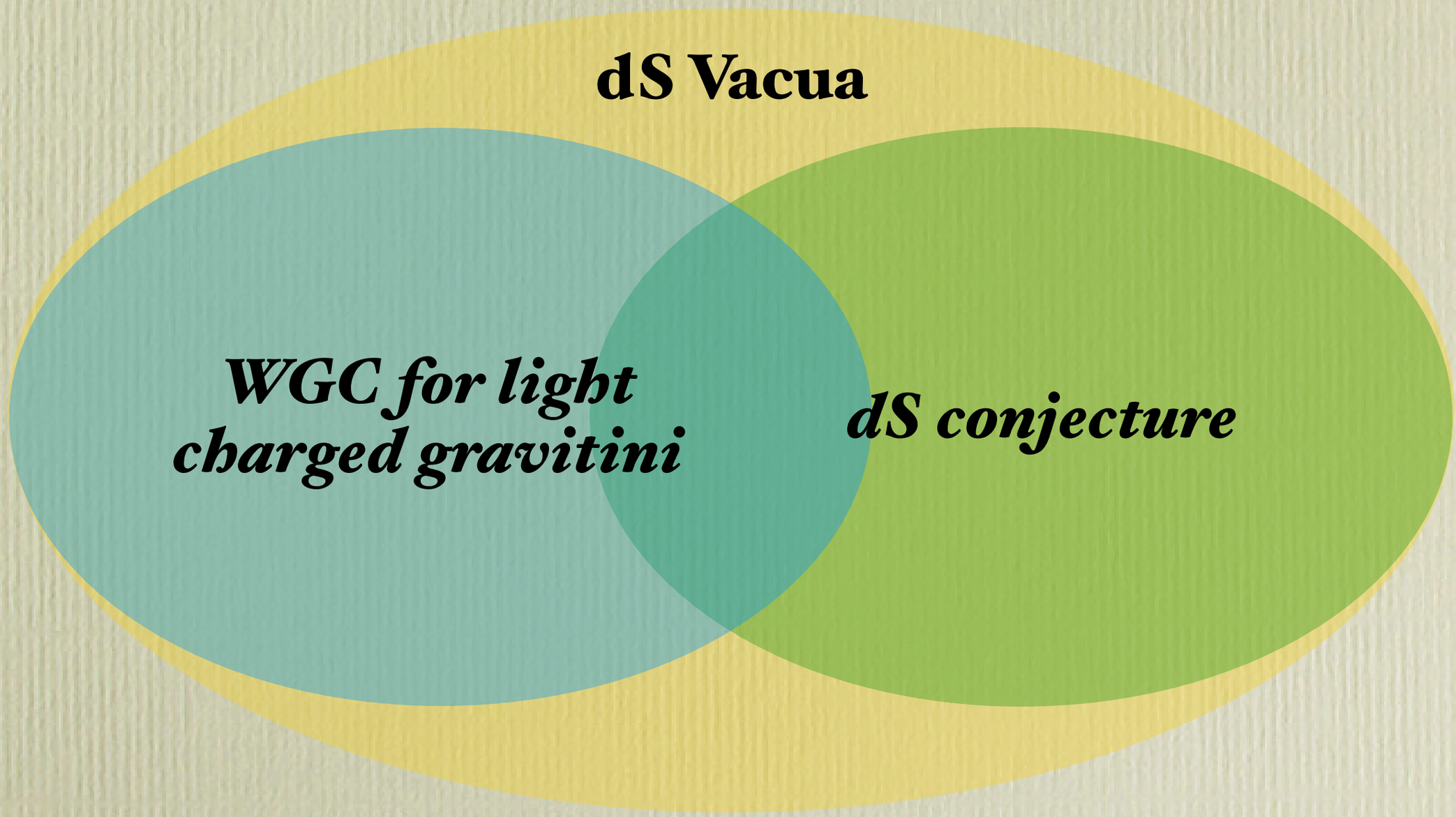
GD, Emelin, Farakos, Morittu

- ***General result:***
  - ***Massless charged gravitini*** *w.r.t.* ***Abelian*** *residual gauge groups in gauged sugra put* ***ANY*** *de Sitter critical point in the swampland*

- *Direct proofs:* N=1 D-terms, N=2, N=8
- *WGC enough* (no need of dS conjectures)
- Large variety of examples of models within this class
- Proof of existence of models outside

Weak Gravity vs. De Sitter

GD, Emelin, Farakos, Morittu



Summarizing:

Small progress, but precise and consistent results on the consequences of Swampland criteria in Supergravity:

Scale separation severely constrained

de Sitter vacua even more challenging than expected

sparse landscape, characterization still uncertain

Parametrically light charged gravitini are in the swampland