

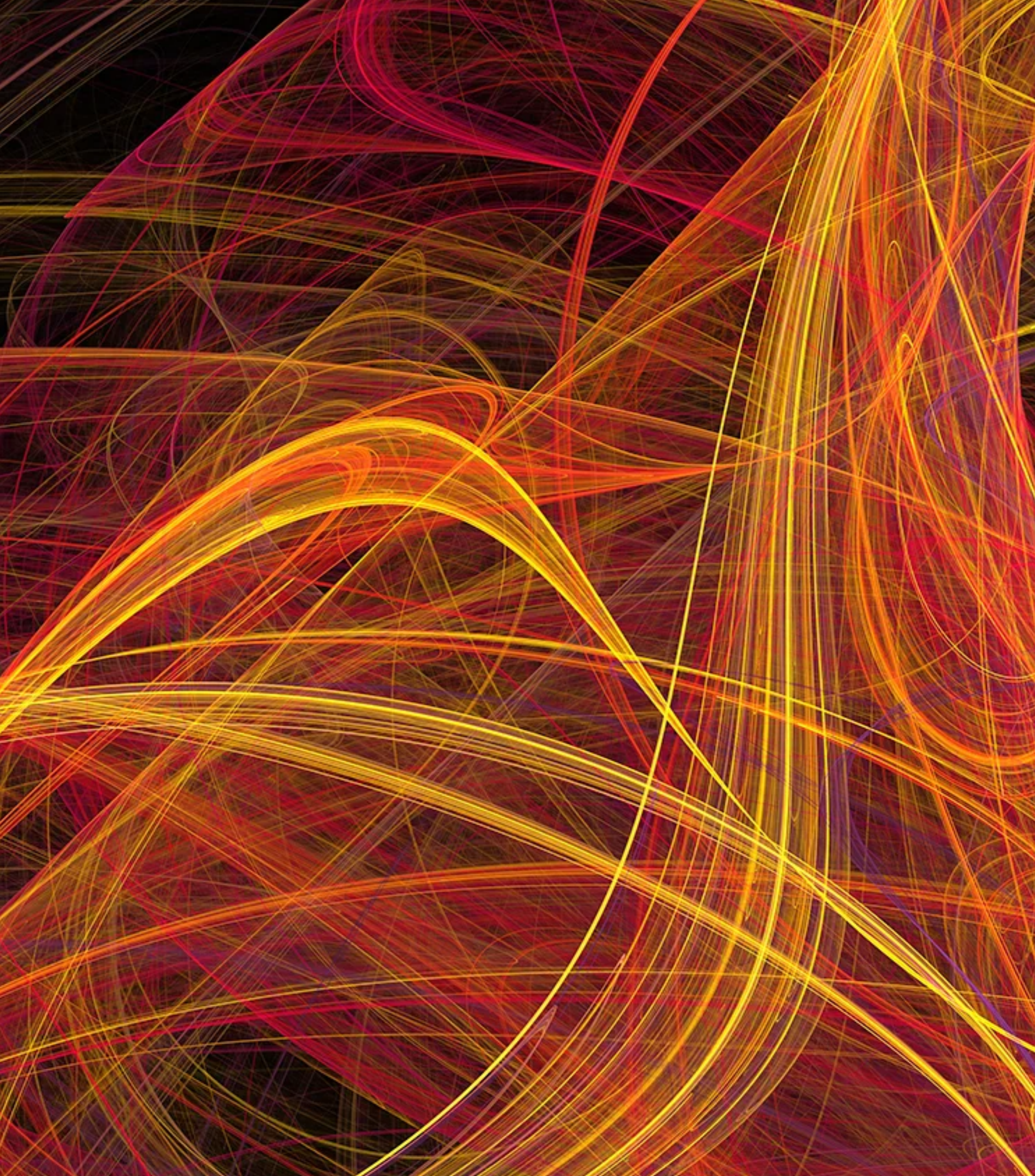


NON-SUPERSYMMETRIC STRINGS

Ivano Basile | UMONS

the good, the bad, and the swamp





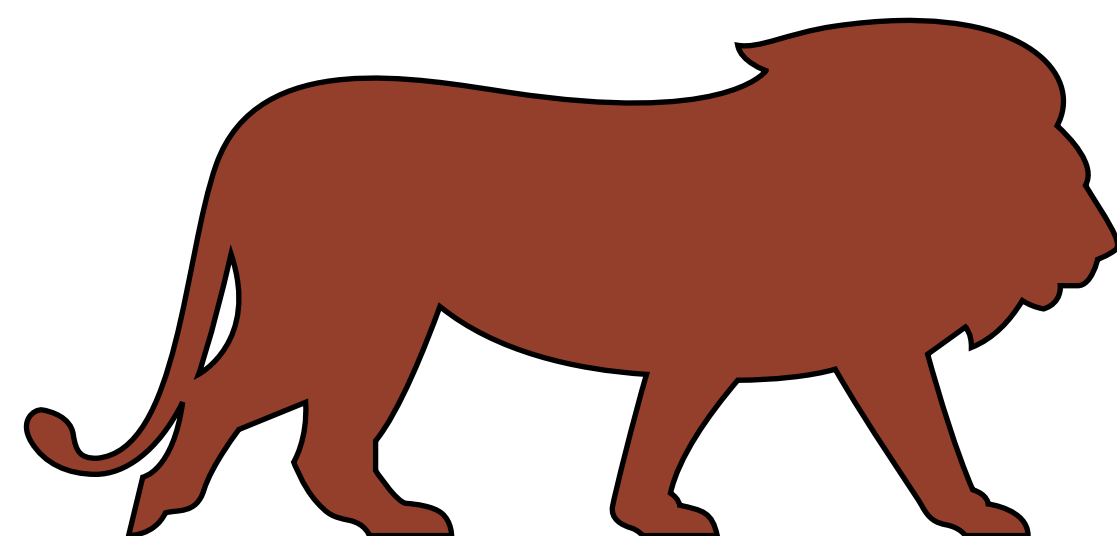
BREAKING SUSY IN STRING THEORY

- the good: *controlled metastable vacua*
- the bad: *instabilities everywhere*
- the swamp:
 - *no scale separation*
 - *no de Sitter*
 - *WGC*
 - *SDC, ADC, ...*



“the pheno”: *de Sitter braneworlds?*

here be lions

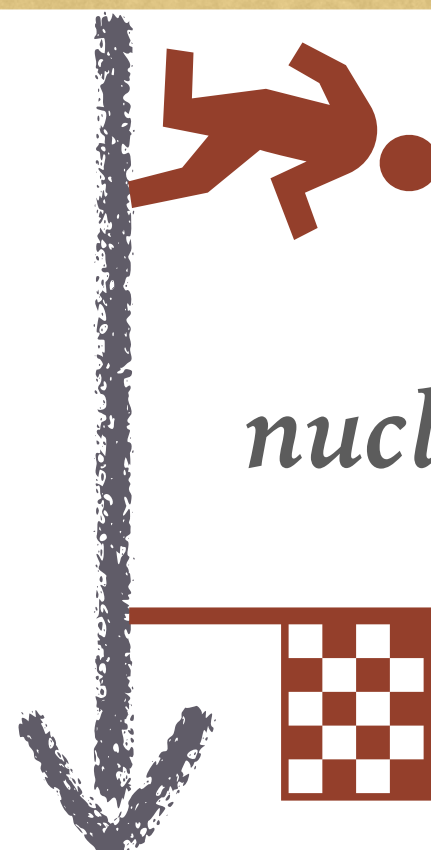


swampland...

breaking SUSY

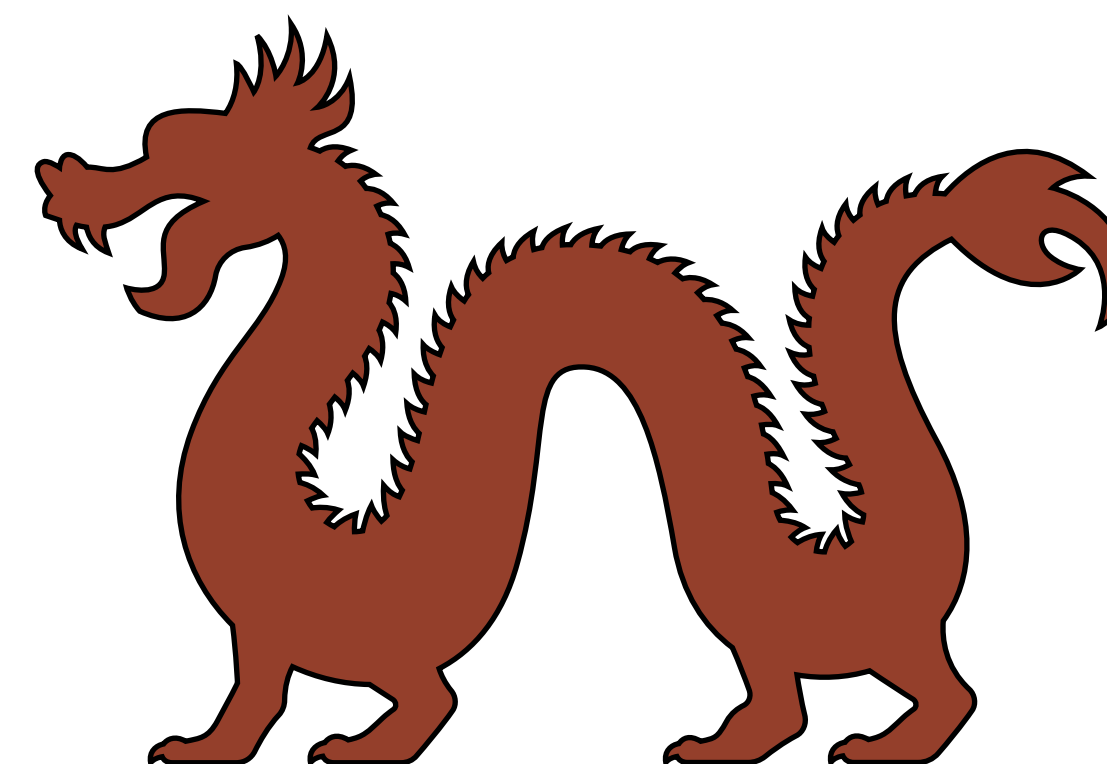
instabilities

nucleation



phenomenology?

here be dragons



...constraints

THE SWAMP PT. 0 — BREAKING SUSY

SUSY-breaking scale undetermined:

- *naïvely: string scale*
- *in EFT: becomes unwieldy*

$$m_{3/2} \rightarrow 0$$



∞ tower of light states

cf. Castellano's talk!

Remarkable finiteness properties

- *misaligned SUSY*

cf. Tonioni's talk!

Worldsheet tools

- *modular invariance*
- *spinor-vector dualities*

cf. talks by Matyas, Percival & Sethi!

conclusion:

break SUSY @ string scale

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...conspiracy or swampland?



(Cribiori, Lüst, Scalisi, 2021)

(Castellano, Font, Herráez, Ibáñez, 2021)

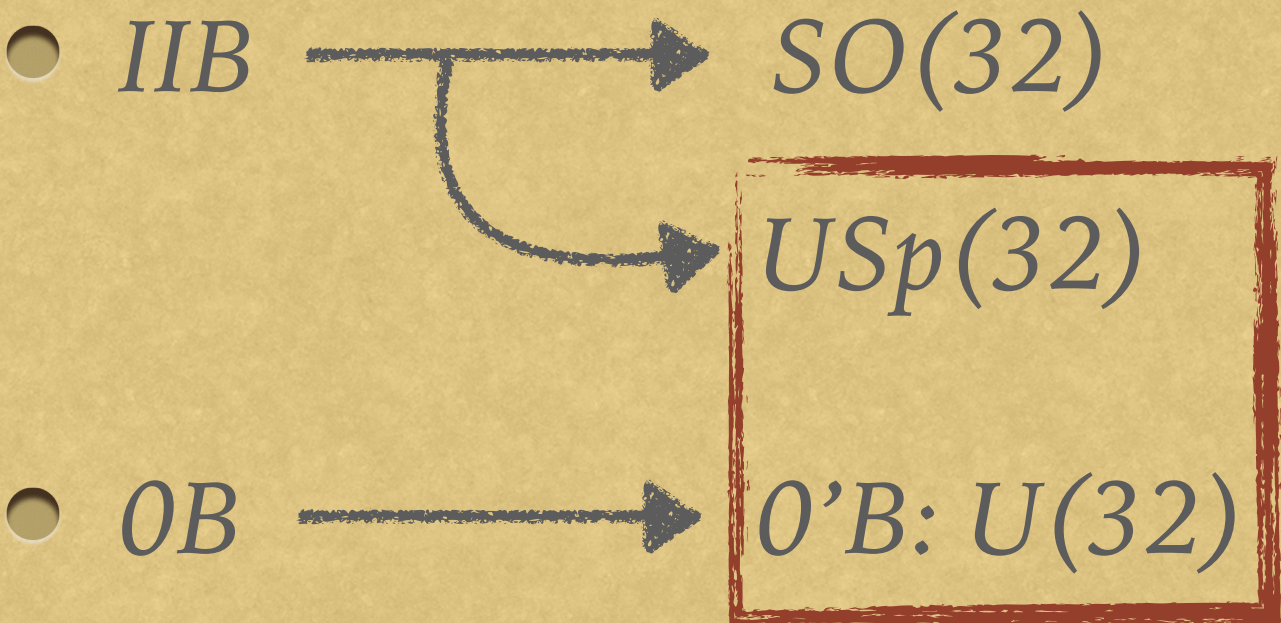
(Dall'Agata, Emelin, Farakos, Morittu, 2021)

conclusion:

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BREAKING SUSY — BEYOND EFT

➤ orientifold models: IIB or 0B

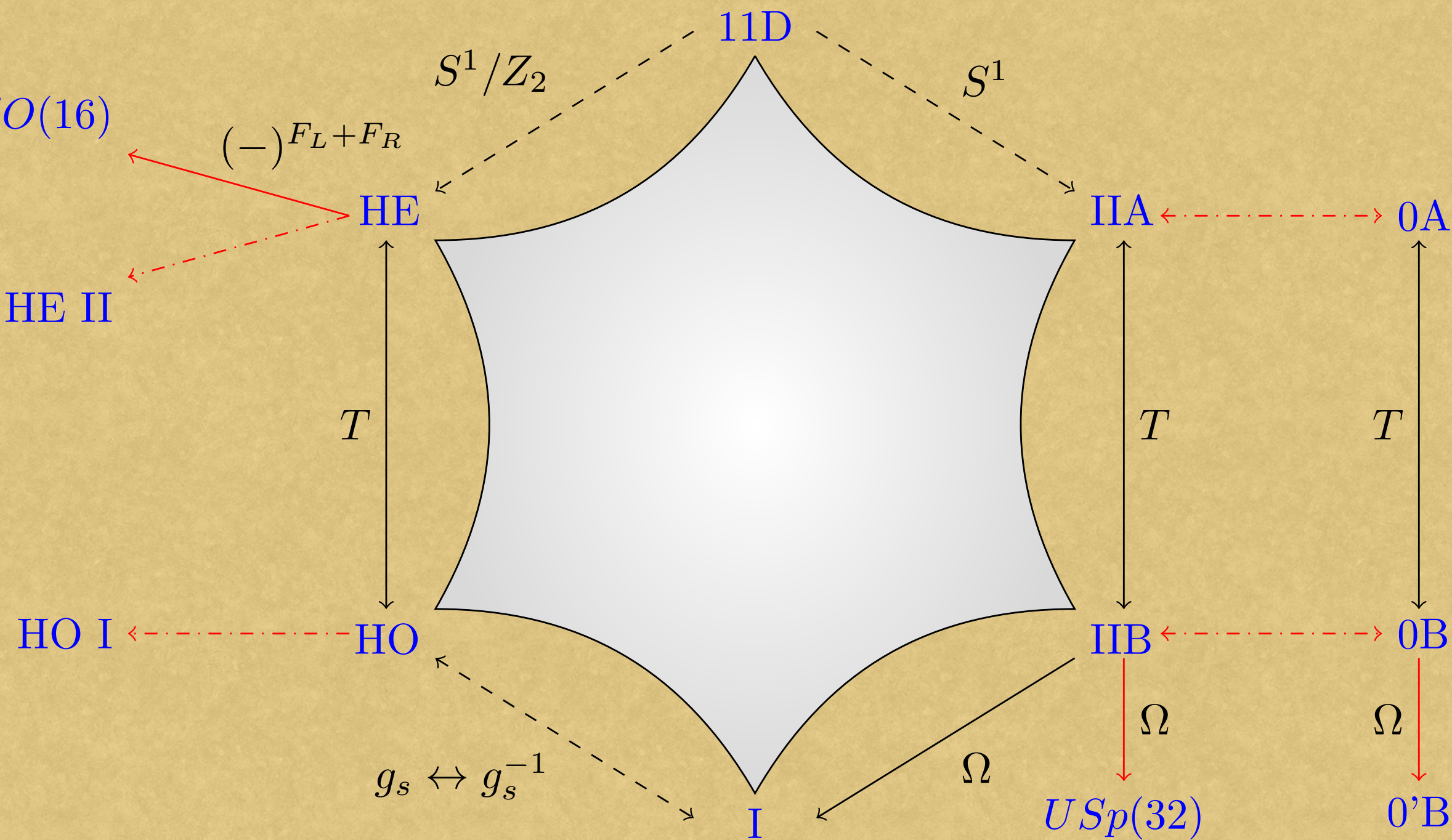


tension: $2k_{10}^2 (32 T_{\overline{D9}} + T_{O9}) = \frac{16}{\pi^2 \alpha'} e^{-\phi}$

➤ heterotic model: $E_8 \times E_8$



vacuum energy: $2k_{10}^2 \Lambda_{1-loop} = \frac{\mathcal{O}(1)}{\alpha'}$



effective potential: $e^{\gamma \phi} \quad \gamma = \frac{3}{2}, \frac{5}{2}$

LOW-ENERGY EFFECTIVE DESCRIPTION

$$\mathcal{L}_{10d} = R - \frac{1}{2} (\partial\phi)^2 - \frac{1}{12} e^{\alpha\phi} |H_3|^2 - \boxed{V_0 e^{\gamma\phi}}$$

- $D1, D5$ in orientifolds, $\alpha = 1$
- $NS5$ in heterotic, $\alpha = -1$

SUSY breaking tadpole

+ $D3, D7$ in $O'B$
rest is uncharged

alternative: stringy effective potential?

(Angelantonj, Florakis, 2013) (Abel, Dienes, 2021) (Abel, IB, to appear)

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*positive potential.
maybe de Sitter...?*



THE SWAMP PT. 1 — DE SITTER NO-GO

generalize classic no-go theorem including tadpole

(Maldacena, Nuñez, 2000) (IB, Lanza, 2020) (see also Sethi's talk)

$$\Lambda_X = \left(1 - (q-1)\frac{\gamma}{\alpha}\right) \int_Y \star_Y e^{2cu + \gamma\phi}$$

always < 0 ! precise obstruction predicted by dS conjecture

(Obied, Ooguri, Spodyneiko, Vafa, 2018) (...many others)

$$|\nabla V|_{V>0} \geq \mathcal{O}(1) V$$

$$\mathcal{M}_{10} = X_{10-q} \times_u Y_q$$
$$ds_{10}^2 = e^{2u(y)} ds_X^2 + ds_Y^2(y)$$

me: $V > 0$, maybe dS?
string theory:

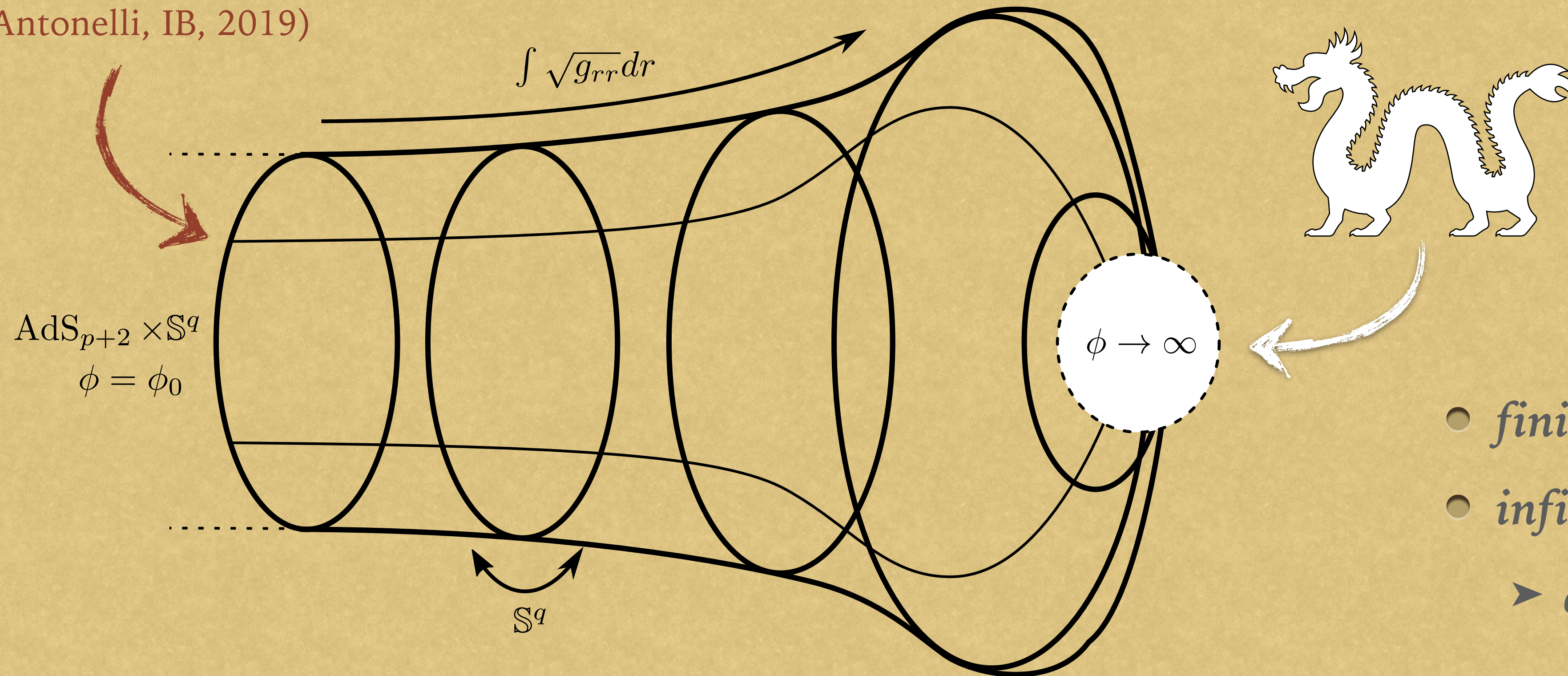


NEXT ATTEMPT... USING BRANES

$SO(1,p) \times SO(q)$ symmetry + flux

$$N_{el} = \int_{S^7} \star e^\phi H_3 \quad \text{orientifolds}$$
$$N_{mag} = \int_{S^3} H_3 \quad \text{heterotic}$$

(Antonelli, IB, 2019)



- *finite spacetime distance*
- *infinite field distance*
- *dynamical cobordisms*

(IFT group, 2021-2022)

cf. talks by Angius, Makridou, Huertas, Delgado & Calderón-Infante!

(Blumenhagen, Cribiori, Kneissl, Makridou, 2022)

THE GOOD — CONTROLLED ADS VACUA

near-horizon limit of branes:

simple Freund-Rubin vacua

$AdS_3 \times \mathcal{M}_7$ orientifolds

(Mourad, Sagnotti, 2016)

$AdS_7 \times \mathcal{M}_3$ heterotic

$$\alpha' R^2 \sim N^{\frac{3}{8}} \gg 1 \quad g_s \sim N^{-\frac{1}{4}} \ll 1$$

$$\alpha' R^2 \sim N^{\frac{5}{4}} \gg 1 \quad g_s \sim N^{-\frac{1}{2}} \ll 1$$

good stuff:

- *no moduli*
- *single discrete parameter*
- *parametric control*

bad stuff:

- *no scale separation*
- *unstable*

(more on that later)

THE SWAMP PT. 2 — NO SCALE SEPARATION

$$AdS \times \mathcal{M} \longrightarrow \boxed{R \sim L_{AdS}}$$

maybe 3 fluxes?
 $AdS_3 \times S^3 \times S^3 \times S^1$
cf. Sethi's talk!

is it an accident? can we cheat to get scale separation?

► try heterotic $AdS_4 \times \mathcal{M}_3 \times \mathcal{N}_3$

$$n_1 = \int_{\mathcal{M}_3} H_3$$

$\ll$

$$n_2 = \int_{\mathcal{N}_3} H_3$$

“inverse” scale separation!

$$L_{AdS} \sim R_1 \sim \left(\frac{n_1}{n_2} \right)^{\frac{1}{3}} R_2 \ll R_2$$

cf. talks by Cribiori, Wiesner, Van Riet, Andriot & Prieto!

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...conspiracy or swampland?



(Gautason, Schillo, Van Riet, Williams, 2015)

(Lüst, Palti, Vafa, 2019) (Lüst, Tsimpis, 2020)

(Apers, Montero, Van Riet, Wrase, 2022)

(Lüst, Vafa, Wiesner, Xu, 2022) (...)

THE BAD — INSTABILITIES

perturbative: BF bound violations

(IB, Mourad, Sagnotti, 2018)

orientifolds

- $\ell = 2, 3, 4$ on $AdS_3 \times S^7$
 - couldn't find easy fix :(

heterotic

- $\ell = 1$ on $AdS_7 \times S^3$
 - $S^3/\mathbb{Z}_2$ stable!

any Einstein works...

➤ Laplace spectrum hard

non-perturbative: brane nucleation

(IB, Antonelli, 2019)

$$\log \Gamma \sim \begin{cases} -\sqrt{N} & \text{orientifolds} \\ -N^4 & \text{heterotic} \end{cases}$$

consistency: fixes brane tension

$$g_s^{-1-\alpha_s/2}$$

requires $v_0(\gamma, \alpha) > 1$

THE SWAMP PT. 3 — WEAK GRAVITY CONJECTURE

microscopic intuition:

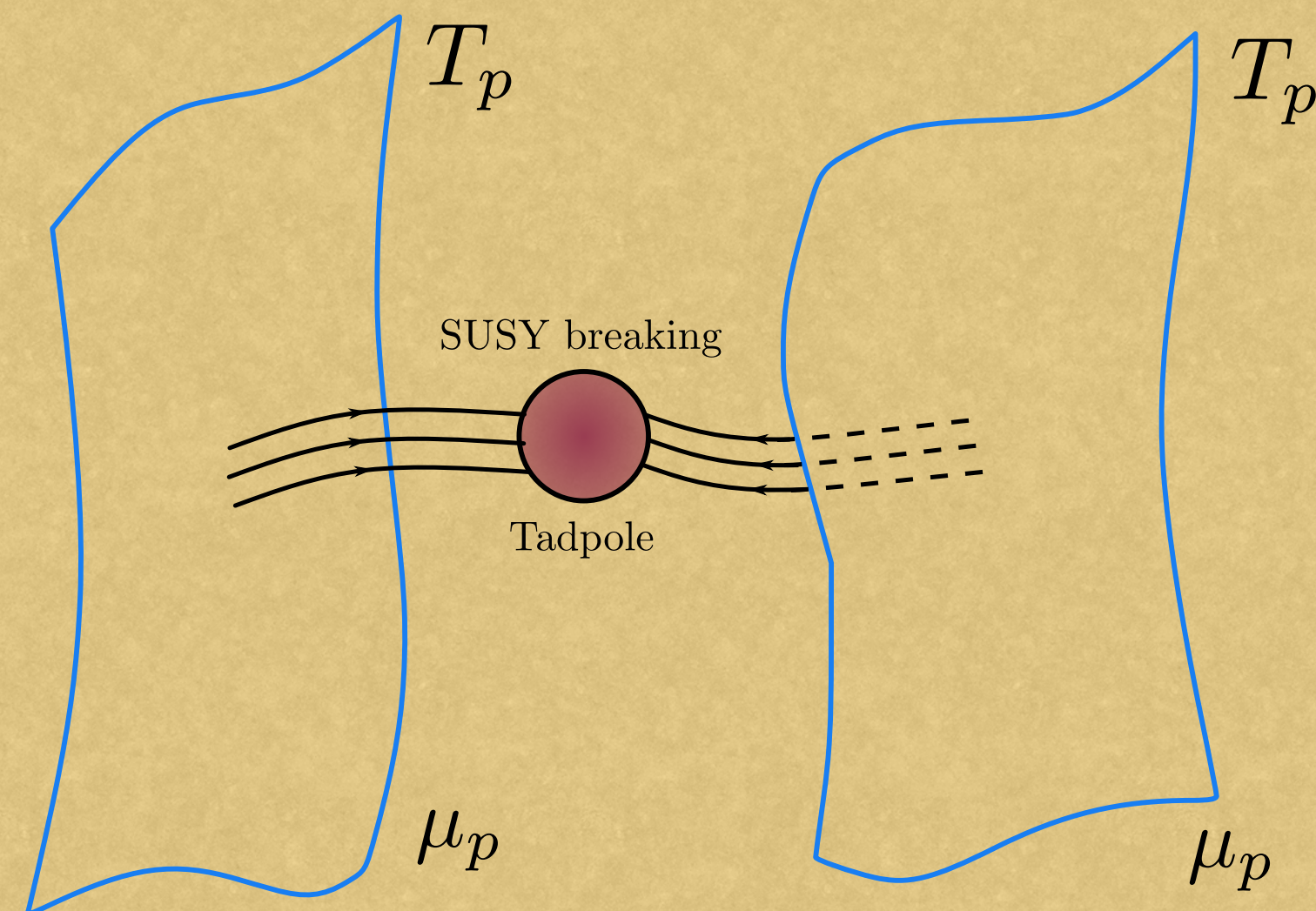
➤ *nucleation from brane repulsion*

(IB, Antonelli, 2019) (IB, 2021)

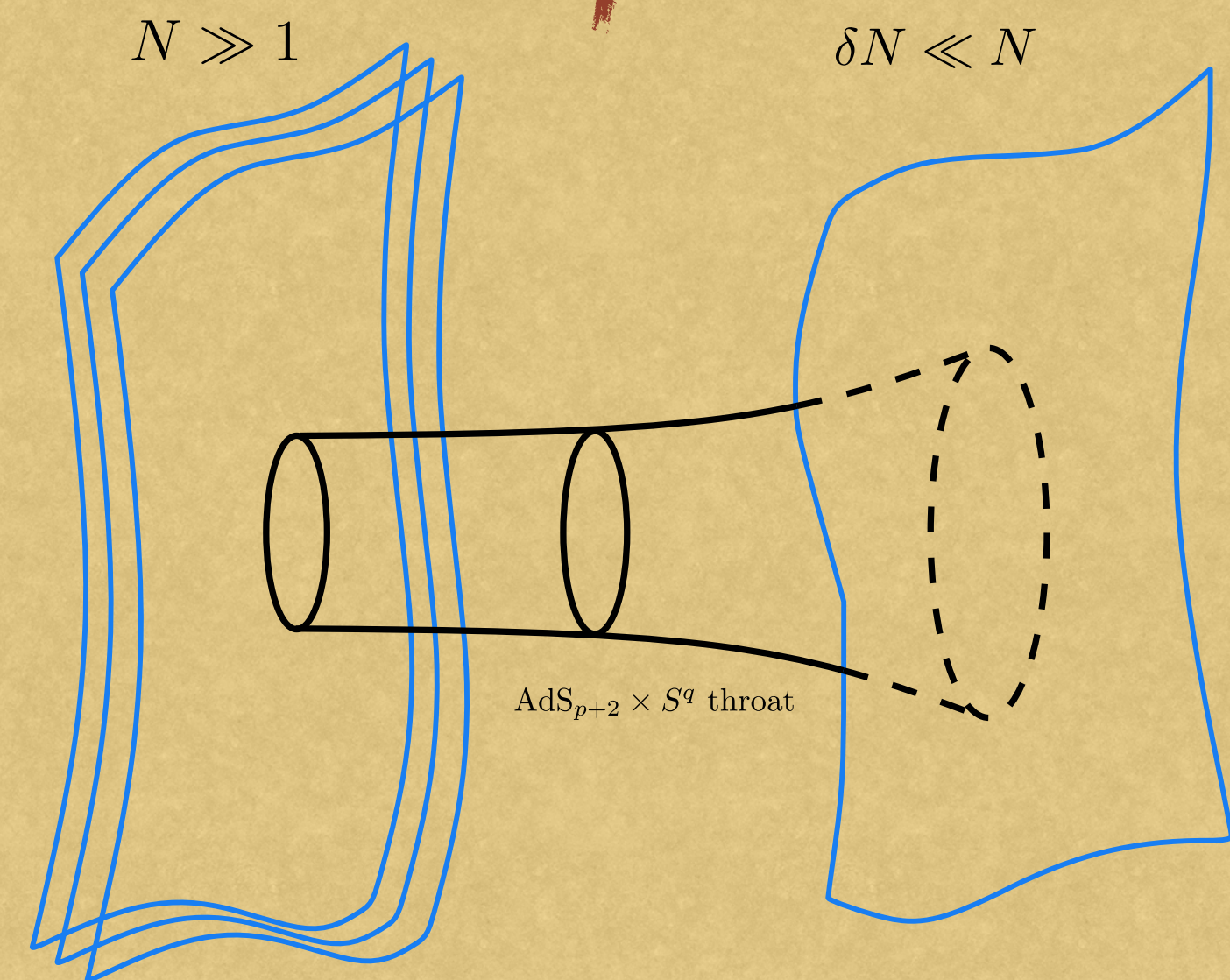
$$V_{p-p}(r) = T_p L_{AdS}^{p+1} \left(1 \pm \boxed{v_0(\gamma, \alpha)} \frac{\mu_p}{T_p} \right) e^{\frac{(p+1)}{L_{AdS}} r}$$

same as decay!

$$v_0 = \sqrt{\frac{3}{2}}, \sqrt{\frac{5}{3}} > 1 \quad \checkmark$$



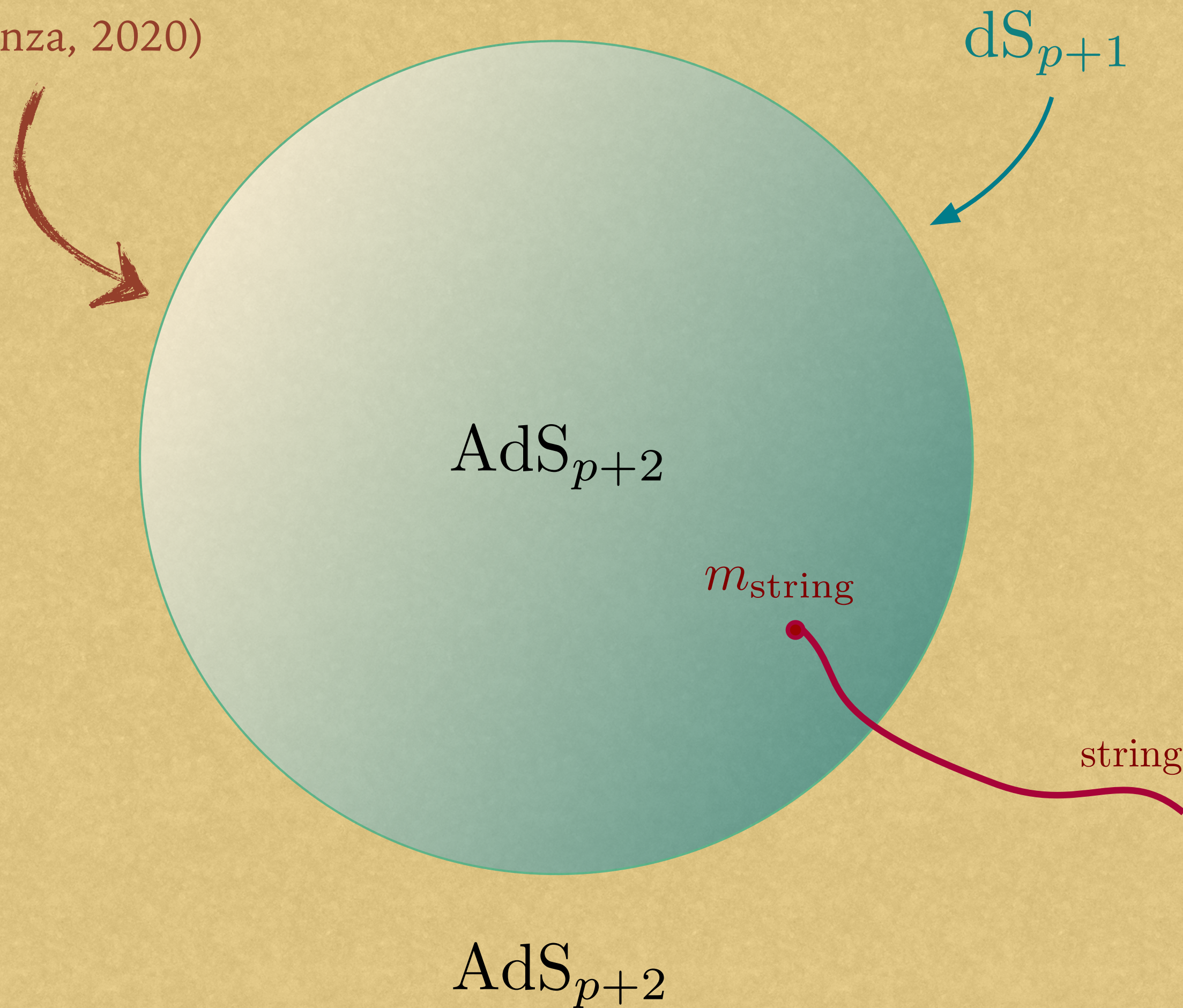
stringy regime: tadpole-mediated



EFT regime: probe brane in AdS throat

“RIDE THE BUBBLE” — DE SITTER BRANEWORLD COSMOLOGY

(IB, Lanza, 2020)



$$ds_{\text{induced}}^2 = -dt^2 + a^2(t) d\Omega_p^2$$

$$\left(\frac{\dot{a}}{a}\right)^2 = -\frac{1}{a^2} + \frac{(v_0 \mu_p / T_p)^2 - 1}{L_{\text{AdS}}^2}$$

full Einstein eqs. w/ matter — EFT unknown

(Uppsala group, 2018-2021)

cf. Panizo's talk!



OUTLOOK

- *consistency & naturalness with swampland conditions*
- *novel pheno: “ride the bubble” — stringy embedding*

-
- *full gravity EFT on the branes?*
 - *final state: non-SUSY duality?*

Thank you!

...btw, this is what strings do when you break SUSY →

