Misaligned SUSY in String Vacua

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C. Angelantonj, I. Florakis, G. L., arXiv:2302.13702

G.L., to appear soon

SUSY, July 2023

SUSY breaking at the string scale induces instabilities

- Best case scenario $\longrightarrow$ tachyon free vacua with non vanishing contributions to dilaton potential from tadpoles or perturbative corrections

- Worst case scenario $\longrightarrow$ tachyons in the tree level spectrum

$\longrightarrow$ can we distinguish the two? Yes, *Misaligned SUSY*

Interplay between IR and UV properties

[Dienes, 1995]

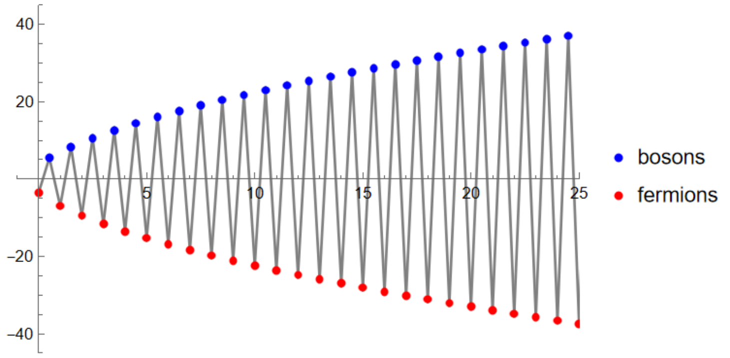
$$\mathcal{T} = \sum_{i,\bar{\imath}} N_{i\bar{\imath}}\, \chi_i(\tau)\, \bar{\chi}_{\bar{\imath}}(\bar{\tau})$$

$$\sum_{n=0}^{\infty} d_i(n)\; q^{n+H_i}$$

$$\langle d(n) \rangle = \sum_{i\bar{\imath}} N_{i\bar{\imath}}\, d_i(n) \bar{d}_{\bar{\imath}}(n) \;\sim\; e^{C_{\text{eff}}\sqrt{n}}$$

Sector averaged sum ➡ counts dof in the large mass regime

Partial cancellations reflect oscillations

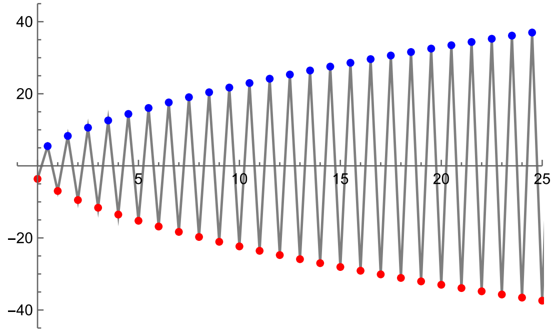


Misaligned SUSY

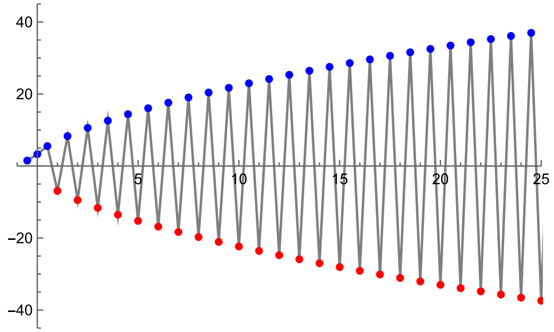
A remark on oscillations

In literature oscillations thought to be trademark for absence of tachyons

However this is **<u>not</u>** true



SO(16) x SO(16) in 10 d



SO(16) x E_8 in 10 d

⟶ reflect presence of fermions

Leading growth

$$d_i(n) \sim e^{4\pi\sqrt{\frac{c}{24}\,n}} \longrightarrow$$ universal contribution

sum over all characters

Sector averaged sum $\langle d(n)\rangle = \sum_{i\bar{\imath}} N_{i\bar{\imath}} d_i(n) \bar{d}_{\bar{\imath}}\left(n + H_i - \bar{H}_{\bar{\imath}}\right)$

$$\langle d(n)\rangle \sim e^{4\pi C_{tot}\sqrt{n}} \sum_{i\bar{\imath}} N_{i\bar{\imath}} + \dots$$

$$4\pi\left(\sqrt{\tfrac{c_L}{24}} + \sqrt{\tfrac{c_R}{24}}\right)$$

$C_{\rm eff} < C_{\rm tot}$ $\Longleftrightarrow$ fermions

Subleading orders

Refinement of subleading terms [Cribiori et al., 2021]

Clever rearrangement of levels and modular invariance simplify the expression

$$\langle d(n)\rangle = \sum_{l=1}^{\infty} \sum_{\substack{i,\bar{\imath} \\ H_i=\bar{H}_{\bar{\imath}}<0}} N_{i\bar{\imath}}\, e^{\frac{8\pi}{l}\sqrt{|H_i| n}}$$

determined by mass of *deepest* tachyon

→ contributions only from level matched tachyons

Effective Central Charge Criterion

Modular invariance implies

No tachyons level matched $\longrightarrow$ $C_{\text{eff}} = 0$

Tachyons level matched $\longrightarrow$ $C_{\text{eff}} \neq 0$

but

$C_{\text{eff}} < C_{\text{tot}}$

Examples in 10d

$$C_{\text{tot}} = 4\pi\left(\sqrt{\tfrac{1}{2}} + 1\right)$$

$SO(16) \times SO(16)$ heterotic string

[Alvarez-Gaumé et al., 1986]
[Dixon, Harvey, 1986]

No tachyons level matched

$$\langle d(n)\rangle = 0 \longrightarrow C_{\text{eff}} = 0$$

[Cribiori et al., 2021]

$SO(16) \times E_8$ heterotic string

Tachyon level matched

$$\langle d(n)\rangle \sim \left\{e^{8\pi\sqrt{\frac{n}{2}}} + \ldots\right\} \longrightarrow C_{\text{eff}} \neq 0$$

A comment on orientifold vacua

What happens without modular invariance?

$\longrightarrow$ exponential behaviour dictated by tachyons in transverse channel and «viceversa»

Properties of Rademacher expansion

But unable to compare amplitudes

$\longrightarrow$ if tachyons are projected out there is no corresponding cancellation of sector averaged sums

Conclusions

Oriented Closed Strings

Fermions $\longleftrightarrow$ $C_{\text{eff}} < C_{\text{tot}}$

No physical tachyons $\longleftrightarrow$ $C_{\text{eff}} = 0$

Orientifolds

Direct (transverse) $C_{\text{eff}} = 0$ $\longleftrightarrow$ No transverse (direct) tachyons

Outlook

Connection with Rankin-Selberg-Zagier?

[Kutasov, Seiberg, 1990]
[Angelantonj et al., 2011]

New technology for orientifolds?

THANK YOU FOR THE ATTENTION

Examples in 9d à la Scherk-Schwarz

$C_{\mathrm{tot}} = 4\pi\sqrt{2}$

General formula for type IIB

$$\mathrm{C}_{\mathrm{eff}} = \begin{cases} 2\pi\sqrt{8-R^2} & R^2 < 8 \\ 0 & R^2 \geq 8 \end{cases}$$

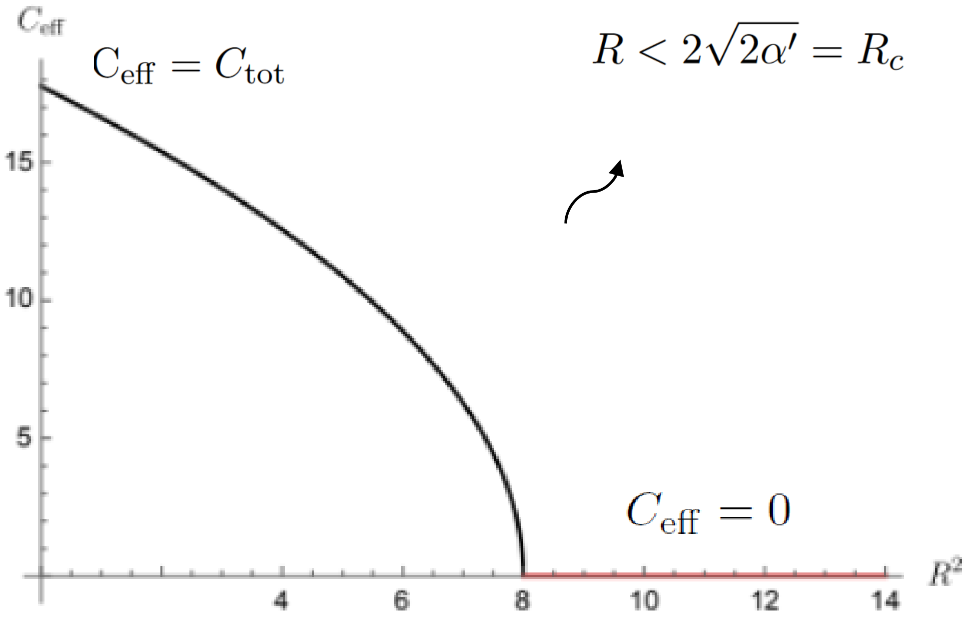
$\mathrm{R} \to 0$ ➡ 0B (purely bosonic)

$\mathrm{R} \to \infty$ ➡ IIB in 10d (SUSY)

Phase transition?

tachyons if

$R < 2\sqrt{2\alpha'} = R_c$



$R < R_c$ $R > R_c$

Type 0B3

[Sagnotti,1995]

Closed sector

$$\mathcal{T} = |O_8|^2 + |V_8|^2 + |S_8|^2 + |C_8|^2 \qquad \mathcal{K} = -O_8 \ + \ V_8 \ + \ S_8 \ - \ C_8 \qquad \tilde{\mathcal{K}} = -C_8$$

Sector averaged sums

$$\langle d(n) \rangle \, (\mathcal{T}) = \sum_{\ell=1}^{\infty} \frac{e^{\frac{8\pi}{\ell}\sqrt{n/2}}}{2^{15/2} n^{11/2}} \qquad \langle d(n) \rangle \, (\mathcal{K}) = 0 \qquad \langle d(n) \rangle \, (\tilde{\mathcal{K}}) = -\frac{e^{2\sqrt{2}\pi\sqrt{n}}}{8 \ 2^{3/4} n^{11/4}}$$

Open sector $\longrightarrow$ tachyon in bifundamental of $U(32+n) \times U(n)$

tachyon not projected

Type 0B2

[Sagnotti,1995]

Closed sector: tachyons survives the projection

Open sector → tachyon in antisymmetric of $U(1)$

$\mathcal{A} = O_8 \ + \ V_8$ $\quad$ $\mathcal{M} = -\hat{O}_8$ $\quad$ $\tilde{\mathcal{A}} = O_8 + V_8$ $\quad$ $\tilde{\mathcal{M}} = \hat{O}_8$

Sector averaged sum

$$\langle d(n) \rangle \, (\mathcal{A}) = \frac{e^{4\pi\sqrt{n/2}}}{8 \ 2^{3/4} n^{11/4}} \qquad \langle d(n) \rangle \, (\mathcal{M}) = \frac{e^{2\pi\sqrt{n/2}}}{4 \ 2^{1/4} n^{11/4}} \qquad \langle d(n) \rangle \, (\tilde{\mathcal{A}}) = \frac{e^{4\pi\sqrt{n/2}}}{2^{3/4} n^{11/4}} \qquad \langle d(n) \rangle \, (\tilde{\mathcal{M}}) = -\frac{e^{2\pi\sqrt{n/2}}}{4 \ 2^{1/4} n^{11/4}}$$