Costas Kounnas memorial day

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COSTAS

Words are not enough

COSTAS

A short time line of our interaction

- first met Costas in Paris in 2006
- PhD at ENS, 2007-2011
- 3+1 joint papers

COSTAS

An extraordinary man of many passions

- Cyprus, Greece, Family
- Physics
- Smoking :(
- …

COSTAS

The first encounter

- before Paris
- the “shy” Physicist
- the famous blackboard & laptop

COSTAS

SUPER visor

- you know nothing, I will teach you!
- the lectures

COSTAS

an exercise you must solve!

$$\vartheta_3^4(0|\tau) - \vartheta_4^4(0|\tau) - \vartheta_2^4(0|\tau) = 0$$

Jacobi's "abstrusa" (SUSY)

$$\frac{1}{2}\left(\frac{\vartheta_3(0|\tau)}{\eta(\tau)}\right)^{12} - \frac{1}{2}\left(\frac{\vartheta_4(0|\tau)}{\eta(\tau)}\right)^{12} - \frac{1}{2}\left(\frac{\vartheta_2(0|\tau)}{\eta(\tau)}\right)^{12} = 24$$

"MSDS"

$$V_{24} - S_{24} = 24$$

$$24 + \binom{24}{3} = 2^{11}$$

The first paper

- you didn’t prove it, I did !
- the “trivial” stuff

COSTAS

Later memories

- don’t tamper with my windings!
- the unique model that solves everything
- the smile

The last paper

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$\mathcal{N} = 2 \to 0$ super no-scale models and moduli quantum stability

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Abstract

We consider a class of heterotic $\mathcal{N} = 2 \to 0$ super no-scale $\mathbb{Z}_2$-orbifold models. An appropriate stringy Scherk–Schwarz supersymmetry breaking induces tree level masses to all massless bosons of the twisted hypermultiplets and therefore stabilizes all twisted moduli. At high supersymmetry breaking scale, the tachyons that occur in the $\mathcal{N} = 4 \to 0$ parent theories are projected out, and no Hagedorn-like instability takes place in the $\mathcal{N} = 2 \to 0$ models (for small enough marginal deformations). At low supersymmetry breaking scale, the stability of the untwisted moduli is studied at the quantum level by taking into account both untwisted and twisted contributions to the 1-loop effective potential. The latter depends on the specific branch of the gauge theory along which the background can be deformed. We derive its expression in terms of all classical marginal deformations in the pure Coulomb phase, and in some mixed Coulomb/Higgs phases. In this class of models, the super no-scale condition requires having at the massless level equal numbers of untwisted bosonic and twisted fermionic degrees of freedom. Finally, we show that $\mathcal{N} = 1 \to 0$ super no-scale models are obtained by implementing a second $\mathbb{Z}_2$ orbifold twist on $\mathcal{N} = 2 \to 0$ super no-scale $\mathbb{Z}_2$-orbifold models.

Supersymmetry breaking in String Theory

tachyons

background instabilities (tadpoles)

quantum corrections

runaway moduli

decompactification problem

Supersymmetry breaking in Heterotic Strings

effective 1-loop potential

hard breaking $\sim M_s^4$

unbroken $= 0$

coordinate-dependent compactifications $m_{3/2} = 1/R$

$$\sim (n_F - n_B)\, m_{3/2}^4 + \alpha\, m_{3/2}^2 M_s^2\, e^{-M_s/m_{3/2}} + \ldots$$

still too large

Supersymmetry breaking in Heterotic Strings

"super no-scale" : extend no-scale structure to 1-loop

$$\sim (n_F - \cancel{n_B})\, m_{3/2}^4 + \alpha\, m_{3/2}^2 M_s^2\, e^{-M_s/m_{3/2}} + \ldots$$

exponentially suppressed at $m_{3/2} << M_s$

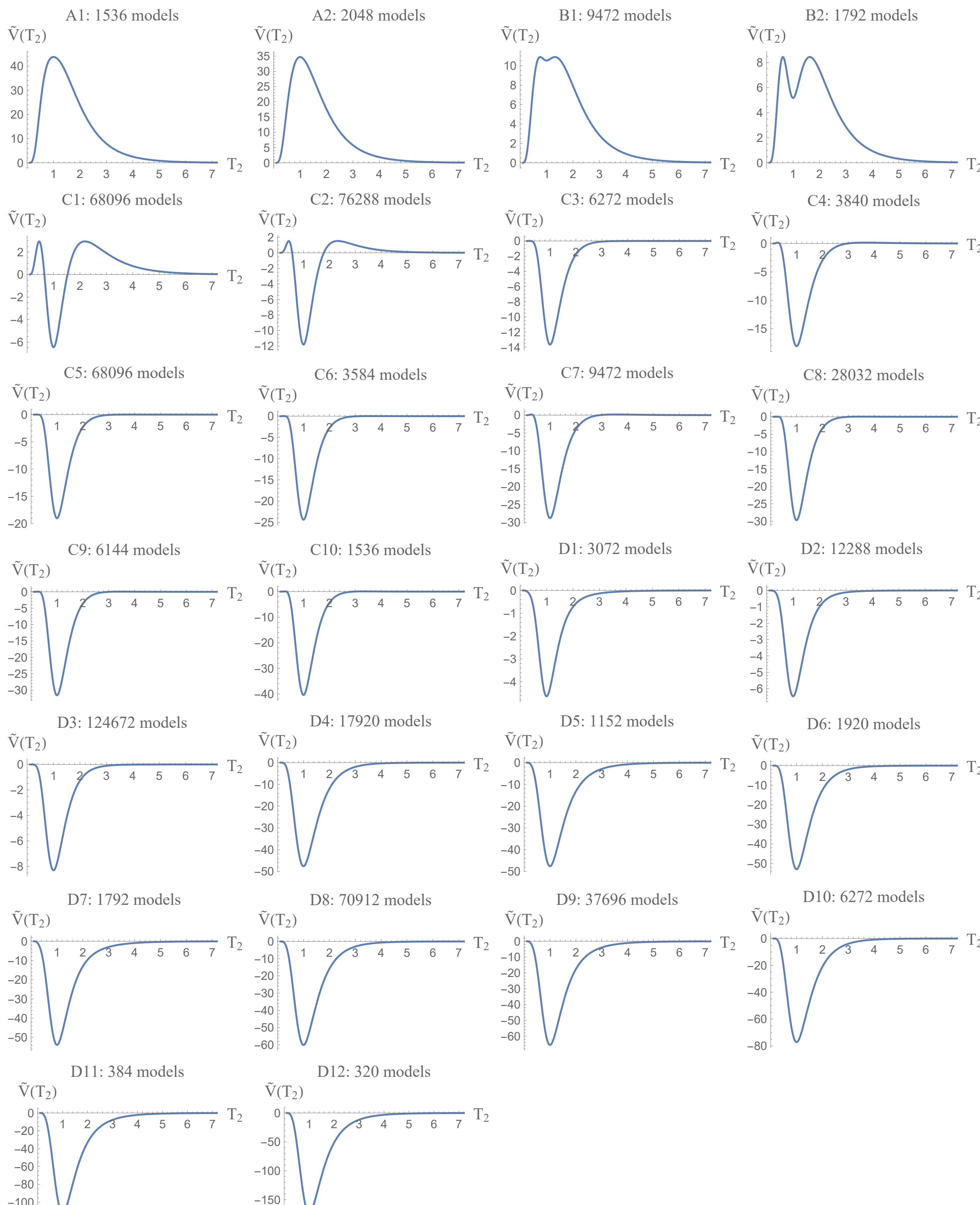
$$\boxed{n_B = n_F}$$

massless boson-fermion degeneracy

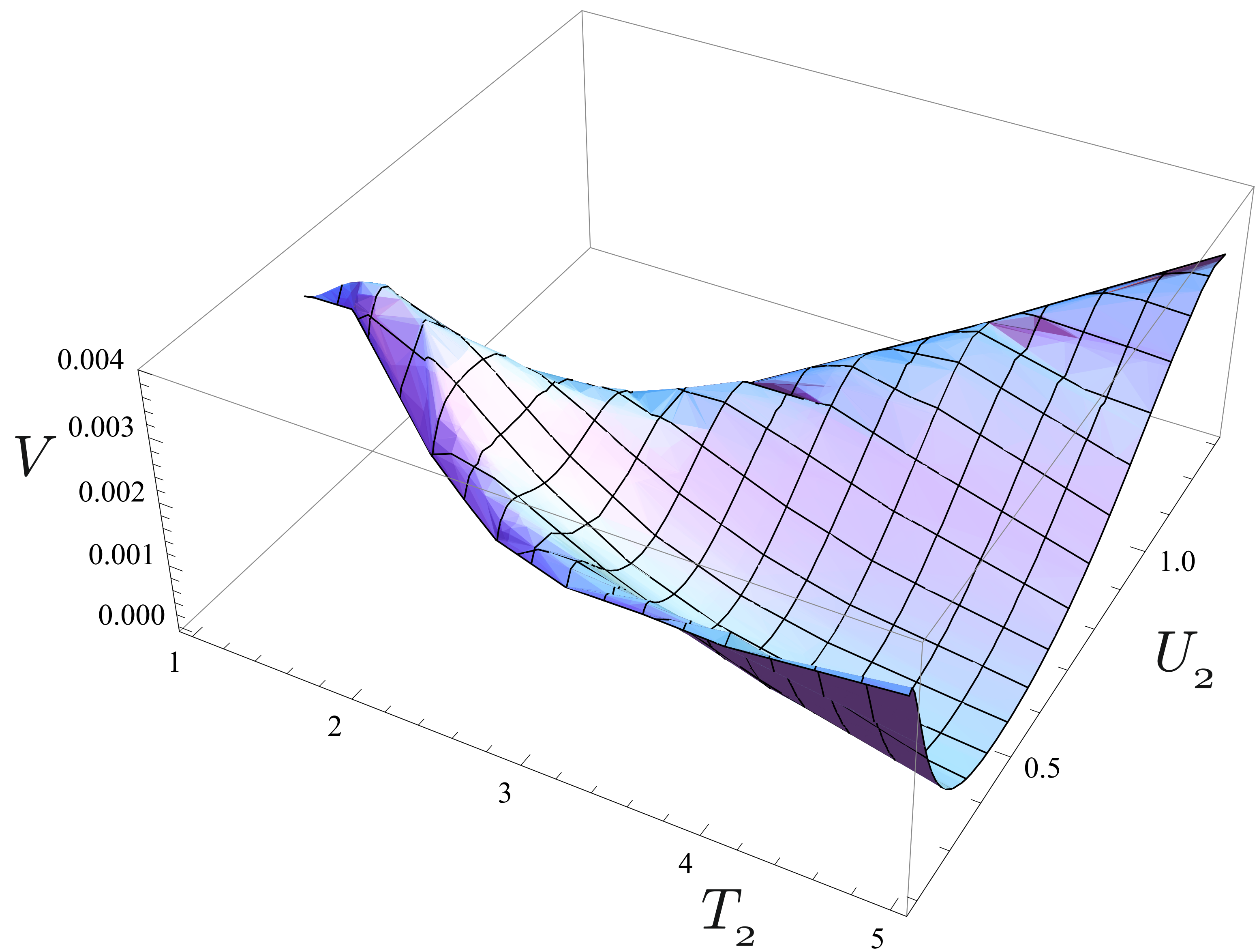
"calibration" of hidden sector

in general, much richer structure $V_{\text{eff}}(T_I, U_I, W_I)$

Supersymmetry breaking in Heterotic Strings



Supersymmetry breaking in Heterotic Strings

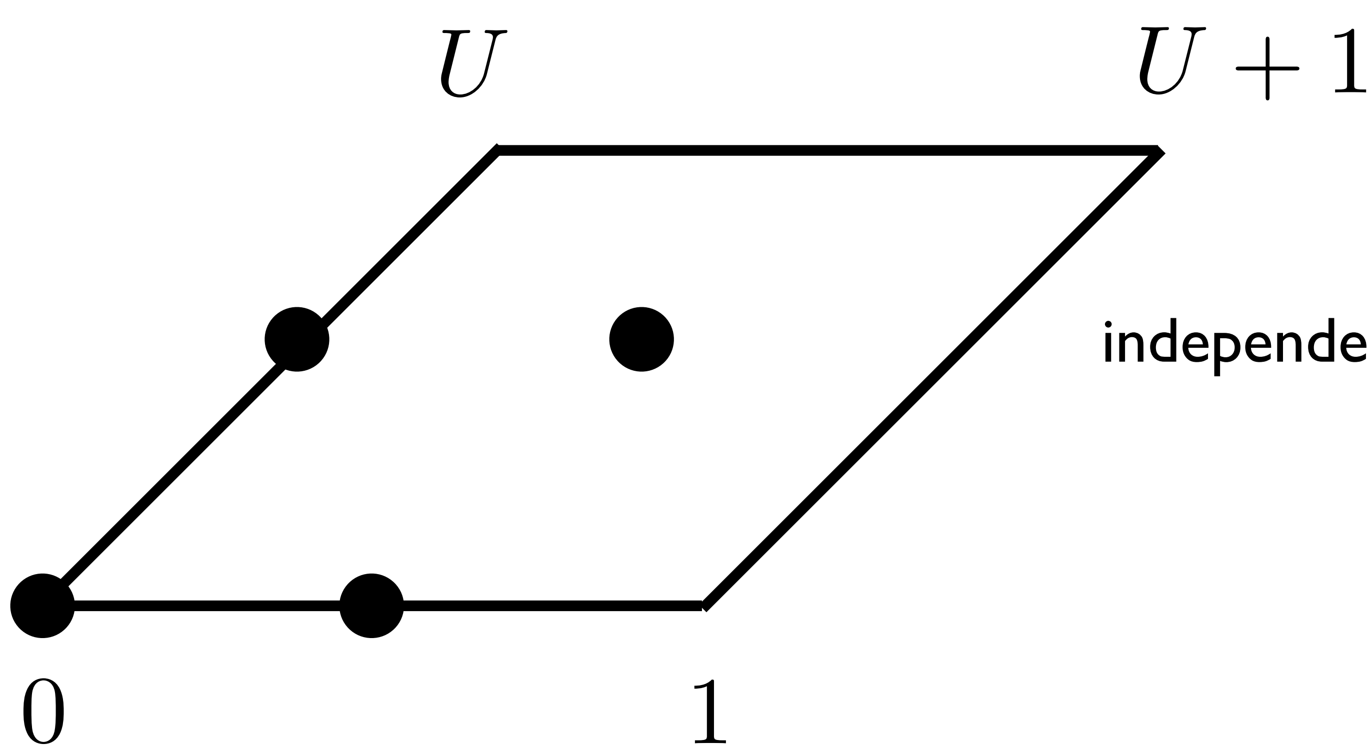


Supersymmetry breaking in Heterotic Strings

chirality $\mathcal{N}=1\to 0$ $\qquad T^2\times T^2\times T^2/\mathbb{Z}_2\times\mathbb{Z}_2\times\Gamma$

$$V_{\rm eff} = -\frac{M_s^2}{2(2\pi)^4}\int_{\mathcal{F}}\frac{d^2\tau}{\tau_2^3}\,Z(\tau,\bar\tau;\ldots)$$

moduli dependence from N=2 “sectors”, dominated by light KK modes



independent shifts along both non-trivial cycles
to shuffle all fixed points

3 generations

Supersymmetry breaking in Heterotic Strings

chirality $\mathcal{N}=1 \to 0$ $\quad T^2 \times T^2 \times T^2/\mathbb{Z}_2 \times \mathbb{Z}_2 \times \Gamma$

$$V_{\text{eff}} \sim -\frac{1}{(\text{Im}T)^2}\left[(\ldots)E^\star_\infty(3;U) + (\ldots)E^\star_\infty(3;2U)\right] + \ldots$$

$$E^\star_\infty(s;z) = \frac{1}{2}\zeta^\star(2s) \sum_{\substack{c,d\in\mathbb{Z} \\ (2c,d)=1}} \frac{(\text{Im}z)^s}{|2cz+d|^{2s}}$$

(at least) two independent conditions

$$M^2 = \frac{|m_2 - U m_1|^2}{\text{Im}T\,\text{Im}U} \qquad M^2 = \frac{|m_2 + \frac{1}{2} - U m_1|^2}{\text{Im}T\,\text{Im}U}$$

massless states accompanied by infinite KK tower

$$n_B = n_F$$

infinite KK tower with mass gap

$$n'_B = n'_F$$

Supersymmetry breaking in Heterotic Strings

chirality $\mathcal{N} = 1 \to 0$ $T^2 \times T^2 \times T^2 / \mathbb{Z}_2 \times \mathbb{Z}_2 \times \Gamma$

$$V_{\rm eff} \sim - \int \frac{dt}{t^2}\, {\rm Str}(-1)^Q\, e^{-\pi t M^2} + \ldots$$

$$M^2 = \frac{|m_2 + \frac{H}{2} - U m_1|^2}{{\rm Im}T\, {\rm Im}U} + \ldots$$

super no-scale condition: massive but light KK states must enjoy separate boson-fermion matching

$V_{\rm eff}(T_I, U_I, W_I)$

Lessons and inspiration for years to come