Heterotic Strings with Positive Cosmological Constant

Ioannis Florakis

LPTHE Paris

Based on work with J. Rizos

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Recent Developments in Strings & Gravity - Corfu

Non-supersymmetric constructions

- Non-supersymmetric constructions have been extensively studied in the past
- Renewed interest in the context of String Phenomenology
- Attempts to construct non-supersymmetric heterotic vacua

with semi-realistic spectra

Blaszczyk, Groot-Nibbelink
Loukas, Ramos-Sanchez
Abel, Dienes, Mavroudi
Lukas, Lalak, Svanes
Ashfaque, Athanasopoulos
Faraggi, Sonmez, Ruehle
Kounnas, Partouche
Angelantonj, Tsulaia, Rizos
…

Two fundamental questions

- Tachyonic instabilities : either explicit, or spontaneous (Hagedorn, …)
- Destabilisation of the classical vacuum : one loop tadpoles

I will return to these points later in the talk

A way to break supersymmetry

(stringy) Scherk-Schwarz mechanism

Scherk, Schwarz 1979
Rohm 1984
Kounnas, Porrati 1988
Kounnas, Rostand 1990

- Flat gauging of N=4 supergravity
- Spontaneous breaking of SUSY with exactly tractable worldsheet description
- Freely-acting orbifolds

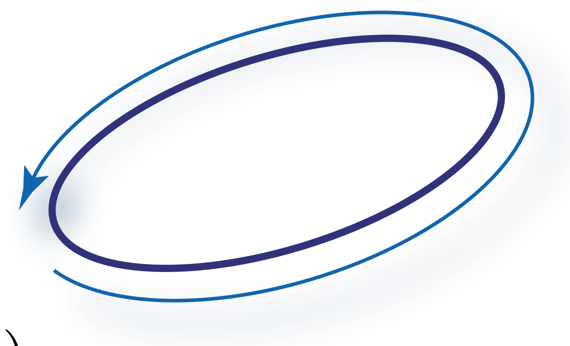
Assume SUSY is (spontaneously) broken but the vacuum is classically stable

Study one-loop corrections to couplings in the low energy effective action

Scherk Schwarz mechanism

Deformation of vertex operators / fields by symmetry Q

$$\Phi(X_5 + 2\pi R) = e^{iQ}\,\Phi(X_5)$$



$$\Phi(X_5)$$

$$\Phi(X_5) = e^{iQX_5/2\pi R}\sum_{m\in\mathbb{Z}} \Phi_m\, e^{imX_5/R}$$

Kaluza-Klein spectrum of charged states is shifted $\quad M_{\rm KK} = \dfrac{|Q|}{2\pi R}$

Choose Q=F (spacetime fermion number)

Assigns different boundary conditions (& masses) to states within the same supermultiplet : spontaneous breaking of supersymmetry

Breaking scale ~1/R, tied to the size of compact dimensions

Non-supersymmetric Universality

Under certain well-defined conditions

Angelantonj, I.F. , Tsulaia '14, '15

$$\Delta_{ab} = \sum_{i=1,2,3} \alpha_i \, \log \left[T_2^{(i)} U_2^{(i)} \, |\eta(T^{(i)})\eta(U^{(i)})|^4 \right] + \beta_i \, \log \left[T_2^{(i)} U_2^{(i)} \, |\vartheta_4(T^{(i)})\vartheta_2(U^{(i)})|^4 \right]$$

$$+ \gamma_i \, \log \left| j_2(T^{(i)}/2) - j_2(U^{(i)}) \right|^4$$

α , β , γ : model dependent constants computable from the massless spectrum

Effective potential

What about the potential ?

- Scherk-Schwarz breaking exhibits no-scale structure
- The scale of SUSY breaking is not determined at tree level

$$m_{3/2} = \frac{|U|}{\sqrt{T_2 U_2}}$$

T, U are moduli at tree level

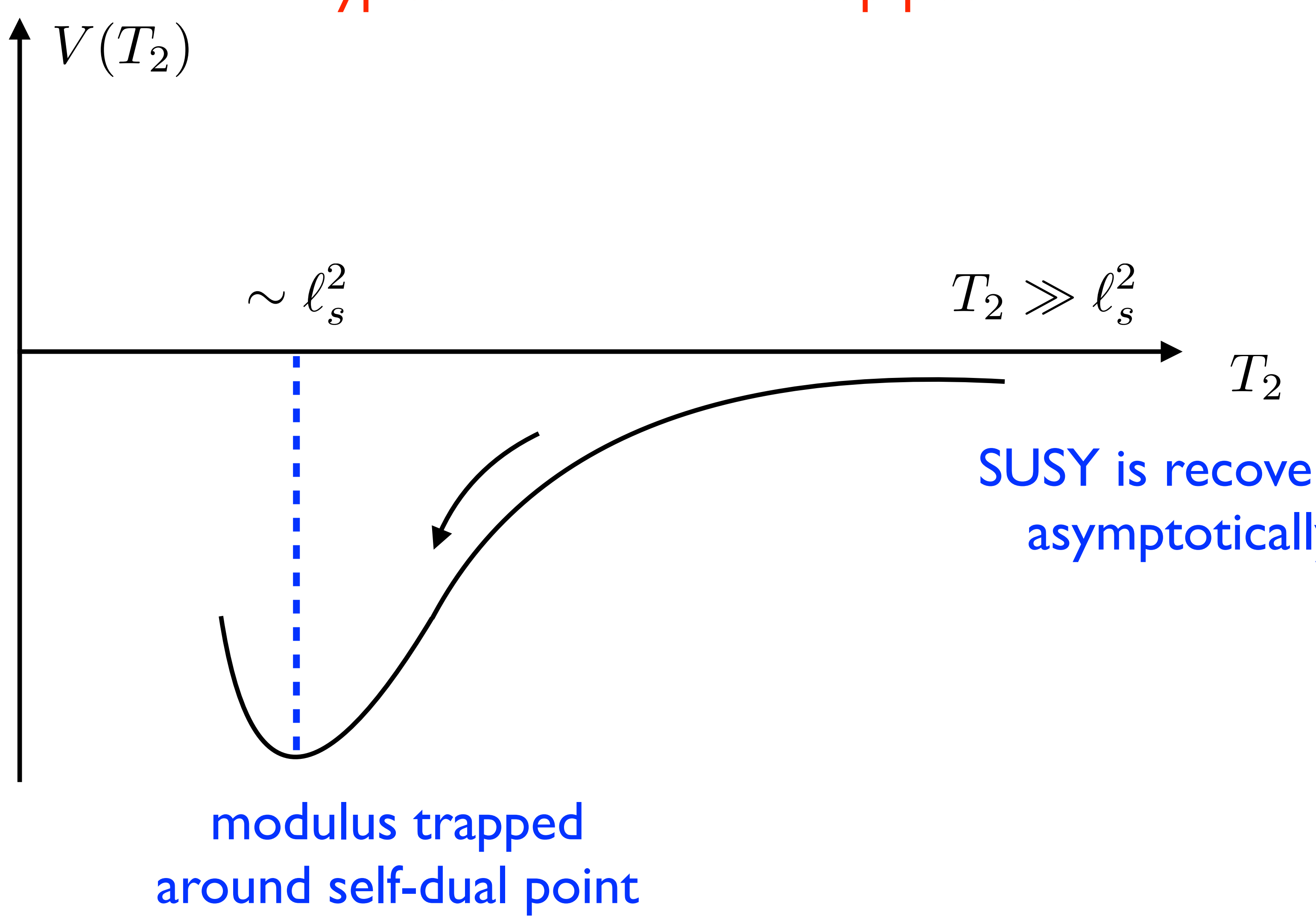
- Loop corrections to the effective potential may (de)stabilise the no-scale moduli
- Dynamical determination of SUSY breaking scale

What is the morphology of the one loop effective potential
in such models ?

What about the potential ?

- Fixed points of the lattice (T-self dual) correspond to local extrema of the potential
- Natural scale in this problem : the string scale

typical form of the 1-loop potential



What about the potential ?

- Standard Scherk-Schwarz breaking : fermions become massive $g = (-1)^{F_{\rm s.t.}}\,\delta$
- # bosons > # fermions at the massless level

$$V = -\int_{\mathcal{F}} d\mu\, Z(\tau,\bar\tau) \sim (n_F - n_B)/R^4$$

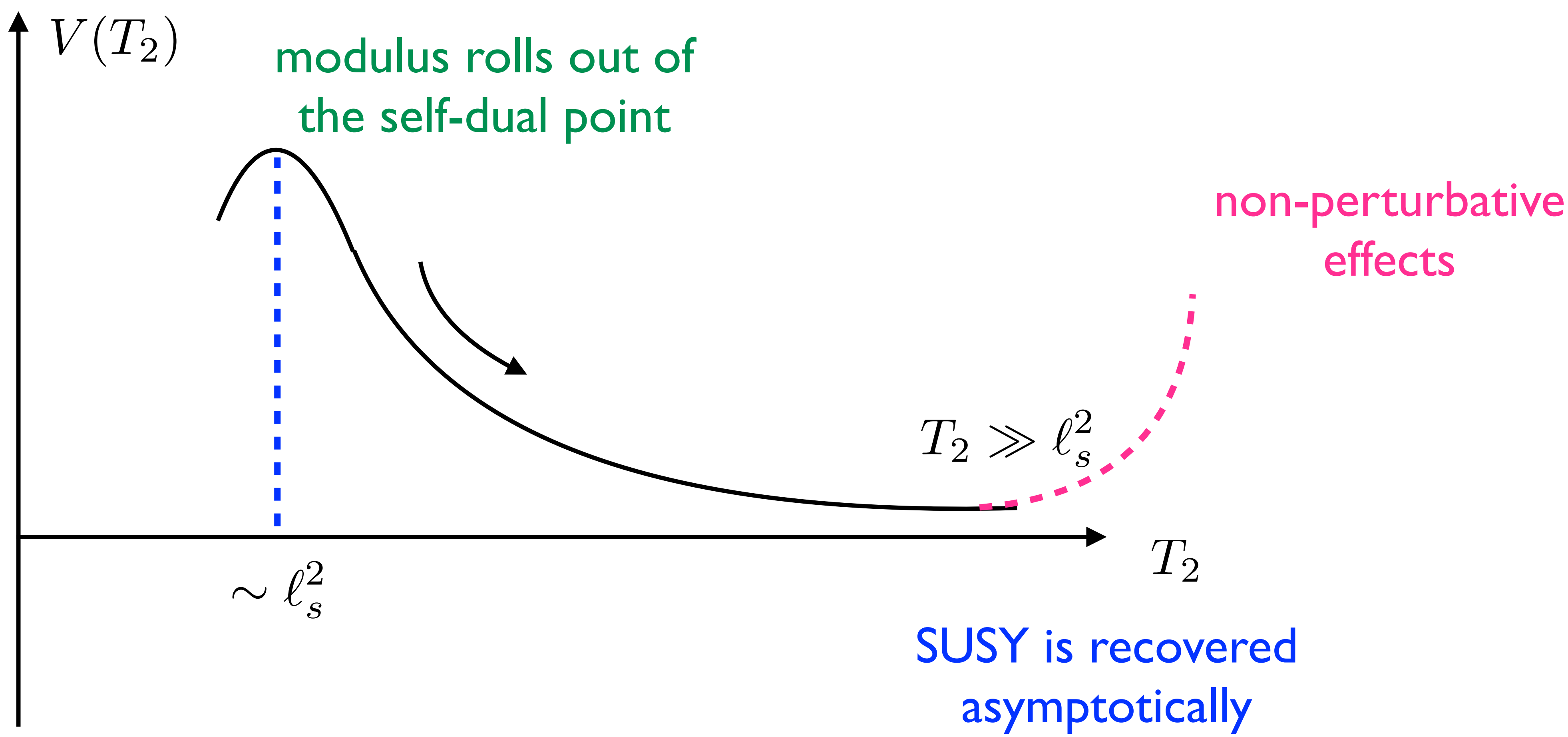
No decompactification problem : gauge couplings do not explode

SUSY is broken at the string scale $m_{3/2} \sim M_s$

Danger of encountering tachyonic modes ?

What about the potential ?

- Can we construct solutions with an abundance of massless fermions ?
- If so, we could expect a local maximum "spontaneous decompactification"

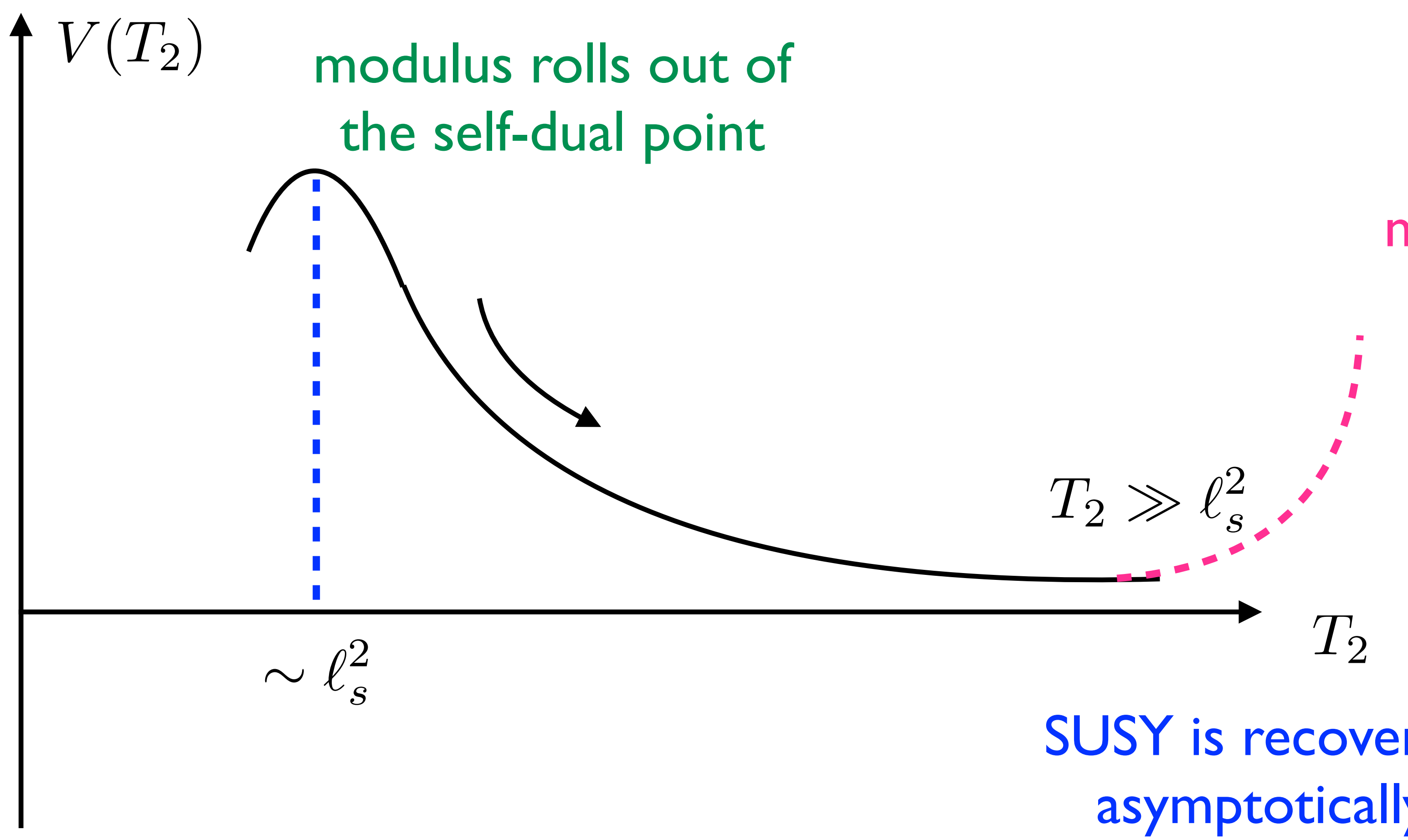


Opens the possibility for low scale SUSY breaking $m_{3/2} \sim 1/\sqrt{T_2}$

Favours large volume : no tachyons

What about the potential ?

- Can we construct solutions with an abundance of massless fermions ?
- If so, we could expect a local maximum "spontaneous decompactification"



For SUSY breaking at TeV range, the potential is still too large

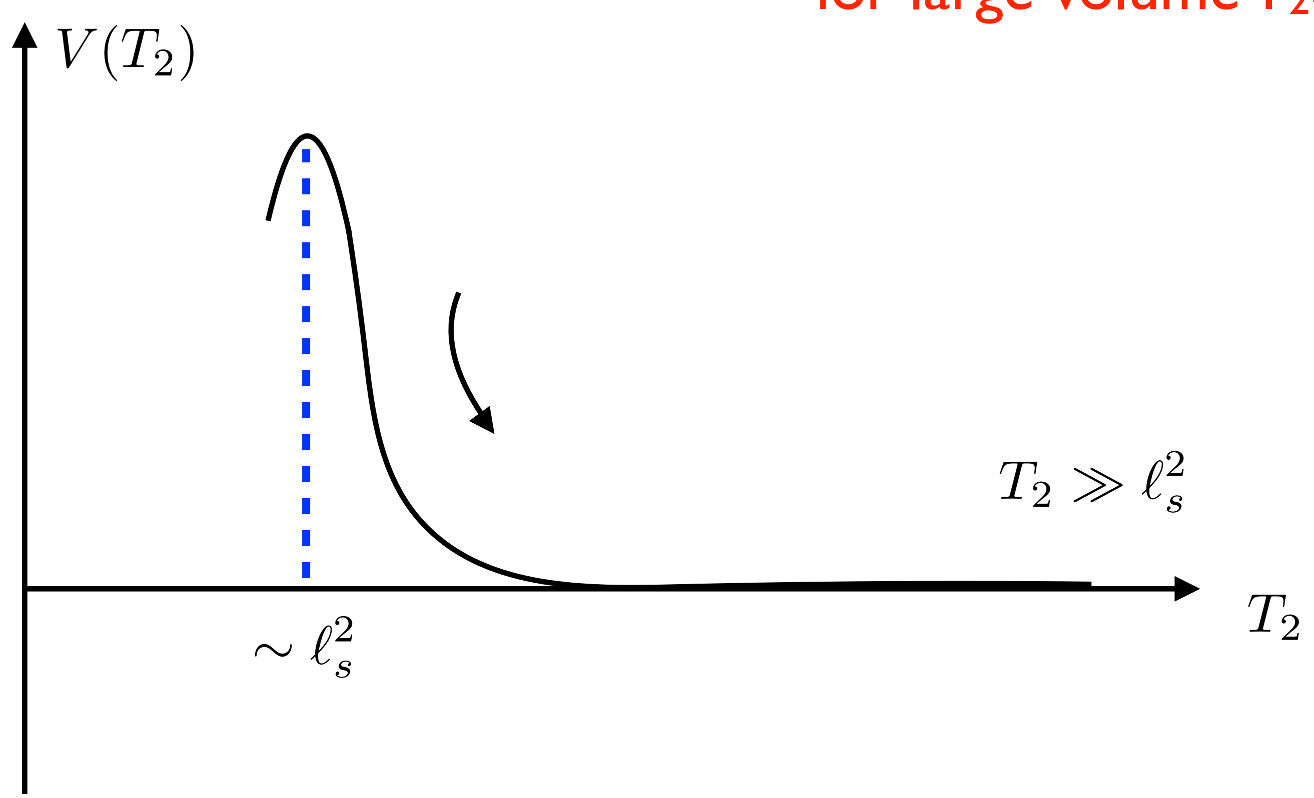
What about the potential ?

Abel, Dienes, Mavroudi
Kounnas, Partouche

Possible way out : $n_B = n_F$ at the massless level

$$V_{\rm one-loop} \sim \cancel{\frac{n_F - n_B}{R^4}} + \sum_N c(N) \sum_{m_i} \frac{U_2^{3/2}}{|m_1 + \frac{1}{2} + U m_2|^3} K_3 \left(2\pi \sqrt{\frac{N T_2}{U_2}} \left| m_1 + \frac{1}{2} + U m_2 \right| \right)$$

exponentially suppressed vacuum energy
for large volume $T_2 >> 1$



"super no-scale models"

What about the potential ?

I.F. and J. Rizos 2016

Question : Is it possible to construct such chiral models ?

- Answer: YES

BUT

although being necessary for suppressing the value of the cosmological constant, the condition for bose-fermi degeneracy is NOT sufficient

it turns out that non level-matched states around self-dual points crucially affect the shape of the potential, including its sign !

Model Classification

I.F. and J. Rizos 2016

Using the fermionic construction with 9 basis vectors

$$v_1 = \mathbf{1} = \{\psi^\mu,\, \chi^{1,\dots,6},\, y^{1,\dots,6},\, \omega^{1,\dots,6} | \bar{y}^{1,\dots,6}, \bar{\omega}^{1,\dots,6},\, \bar{\psi}^{1,\dots,5},\, \eta^{1,2,3},\, \bar{\phi}^{1,\dots,8}\}$$

$$v_2 = S = \{\psi^\mu,\, \chi^{1,\dots,6}\}$$

$$v_3 = e_{12} = \{y^{1,2},\, \omega^{1,2} | \bar{y}^{1,2},\, \bar{\omega}^{1,2}\}$$

$$v_4 = e_{34} = \{y^{3,4},\, \omega^{3,4} | \bar{y}^{3,4},\, \bar{\omega}^{5,6}\}$$

$$v_5 = e_{56} = \{y^{5,6},\, \omega^{5,6} | \bar{y}^{3,4},\, \bar{\omega}^{5,6}\}$$

$$v_6 = b_1 = \{\chi^{3,4},\, \chi^{5,6},\, y^{3,4},\, y^{5,6} | \bar{y}^{3,4},\, \bar{y}^{5,6},\, \bar{\eta}^1,\, \bar{\psi}^{1,\dots5}\}$$

$$v_7 = b_2 = \{\chi^{1,2},\, \chi^{5,6},\, y^{1,2},\, y^{5,6} | \bar{y}^{1,2},\, \bar{y}^{5,6},\, \bar{\eta}^2,\, \bar{\psi}^{1,\dots5}\}$$

$$v_8 = z_1 = \{\bar{\phi}^{1,\dots,4}\}$$

$$v_9 = z_2 = \{\bar{\phi}^{5,\dots,8}\}$$

+ choice of GGSO coefficients ~ 10^8 models

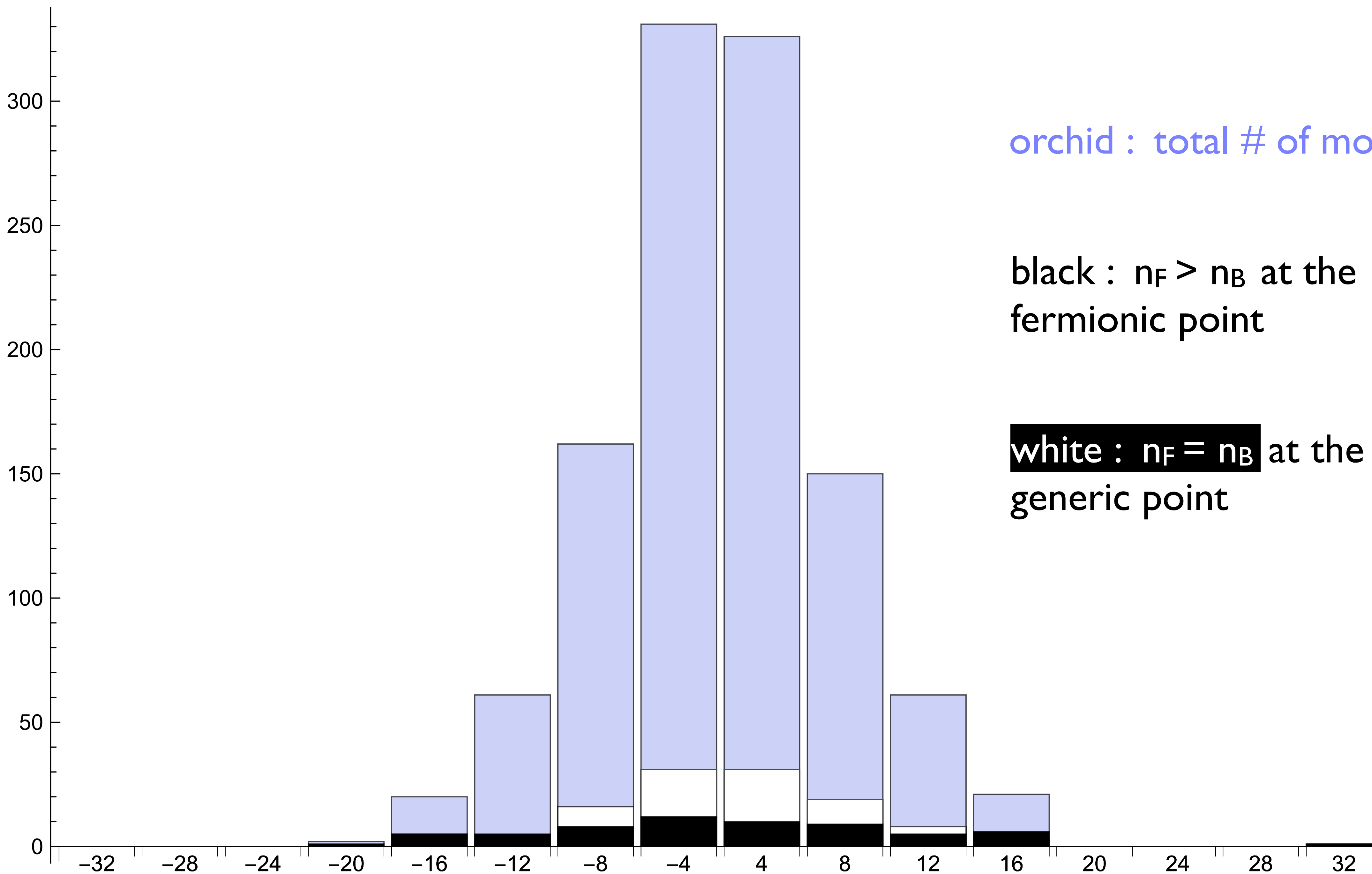
Conditions

- chirality
- spontaneous breaking of N=1 SUSY
- no tachyons (at the fermionic point)

Model Classification

I.F. and J. Rizos 2016

Scan of random sample of 10^6 models satisfying these conditions : 1135 models



orchid : total # of models

black : $n_F > n_B$ at the fermionic point

white : $n_F = n_B$ at the generic point

Example A

I.F. and J. Rizos 2016

Example A : net chirality 12 and $n_F > n_B$

$$C_{(\alpha|\beta)} = \begin{pmatrix} 1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & 1 \\ 1 & 1 & -1 & 1 & 1 & -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & -1 & -1 \\ -1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & 1 & 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 & -1 & -1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & 1 & -1 & -1 & 1 \end{pmatrix}$$

$$Z = -312 - 12320q + \frac{2}{\bar{q}} + \frac{56q}{\bar{q}} + \frac{792q^2}{\bar{q}} - \frac{16q^{1/4}}{\bar{q}^{3/4}} - \frac{416q^{5/4}}{\bar{q}^{3/4}} - \frac{5520q^{9/4}}{\bar{q}^{3/4}} + \frac{32\sqrt{q}}{\sqrt{\bar{q}}} - \frac{256q^{3/2}}{\sqrt{\bar{q}}} + \frac{512q^{3/4}}{\bar{q}^{1/4}} + \frac{11264q^{7/4}}{\bar{q}^{1/4}} + 4064q^{1/4}\bar{q}^{1/4} + 101568q^{5/4}\bar{q}^{1/4} + \dots$$

$$V = -\frac{1}{2(2\pi)^4} \int_{\mathcal{F}} \frac{d^2\tau}{\tau_2^3}\, Z \simeq +0.054$$

Example A

I.F. and J. Rizos 2016

Example A : net chirality 12 and $n_F > n_B$

$$T^2 \times T^2 \times T^2/(\mathbb{Z}_2)^6$$

$$X^{1,2} \;\; X^{3,4} \;\; X^{5,6}$$

$\mathbb{Z}_2^{(1)} \times \mathbb{Z}_2^{(2)}$ + standard embedding : explicitly breaking N=4 down to N=1

$\mathbb{Z}_2^{(3)} \; : \; (-1)^{F_{\rm s.t.}+F_2}\,\delta_1$ Scherk-Schwarz breaking of N=1 to N=0

$\mathbb{Z}_2^{(4)} \; : \; (-1)^{F_1}\,\delta_3$ discrete Wilson line

$\mathbb{Z}_2^{(5)} \; : \; \delta_5$

$\mathbb{Z}_2^{(6)} \; : \; (-1)^{F_1}\, r = (0^6, 1^2; 0^4, \tfrac{1}{2}^2)$

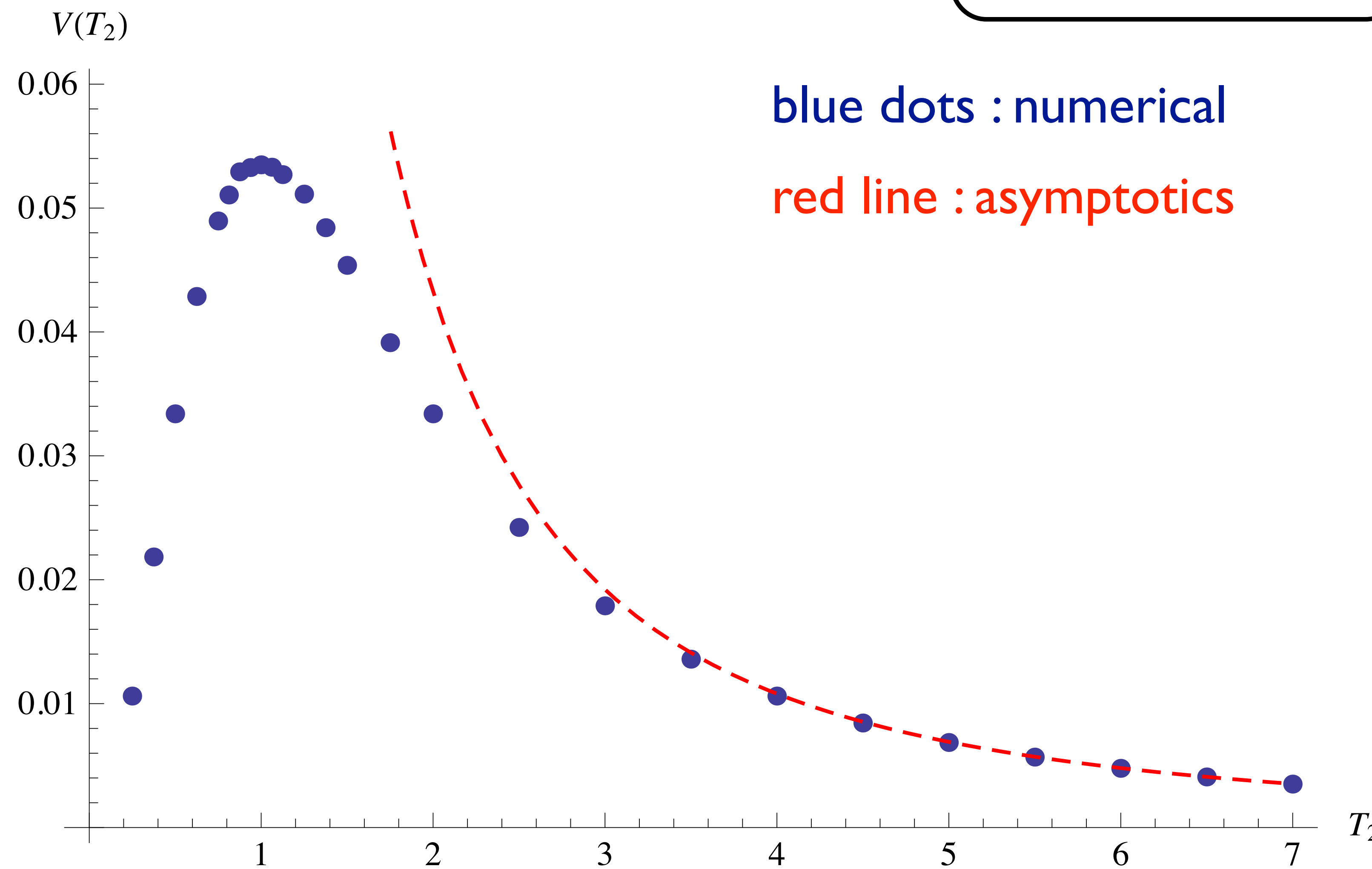
+ a particular choice of discrete torsions

$$\epsilon(1,2),\ \epsilon(1,4),\ \epsilon(1,5),\ \epsilon(1,6),\ \epsilon(2,3),\ \epsilon(2,4),\ \epsilon(3,6),\ \epsilon(4,5),\ \epsilon(4,6)$$

gauge group $\mathrm{SO}(10) \times \mathrm{SO}(8)^2 \times \mathrm{U}(1)^3$

Example A

I.F. and J. Rizos 2016



blue dots : numerical

red line : asymptotics

$$T^{(1)} = 1 + iT_2$$

$$T^{(2)} = T^{(3)} = 1 + i$$

$$U^{(1)} = U^{(2)} = U^{(3)} = \frac{1+i}{2}$$

Dominant asymptotics via unfolding

$$V = \frac{32}{945\pi T_2^2}\left[2^5\, E(3;2U) - E(3;U)\right] \quad \sim 1/R^4$$

$$+ \frac{1}{4\pi^4\sqrt{2T_2}} \sum_{N\geq 1} N^{3/2}\, c[{}^0_1](N,0) \sum_{m_1,m_2\in\mathbb{Z}} \frac{U_2^{3/2}}{\left|m_1+\frac{1}{2}+Um_2\right|^3} K_3\left(2\pi\sqrt{\frac{NT_2}{U_2}\left|m_1+\frac{1}{2}+Um_2\right|^2}\right)$$

$$+\mathcal{O}(e^{-4\pi T_2})$$

Counter Example B

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Example B : net chirality 8 and $n_F = n_B$ at the generic point

$$c_{(\mathrm{B})}\begin{bmatrix}\beta_i\\\beta_j\end{bmatrix} = \begin{pmatrix} 1 & 1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 \\ 1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 \\ -1 & 1 & -1 & 1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & 1 & -1 & 1 & -1 & -1 & -1 \\ 1 & -1 & -1 & 1 & 1 & 1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 \\ 1 & 1 & -1 & -1 & -1 & -1 & -1 & 1 & 1 \\ -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 \end{pmatrix}$$

$$Z = 8 + 1760q + \frac{2}{\bar{q}} + \frac{56q}{\bar{q}} - \frac{32q^{1/4}}{\bar{q}^{3/4}} + \frac{224\sqrt{q}}{\sqrt{\bar{q}}} - \frac{1024q^{3/4}}{\bar{q}^{1/4}}$$
$$+ 1984q^{1/4}\bar{q}^{1/4} + 30720\sqrt{q}\sqrt{\bar{q}} + \frac{2048\bar{q}^{3/4}}{q^{1/4}} + \dots$$

super no-scale model but with abundance of massless bosons at the fermionic point !

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$\mathbb{Z}_2^{(5)} \ : \ \delta_5$

$\mathbb{Z}_2^{(6)} \ : \ (0^8; 0^4, \tfrac{1}{2}^2)$

+ a particular choice of discrete torsions

$$\epsilon(1,4), \ \epsilon(1,5), \ \epsilon(2,3), \ \epsilon(2,4), \ \epsilon(3,4), \ \epsilon(5,6)$$

gauge group $\mathrm{SO}(10) \times \mathrm{SO}(8)^2 \times \mathrm{U}(1)^3$

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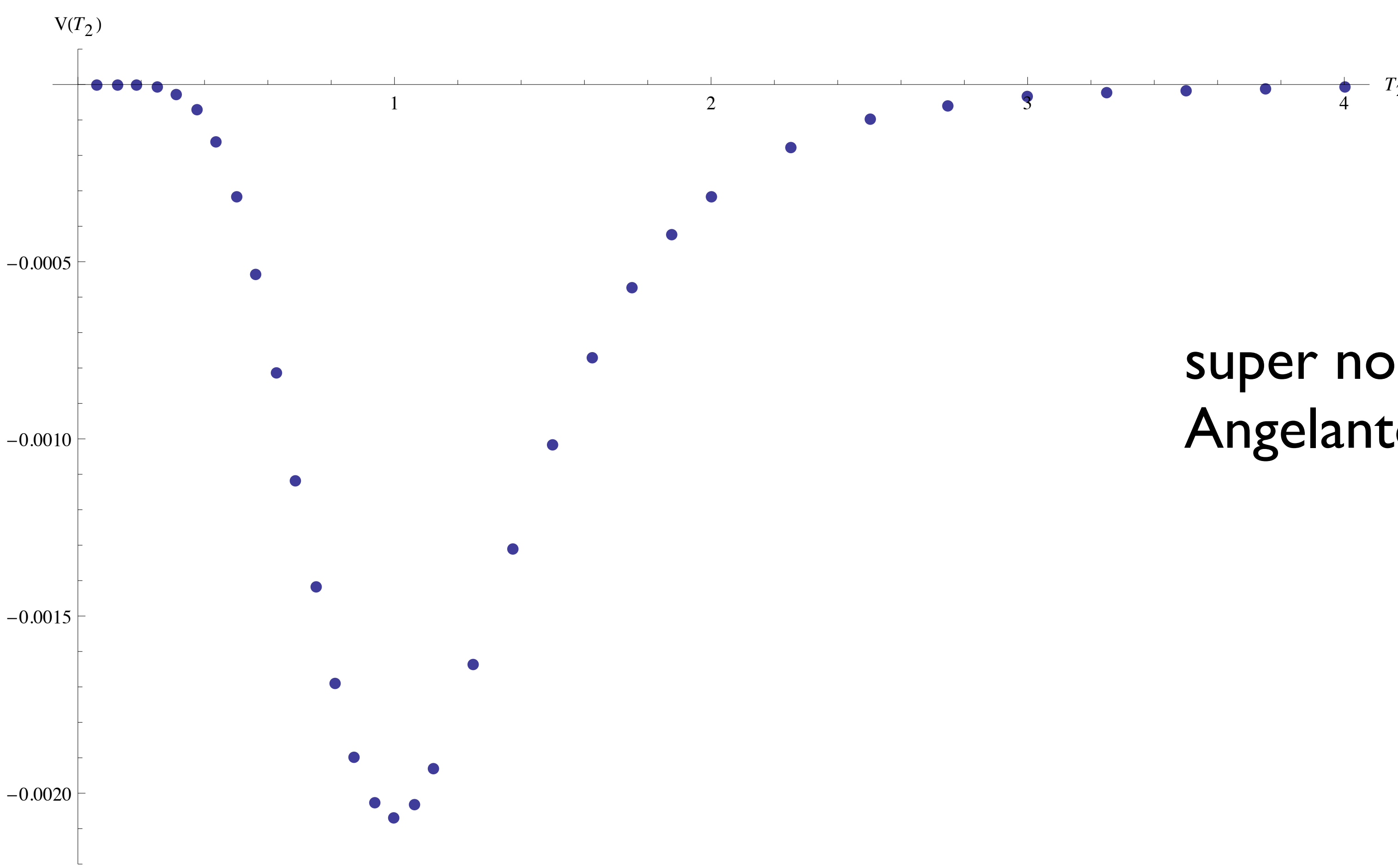


super no-scale analogue of the model by Angelantonj, Cardella, Irges 2006

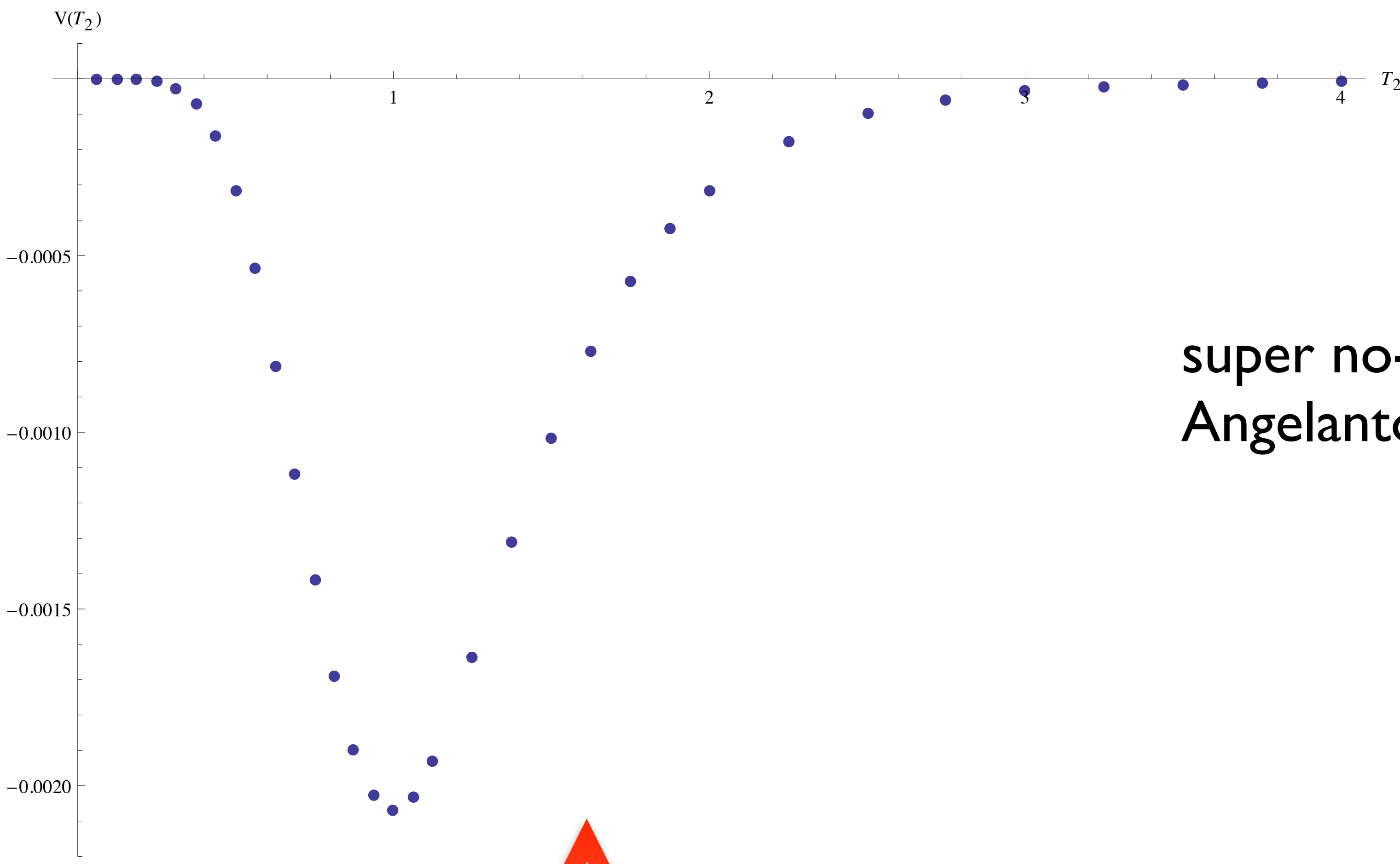
SUSY is broken at the string scale $m_{3/2} \sim M_s$

Danger of encountering tachyonic modes ?

Counter Example B

I.F. and J. Rizos 2016

Example B : net chirality 8 and $n_F = n_B$ at the generic point



super no-scale analogue of the model by Angelantonj, Cardella, Irges 2006

super no-scale condition does not suffice to determine the global shape and sign of the potential

what are the conditions for having the right shape for the potential ?

Small, positive cosmological constant ?

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impose super no-scale condition $n_B = n_F$
at the massless level and at the generic point

$$V_{\text{one-loop}} \sim \cancel{\frac{n_F - n_B}{R^4}} + \sum_N c(N) \sum_{m_i} \frac{U_2^{3/2}}{|m_1 + \frac{1}{2} + U m_2|^3} K_3 \left(2\pi \sqrt{\frac{N T_2}{U_2}} \left| m_1 + \frac{1}{2} + U m_2 \right| \right)$$

exponentially suppressed vacuum energy
for large volume $T_2 >> 1$

how do we ensure that the potential has a positive maximum at the fermionic point ?

Naively : one might think about additionally imposing $n_F > n_B$ at the fermionic point

this will not work ! (chirality & super no-scale structure) an Anatomy of the Vacuum Energy

I.F. and J. Rizos 2016

expand the partition function as

"asymmetry" "mass level"

$$Z = \sum_{\substack{n \in \mathbb{Z}/2 \\ n \geq -1/2}} \left[\sum_{m=-[n]-1}^{[n]+2} Z_{n,m}\, q_{\mathrm{i}}^{m} \right] q_{\mathrm{r}}^{n}$$

$$q_{\mathrm{r}} = e^{-2\pi\tau_2}$$

$$q_{\mathrm{i}} = e^{2\pi i \tau_1}$$

model dependent degeneracies

$$\tau = \tau_1 + i\tau_2$$

complex structure of the worldsheet torus

$\mathcal{F}$ partition $\longrightarrow$ $\mathcal{S}_1$ + $\mathcal{S}_2$

level matched only m=0

also unphysical ones!

$$V = -\int_{\mathcal{F}} d\mu\, Z(\tau,\bar{\tau}) \qquad = I^1 + I^2$$

intuition from field theory is based on S_1 but is S_2 negligible at self-dual points?

an Anatomy of the Vacuum Energy

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expand the integrals as

$$V = \sum_n Z_{n,0}\, I^1_{n,0} + \sum_{n,m} Z_{n,m}\, I^2_{n,m}$$

$$I^1_{n,m} \equiv -\delta_{m,0} \int_1^\infty dy\, \frac{e^{-2\pi n y}}{y^3} = -\delta_{m,0}\,(2\pi n)^2\,\Gamma(-2, 2\pi n)\,,$$

$$I^2_{n,m} \equiv -\int_{-1/2}^{1/2} dx\, e^{2\pi i |m| x} \int_{\sqrt{1-x^2}}^{1} dy\, \frac{e^{-2\pi n y}}{y^3}$$

model independent

consider level-matched states first

$$I^1_{0,0} = -1/2$$

$$I^1_{n,0} \sim -\frac{e^{-2\pi n}}{2\pi n}$$

negative contributions, as expected from field theory

exponentially suppressed with increasing level n

$$I^2_{0,0} = -(\log 3 - 1)/2$$

$$I^2_{n,0} \sim -\frac{4}{3}\,\frac{e^{-\pi n\sqrt{3}}}{\pi n\sqrt{3}}\left[1 - \frac{3\sqrt{3}}{4\sqrt{2}}(\sqrt{3}-1)\left(1 - \frac{2+\sqrt{3}}{2\pi n}\right)\right] + \frac{e^{-2\pi n}}{2\pi n}$$

an Anatomy of the Vacuum Energy

I.F. and J. Rizos 2016

expand the integrals as

$$V = \sum_n Z_{n,0}\, I^1_{n,0} + \sum_{n,m} Z_{n,m}\, I^2_{n,m}$$

$$I^1_{n,m} \equiv -\delta_{m,0} \int_1^\infty dy\, \frac{e^{-2\pi n y}}{y^3} = -\delta_{m,0}\,(2\pi n)^2\, \Gamma(-2, 2\pi n)\,,$$

$$I^2_{n,m} \equiv -\int_{-1/2}^{1/2} dx\, e^{2\pi i |m| x} \int_{\sqrt{1-x^2}}^{1} dy\, \frac{e^{-2\pi n y}}{y^3}$$

model independent

now consider non-level matched states

$$I^2_{0,m} \sim (-1)^{m+1} \left(\frac{2}{3\pi m}\right)^2$$

exponentially suppressed with increasing level n

unlike field theory : alternating signs !

$$I^2_{n,m} \sim \frac{(-1)^{m+1}}{2(\pi m)^2} \left(1 - \frac{1}{2m}\right) \frac{e^{-2\pi n \sqrt{1 - \frac{1}{4}\left(1 - \frac{1}{2m}\right)^2}}}{\left[1 - \frac{1}{4}\left(1 - \frac{1}{2m}\right)^2\right]^2}$$

unphysical states of low “mass” can reverse the sign of the potential !

an Anatomy of the Vacuum Energy

I.F. and J. Rizos 2016

expand the integrals as

$$V = \sum_n Z_{n,0}\, I^1_{n,0} + \sum_{n,m} Z_{n,m}\, I^2_{n,m}$$

n	m 0	±1	±2	±3
-1	N/A	0	N/A	N/A
$-\frac{1}{2}$	N/A	0	N/A	N/A
0	-0.500	0	0	N/A
$\frac{1}{2}$	-0.00755	0	0	N/A
1	-0.000208	0	0	0
$\frac{3}{2}$	-6.61×10^{-6}	0	0	0

$I^1_{n,m}$

n	m 0	±1	±2	±3
-1	N/A	12.2	N/A	N/A
$-\frac{1}{2}$	N/A	0.617	N/A	N/A
0	-0.0493	0.0315	-0.00989	N/A
$\frac{1}{2}$	-0.00245	0.00163	-0.000587	N/A
1	-0.000123	0.0000846	-0.0000346	0.0000180
$\frac{3}{2}$	-6.24×10^{-6}	4.45×10^{-6}	-2.02×10^{-6}	1.11×10^{-6}

$I^2_{n,m}$

an Anatomy of the Vacuum Energy

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expand the integrals as

$$V = \sum_n Z_{n,0}\, I^1_{n,0} + \sum_{n,m} Z_{n,m}\, I^2_{n,m}$$

n	Model	A	B
-1		24.4	24.4
$-\frac{1}{2}$		-9.87	-19.7
0		172.	2.11
$\frac{1}{2}$		-29.6	-17.7
1		3.13	-2.73
$\frac{3}{2}$		9.71	8.18
Total		$+170.$	-5.47

unphysical tachyons have significant contribution !

the first few massive levels should be taken into account as well !

Example C

I.F. and J. Rizos 2016

Example C : net chirality 12 and $n_F = n_B$ at the generic point

$$c_{(\mathrm{C})}\left[{}^{\beta_i}_{\beta_j}\right] = \begin{pmatrix} 1 & 1 & 1 & 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & 1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 \\ 1 & -1 & 1 & -1 & -1 & 1 & -1 & -1 & -1 \\ -1 & -1 & 1 & -1 & 1 & 1 & -1 & -1 & 1 \\ 1 & -1 & -1 & 1 & 1 & 1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & -1 & -1 & 1 & 1 & 1 & -1 \\ -1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 \end{pmatrix}$$

$$\begin{aligned} Z_{(C)} = {} & \frac{2q_{\mathrm{i}}}{q_{\mathrm{r}}} - \frac{16q_{\mathrm{i}}}{\sqrt{q_{\mathrm{r}}}} + (40 + 64q_{\mathrm{i}} + 56q_{\mathrm{i}}^2) + \left(224 + \frac{6912}{q_{\mathrm{i}}} + 768q_{\mathrm{i}} - 672q_{\mathrm{i}}^2\right)\sqrt{q_{\mathrm{r}}} \\ & + \left(14336 + \frac{9216}{q_{\mathrm{i}}^2} + \frac{118656}{q_{\mathrm{i}}} - 10144q_{\mathrm{i}} + 3072q_{\mathrm{i}}^2 + 792q_{\mathrm{i}}^3\right) q_{\mathrm{r}} \\ & + \left(-203776 + \frac{934400}{q_{\mathrm{i}}^2} + \frac{498224}{q_{\mathrm{i}}} - 39744q_{\mathrm{i}} + 12800q_{\mathrm{i}}^2 - 10128q_{\mathrm{i}}^3\right) q_{\mathrm{r}}^{3/2} + \ldots \end{aligned}$$

super no-scale model with abundance of massless bosons at the fermionic point !

naively, worse than Model B !!!

Example C

I.F. and J. Rizos 2016

Example C : net chirality 12 and $n_F = n_B$ at the generic point

n	Model C
-1	24.4
$-\frac{1}{2}$	-9.87
0	-20.5
$\frac{1}{2}$	10.6
1	4.04
$\frac{3}{2}$	2.73
Total	$+11.4$

the unphysical states manage to reverse the sign of the potential
- checked to very high orders !

Example C

I.F. and J. Rizos 2016

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$$T^2 \times T^2 \times T^2/(\mathbb{Z}_2)^6$$

$$X^{1,2} \; X^{3,4} \; X^{5,6}$$

$$\mathbb{Z}_2^{(1)} \;:\; X^{1,2,5,6} \to -X^{1,2,5,6}$$
$$\mathbb{Z}_2^{(2)} \;:\; X^{3,4,5,6} \to -X^{3,4,5,6}$$
$$\mathbb{Z}_2^{(3)} \;:\; (-1)^{F_{\rm s.t.}+F_2}\,\delta_1 \quad , \; \delta_1 : \{X_1 \to X_1 + \pi R_1\}$$
$$\mathbb{Z}_2^{(4)} \;:\; (-1)^{F_2}\,\delta_3 \quad , \; \delta_3 : \{X_3 \to X_3 + \pi R_3\}$$
$$\mathbb{Z}_2^{(5)} \;:\; (-1)^{F_1+F_2}\,\delta_5 \quad , \; \delta_5 : \{X^5 \to X^5 + \pi R_5\}$$
$$\mathbb{Z}_2^{(6)} \;:\; (-1)^{F_1}\,r \quad , \; r : (0^8; 0^4, \tfrac{1}{2}^2)$$

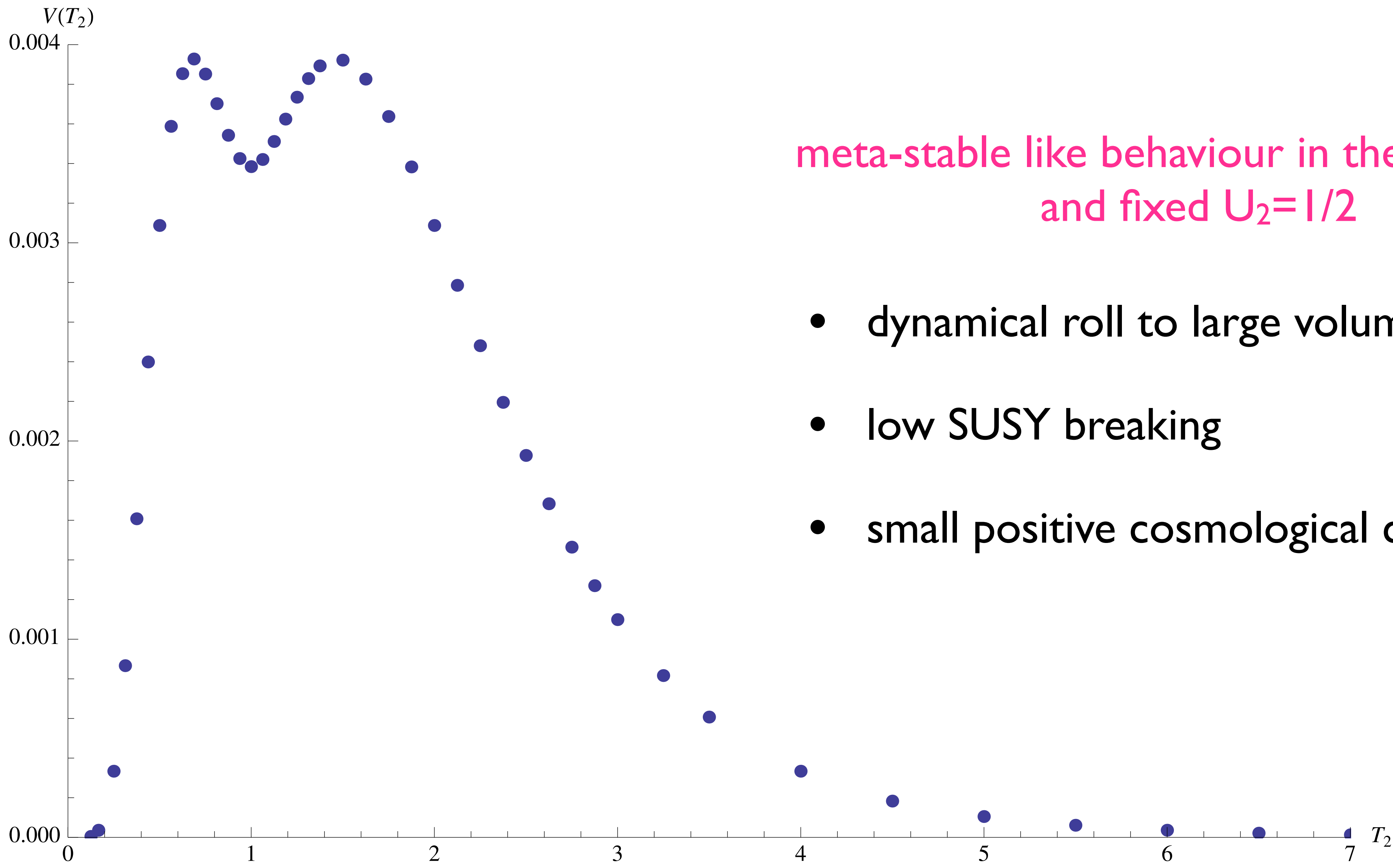
+ a particular choice of discrete torsions

$$\epsilon(2,3), \; \epsilon(2,5), \; \epsilon(4,5), \; \epsilon(5,6)$$

Example C

I.F. and J. Rizos 2016

Example C : net chirality 12 and $n_F = n_B$ at the generic point



meta-stable like behaviour in the volume T_2 and fixed U_2=1/2

- dynamical roll to large volume
- low SUSY breaking
- small positive cosmological constant

what happens around T_2=1 ? is the "false vacuum" really stable ?

Example C

I.F. and J. Rizos 2016

Example C : net chirality 12 and $n_F = n_B$ at the generic point

what happens around $T_2=1$? is the "false vacuum" really stable ?

mass formula for lowest tachyonic states

$$M^2_{\rm BPS} = \frac{1}{2}\left(T_2 + \frac{1}{T_2}\right)\left(U_2 + \frac{1}{4U_2} - \left|U_2 - \frac{1}{4U_2}\right|\right) - 1$$

tachyon free region in T,U parameter space

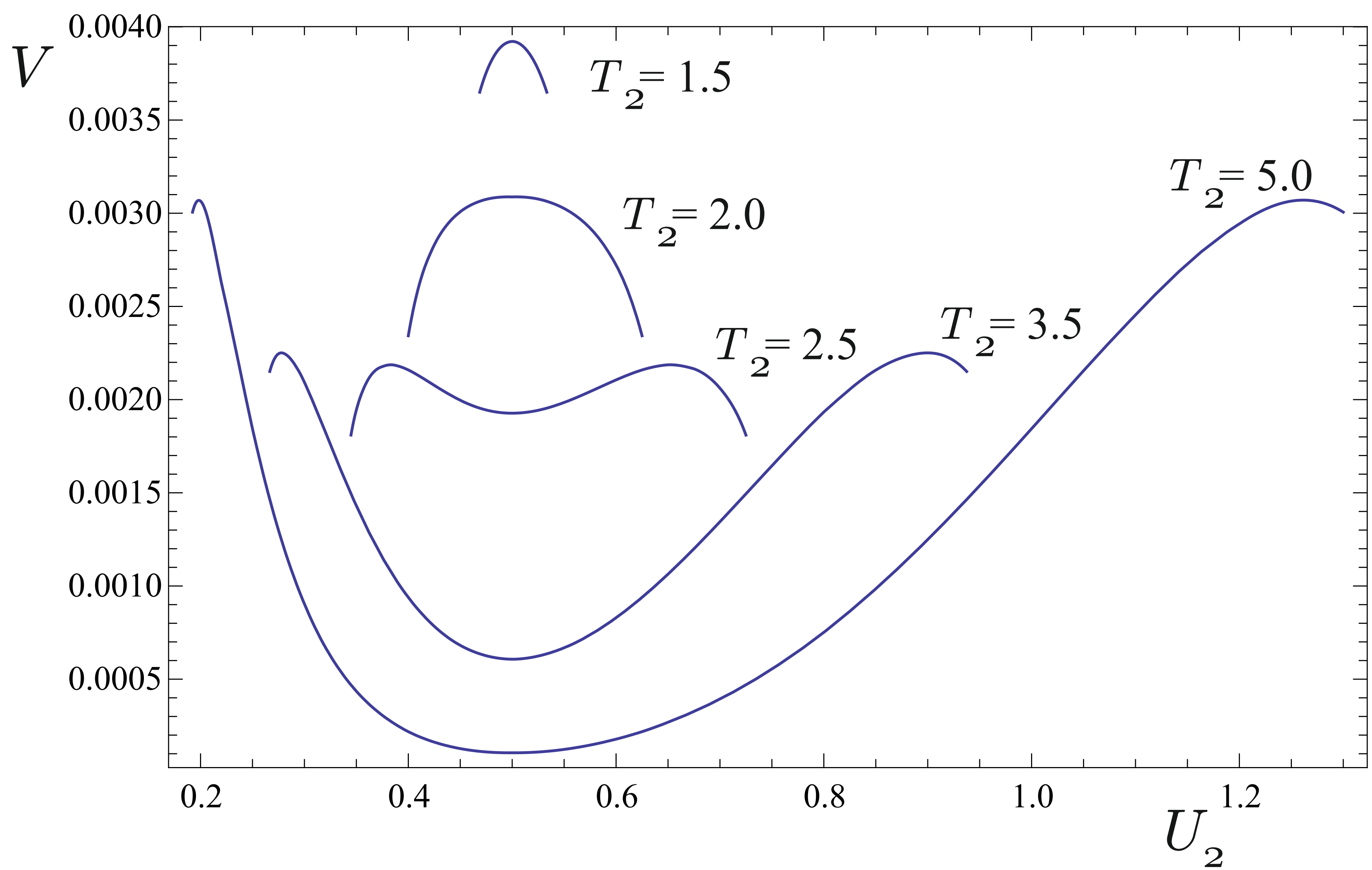
$$\left(T_2 + \frac{1}{T_2}\right)^{-1} \leq U_2 \leq \frac{1}{4}\left(T_2 + \frac{1}{T_2}\right)$$

Example C

I.F. and J. Rizos 2016

Example C : net chirality 12 and $n_F = n_B$ at the generic point

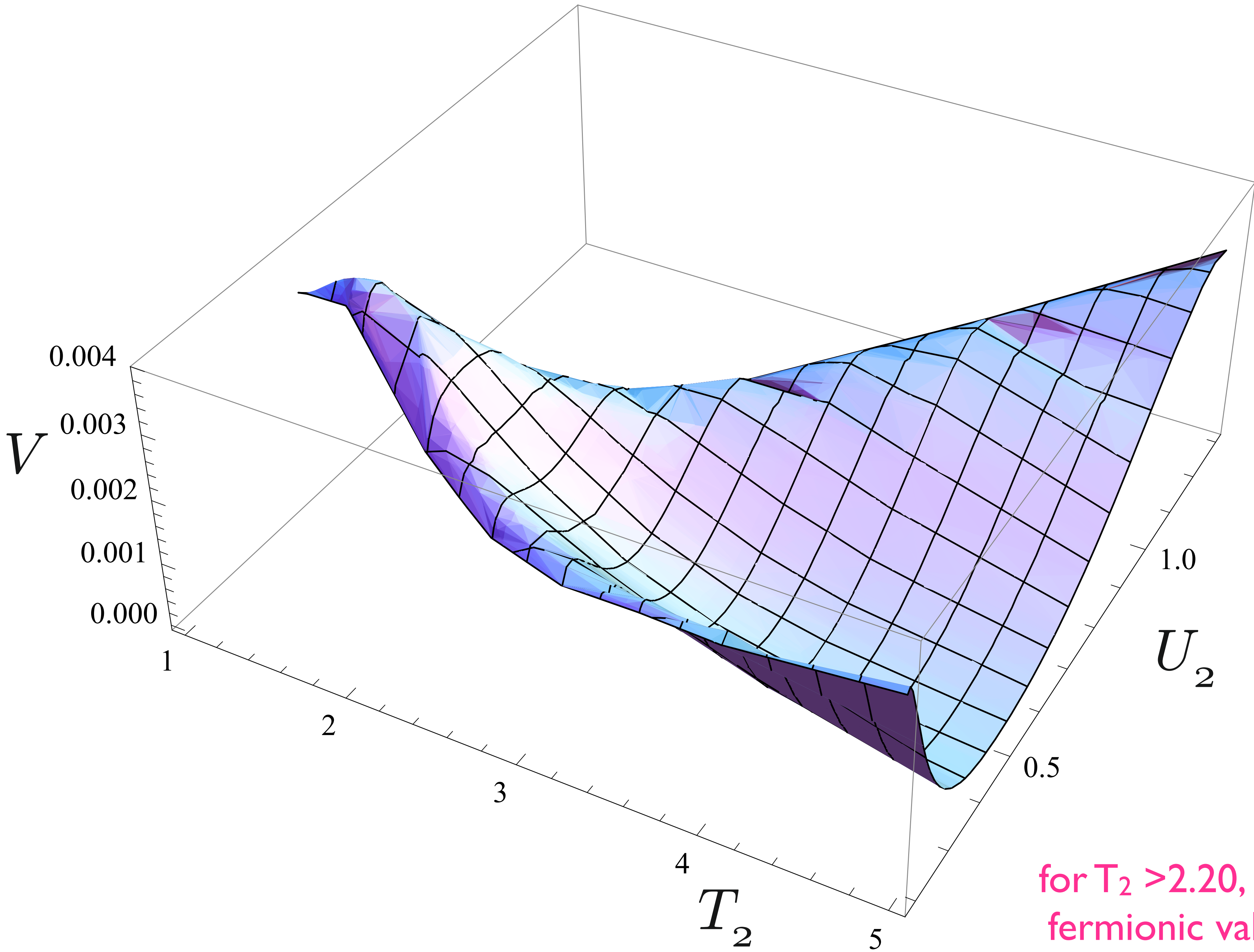
what happens around T_2=1 ? is the "false vacuum" really stable ?



Example C

I.F. and J. Rizos 2016

Example C : net chirality 12 and $n_F = n_B$ at the generic point



for T_2 >2.20, stabilisation of U_2 at its fermionic value and the potential is dynamically stable

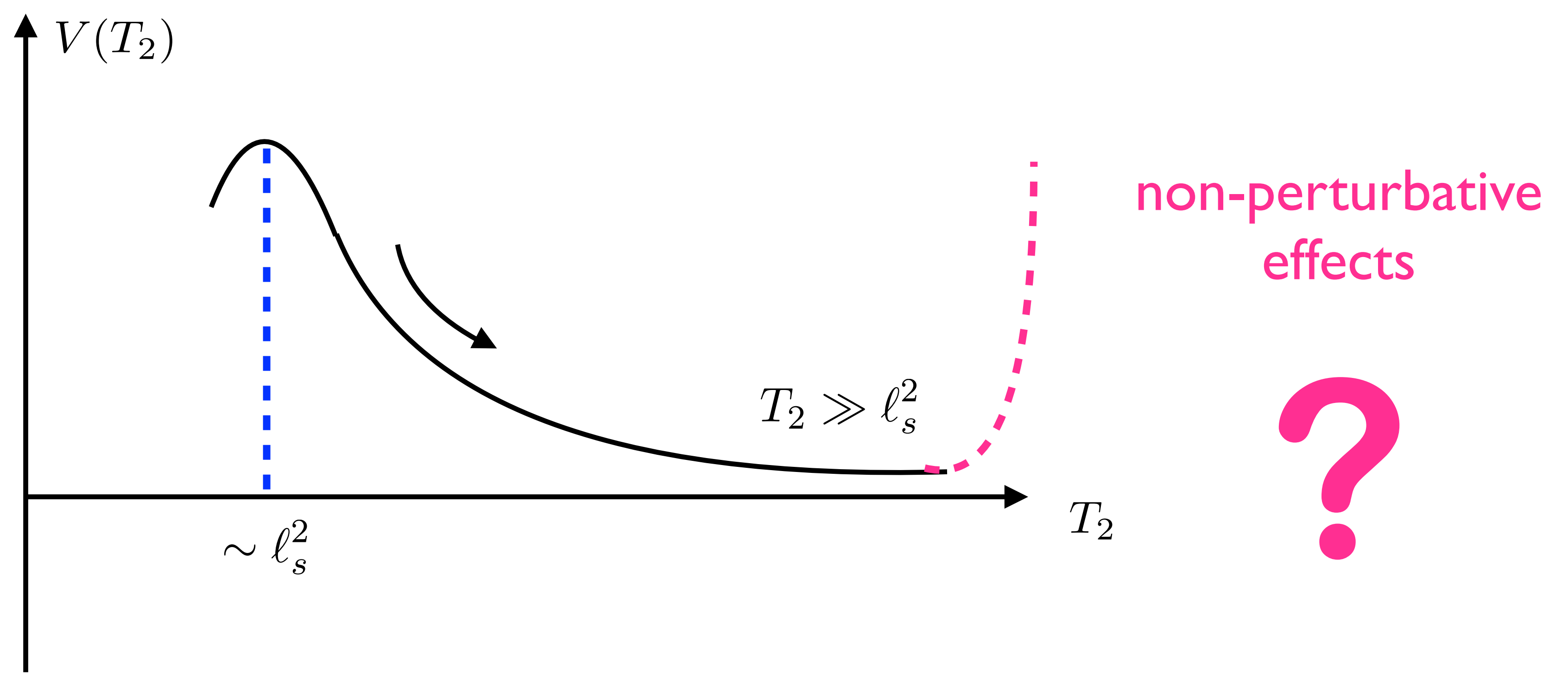
Some open questions

- Running of couplings : decompactification problem

- Linked to the presence of N=2 sectors and chirality

- Could it be that accidental cancellations occur in the beta functions for specific models ?

- Can this picture be coupled to a viable mechanism to stop the roll ? Abel 2016



Thank you !