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Mainz, 24/5/19

High scale supersymmetry in field theory & string theory

'15 ... : Dreiegl, Schweizer, Rühle, ..., Dudes, ... Tatsuta

BSM: GUT ($\Lambda_{GUT} \sim 10^{15}$ GeV), SUSY ($\Lambda_{SB} = ?$)

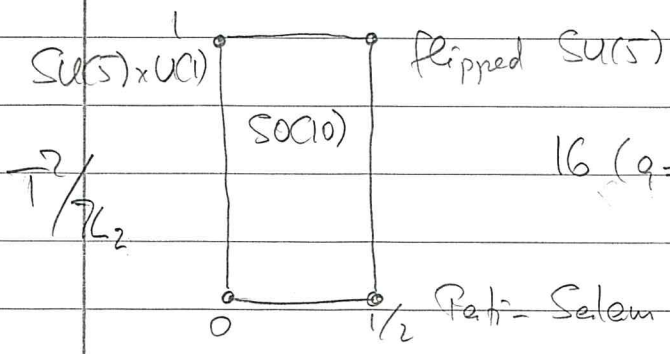
$\rightarrow \Lambda_{SB} \sim \Lambda_{GUT} \sim R_c^{-1}$?

(low energy consequences from matching at 'high scale' ?)

Badas '95: SUSY breaking from magnetic flux (higher dimensions)

→ Blumenhagen, Lust, ..., Ibanez et.al, Antoniadis et al ...,
Sequotti, Dudas, ...
(Intersecting D-brane models, flux compactifications)

Example: 6D orbifold GUT, $SO(10) \times U(1)_A$



$(H_1, H_2, \ldots)$

16 ($q=1$), 10's ($q=0$), ...

U(1) flux: $\langle F_{56} \rangle = 2\pi N$

↑ # generations

zero modes: N 16's $(q, l, u^c, e^c, d^c, \nu^c)$,

H_1, H_2, h_1, h_2 (Higgs, higgsinos)

heavy states: $m^2_{\tilde{q}} = m^2_{\tilde{e}} = \frac{4\pi N}{V_2} \sim (10^{15}\ \mathrm{GeV})^2$, ...

→ 6d: GUT & SUSY

4d: SUSY broken (matter sector) or
GUT broken (Higgs sector)

→ quantum corrections? (cancellations for U(1)

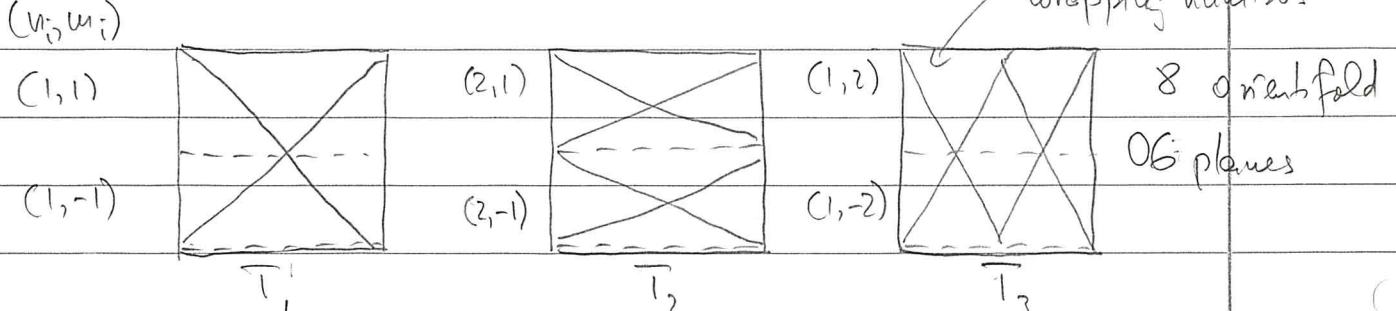
Wilson-line scalar $\varphi \sim A_6 + iA_5$)

→ 10d → string theory

D-brane model with broken supersymmetry

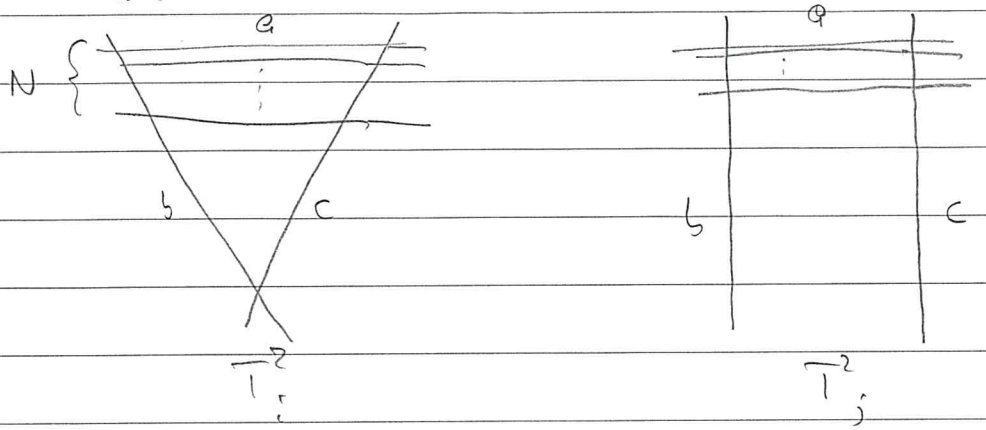
(cf. Schomerus, Ibanez & Uranga, Sagnotti et al)

type IIA on orientifold $(T^6/\mathbb{Z}_2)$: D6-branes with wrapping numbers



$z_i = x_{3+2i} + i x_{4+2i}$, $R: (z_1, z_2, z_3) \to (\bar{z}_1, \bar{z}_2, \bar{z}_3)$

D-brane model:



mirror branes: a', b', c'

tori T^2_i, integers

model: specify wrapping numbers (n^i_a, m^i_a) chiral fermions from intersection numbers

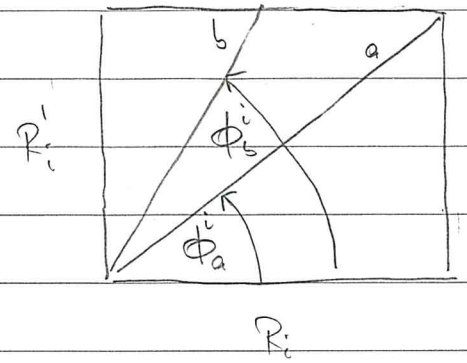
$$I_{ab} = \prod_i (n^i_a m^i_b - n^i_b m^i_a) \qquad \text{(bi-fundamental)}$$

example: $G = U(N) \times U(1) \times U(1)$

brane sector	intersection #	rep	name	spectrum
ab	$-3(\ell-2)$	$\overline{N}_{1,0}$	d^c	chiral, no SUSY
ab'	$\ell+2$	$N_{1,0}$	u	
ac	$-(\ell+2)$	$\overline{N}_{0,1}$	u^c	
ac'	$3(\ell-2)$	$N_{0,1}$	d	
bc	0	$1_{1,-1}$, $1_{-1,1}$	h_1, h_1'	vector-like, $N=2$ SUSY
bc'	0	$1_{1,1}$, $1_{-1,-1}$	h_2, h_2'	

RR tadpole cancellations: $N = 14$, $\ell = 7$

(n_a^i, m_a^i)



a : (1, 1)

b : (1, 2)

(wrapping numbers)

Φ_a^i : angles w.r.t orientifold

$\Theta_{ab}^i = |\Phi_a^i - \Phi_b^i|$ relative angles, determine scalar mass spectrum, tachyons ?

$\tan \Phi_a^i \simeq \Phi_a^i \simeq m_a^i \frac{R_i^1}{R_i} < 1$, 3 "light" scalars

structure of couplings (for simplicity superpotential):

$$W_Y = \sum_{\alpha,\beta=1}^{3(l-2)} y^d_{\alpha\beta}\, d^c_\alpha\, d_\beta\, H_2' + \sum_{\alpha,\beta=1}^{l+2} y^u_{\alpha\beta}\, u^c_\alpha\, u_\beta\, H_2'$$

calculation in dual picture

uplift of tachyonic Higgs (ξ : modulus, brane separation):

$$W_{\xi,\xi'} = \lambda_1\, \xi_1 H_1 H_1' + \lambda_2\, \xi_2 H_2 H_2'$$

moduli

stable vacuum ?

Effective action : use T-duality to type-I string compactified on T^6
(in general DQ-branes, DS-branes)

$R_i \to \frac{\alpha'}{R_i}$ ↷ dual torus

$\tan \Phi_a^i = \alpha' f_a^i$, $f_a^i = \frac{w_a^i R_i}{\alpha' R_i}$ quantized flux:

$$\int_{T_i} f_a^i = 2\pi w_a^i$$

SUGRA limit: adjoint of SO(32) on T^6 (open string states)

correspondence: $SO(32) \supset U(16) \times U(1) \times U(1)$

$SO(32) \sim$

$U(N)$	$\bar{N}_{1,0}$	$\bar{N}_{0,1}$	A	$N_{1,0}$	$N_{0,1}$
a_a	a_b	a_c	$a_{a'}$	$a_{b'}$	$a_{c'}$
$N_{-1,0}$	$\bar{U}(1)$	$I_{-1,1}$	$N_{1,0}$	0	$I_{1,1}$
b_a	b_b	b_c	$b_{a'}$	$b_{b'}$	$b_{c'}$
$N_{0,-1}$	$I_{1,-1}$	$U(1)$	$N_{0,1}$	$I_{1,1}$	0
c_a	c_b	c_c	$c_{a'}$	$c_{b'}$	$c_{c'}$
			$U^*(N)$	...	

10d gauge coupling ~ Yukawa couplings

3 U(1) factors!

Wilson line in U(2) sector:

10d SUSY Yang Mills action $S_{10}[V, \Phi^a, \bar{\Phi}^a]$

vector superfield; chiral superfields

$$V = V_a H_a + V_- \bar{T}_+ + V_+ \bar{T}_-$$

Cartan; step generators; (N=4 SUSY)

$$\Phi^i = X^i_a H_a + \Phi^i_- \bar{T}_+ + \Phi^i_+ \bar{T}_- \quad , \ldots$$

flux and Wilson line background:

$$X^i_a = \frac{f^i}{\sqrt{2}} \bar{z}_a + \xi^i_a + \varphi_i$$

mode expansion, e.g.

$$\Phi^i_+(x^\mu; z_1, z_2, z_3) = \sum_{njmlm'l'} \varphi^i_{+njmlm'l'}(x)\, \rho_{nj}(z_1)\, M_{lm}(z_2)\, M_{l'm'}(z_3)$$

harm. oscillator; KK modes

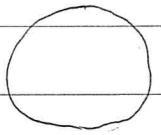
$$M^2(\xi) = |gf(n+1)| + |2\bar{u}(m+il) + \sqrt{2}g\,\xi_2|^2 + |2\bar{u}(m'+il') + \sqrt{2}g\,\xi_3|^2$$

potential tachyon: $M^2_0(\xi) = -gf + 2g^2(|\xi_2|^2 + |\xi_3|^2) < 0$

for $|\xi_2|^2 + |\xi_3|^2 < \frac{f}{2g}$

one-loop potential:

$$V = \frac{1}{i} \sum_I (-)^{F_I} \int \frac{d^4k}{(2\pi)^4} \ln(k^2 + M_I^2)$$

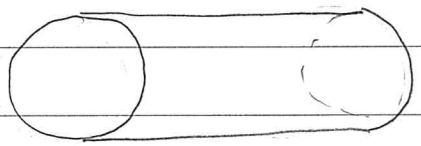


$$= -\frac{1}{16\pi^2} \int \frac{dt}{t^3} e^{-M_I^2 t}$$

$$= -\frac{N}{16\pi^2} \int \frac{dt}{t^3} \frac{1}{2\sinh(gft)} \sinh^4\left(\frac{gft}{2}\right) \sum_{w l w' l'} \dots$$

N: # of flux quanta (breaks SUSY)

one-loop string:

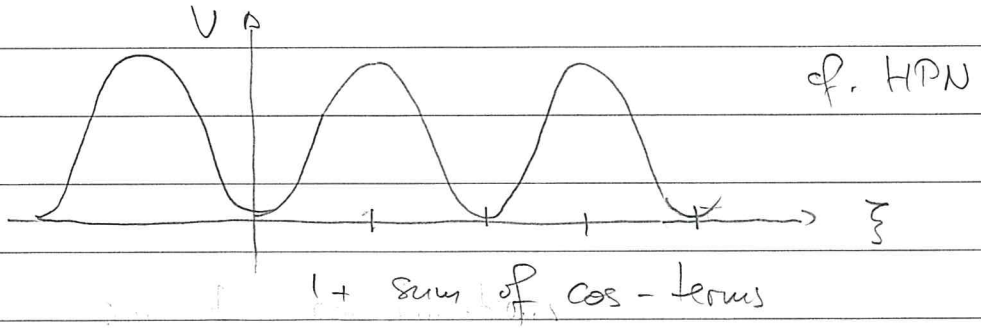


V ~ annulus amplitude

$$= \dots \int_0^\infty \frac{d\tau_2}{\tau_2^3} \text{ Jacobi-theta functions}$$

decouple osc. modes → field theory result

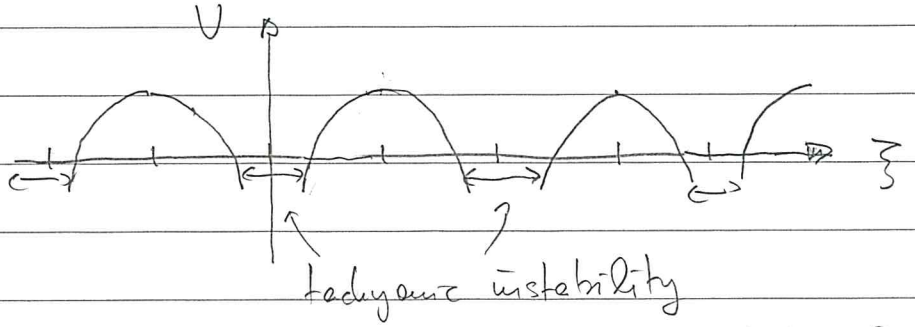
no flux: (bosonic contributions)



cf. HPN

1 + sum of cos-terms

with flux



Only saddle points! no stable ground state ?!