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Low Scale String Physics at LHC

Recent Review:
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to appear in Physics Reports

Plan of the presentation

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- "Old" (Heterotic) Model Building
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- Non-abelian gauge symmetry
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Introduction

- String theory has been around for some time. Its popularity is connected more with conceptual issues, notably a consistent theory of quantum gravity and its unification with gauge forces.

- The theory had successes in the gravitational domain. It has also accommodated popular beyond the standard model ideas like supersymmetry, unification (in its generalized form) as well as Yukawa unification etc.

- A lot of work, focusing on just beyond the SM physics has been done in the past twenty years.
Today I will focus on recent developments mostly.

- There has been important progress in the last 5 years. I will try to describe both the underlying conceptual developments (connected with D-branes) and their potential implications for collider physics, (LHC in particular).

“Old” (Heterotic) Model Building

The starting point is the 10D $E_8 \times E_8$ heterotic string.

$$S_{10} \sim \frac{M_s^8}{g_s^2} \int d^{10}x \left[R_{(10)} + \frac{1}{4M_s^2} Tr(F_{\mu\nu}^2) + \cdots \right]$$

Compactifying on a 6D manifold of volume V_6 we obtain in 4D.

$$S_4 \sim \frac{V_6 M_s^8}{g_s^2} \int d^4x \left[R_{(4)} + \frac{1}{4M_s^2} Tr(F_{\mu\nu}^2) + \cdots \right]$$

$$M_P^2 = \frac{V_6 M_s^8}{g_s^2} \quad , \quad \frac{1}{g_U^2} = \frac{V_6 M_s^6}{g_s^2}$$

$$\Rightarrow \quad \frac{M_s^2}{M_P^2} = g_U^2 \quad , \quad \text{and} \quad g_U \sim 0.2$$

$$M_s \sim M_P$$

A lot of progress has been made in this direction. The basic ingredients are:

- N=1 supersymmetry down to the TeV scale.

- Fundamental scale $M_s \sim 10^{16}$ GeV.

- Ideas on SUSY breaking

- No perfect model but concrete suggestions on the structure of the effective theory

- at TeV range, an MSSM-like theory with a few extras depending on the models.

♣ Fractional charges is a generic problem and they must be "confined" using hidden gauge group.

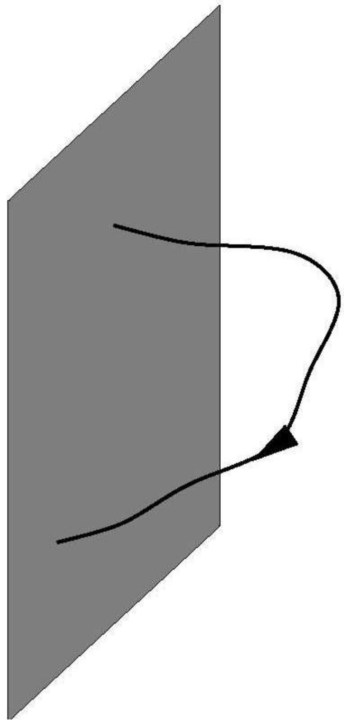
String model building is very difficult!!!

Even if you manage to find something the looks promising you will have to calculate to high order the superpotential of 100-1000 fields and then solve hundredths of equations for F- and D-flatness conditions.

D-branes

D-branes give new vistas in string model building.

A D_p-brane is roughly a p-dimensional submanifold embedded in the 9 spatial dimensions of space-time.



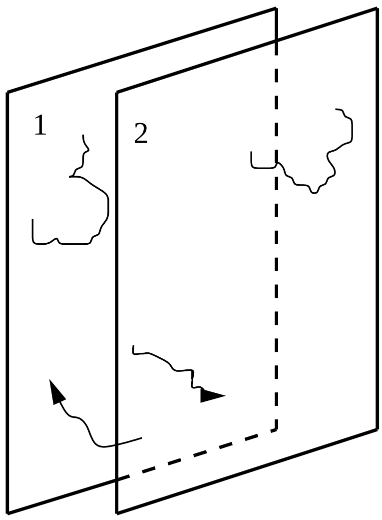
The difference from a simple wall is that they can fluctuate via open strings whose endpoints are attached to the branes.

Their fluctuations are therefore fields living on their world-volume. Their spectrum is obtained by quantizing the open strings attached to them.

In particular a generic massless fluctuation is a vector. Therefore the world-volume theory is essentially a (p+1)-dimensional gauge theory

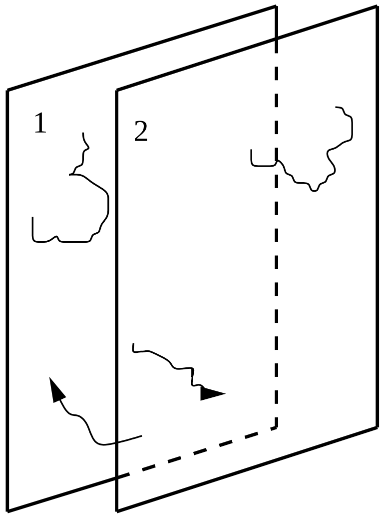
Non-abelian gauge symmetry

D-branes have a remarkable property that leads to a "geometrization" of gauge dynamics which eventually led to AdS/CFT and bulk-boundary correspondence



Two parallel coincident D-branes have four distinct open string fluctuations (11, 12, 21, 22). Each one provides a massless gauge boson. The gauge group turns out to be U(2) !!!

Consider moving one of the two branes a distance L apart, in transverse space.



Two of the strings (12, and 21) are now stretched a distance L apart and their ground state energy is

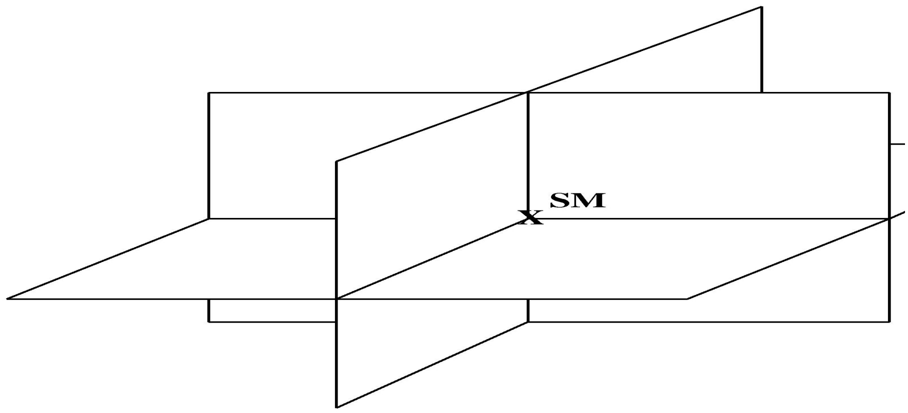
$$E_0 = T\ L$$

The gauge bosons A^μ_{12}, A^μ_{21} have acquired a mass.

This is none else but the Higgs effect

$$U(2) \to U(1) \times U(1)$$

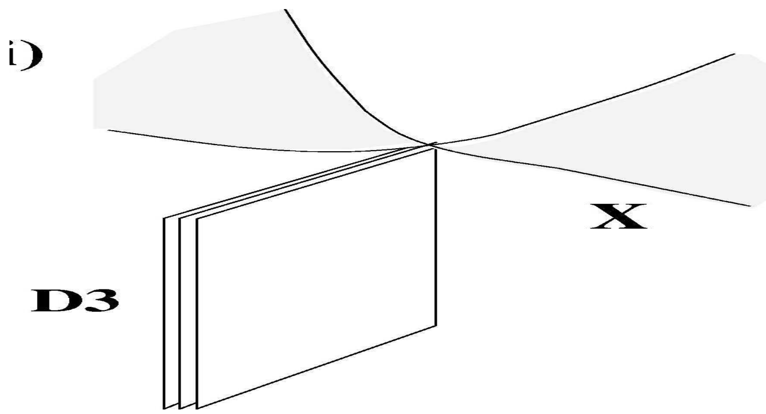
There are more complicated configurations , like branes intersecting at angles. They are dual to branes with background internal magnetic fields.



Such magnetic fields:

- Reduce the amount of supersymmetry
- Generate chirality

Chirality can also be obtained when D-branes are transverse to appropriate conical singularities.

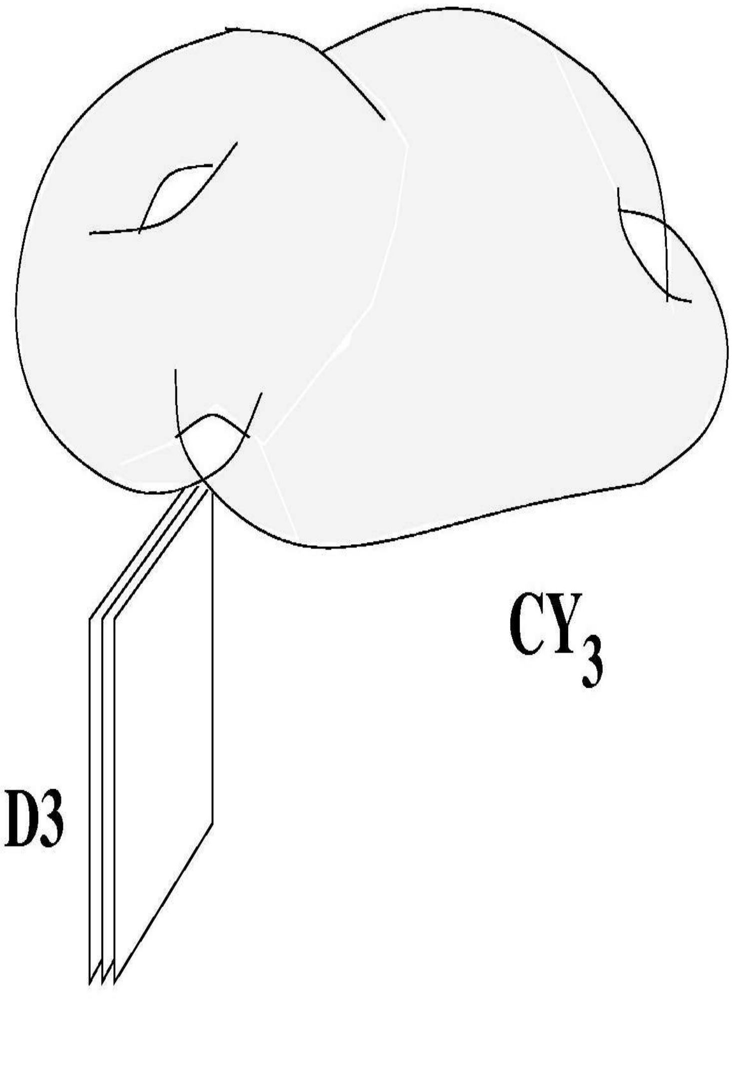


The mathematical formalism of describing the dynamics of D-branes in string theory is known as BCFT.

Orientifolds

BCFT describes a new class of vacua of string theory, which on top of a partly compactified space-time, contain also D-branes that stretch along the four Minkowski directions and may or may not wrap some internal dimensions.

Since D-branes carry gauge bosons as well as matter fermions they contribute to the gauge group and matter content of the particular ground-state.



Compact Orientifolds

We may now redo the compactification estimates for orientifolds. For gravity the story is the same as in the heterotic string.

$$S_{10} \sim \frac{M_s^8}{g_s^2}\int d^{10}x\ R_{(10)} \to \frac{V_6 M_s^8}{g_s^2}\int d^4x\ R_{(4)}$$

Consider however a (p+3)-brane wrapping a compact cycle of volume $V_{||}$. Then

$$\frac{M_s^p}{4g_s}\int d^{p+3}x\ Tr(F_{\mu\nu})^2 \to \frac{V_{||}M_s^p}{4g_s}\int d^4x\ Tr(F_{\mu\nu}^2)$$

We may then read: $(V_6 = V_{||}V_{\perp})$

$$M_P^2 = \frac{V_6 M_s^8}{g_s^2} \quad , \quad \frac{1}{g_U^2} = \frac{V_{||}M_s^p}{g_s}$$

$$\Rightarrow \quad \frac{M_s^2}{M_P^2} = \frac{g_s}{V_{\perp}M_s^{6-p}}\, g_U^2 \quad , \quad \text{with} \quad g_U \sim 0.2$$

For large internal volume $V_{\perp}M_s^{6-p} >> 1$

$$M_s << M_P$$

Therefore the string scale can be as low as a TeV. In that case, the size of strings would be directly visible in LHC.

♣ This is not a necessity , but it is possible. Otherwise the string scale can be anywhere between a TeV and the Planck scale.

♢ If $M_s \sim M_P$ we need SUSY or something equivalent (split susy?)

♡ If $M_s \sim$ TeV there is no need for SUSY (but we need a mechanism to generate large dimensions). Since string theory is always supersymmetric in the UV, SUSY is broken at M_s in this case.

The string phenomenology of $M_s \sim M_P$ string models was analyzed in the 80's.

I will be discussing here the characteristics of string (orientifold) models with $M_s \sim 1 - 100 TeV$ whose physics is novel.

There are also string examples of split susy. I will not discuss them here. *Antoniadis+Dimopoulos*

Low string scale vacua

Important issues in low scale string models
$(M_s \sim TeV)$

♣Since the "unification" scale is low, GOOD lepton number and baryon number symmetries are CRUCIAL.

We will see that gauge U(1) symmetries abundant in orientifold vacua come to the rescue.

♠ Must find an analog of the SEE-SAW mechanism for neutrino masses. Here a large internal dimension comes handy.

♡ Families can be generated from multiple intersections

Neutrino Masses

Consider the left-handed neutrino ν_L being a fluctuation of a 3-brane. Consider also a right-handed neutrino ν_R being a fluctuation of a (p+3)-brane wrapping a p-dimensional internal large volume V_p.

Dienes, Dudas, Gherghetta

We have the following action

$$S \sim \int d^{p+4}x \; (\; \bar{\nu}_R \; \partial\!\!\!/ \; \nu_R \;) + g \int d^4x \; (\; \bar{\nu}_R \; H \; \nu_L \;)$$

which upon compactification and symmetry breaking becomes

$$S \to \int d^3x \;\; [V_p \; (\; \bar{\nu}_R \; \partial\!\!\!/ \; \nu_R \;) + m \; \bar{\nu}_R \; \nu_L]$$

$m = g \; v \sim M_Z$ Normalizing kinetic terms by $\nu_R \to \nu_R/\sqrt{V_p}$ we obtain

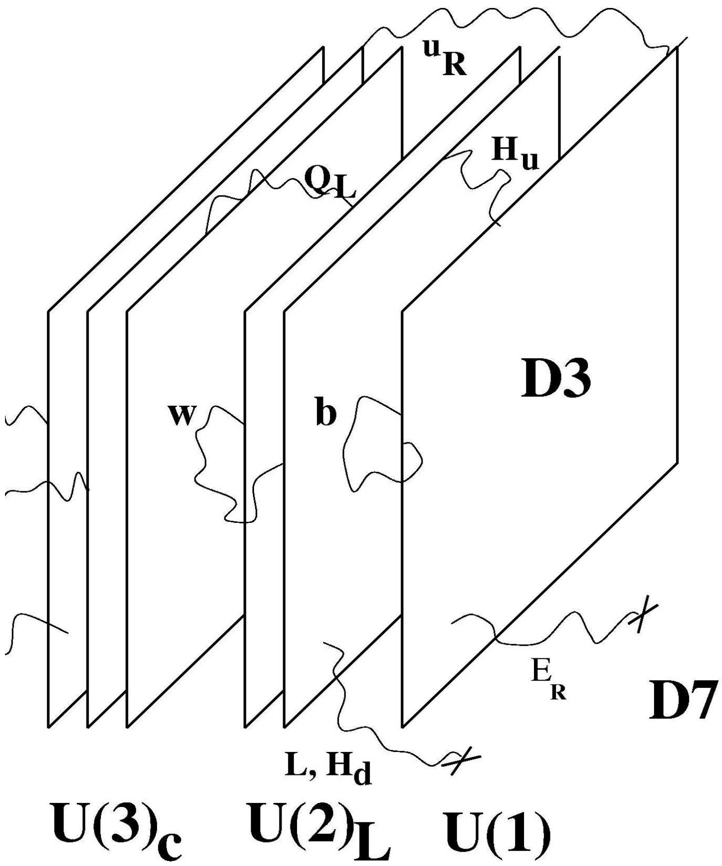
$$S \sim \int d^3x \; \left[\; \bar{\nu}_R \; \partial\!\!\!/ \; \nu_R + \frac{m}{\sqrt{V_p}} \; \bar{\nu}_R \; \nu_L \right]$$

$$m_\nu \sim \frac{M_Z}{\sqrt{V_p}} \sim M_Z \left(\frac{M_s}{M_P} \right) \sqrt{g_s} \; g_U$$

This gives $m_\nu \sim 10^{-6} - 10^{-3}$ eV.

The SM gauge group

We must embed the SM gauge group $SU(3)\times SU(2)\times U(1)_Y$ in a product of unitary factors coming for brane stacks.



Although the minimal such group is $U(3)\times U(2)$, it does not work. For a low string scale the minimal choice is $U(3)\times U(2)\times U(1)\times U(1)'$.

We will take two of the six compact directions to be large. We will wrap only the U(1)' brane around them.

SM particle	$U(1)_3$	$U(1)_2$	$U(1)$	$U(1)'$
$Q(\mathbf{3},\mathbf{2},+\frac{1}{6})$	$+1$	w	0	0
$u^c(\bar{\mathbf{3}},\mathbf{1},-\frac{2}{3})$	-1	0	a_1	a_2
$d^c(\bar{\mathbf{3}},\mathbf{1},+\frac{1}{3})$	-1	0	b_1	b_2
$L\ (\mathbf{1},\mathbf{2},-\frac{1}{2})$	0	$+1$	c_1	c_2
$e^c(\mathbf{1},\mathbf{1},+1)$	0	0	d_1	d_2
$H_u\ (\mathbf{1},\mathbf{2},+\frac{1}{2})$	0	$-w$	c_3	c_4
$H_d\ (\mathbf{1},\mathbf{2},-\frac{1}{2})$	0	$-w$	c_5	c_6
$\nu^c(\mathbf{1},\mathbf{1},0)$	0	0	d_1	d_2

♣ It is already obvious that baryon number is a gauged symmetry namely, $U(1)_3$

♣ The charges are assigned using the principle that each end-point has charges ±1

♣ The hypercharge must be a linear combination of the 4 U(1) factors:

$$Y = k_3Q_3 + k_2Q_2 + k_1Q_1 + k_1'Q_1'$$

Since U(1)' wraps large dimensions, to avoid a tiny α_Y we must take $k_1' = 0$.

Gauge couplings

The hypercharge gauge coupling is given by

$$\frac{1}{g_Y^2} = \frac{6k_3^2}{g_3^2} + \frac{4k_2^2}{g_2^2} + \frac{2k_1^2}{g_1^2} + \frac{2k_1'^2}{g_1'^2}$$

with

$$\frac{1}{g_i^2} = \frac{V_i}{g_s}$$

This explains why k_1' must be zero.

We may now determine k_i and the possible charge assignments by asking: • The hypercharge values of the SM particles are correct (This is anomaly freedom up to an overall scale).

• Lepton number is one of the gauge U(1) symmetries

• That the gauge couplings fit the data with a low M_s.

This selects two models A, B, each coming in two slightly different versions (A',B').

We will call them minimal Low Scale Orientifolds (mLSO). We will labelled them as $mLSO_{A,A',B,B'}$ for simplicity.

The fate of anomalous U(1)s

♢ All U(1)s except Y have anomalies: mixed abelian-non-abelian anomalies with SU(2) and SU(3) and (abelian)^3 anomalies.

♣ These anomalies are cancelled by the GS mechanism.

The gauge boson is now massive
and the associated gauge symmetry broken.

♠ For symmetric values of bulk moduli the global U(1) symmetry remains intact.

♡ The global symmetry is broken however beyond perturbation theory by instantons. In the case of Baryon and Lepton number, these are the SU(2) instantons, and such a rate (calculated by 't Hooft) is VERY small. This need not be the case for the PQ symmetry.

To summarize, the remaining global U(1) symmetry remains a good symmetry if the instanton effects are small and the bulk moduli have special values.

The fate of anomalous U(1)s

♣ Example: A U(1) gauge symmetry that has a mixed triangle anomaly (e.g. $\zeta = Tr[QT^aT^a] \neq 0$) The one-loop fermionic determinant induces a non-invariance to U(1) gauge transformations

$$A_\mu \to A_\mu + \partial_\mu \epsilon$$

$$\delta L_{1-\text{loop}} = \epsilon\ \zeta\ Tr[G \wedge G]$$

This is cancelled by a non-invariance of the classical (tree level action).

$$\mathcal{L}_{\text{class}} \sim -\frac{1}{4g^2} F_{\mu\nu}^2 + \frac{M^2}{2}(\partial_\mu a + A_\mu)^2 + \zeta\ a\ Tr[G \wedge G]$$

The axion now transforms

$$a \to a - \epsilon$$

$$\mathcal{L}_{\text{class}} \to \mathcal{L}_{\text{class}} - \zeta\ \epsilon\ Tr[G \wedge G]$$

and the anomaly is cancelled.

- The D-term-like potential is of the form

$$V \sim \left(s + \sum_i q_i |\phi_i|^2 \right)^2$$

where s is a bulk modulus. In SUSY Theories it is the chiral partner of the axion "eaten up" by the anomalous U(1) gauge boson. If $< s >= 0$, the global U(1) symmetry remains intact.

Anomalous U(1) masses

There are two sources for the masses of anomalous U(1)s:

• The UV mass-term responsible for anomaly cancellation

$$L_{UV} \sim \frac{1}{2} M^2 (\partial_\mu a + A_\mu)^2$$

This is computable only in string theory. It turns out that

$$M \sim g \frac{M_s}{\sqrt{V}}$$

Depending on V it can be $\sim M_s$ or $<< M_s$ (unlike the heterotic string).

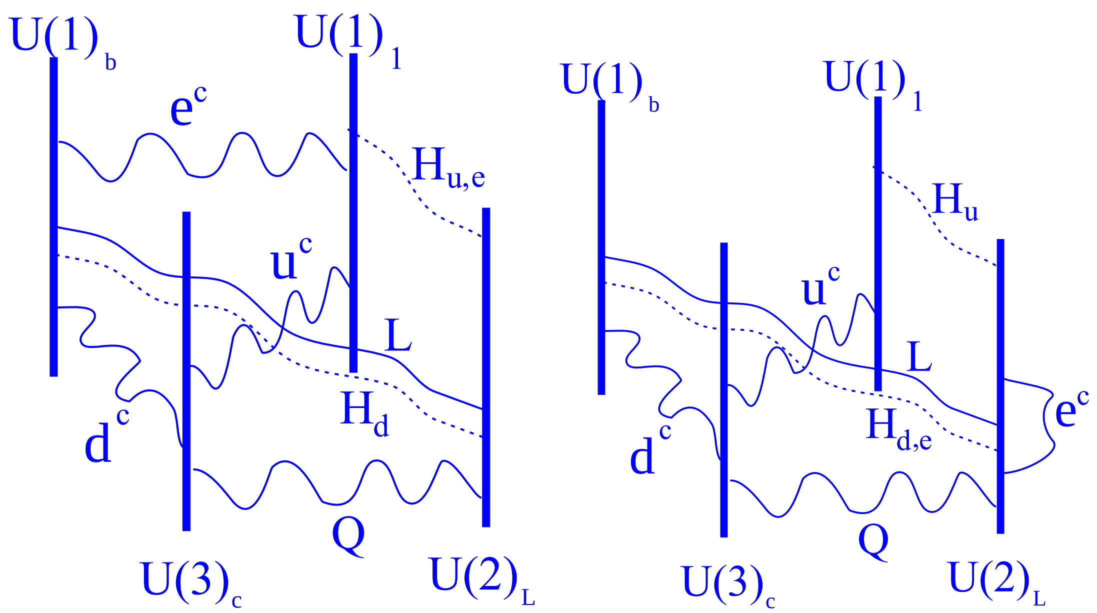
• contributions from spontaneous symmetry breaking. The standard Higgses when they get vevs they break also the U(1) symmetries In total:

$$M \simeq \sqrt{M^2 + g^2 v^2} \simeq \sqrt{M^2 + M_Z^2}$$

In this class of models, such Z's are generic, their low energy couplings fixed by charges and anomalies and only M depends on UV physics.

Models mSLO$_A$ and mSLO$_{A'}$

SM particle	$U(1)_3$	$U(1)_2$	$U(1)$	$U(1)'$
$Q(\mathbf{3},\mathbf{2},+\frac{1}{6})$	$+1$	-1	0	0
$u^c(\bar{\mathbf{3}},\mathbf{1},-\frac{2}{3})$	-1	0	-1	0
$d^c(\bar{\mathbf{3}},\mathbf{1},+\frac{1}{3})$	-1	0	0	-1
$L\ (\mathbf{1},\mathbf{2},-\frac{1}{2})$	0	$+1$	0	-1
$e^c(\mathbf{1},\mathbf{1},+1)$	0	0(2)	1(0)	1(0)
$H_u\ (\mathbf{1},\mathbf{2},+\frac{1}{2})$	0	1	1	0
$H_d\ (\mathbf{1},\mathbf{2},+\frac{1}{2})$	0	-1	0	-1
$\nu^c(\mathbf{1},\mathbf{1},0)$	0	0	0	± 2



Models mSLO$_A$ and mSLO$_{A'}$

Hypercharge:

$$Y = -\frac{1}{3}Q_3 - \frac{1}{2}Q_2 + Q_1$$

Gauge couplings and string scale: $g_2(M_s)$ and $g_3(M_s)$ are determined by data. By varying $g_1(M_s)$ we can determine M_s from $\alpha_Y(M_Z)$:

$$V_1 = V_2 \quad , \quad M_s \simeq 800 \quad GeV$$

$$3V_1 = 2V_2 + 2V_3 \to \quad M_s \simeq 1.5 \; TeV$$

$$2V_1 = V_2 + V_3 \to \quad M_s \simeq 56 \; TeV$$

Remember: at M_s, $1/g_i^2 = V_i/g_s$.

Global symmetries:

$$\text{Baryon Number} \quad B = \frac{1}{3}Q_3$$

$$\text{Lepton Number} \quad L = \frac{1}{2}(Q_3 + Q_2 - Q_1 - Q_1')$$

$$\text{Peccei} - \text{Quinn} \quad PQ = -\frac{1}{2}(Q_3 - Q_2 - 3Q_1 - 3Q_1')$$

All U(1)'s except Y are "anomalous" and therefore massive. All except PQ remain as good global symmetries.

Quark and Lepton masses

For the 3rd generation the structure of masses is:

$$M_{\text{model A}} = \lambda_u\, Q\, u^c\, H_u + \lambda_d\, Q\, d^c\, H_d^\dagger + \lambda_e\, L\, e^c\, H_u^\dagger +$$

$$+ \lambda_\nu\, L\, H_d\, \nu_R$$

at tree level, in the particular brane configuration

$$\lambda_u = \lambda_e = \sqrt{2} g_2\,, \quad \lambda_d = \sqrt{2 g_s}\,, \quad \lambda_\nu = \sqrt{2} g_b\,.$$

Fitting $m_b \simeq 4$ GeV we get

$$m_t \simeq 162 \quad \text{GeV} \quad \text{(not so bad!)}$$

But $m_\tau \sim m_t$ which is unrealistic. The way out is to have $\lambda_e = 0$ at tree level so that the τ mass is generated from higher order terms. Turning to model A'

$$M_{\text{model A}'} = \lambda_u\, Q\, u^c\, H_u + \lambda_d\, Q\, d^c\, H_d^\dagger + \lambda_e\, L\, e^c\, H_d^\dagger +$$

$$+ \lambda_\nu\, L\, H_d\, \nu_R$$

m_b and m_t are as above, but now

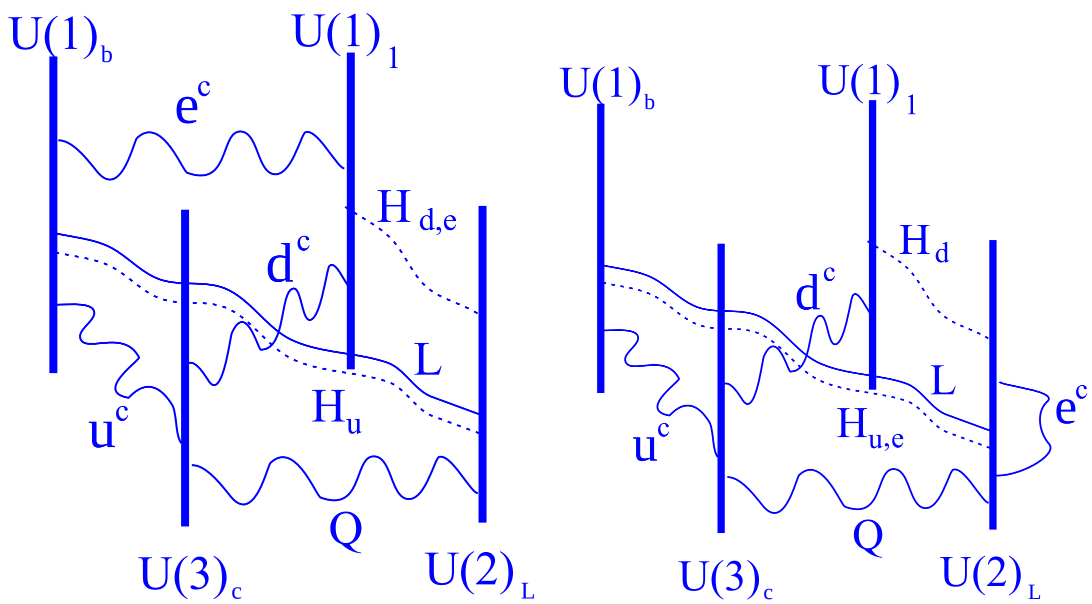
$$\frac{m_b}{m_\tau} = \frac{g_3}{g_2} \Rightarrow m_\tau(M_s) = 1.75 \quad \text{GeV}$$

not very far from the measured value $m_\tau(M_Z) = 1.46$ GeV

The neutrino masses are in the range $10^{-5} = 10^{-3}$ eV.

Models mSLO$_B$ and mSLO$_{B'}$

SM particle	$U(1)_3$	$U(1)_2$	$U(1)$	$U(1)'$
$Q(\mathbf{3},\mathbf{2},+\frac{1}{6})$	$+1$	-1	0	0
$u^c(\bar{\mathbf{3}},\mathbf{1},-\frac{2}{3})$	-1	0	0	1
$d^c(\bar{\mathbf{3}},\mathbf{1},+\frac{1}{3})$	-1	0	1	0
$L\ (\mathbf{1},\mathbf{2},-\frac{1}{2})$	0	$+1$	0	-1
$e^c(\mathbf{1},\mathbf{1},+1)$	0	0(2)	1(0)	1(0)
$H_u\ (\mathbf{1},\mathbf{2},+\frac{1}{2})$	0	-1	0	-1
$H_d\ (\mathbf{1},\mathbf{2},+\frac{1}{2})$	0	1	1	0
$\nu^c(\mathbf{1},\mathbf{1},0)$	0	0	0	± 2



Models mSLO$_B$ and mSLO$_{B'}$

Hypercharge:

$$Y = \frac{2}{3}Q_3 - \frac{1}{2}Q_2 + Q_1$$

Gauge couplings and string scale:

$$V_1 = V_3 \quad , \quad M_s \sim 7 \quad TeV$$

$$3V_1 = V_2 + V_3 \quad , \quad M_s \sim 3.5 \quad TeV$$

Global symmetries:

$$\text{Baryon Number} \quad B = \frac{1}{3}Q_3$$

$$\text{Lepton Number} \quad L = -\frac{1}{2}(Q_3 - Q_2 + Q_1 + Q_1')$$

$$\text{Peccei} - \text{Quinn} \quad PQ = \frac{1}{2}(-Q_3 + 3Q_2 + Q_1 + Q_1')$$

All U(1)'s except Y are "anomalous" and therefore massive. All except PQ remain as good global symmetries.

The Higgs sector

Although the low energy spectrum is non-supersymmetric, we have a Higgs sector reminiscent of the MSSM.

Here a priori more general terms are allowed.

• If the breaking of supersymmetry is due to internal magnetic fields, then all quartic terms can a priori appear at tree level. This changes the bounds on the lightest Higgses.

• If supersymmetry breaks via the branes sitting at singularities, then the tree-level terms in the potential are the usual supersymmetric D-terms that align the vev's of the Higgses. However, as in the SM , at loop level all terms will be generated.

• The PQ symmetry is broken by the potential. This is important in order to give a mass to the associated PQ axion. The dimension-2 term with this property is the μ-term of the MSSM

Axions

To indicate the problem consider

$$S = -\frac{1}{4g^2}F_{\mu\nu}^2 - \frac{1}{2}(k\partial_\mu a + M\ A_\mu)^2 + \mathcal{A}_i\ aTr[G_i \wedge G_i] -$$

$$-\frac{1}{2}|\partial_\mu H + ie\ A_\mu\ H|^2 + V(|H|) + \gamma\ H\ \psi\bar{\psi}$$

where $\mathcal{A}_i$ is the mixed anomaly $Tr[Q\ T_i^a T_i^a]$. Diagonalizing and gauge fixing we obtain

$$S = -\frac{1}{4g^2}F_{\mu\nu}^2 - \frac{M^2 + e^2v^2}{2}\ A_\mu^2 - \frac{1}{2}(\partial_\mu\chi)^2 -$$

$$-\frac{\mathcal{A}_i ev}{k\sqrt{M^2+e^2v^2}}\ \chi\ Tr[G_i \wedge G_i] + \gamma v\ e^{\frac{iM\ \chi}{v\sqrt{M^2+e^2v^2}}}\ \psi\bar{\psi}$$

Putting the anomaly into the fermion phase the linearized Yukawa coupling of the axion χ to the fermions is

$$\gamma_\psi \simeq \frac{m_\psi M}{v\sqrt{M^2+e^2v^2}} + \frac{\mathcal{A}_i\ m_\psi\ ev}{k\sqrt{M^2+e^2v^2}}$$

$$\frac{1}{g^2} = \frac{V_c V_A}{g_s} \quad , \quad M^2 = \frac{V_c}{V_a}M_s^2 \quad , \quad k^2 = \frac{V_c V_a}{g_s^2} \quad , \quad \mathcal{A}_i \sim \frac{a_i}{M_s}$$

For $M >> M_Z$ the first term is important for heavy quarks.

For $M << M_Z$, both factors can be small, but then the Z' must be unobservable. This will happen for $g << 1$ which needs four large dimensions, and then there is trouble with supernovae energy loss.

The bulk U(1)'

We have seen that U(1)' wraps the two large dimensions. Therefore its gauge boson has finely spaced KK states, like the KK gravitons. The only other SM filed that feels the large dimensions is the right-handed neutrino

An estimate of its coupling is

$$g^2 \simeq (4\pi\alpha_{\text{strong}})\frac{M_s^2}{M_P^2} \sim 5 \times 10^{-31}$$

if its UV mass is $M \sim M_s$ then its physical mass is

$$M_{\text{phys}} = gM_s \sim 5 \times 10^{-3} \quad \text{eV}$$

Although this is allowed by table-top experiments it is excluded by Supernova data because

$$\frac{P_A}{P_g} \sim \frac{1}{g_s}\left(\frac{M_s}{T}\right)^2 \sim 10^8 - 10^{10}$$

Therefore, this gauge boson must take a mass from an N=2 sector.

$$\frac{1}{g^2} = \frac{V_c V_A}{g_s} \quad , \quad M^2 = \frac{V_c}{V_a} M_s^2 \quad ,$$

This corresponds to $V_c >> 1$, $V_a, V_A \sim 1$ which would imply $M_{\text{phys}} \sim M_s$ which is acceptable.

WARNING !!!!!

♣ There are orientifold models with light spectrum only the one I presented (SM, 2 Higgses, right-handed neutrinos plus extra U(1)s)

♣ There are orientifold models with large compactification manifold, as advocated here.

♠ There are orientifold models where SUSY is broken at the String scale without closed or (unrealistic) open string tachyons.

♠ There are orientifold models where SUSY is broken completely and which are in equilibrium at tree level (cancelled tadpoles → cancellation of UV divergences in open theory)

♢ There are orientifold models, with all moduli (including the dilaton) are stabilized.

♡ There are orientifold models, with no fractional charged particles.

♡ There are orientifold models with no SM exotics.

There are combinations of the above.

HOWEVER, THERE IS NO STRAIGHT

(♣♢♠♡)

YET!

Experimental implications

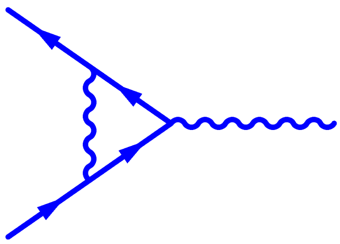
Low scale string models have several characteristic signals that distinguish them from high scale ones.

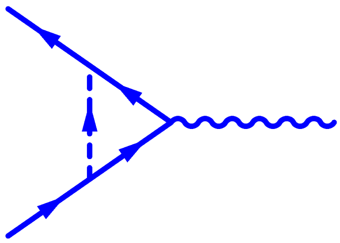
• Their minimal spectrum is that of the standard model with two Higgs doublets, and three massive Z' gauge bosons

• Two of the massive Z's have masses ranging from several hundred GeV to several TeV. The third one, being very weakly coupled, can be much lighter. The charges of the SM model particles under the three Z's are fixed in each of the four mLSO.

The Z' can be produced directly at LHC or they can affect precision parameters (g-2, ρ).

• They are constrained by $g-2$ measurements via contributions of the form:





Apart from their decay to di-leptons they have also a unique signal: their decay (parity violating) to two photons, due to very special anomaly-related CS interactions. They can provide direct signals at LHC by being produced or indirect (g-2, ρ parameter etc)

Ibanez et al.
Anastasopoulos, EK

In LHC, $pp \to Z' \to e^+e^-$ is visible with $M_{Z'}$ up to 5 TeV.

• The Higgs sector is MSSM like, but with more general couplings a priori.

• The neutrinos come from large dimensions. Their mixing with KK descendants might be observable.

• The KK states of the bulk fields (graviton et al.) are those of two large extra dimensions with all the known implications for LHC.

• String states may be also produced if the string scale is $M_s < 5TeV$. The superpartners are in this class.

Whether nature has chosen this avenue to express its whims remains to be seen.