Z_{12} Orbifold Compactification toward Standard Model

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1. Introduction
2. Strings on orbifolds
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4. Phenomenology
5. Harmless R-parity violation

Works done with
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I. Introduction

Standard model with 45 (+3) chiral fields are remarkable.
"How does this standard model arise?"
(Big problem)

There were attempts to obtain from superstring, but a model free of any phenomenological problems has not appeared yet.

So still search for a good string vacuum is an important issue. (LHC, PLANCK, CAST, PVLAS)

Here, we follow the compactification route through orbifold. (The easiest way.) It is basically a geometric one.

Manifold with discrete action
$\Longrightarrow$ orbifold

$\boxed{\text{Supersymmetric standard model}}$ We have

→ Directly from compactification (KKK)
→ Through intermediate GUTs (K-Kyae)

Early attempts were just standard-like models

$$\begin{cases} SU(3)\times SU(2)\times U(1)^n \\ 3 \text{ families} \end{cases}$$

late '80s

Recently, more ambitious attempts were tried.

From orbifold compactification, we obtain

$$\begin{cases} SU(3)^3 & \text{trinification} \\ SU(5)\times U(1) & \text{flipped } SU(5) \\ SU(3)\times SU(2)\times U(1) & \text{SM} \end{cases}$$

also from fermionic construc. also

There was the adjoint problem that at $k=1$ (Kac-Moody level) no adjoint is possible. Thus, GUTs $SU(5)$, $SO(10)$ E_6 are not good toward MSSM.

This prefers GUTs with factor groups:

$SU(3)^3$ ⟵ best for $\sin^2\theta_W$

$SU(4) \times SU(2) \times SU(2)$
$SU(5) \times U(1)$

} manageable with matter content

OR DIRECTLY

Standard model !!! (KIM, KIM, KYAE)

There are several problems to be solved:

1. Approximate R parity, for proton longevity
2. Exotics problem: if exotics are not removed, severe phen. prob.
3. Vectorlike pairs problem
4. Successful fit to quark and lepton masses and mixing angles
5. Strong CP problem, etc.

The most important thing to be solved is the R parity problem: proton must live long enough!!!

SO(10) GUT : R-parity $-1\ -1\ 1$

Spinor, Vector $\Rightarrow$ Yukawa SSV

But if we consider nonrenormalizable couplings with singlets attached, there must be some conditions. SSV111...

Exactly, this kind of affair arises in string compactification. Namely, R-parity condition is the most perilous disaster. I guess all string compactifications assumed R so far.

No global U(1) allowed.

NOTE But discrete symmetry may be allowed.

For the discrete symmetry to be good,
it must be discrete gauge symmetry.
We consider global U(1)s,
which must be approximate.

So most likely, the R-parity is
approximate. We hope that it is

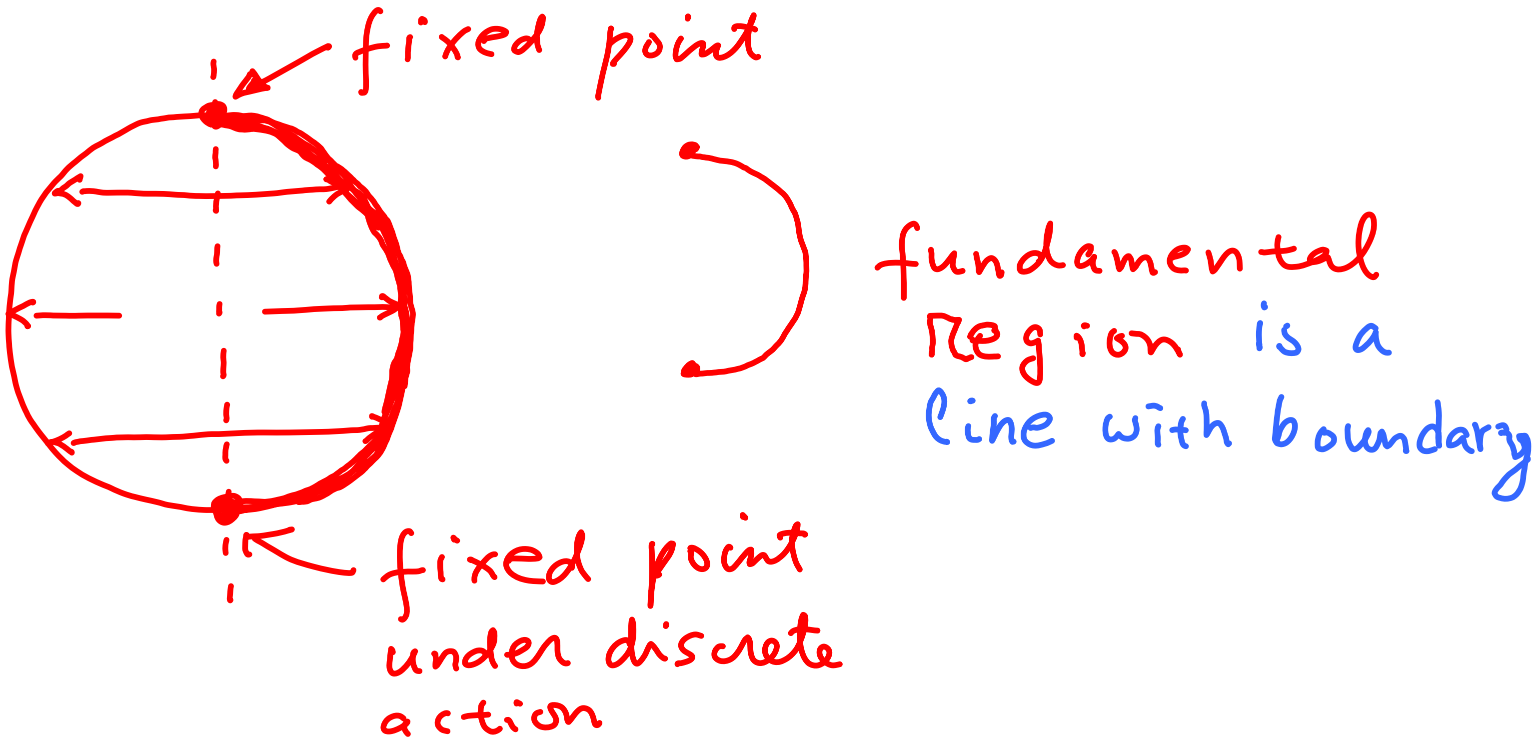
Approximate but sufficiently suppressed
R violating terms are {I. W. Kim, JEK, B. Kyae}

hep-ph/0612365

II Strings on Orbifolds

Manifolds moded by discrete action

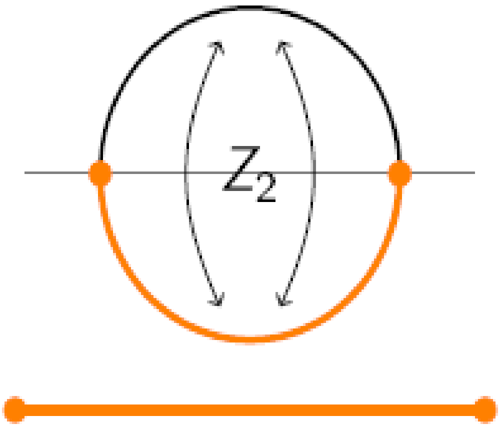
S_1 / Z_2



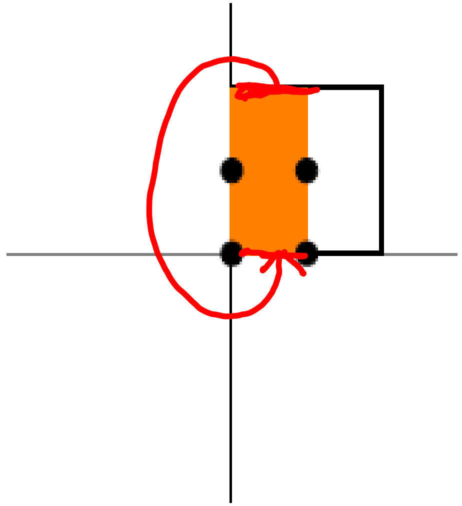
Orbifold Compactification

- Orbifold can be obtained by identifying a manifold by discrete action.

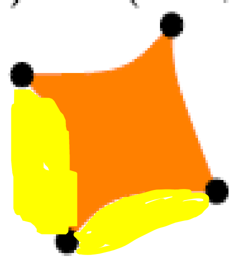
The simplest orbifold is S^1/Z_2.



two dimensional version T^2/Z_2

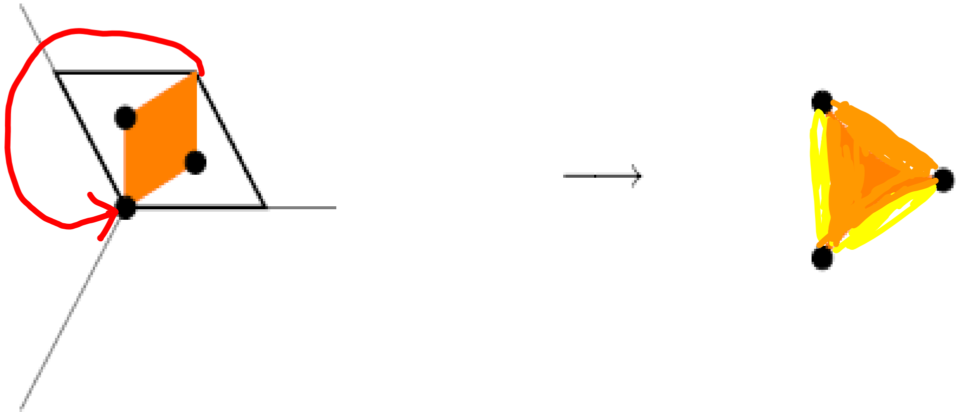


$(x, y) \leftrightarrow (-x, -y)$



4 fixed pts

For specially symmetric manifold, we can mod out the manifold by different discrete group.
e.g.) T^2/Z_3



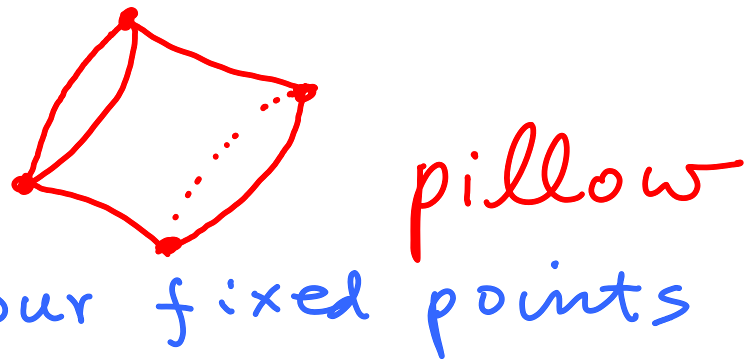
We compactify 6 dimensions. We consider a flat internal space only except singular fixed points. Starting from $T^6 = T^2 \otimes T^2 \otimes T^2$, identify the space by

$$z = (z_1, z_2, z_3) \sim \theta \cdot z = (e^{2\pi i \phi_1} z_1, e^{2\pi i \phi_2} z_2, e^{2\pi i \phi_3} z_3).$$

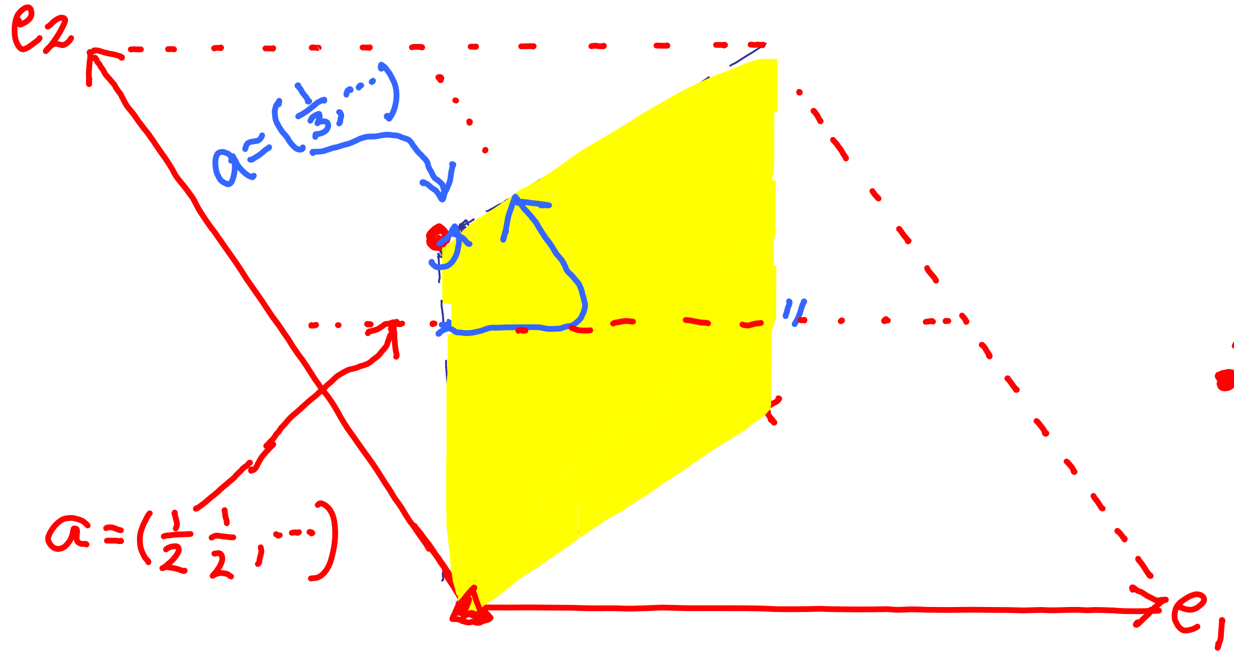
For $\mathrm{Z_N}$ string orbifold, consistent condition $\theta^N = 1$ for world-sheet spinor requires

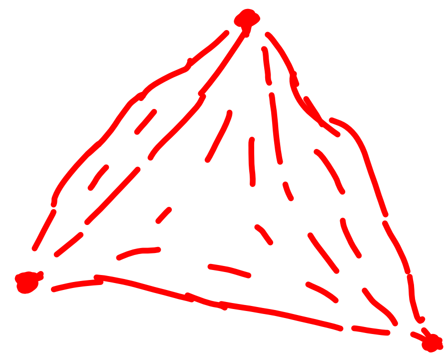
$$N \sum_i \phi_i = \text{even integer}$$

S_2/Z_2



(Ex) T_2/Z_3 $120°$ rotation = discrete action





triangular ravioli

6 internal space compactified

T_6/Z_3 : 27 fixed points

Six internal space $\phi = (\frac{2}{3}\ \frac{1}{3}\ \frac{1}{3})$

We embed this orbifold action in $E_8 \times E_8'$ group space

$$(v\ v\ v\ v\ v\ v\ v\ v)(v\ v\ v\ v\ v\ v\ v\ v)'$$
$$E_8 \qquad \times \qquad E_8'$$

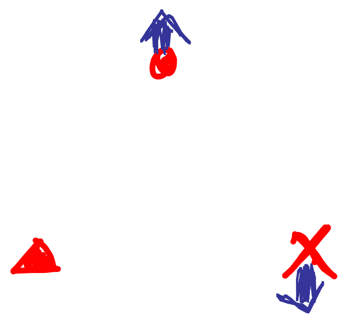
Standard embedding

$$V \equiv (\tfrac{2}{3}\ \tfrac{1}{3}\ \tfrac{1}{3}\ 0\ 0\ 0\ 0\ 0)(0\ 0\ 0\ 0\ 0\ 0\ 0\ 0)'$$

$$E_8 \longrightarrow E_6$$

Wilson lines : e.g. $a_i = (0\ 0\ 0\ \tfrac{2}{3}\ \tfrac{1}{3}\ \tfrac{1}{3}\ 0\ 0)(0)'$

If Wilson lines are present, then 3 fixed points are distinguished



3 fixed points are distinguished by fluxes, or Wilson lines

V	$V+a_3$	$V-a_3$
$V+a_1$	$V+a_3+a_1$	- - - - -
$V-a_1$	$V+a_3-a_1$	- - - - - - - -

II Model : Z_{12-I} Model

$$\phi = \left(\frac{5}{12} \quad \frac{4}{12} \quad \frac{1}{12} \right)$$

: In total, 3 fixed points

prime Z_{12} 1 fixed pt.

Z_3 3 fixed pts

flipped SU_5

$$V = \left(\frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}\ \frac{1}{4}\ \frac{5}{12}\ \frac{6}{12}\ 0 \right)\left(\frac{2}{12}\ \frac{2}{12}\ 0\ 0^5 \right)$$

$$a_3 = a_4 = \left(0^5 \quad 0\ \frac{-1}{3}\ \frac{1}{3} \right)\left(0\ 0\ \frac{2}{3}\ 0^5 \right)$$

$$a_1 = a_2 = a_5 = a_6 = 0$$

Kyae + JEK
th/0608085
86

Gauge group

$$\underbrace{SU(5)\times U(1)}_{\text{flipped } SU(5)} \times U(1)^3 \times SU(2)' \times SO(10)' \times U(1)'^2$$

NAHE from fermionic construction

flipped $SU(5)$ which can be broken by $\langle 10_1 \rangle$ to SM. This model gives 3 families plus 1 pair of Higgs doublets, by Yukawa couplings of cubic order.

- Spectrum of the model

There are 12 sectors from Z_{12} twisting.

$$\overbrace{\left(\begin{array}{c}\textit{Untwisted}\\ T6\end{array}\right)}^{\text{Self CPT conjugate}}$$

$$T1 \overset{CPT}{\longleftrightarrow} T11$$

$$T2 \overset{CPT}{\longleftrightarrow} T10$$

No T3, T9

$$T4 \overset{CPT}{\longleftrightarrow} T8$$

$$T7 \overset{CPT}{\longleftrightarrow} T5$$

Each sector has three subsectors distinguished by Wilson line.

$T_6 T_6 U_2$

b

$$U \;:\; \boxed{(\mathbf{1}_{-5}+\mathbf{5}_3+\overline{\mathbf{10}}_{-1})_{U_3}},\quad \boxed{(\overline{\mathbf{5}}_2)_{U_2}},$$

$$\boxed{(\mathbf{1}_{-5}+\mathbf{5}_3+\overline{\mathbf{10}}_{-1})_{U_1}},\quad (\mathbf{1}_0)_{U_2},$$

$$T_6 \;:\; \boxed{\overline{\mathbf{10}}_{-1}} + \boxed{\{2(\mathbf{1}_{-5}+\mathbf{1}_5+\mathbf{5}_{-3}+\overline{\mathbf{5}}_3)} \; + \boxed{3(\boxed{\overline{\mathbf{10}}_{-1}+\mathbf{10}_1})}\;\} + 22\{\mathbf{1}_0\},$$

$$T_2 \;:\; \boxed{\mathbf{1}_{-5}} + \boxed{\mathbf{5}_3} + 11\{\mathbf{1}_0\} + 4\mathbf{D} + \boxed{\mathbf{O10}+\mathbf{O\overline{16}}}$$

Breaks SUSY

(Murayama '95)

$T_6 T_2 T_4$

$$T_4 \;:\; \boxed{\mathbf{5}_{-2}} + \boxed{2(\mathbf{5}_{-2}+\overline{\mathbf{5}}_2)} + 30\{\mathbf{1}_0\} + 12\mathbf{D},$$

$$T_1 \;:\; 2(\overline{\mathbf{5}}_{-\frac12}) + 2(\mathbf{5}_{+\frac12}) + 6(\mathbf{1}_{-\frac52}) + 6(\mathbf{1}_{+\frac52}) + (\mathbf{D1}_{+\frac52}) + (\mathbf{D1}_{-\frac52}),$$

$$T_7 \;:\; 2(\mathbf{5}_{+\frac12}) + 2(\overline{\mathbf{5}}_{-\frac12}) + 6(\mathbf{1}_{+\frac52}) + 6(\mathbf{1}_{-\frac52}) + (\mathbf{D1}_{+\frac52}) + (\mathbf{D1}_{-\frac52}),$$

UT : $(1_{-5}+5_3+\overline{10}_{-1})^L_{U_3}$, $(\bar{5}_2)^L_{U_2}$, $(1_{-5}+5_3+\overline{10}_{-1})^L_{U_1'}$, $1^L_{0\,U_2}$

T_6 : T_6^0 $\quad T_6^+$ $\quad T_6^-$ distinguished by wilson line

T_1^{0+-} : No E_8 spectrum

T_2^{0+-} : Yes observ. matter

T_3 : No matter

T_4^{0+-} : Yes

Quarks

T_5^{0+-} : Exotic matter $Q_{em}=\pm\frac{1}{2},\ \pm\frac{1}{6}$

$\to T_7$ (opposite chirality)

Visible states	$SU(5)\times U(1)_X$	Γ	Visible states	$SU(5)\times U(1)_X$	Γ
$(\underline{+----};+++)$	$5^L_3(U_3)$	3	$(\underline{1,0,0,0,0};\frac{-1}{3},0^2)$	$3\cdot 5^L_{-2}(T4^0)$	-2
$(\underline{+++--};+--)$	$\overline{10}^L_{-1}(U_3)$	-1	$(\underline{-1,0,0,0,0};\frac{-1}{3},0^2)$	$2\cdot\overline{5}^L_2(T4^0)$	2
$(+++++;+++)$	$1^L_{-5}(U_3)$	-5	$(\underline{+----};+\ 0\ 0)$	$2\cdot 5^L_3(T6)$	4
$(\underline{-1,0,0,0,0};-1,0,0)$	$\overline{5}^L_2(U_2)$	2	$(\underline{+++--};+\ 0\ 0)$	$4\cdot\overline{10}^L_{-1}(T6)$ tbb^c	-2, -1
$(\underline{+----};+--)$	$5^L_3(U_1)$	3	$(+++++;+\ 0\ 0)$	$2\cdot 1^L_{-5}(T6)$	-6
$(\underline{+++--};+++)$	$\overline{10}^L_{-1}(U_1)$	-1	$(\underline{++++-};-\ 0\ 0)$	$2\cdot\overline{5}^L_{-3}(T6)$	-4
$(+++++;+--)$	$1^L_{-5}(U_1)$	-5	$(\underline{++---};-\ 0\ 0)$	$3\cdot 10^L_1(T6)$	2
$(\underline{+----};\frac{-1}{6}\ 0\ 0)$	$5^L_3(T2^0)$ t^c	3	$(-----;-\ 0\ 0)$	$2\cdot 1^L_5(T6)$	6
$(+++++;\frac{-1}{6}\ 0\ 0)$	$1^L_{-5}(T2^0)$	-5			

We studied all Yukawa couplings up to $D=8$ superpotential terms and showed that we removed all exotics at GUT scale and obtain

$U: (1_{-5}+5_3+\overline{10}_{-1})(U_1),\ (1_{-5}+5_3+\overline{10}_{-1})(U_3),\ (\overline{5}_2)(U_2)$

$T_6: \quad \overline{10}_{-1}\ (T_6)$ t, b, e Inverted relation for leptons

$T_2: \quad 1_{-5}+5_3\ (T_2)$

$T_4: \quad 5_{-2}\ (T_4)$

Higgs

Six gauged U(1) charges:

$$Z_1 = (2\,2\,2\,2\,2\,;0^3)(0^8)'$$

$$Z_2 = (0^5\,;1\,0\,0)(0^8)'$$

$$Z_3 = (0^5\,;0\,1\,0)(0^8)'$$

$$Z_4 = (0^5\,;0\,0\,1)(0^8)'$$

$$Z_5 = (0^8)(1\,1\,;0\,;0^5)'$$

$$Z_6 = (0^8)(0\,0\,;1\,;0^5)'$$

$$Q_X = -Z_1,\quad Q_1 = Z_2 + 6Z_4,\quad Q_2 = -Z_2 + 6Z_4$$

$$Q_3 = Z_5,\quad Q_4 = 2Z_2 + 3Z_6$$

$$\boxed{Q_{an} = -6Z_2 + Z_3 - Z_4 + 4Z_6}$$

$$= (0\,0\,0\,0\,0\,-6\,1\,-1)(0\,0\,4\,0\,0\,0\,0\,0)$$

IV Phenomenology

Except gauge interactions, phenomenology results from Yukawa couplings.

Yukawa couplings respect

1. gauge symmetries

2. in particular Lorentz symmetry
   $\Longrightarrow$ H-momentum conservation
   (from internal coordinates)

- Twisted sector fields must satisfy (modular invariance): for $T_k^{m_f}$

$$\sum_z k(z) = 0 \mod 12$$

$$\sum_z [k m_f](z) = 0 \mod 3$$

In $\mathbb{Z}_3$, the counterparts of these with gauge invariance are sufficient.

- Modular invariance require the sum of H-momenta

$$(-1,\ 1,\ 1) \bmod (12, 3, 12)$$

This condition restricts further !!!

Extensive discussion & Refs.
K.-S. Choi & JEK
"Quarks and Leptons from Orbifolded Superstring"
(Springer LNP696, 2006)

Z_{12} :

$U_1\,(-1\ 0\ 0)$ $\quad U_2\,(0\ 1\ 0)$ $\quad U_3\,(0\ 0\ 1)$

$T_1\,(-7/12\ \ 4/12\ \ 1/12)$ $\quad T_3\,(1/4\ \ 0\ \ -3/4)$ $\quad T_7\,(-1/12\ \ 4/12\ \ 7/12)$

$T_2\,(-1/6\ \ 4/6\ \ 1/6)$ $\quad T_4\,(-1/3\ \ 1/3\ \ 1/3)$ $\quad T_6\,(-1/2\ \ 0\ \ 1/2)$

$$T_2 T_4 T_6 = (-1, 1, 1)$$

From these rules, with gauge invariance, all Yukawa couplings can be calculated. Since there are O(100) chiral fields, computer search is necessary.

Higgs

$U: (1_{-5} + 5_3 + \overline{10}_{-1})(U_1),\ (1_{-5} + 5_3 + \overline{10}_{-1})(U_3),\ (\overline{5}_2)(U_2)$

$T_6: \quad \overline{10}_{-1}\ (T_6)$ t, b, e {Inverted relation for leptons

$T_2: \quad 1_{-5} + 5_3\ (T_2)$

$T_4: \quad 5_{-2}\ (T_4)$

Higgs

$\overline{10}_{-1}(T_6)\cdot 5_3(T_2)$

$\cdot \langle 5_{-2}(T_4) \rangle$

top mass

If neutral singlets are allowed to get GUT scale VEVs, then all needed phenomenology can be obtained.

K+Kyae th/0608086

Choi+JEK+I.W.Kim ph/0612107

I.W. Kim+JEK+Kyae ph/0612365

axion study

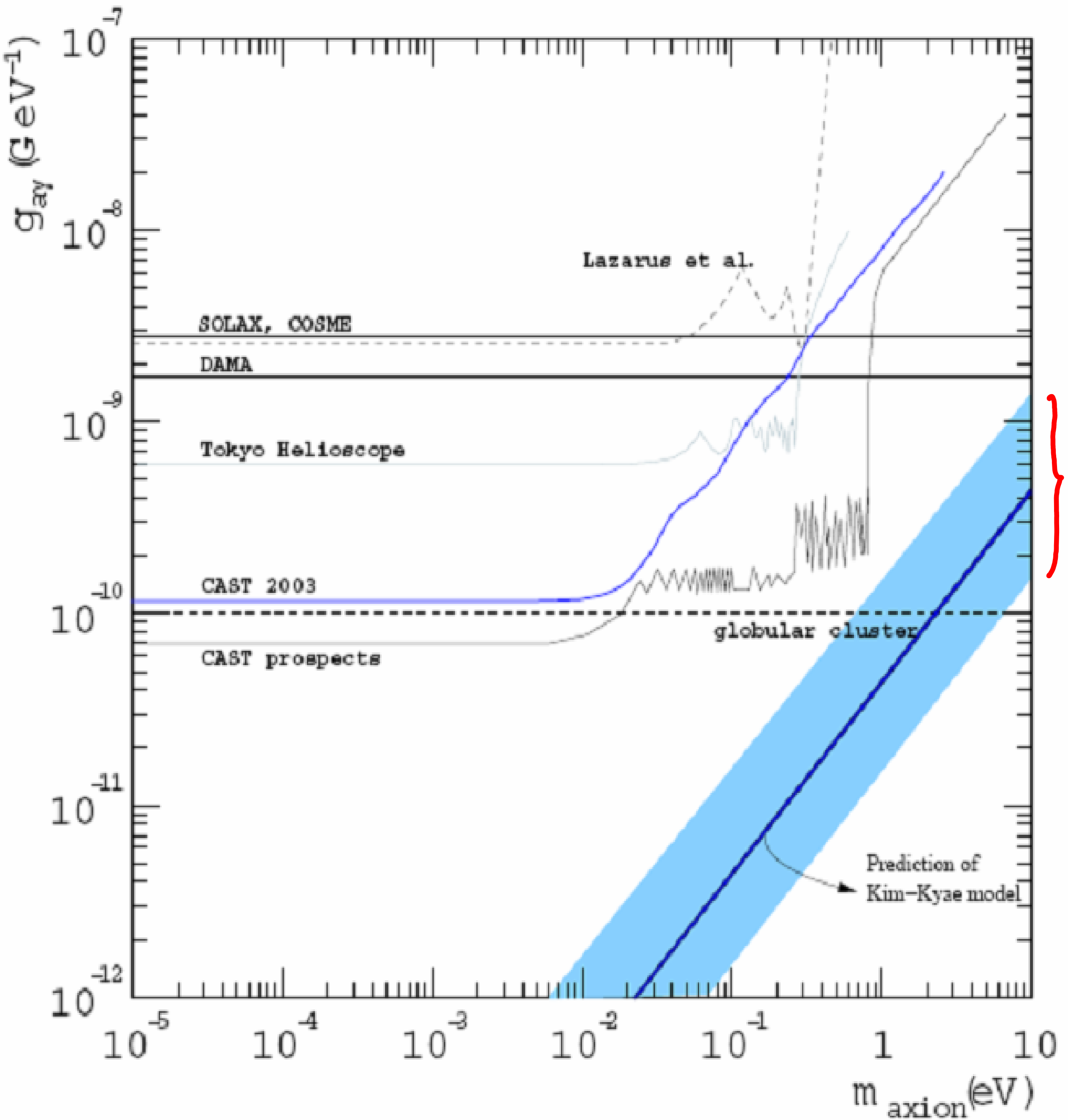
R-parity study

PQ symmetries : $U(1)_{an} \otimes U(1)_{global}$, approx

We find that QCD axion is possible but the decay constant at M_{GUT}

Calculated $C_{a\gamma\gamma}$ for the first time in string

$$C_{a\gamma\gamma} = \bar{C}_{a\gamma\gamma} - \underbrace{1.93}_{\text{chiral symm. breaking contribution}} \simeq -0.26$$



$\pm 20\%$ th error: two loop. $m_u \neq 0$ with inst. contr.

This kind of study must be performed in a specific model. In the community, there are papers just looking at piecemeal phenomenon, which is not warranted in string phenomenology.

For example, one may consider R-sym. toward PQ symmetry. It is at best a SUGRA strategy since strings do not allow any global symmetry. It must be approximate except $U(1)_{anom}$.

In the same vein, R-parity must be studied in a specific model. We know that there are many singlets

$\Rightarrow$ Many of them need GUT scale VEVs.

$\Rightarrow$ This fact must be taken into account.

SUSY R PARITY

S: spinor, V: vector
SO(10)

$$\begin{array}{ccc} S & S & V \\ -1 & -1 & 1 \end{array}$$

matter in 16_F
Higgs in 10_H

But SSV(111 ....) allowed in string, and fails for an exact R-parity in general

U(1) SYMMETRIES

Flipped SU(5) gauged $U(1)_X$

$X = (-2\ -2\ -2\ -2\ -2\ 0\ 0\ 0)(0^8)'$

Untwisted matter :

spinor : $(\pm\frac{1}{2}\ \pm\frac{1}{2}\ \pm\frac{1}{2}\ \pm\frac{1}{2}\ \pm\frac{1}{2}\ \pm\frac{1}{2}\ \pm\frac{1}{2}\ \pm\frac{1}{2})$

$X = \pm 1, \pm 3, \pm 5$

Vector : $(\pm 1\ 0\ 0\ 0\ 0\ \pm 1\ 0\ 0)$

$(\pm 1\ \pm 1\ 0\ 0\ 0\ 0\ 0\ 0)$, etc

$X = \pm 2, \pm 4, 0, \ldots$

If $U(1)_X$ is broken by $\langle V(X=2)\rangle$,

then

$$U(1)_X \longrightarrow Z_2$$

vectors : Z_2 even

spinors : Z_2 odd

} perfect R parity

But, it must be discussed in a specific model such that all SM matter fermions are in spinor, and all Higgs are in vector, including singlets.

For a successful R parity, one must succeed in Yukawa couplings. The argument of the preceding paragraph is just an idea. It must be realized in a specific model.

So far, we have not found any model. Maybe in the future?

$\Rightarrow$ LSP is not likely to exist.

V. Harmless R-parity Violation

In our Z_{12-I} model, we removed all exotics, vectorlike pairs by VEVs of singlets. These singlets belong to V and S types. So R-parity is violated. Note all SM matter appears in the S type representation, but some needed singlets also belong to S-type.

$$D = 4:$$

$$[d^c d^c u^c]_F,\ [q d^c l]_F \Leftarrow \langle \overline{\mathbf{10}}^H \rangle\ \overline{\mathbf{10}}\ \overline{\mathbf{10}}\ \mathbf{5}, \tag{8}$$

and

$$D = 5:$$

$$O_1 = [qqql]_F \Leftarrow \overline{\mathbf{10}}\ \overline{\mathbf{10}}\ \overline{\mathbf{10}}\ \mathbf{5}, \qquad O_2 = [u^c u^c d^c e^+]_F \Leftarrow \mathbf{5}\ \mathbf{5}\ \overline{\mathbf{10}}\ \mathbf{1}$$

$$O_3 = [qqqH_d]_F \Leftarrow \langle \mathbf{10}^H \rangle\ \overline{\mathbf{10}}\ \overline{\mathbf{10}}\ \overline{\mathbf{10}}\ \overline{\mathbf{5}}_2, \qquad O_4 = [qu^c e^+ H_d]_F \Leftarrow \langle \mathbf{10}^H \rangle\ \overline{\mathbf{10}}\ \mathbf{5}\ \mathbf{1}\ \overline{\mathbf{5}}_2$$

$$O_5 = [llH_uH_u]_F \Leftarrow \langle \overline{\mathbf{10}}^H \rangle \langle \overline{\mathbf{10}}^H \rangle\ \mathbf{5}\ \mathbf{5}\ \mathbf{5}_{-2}\ \mathbf{5}_{-2}, \quad O_6 = [lH_dH_uH_u]_F \Leftarrow \langle \overline{\mathbf{10}}^H \rangle\ \mathbf{5}\ \overline{\mathbf{5}}_2\ \mathbf{5}_{-2}\ \mathbf{5}_{-2}$$

These terms appear at high orders.
$D=5$ terms are not problematic: $O(10^{-7})$.
$D=4$ terms multiplied together gives proton decay operator. $O(10^{-26})$
$\Rightarrow$ individual terms $O(10^{-13})$.

$\mathbf{5}_3$	$\overline{\mathbf{10}}_{-1}$	$\overline{\mathbf{10}}_{-1}$	$\overline{\mathbf{10}}_{-1}$	H-mom.	N	$\mathbf{5}_3$	$\overline{\mathbf{10}}_{-1}$	$\overline{\mathbf{10}}_{-1}$	$\overline{\mathbf{10}}_{-1}$	H-mom.	N
U_1	U_1	U_1	$T6$	$(\frac{-7}{2},0,\frac{1}{2})$	11	U_3	U_3	U_3	$T6$	$(\frac{-1}{2},0,\frac{7}{2})$	11
U_1	U_1	U_3	$T6$	$(\frac{-5}{2},0,\frac{3}{2})$	11	U_3	U_3	$T6$	$T6$	$(-1,0,3)$	12
U_1	U_1	$T6$	$T6$	$(-3,0,1)$	12	U_3	$T6$	$T6$	$T6$	$(\frac{-3}{2},0,\frac{5}{2})$	11
U_1	U_3	U_3	$T6$	$(\frac{-3}{2},0,\frac{5}{2})$	11	$T2$	U_1	U_1	$T6$	$(\frac{-8}{3},\frac{2}{3},\frac{2}{3})$	10
U_1	U_3	$T6$	$T6$	$(-2,0,2)$	12	$T2$	U_1	U_3	$T6$	$(\frac{-5}{3},\frac{2}{3},\frac{5}{3})$	10
U_1	$T6$	$T6$	$T6$	$(\frac{-5}{2},0,\frac{3}{2})$	11	$T2$	U_1	$T6$	$T6$	$(\frac{-13}{6},\frac{2}{3},\frac{7}{6})$	11
U_3	U_1	U_1	$T6$	$(-\frac{5}{2},0,\frac{3}{2})$	11	$T2$	U_3	U_3	$T6$	$(\frac{-2}{3},\frac{2}{3},\frac{8}{3})$	10
U_3	U_1	U_3	$T6$	$(\frac{-3}{2},0,\frac{5}{2})$	11	$T2$	U_3	$T6$	$T6$	$(\frac{-7}{6},\frac{2}{3},\frac{13}{6})$	11
U_3	U_1	$T6$	$T6$	$(-2,0,2)$	12	$T2$	$T6$	$T6$	$T6$	$(\frac{-5}{3},\frac{2}{3},\frac{5}{3})$	10

$\mathbf{5}_3$	$\mathbf{5}_3$	$\overline{\mathbf{10}}_{-1}$	$\mathbf{1}_{-5}$	H-mom.	N	$\mathbf{5}_3$	$\mathbf{5}_3$	$\overline{\mathbf{10}}_{-1}$	$\mathbf{1}_{-5}$	H-mom.	N	$\mathbf{5}_3$	$\mathbf{5}_3$	$\overline{\mathbf{10}}_{-1}$	$\mathbf{1}_{-5}$	H-mom.	N
U_1	U_1	U_1	U_1	$(-4,0,0)$	12	U_1	$T2$	U_1	U_1	$(\frac{-19}{6},\frac{2}{3},\frac{1}{6})$	11	U_3	$T2$	U_1	U_1	$(\frac{-13}{6},\frac{2}{3},\frac{7}{6})$	11
U_1	U_1	U_1	U_3	$(-3,0,1)$	12	U_1	$T2$	U_1	U_3	$(\frac{-13}{6},\frac{2}{3},\frac{7}{6})$	11	U_3	$T2$	U_1	U_3	$(\frac{-7}{6},\frac{2}{3},\frac{13}{6})$	11
U_1	U_1	U_1	$T2$	$(\frac{-19}{6},\frac{2}{3},\frac{1}{6})$	11	U_1	$T2$	U_1	$T2$	$(\frac{-7}{3},\frac{4}{3},\frac{1}{3})$	10	U_3	$T2$	U_1	$T2$	$(\frac{-4}{3},\frac{4}{3},\frac{4}{3})$	10
U_1	U_1	U_3	U_1	$(-3,0,1)$	12	U_1	$T2$	U_3	U_1	$(\frac{-13}{6},\frac{2}{3},\frac{7}{6})$	11	U_3	$T2$	U_3	U_1	$(\frac{-7}{6},\frac{2}{3},\frac{13}{6})$	11
U_1	U_1	U_3	U_3	$(-2,0,2)$	12	U_1	$T2$	U_3	U_3	$(\frac{-7}{6},\frac{2}{3},\frac{13}{6})$	11	U_3	$T2$	U_3	U_3	$(\frac{-1}{6},\frac{2}{3},\frac{19}{6})$	11
U_1	U_1	U_3	$T2$	$(\frac{-13}{6},\frac{2}{3},\frac{7}{6})$	11	U_1	$T2$	U_3	$T2$	$(\frac{-4}{3},\frac{4}{3},\frac{4}{3})$	10	U_3	$T2$	U_3	$T2$	$(\frac{-1}{3},\frac{4}{3},\frac{7}{3})$	10
U_1	U_1	$T6$	U_1	$(\frac{-7}{2},0,\frac{1}{2})$	11	U_1	$T2$	$T6$	U_1	$(\frac{-8}{3},\frac{2}{3},\frac{2}{3})$	10	U_3	$T2$	$T6$	U_1	$(\frac{-5}{3},\frac{2}{3},\frac{5}{3})$	10
U_1	U_1	$T6$	U_3	$(\frac{-5}{2},0,\frac{3}{2})$	11	U_1	$T2$	$T6$	U_3	$(\frac{-5}{3},\frac{2}{3},\frac{5}{3})$	10	U_3	$T2$	$T6$	U_3	$(\frac{-2}{3},\frac{2}{3},\frac{8}{3})$	10
U_1	U_1	$T6$	$T2$	$(\frac{-8}{3},\frac{2}{3},\frac{2}{3})$	10	U_1	$T2$	$T6$	$T2$	$(\frac{-11}{6},\frac{4}{3},\frac{5}{6})$	9	U_3	$T2$	$T6$	$T2$	$(\frac{-5}{6},\frac{4}{3},\frac{11}{6})$	9
U_1	U_3	U_1	U_1	$(-3,0,1)$	12	U_3	U_3	U_1	U_1	$(-2,0,2)$	12	$T2$	$T2$	U_1	U_1	$(\frac{-7}{3},\frac{4}{3},\frac{1}{3})$	10
U_1	U_3	U_1	U_3	$(-2,0,2)$	12	U_3	U_3	U_1	U_3	$(-1,0,3)$	12	$T2$	$T2$	U_1	U_3	$(\frac{-4}{3},\frac{4}{3},\frac{4}{3})$	10
U_1	U_3	U_1	$T2$	$(\frac{-13}{6},\frac{2}{3},\frac{7}{6})$	11	U_3	U_3	U_1	$T2$	$(\frac{-7}{6},\frac{2}{3},\frac{13}{6})$	11	$T2$	$T2$	U_1	$T2$	$(\frac{-3}{2},2,\frac{1}{2})$	9
U_1	U_3	U_3	U_1	$(-2,0,2)$	12	U_3	U_3	U_3	U_1	$(-1,0,3)$	12	$T2$	$T2$	U_3	U_1	$(\frac{-4}{3},\frac{4}{3},\frac{4}{3})$	10
U_1	U_3	U_3	U_3	$(-1,0,3)$	12	U_3	U_3	U_3	U_3	$(0,0,4)$	12	$T2$	$T2$	U_3	U_3	$(\frac{-1}{3},\frac{4}{3},\frac{7}{3})$	10
U_1	U_3	U_3	$T2$	$(\frac{-7}{6},\frac{2}{3},\frac{13}{6})$	11	U_3	U_3	U_3	$T2$	$(\frac{-1}{6},\frac{2}{3},\frac{19}{6})$	11	$T2$	$T2$	U_3	$T2$	$(\frac{-1}{2},2,\frac{3}{2})$	9
U_1	U_3	$T6$	U_1	$(\frac{-5}{2},0,\frac{3}{2})$	11	U_3	U_3	$T6$	U_1	$(\frac{-3}{2},0,\frac{5}{2})$	11	$T2$	$T2$	$T6$	U_1	$(\frac{-11}{6},\frac{4}{3},\frac{5}{6})$	9
U_1	U_3	$T6$	U_3	$(\frac{-3}{2},0,\frac{5}{2})$	11	U_3	U_3	$T6$	U_3	$(\frac{-1}{2},0,\frac{7}{2})$	11	$T2$	$T2$	$T6$	U_3	$(\frac{-5}{6},\frac{4}{3},\frac{11}{6})$	9
U_1	U_3	$T6$	$T2$	$(\frac{-5}{3},\frac{2}{3},\frac{5}{3})$	10	U_3	U_3	$T6$	$T2$	$(\frac{-2}{3},\frac{2}{3},\frac{8}{3})$	10	$T2$	$T2$	$T6$	$T2$	$(-1,2,1)$	8

Product of these two operators would give proton decay.

With singlet VEVs of order

$$\frac{\langle S \rangle}{M_s} \sim \frac{1}{10} \sim \frac{1}{100}$$

proton can be made sufficiently long lived.

CONCLUSION

We constructed a realistic string derived SSM from Z_{12-I} orb. comp.
(through flipped SU(5))

1. Exotics removed by singlet VEVs
2. 3 SM q, ℓ removed except
3. Vectorlike pairs of light Higgs
4. $c_{a\gamma\gamma} = -0.26$, but $F_a \sim 10^{16}$ GeV
5. Harmless R-parity