Observing the coupling constant of stringy Z'

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Outline

Aim

- To analyze the resulting RGE running of couplings of additional $U(1)$ appearing in MSSM-like models coming from orbifold compactifications of the $E_8 \times E_8$ heterotic string.

Abelian orbifold models

- Compactification of the Heterotic String $E_8 \times E_8$ in the $\mathbb{Z}_8$ orbifold

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- Results

Orbifold models	MSSM-like models
$\mathbb{Z}_8$-I $(1,1)$	268
$\mathbb{Z}_8$-I $(2,1)$	246
$\mathbb{Z}_8$-I $(3,1)$	389
$\mathbb{Z}_8$-II $(1,1)$	1978
$\mathbb{Z}_8$-II $(2,1)$	495

Table: Results of our MSSM-like models search on $\mathbb{Z}_8$-I and $\mathbb{Z}_8$-II orbifolds.

Unification and Z'

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- We assume $\Lambda_{Z'} = 1.5$ TeV and 2 TeV with
  - $\Lambda_{SUSY} = \Lambda_{Z'}$
  - $\Lambda_{SUSY} = 10^{12}$ GeV and 10^{17} GeV
- We do not have a dynamical mechanism for the breaking of the Z'.

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- Compute M_{GUT} from the intersection of $\alpha_i^{-1}(M_{GUT}) = \alpha_j^{-1}(M_{GUT})$ where $i, j = 1, 2, 3$ correspond to the gauge couplings of $U(1)_Y, SU(2)_L$ and $SU(3)_C$.

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- Assuming $\alpha_4^{-1}(M_{GUT})$ equals the previous intersection, where α_4 is the gauge coupling of Z', we use the RGEs to compute $\alpha_4^{-1}(M_{GUT}) \longrightarrow \alpha_4^{-1}(\Lambda_{Z'})$.

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- We also select models that present unification, $\alpha_i \sim \alpha_4$, at the M_{GUT} scale.

Results

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The main expressions are

$$\alpha_i^{-1}(M_{GUT}) = \alpha_i^{-1}(\Lambda_{Z'}) - \frac{b_i}{2\pi} ln\left(\frac{M_{GUT}}{\Lambda_{Z'}}\right),$$

$$\alpha_i^{-1}(\Lambda_{Z'}) = \alpha_i^{-1}(M_Z) - \frac{b_i^{SM}}{2\pi} ln\left(\frac{\Lambda_{Z'}}{M_Z}\right),$$

$$i = 1, 2, 3.$$

We get

$$M_{GUT} = \Lambda_{Z'} \exp[2\pi f(b_i - b_j)],$$

$$\alpha_4^{-1}(M_{GUT}) = \alpha_i^{-1}(\Lambda_{Z'}) - b_i f(b_i - b_j),$$

$$\alpha_4^{-1}(\Lambda_{Z'}) = \alpha_i^{-1}(\Lambda_{Z'}) - (b_i - b_4) f(b_i - b_j),$$

where

$$f(b_i - b_j) = \left(\frac{\alpha_i^{-1}(\Lambda_{Z'}) - \alpha_j^{-1}(\Lambda_{Z'})}{b_i - b_j} \right),$$

$$i, j = 1, 2, 3.$$

Observations

- The most frequent combination (b_1, b_2, b_3, b_4) is $(33/5, 1, -3, 0)$ i.e. the MSSM. $b_4 = 0$ is the most frequent value. This happens in all cases.
- Then the majority of the models with unification have the MSSM spectrum in natural form.
- These models have uncharged particles under Z', hence we focus in all the other models (those with $b_4 \neq 0$).

Results for $\Lambda_{Z'} = \Lambda_{SUSY} = 1.5$ TeV and M_{GUT} determined from the intersection of $U(1)_Y$ and $SU(2)_L$.

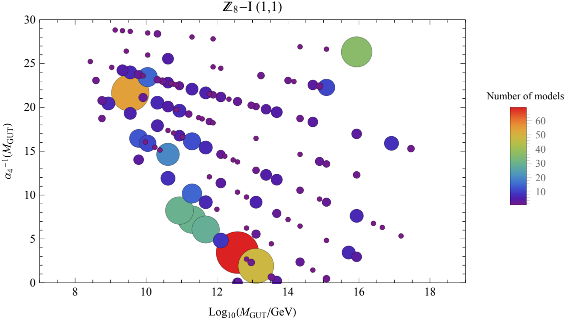

Figure: $Log_{10}(M_{GUT})$ vs. $\alpha_4^{-1}(M_{GUT})$ for all $\mathbb{Z}_8$-I $(1,1)$ models.

Orbifold model	$Log_{10}(M_{GUT})$	$\alpha_4^{-1}(M_{GUT})$	Frequency
$\mathbb{Z}_8$-I $(1,1)$	12.5765	3.44521	69
	9.55496	21.6543	54
	13.0988	1.91411	48
	15.9336	26.3296	36
	11.2947	7.20334	30

Table: The first most frequent values for $(Log_{10}(M_{GUT}), \alpha_4^{-1}(M_{GUT}))$.

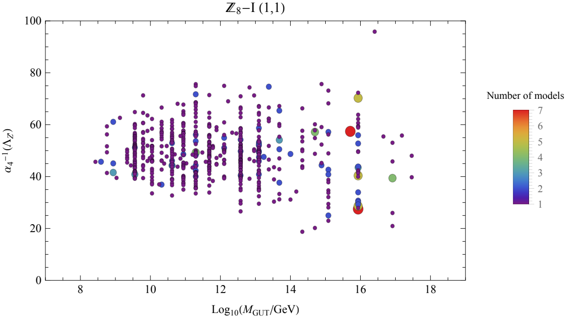

Figure: $Log_{10}(M_{GUT})$ vs. $\alpha_4^{-1}(\Lambda_{Z'})$ for all $\mathbb{Z}_8$-I $(1,1)$ models.

Orbifold model	$Log_{10}(M_{GUT})$	$\alpha_4^{-1}(\Lambda_{Z'})$	Frequency
$\mathbb{Z}_8$-I $(1,1)$	15.9338	27.4984	7
	15.71	57.4162	7
	15.9338	70.2774	5
	15.9338	40.3555	5
	15.9338	28.6672	5

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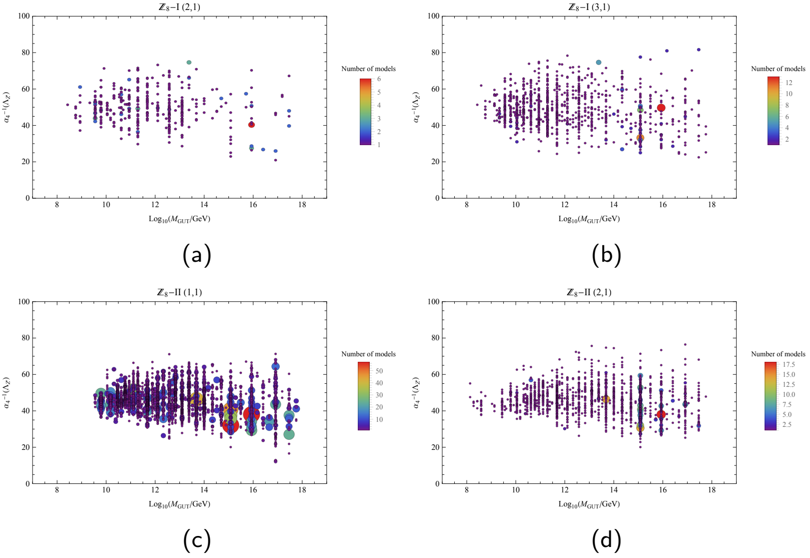
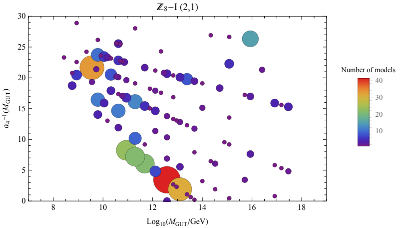
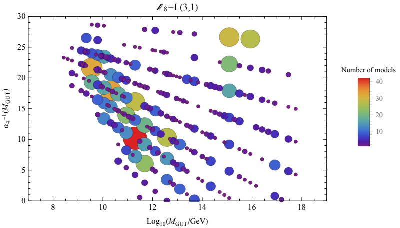


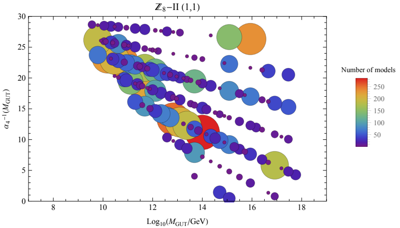
Figure: Results $(Log_{10}(M_{GUT}), \alpha_4^{-1}(\Lambda_{Z'}))$ for the other geometries.



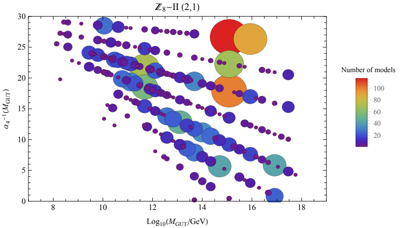
(a)



(b)



(c)



(d)

Figure: Results $(Log_{10}(M_{GUT}), \alpha_4^{-1}(M_{GUT}))$ for the other geometries.

Geometry	$\alpha_4^{-1}(\Lambda_{Z'})$	$\alpha_4^{-1}(M_{GUT})$	$Log_{10}(M_{GUT})$
$\mathbb{Z}_8$-I $(1,1)$	[18.732, 95.853]	[0.0002, 28.823]	[8.429, 17.464]
$\mathbb{Z}_8$-I $(2,1)$	[20.935, 74.641]	[0.0002, 28.893]	[8.429, 17.464]
$\mathbb{Z}_8$-I $(3,1)$	[22.495, 81.622]	[0.0002, 28.667]	[8.429, 17.756]
$\mathbb{Z}_8$-II $(1,1)$	[12.076, 71.284]	[0.459, 28.667]	[9.554, 17.756]
$\mathbb{Z}_8$-II $(2,1)$	[20.095, 76.445]	[0.202, 29.079]	[8.137, 17.756]

Table: Range of values for $\alpha_4^{-1}(\Lambda_{Z'})$, $\alpha_4^{-1}(M_{GUT})$ and $Log_{10}(M_{GUT})$ for the three and two geometries of $\mathbb{Z}_8$-I and $\mathbb{Z}_8$-II.

Results for several cases with $\Lambda_{Z'} = 1.5$ TeV.

a) $\Lambda_{SUSY} = \Lambda_{Z'}$

b) $\Lambda_{SUSY} = 10^{12}$ GeV, $M_{GUT} < \Lambda_{SUSY}$

c) " ", $M_{GUT} > \Lambda_{SUSY}$

d) $\Lambda_{SUSY} = 10^{17}$ GeV, $M_{GUT} < \Lambda_{SUSY}$

e) " ", $M_{GUT} > \Lambda_{SUSY}$

Case	$\alpha_4^{-1}(\Lambda_{Z'})$	$\alpha_4^{-1}(M_{GUT})$	$Log_{10}(M_{GUT})$
a)	[18.732, 95.853]	[0.0002, 28.823]	[8.429, 17.464]
b)	[40.121, 75.775]	[20.274, 42.248]	[8.507, 11.96]
c)	[30.901, 78.3987]	[0.398, 40.522]	[12.038, 17.992]
d)	[10.851, 42.298]	[8.507, 16.915]	[9.554, 17.756]
e)	57.307	32.642	17.019

Table: Ranges obtained for the $\mathbb{Z}_8$-I $(1,1)$ models in several cases.

Unified models

Case $\Lambda_{Z'} = \Lambda_{SUSY} = 1.5$ TeV and 2 TeV.

Geometry	# Models ($\Lambda_{Z'} = 1.5$ TeV)	# Models ($\Lambda_{Z'} = 2$ TeV)
$\mathbb{Z}_8$-I $(1,1)$	1	2
$\mathbb{Z}_8$-I $(3,1)$	2	10
$\mathbb{Z}_8$-II $(1,1)$	11	54
$\mathbb{Z}_8$-II $(2,1)$	1	7

Table: Number of models with $\alpha_3 \sim \alpha_4 = \alpha_1 = \alpha_2$ in all $\mathbb{Z}_8$ orbifold geometries.

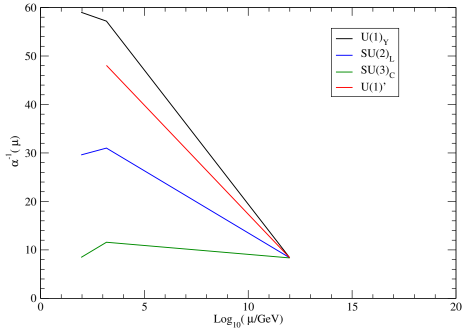


Figure: Gauge coupling evolution for $U(1)_Y, SU(2)_L, SU(3)_C$ and $U(1)'$ for the unified model of $\mathbb{Z}_8$-I $(1,1)$ when $\Lambda_{Z'} = \Lambda_{SUSY} = 1.5$ TeV.

Spectrum

The spectrum of unified models consists of:
MSSM +

- multi Higgses
- right-handed neutrinos
- colored exotics
- left(right)-handed leptons with fractional electric charge

- Particles with fractional charge above $\Lambda_{Z'}$
- All exotic particles disappear when we assume the spontaneous breaking of Z'

Summary

- We predict a large set of values for the coupling constant of Z', e.g. $[18.732, 95.853]$ for $\Lambda_{Z'} = 1.5$ TeV, which might influence future searches at colliders.

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  - Search for a dynamical mechanism of mass generation in these models.
  - Perform the analysis for the non-supersymmetric heterotic string $SO(16) \otimes SO(16)$.

Thanks!