Quasi-Realistic Heterotic String Vacua

Left Right Symmetric Model

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Outline

- Introduction
- Free Fermionic Construction
- ABK Rules and GSO Projections
- Current project and results
- Conclusion

Introduction

- The motivation of this project is to create quasi-realistic string vacua
- This project uses the free fermionic construction of heterotic superstring theory
- The basis vectors chosen produce a Left Right symmetric model
- Therefore the visible gauge group at the string scale is $SU(3) \times U(1) \times SU(2)_L \times SU(2)_R$

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- 3 Chiral Generations of Matter

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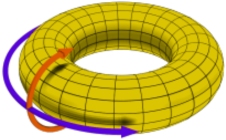
- Instead of associating the degrees of freedom needed to cancel the conformal anomaly as spacetime dimensions, we can interpret them as free fermions which propagate on the string worldsheet
- The string worldsheet can be mapped to a genus g Riemann surface
- We are interested in the partition function which is the integrand of the vacuum to vacuum amplitude
- Therefore we are considering a $g = 1$ Riemann surface *i.e* a torus

Free Fermionic Construction

When the fermions are propagated around the two incontractible loops they pick up a phase

$$f \rightarrow -e^{i\pi\alpha(f)} f \qquad \text{where } \alpha(f) \in (-1, 1]$$



Assigning different boundary conditions to each of the fermions around these loops results in different models

Free Fermionic Construction

The states on the worldsheet are

	Label	Description
Left–moving	X^μ	Bosonic coordinates with spacetime index, $\mu = 0, \ldots, 3$
	ψ^μ	Majorana–Weyl superpartners of the bosonic coordinates with spacetime index
	$\chi^{1,\ldots,6}$	Majorana–Weyl superpartners to the six compactified dimensions
	$y^{1,\ldots,6}, w^{1,\ldots,6}$	Majorana–Weyl fermions that correspond to the bosons describing the six compactified dimensions in the bosonic formulation
Right–moving	$\overline{X}^\mu$	Bosonic coordinates with spacetime index
	$\overline{y}^{1,\ldots,6}, \overline{w}^{1,\ldots,6}$	Majorana–Weyl fermions that correspond to the bosons describing the six compactified dimensions in the orbifold formulation
	$\overline{\psi}^{1,\ldots,5}, \overline{\eta}^{1,2,3}$	Complex fermions that describe the visible gauge sector
	$\overline{\phi}^{1,\ldots,8}$	Complex fermions that describe the hidden gauge sector

There are 18 free fermions in the left moving supersymmetric sector and 44 free fermions in the right moving sector

ABK Rules

A model is defined by specifying two ingredients

- A set of boundary condition basis vectors
- The one loop phases $C\binom{b_i}{b_j}$ for all pairs of the basis vectors

ABK Rules

- The basis vectors and one loop coefficients must satisfy the ABK rules
- These are derived from modular invariance conditions

Spacetime Spin Statistics Index

The Spacetime Spin Statistics Index is

$$\delta_{b_i} = e^{i\pi b_i(\psi^\mu)} = \begin{cases} -1 & b_i(\psi^\mu) = 1 \\ +1 & b_i(\psi^\mu) = 0 \end{cases}$$

- If the basis vector specifies ψ^μ is periodic then $\delta_{b_i} = -1$
- If the basis vector specifies ψ^μ is anti-periodic then $\delta_{b_i} = 0$

GSO Projections

- The equation for the GSO projection is

$$e^{i\pi b_i \cdot F_\alpha} \left| s \right\rangle_\alpha = \delta_\alpha C \begin{pmatrix} \alpha \\ b_i \end{pmatrix}^* \left| s \right\rangle_\alpha$$

- This selects the states that are either kept in or projected out of the spectrum
- If the equation is satisfied by a state then it is kept, else it is projected out.

Current Project

The current project has the basis vectors

$$
\begin{aligned}
\mathbb{1} &= \{\psi^{\mu}_{1,2}, \chi^{12}, \chi^{34}, \chi^{56}, y^{12}, y^{34}, y^{56}, w^{12}, w^{34}, w^{56} \mid \bar{y}^{12}, \bar{y}^{34}, \bar{y}^{56}, \bar{w}^{12}, \\
&\quad \bar{w}^{34}, \bar{w}^{56}, \bar{\psi}^{1,\ldots,5}, \bar{\eta}^{1,2,3}, \bar{\phi}^{1,\ldots,8}\} \\
S &= \{\psi^{\mu}_{1,2}, \chi^{12}, \chi^{34}, \chi^{56}\} \\
e_i &= \{y^i, w^i \mid \bar{y}^i, \bar{w}^i\} \\
b_1 &= \{\chi^{34}, \chi^{56}, y^{34}, y^{56} \mid \bar{y}^{34}, \bar{y}^{56}, \bar{\psi}^{1,\ldots,5}, \bar{\eta}^{1}\} \\
b_2 &= \{\chi^{12}, \chi^{34}, y^{12}, y^{56} \mid \bar{y}^{12}, \bar{y}^{56}, \bar{\psi}^{1,\ldots,5}, \bar{\eta}^{2}\} \\
z_1 &= \{\bar{\phi}^{1,\ldots,4}\} \\
z_2 &= \{\bar{\phi}^{5,\ldots,8}\} \\
z_3 &= \{\bar{\phi}^{1,2}, \bar{\phi}^{7,8}\} \\
\alpha &= \{\bar{\psi}^{1,2,3} = \frac{1}{2}, \bar{\eta}^{1,2,3} = \frac{1}{2}, \bar{\phi}^{1,2} = \frac{1}{2}\}
\end{aligned}
$$

Matter Spectrum B_{pqrs}

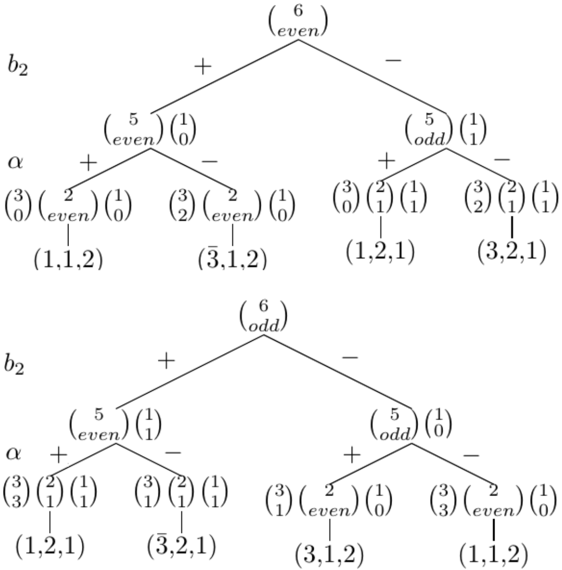
- The observable matter spectrum can be calculated by performing the GSO projections on B_{pqrs} which is a linear combination of basis vectors
- For example

$$\begin{aligned} B^{(1)}_{pqrs} &= S + b_1 + pe_3 + qe_4 + re_5 + se_6 \\ &= \{\psi^{\mu}, \chi^{1,2}, (1-p)y^3\bar{y}^3, pw^3\bar{w}^3, (1-q)y^4\bar{y}^4, qw^4\bar{w}^4, \\ &(1-r)y^5\bar{y}^5, rw^5\bar{w}^5, (1-s)y^6\bar{y}^6, sw^6\bar{w}^6, \bar{\eta}^1, \bar{\psi}^{1,\dots,5}\} \end{aligned}$$

Matter Spectrum $B^{(1)}_{pqrs}$

- Under the GSO projection of the basis vector b_1 the fermions $\{\bar{\eta}^1, \bar{\psi}^{1,\ldots,5}\}$ are isolated
- Under b_2 this splits to give $\{\bar{\eta}^1\}$,$\{\bar{\psi}^{1,\ldots,5}\}$
- Performing the α GSO projection splits this into the Left Right Symmetric model

Matter Spectrum $B^{(1)}_{pqrs}$



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- Currently the observable matter spectrum is being written
- The program can also check for vacua criteria such as light or heavy Higgs, exotic matter states *etc.*

Conclusions

- The choice of basis vectors generates string models which are left right symmetric
- The program currently does give models with $\mathcal{N} = 1$ supersymmetry and 3 chiral generations of matter
- Further work to be completed is to fully complete the section of the program which tests the matter spectrum
- The program must also be extended to correctly test for light and heavy Higgs particles, exotic states and gauge group enhancements

Conclusions

Thank you for listening

References

- ABK rules:
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- Figures 1 and 2:
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- "Classification of the Flipped $SU(5)$ Heterotic-String Vacua" - Hasan Sonmez - String Phenomenology 2014 Trieste Talk
- "Semi-Realistic Heterotic-String Vacua" - Johar M. Ashfaque - String Theory Seminar May 2015