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The absence of observable proton decay in a global SU(5) F-theory model

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Abstract: We begin with an $E_8 \times E_8$ Heterotic model broken to an $\mathrm{SU}(5)_{\mathrm{gauge}} \times \mathrm{U}(1)_X$ and a twin $\mathrm{SU}(5)_{\mathrm{gauge}} \times \mathrm{U}(1)_X$, where one SU(5) and its spectrum is identified as the visible sector while the other can be identified as a hidden twin sector. In both cases we obtain the minimal supersymmetric standard model (MSSM) spectrum after Wilson-line symmetry-breaking enhanced by a low energy R-parity and $\mathbb{Z}_4^R$ symmetry. We argue that there will not be any observable proton decay in this model.

Keywords: Baryon/Lepton Number Violation, Discrete Symmetries, F-Theory

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Contents

1 Introduction

Supersymmetric grand unified theories [SUSY GUTs] [1–3] have many nice properties. These include an explanation of the family structure of quarks and leptons with the requisite charge assignments under the Standard Model [SM] gauge group $SU(3)_C \times SU(2)_L \times U(1)_Y$ and a prediction of gauge coupling unification at a scale of order 10^{16} GeV. The latter is so far the only direct hint for the possible observation of supersymmetric particles at the LHC. UV completions of SUSY GUTs in string theory also provide a consistent quantum mechanical description of gravity. As a result of this golden confluence, many groups have searched for SUSY GUTs in string theory. In fact, it has been shown that by demanding SUSY GUTs in string constructions one can find many models with features much like that of the minimal supersymmetric Standard Model [MSSM] [4–10].

The past several years have seen significant attention devoted to the study of supersymmetric GUTs in F-theory [11–17]. Both local and global SU(5) F-theory GUTs have been constructed where SU(5) is spontaneously broken to the SM via a non-flat hypercharge flux. One problem with this approach for GUT breaking is that large threshold corrections are generated at the GUT scale due to the non-vanishing hypercharge flux [13–15, 18, 19]. An alternative approach to breaking the GUT group is using a Wilson line in the hypercharge direction, i.e. a so-called flat hypercharge line bundle. In this case it is known that large threshold corrections are not generated at the GUT scale (or, in fact, it leads to precise gauge coupling unification at the compactification scale in orbifold GUTs) [20, 21] and [22–25].

2 The model

In this letter we discuss baryon number violation in the model of refs. [26–30]. In this F-theory model starting with $E_8 \times E_8$, each E_8 is broken to $SU(5)_{\text{gauge}} \times U(1)_X$ by a $4+1$ split spectral cover. This is equivalent to first breaking E_8 to SO(10) and then breaking SO(10) to $SU(5)_{\text{gauge}} \times U(1)_X$. After a $\mathbb{Z}_2$ involution which acts freely on the GUT surface, the GUT surface is an Enriques surface with a fundamental group $\Pi_1(S_{\text{GUT}}) = \mathbb{Z}_2$. Simultaneously, SU(5) is broken to the Standard Model gauge group via a hypercharge Wilson line wrapping the GUT surface. The model has 3 families of quarks and leptons which reside in the spinor representation of SO(10) and transform as a 10 and $\bar{5}$ representation of SU(5). Under the involution, $C_{u,v}$, the 10 and $\bar{5}$ representations split into two seperate states which are either even $(10_+, \bar{5}_+)$ and odd $(10_-, \bar{5}_-)$ under the involution. In addition, these states are either

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$\Sigma^{(4)}_{\mathbf{10}} = \{a_5 = z = 0\}$	$C_{u,v}$	L_Y	$\mathcal{L}_{\text{Higgs}}$	$\text{SU}(3) \times \text{SU}(2) \times \text{U}(1)_Y$
$h^0\left(\check{\mathcal{L}}^{(4)[\pm 1]}_{\mathbf{10}}\right)$	$+1$	$+1$	3	$(\mathbf{1},\mathbf{1})_{+1}$
	-1	-1		$(\mathbf{3},\mathbf{2})_{+1/6}$
	$+1$	$+1$		$\left(\bar{\mathbf{3}},\mathbf{1}\right)_{-2/3}$
$h^1\left(\check{\mathcal{L}}^{(4)[\pm 1]}_{\mathbf{10}}\right)$	$+1$	$+1$	0	$(\mathbf{1},\mathbf{1})_{+1}$
	-1	-1		$\left(\bar{\mathbf{3}},\mathbf{2}\right)_{+1/6}$
	$+1$	$+1$		$(\mathbf{3},\mathbf{1})_{+2/3}$

$\Sigma^{(41)}_{\bar{\mathbf{5}}} = \{a_{420} = z = 0\}$	$C_{u,v}$	L_Y	$\mathcal{L}_{\text{Higgs}}$	$\text{SU}(3) \times \text{SU}(2) \times \text{U}(1)_Y$
$h^0\left(\check{\mathcal{L}}^{(41)[\pm 1]}_{\bar{\mathbf{5}}}\right)$	$+1$	$+1$	3	$\left(\bar{\mathbf{3}},\mathbf{1}\right)_{+1/3}$
	-1	-1		$(\mathbf{1},\mathbf{2})_{-1/2}$
$h^1\left(\check{\mathcal{L}}^{(41)[\pm 1]}_{\bar{\mathbf{5}}}\right)$	$+1$	$+1$	0	$(\mathbf{3},\mathbf{1})_{-1/3}$
	-1	-1		$(\mathbf{1},\mathbf{2})_{+1/2}$

Table 1. This table contains the spectrum of 10s and $\bar{5}$s in our model. $C_{u,v}$, $[L_Y]$ is the action of the $\mathbb{Z}_2$ involution, [Wilson line]. Only states which are even under the product remain in the model. h^0, h^1 gives the dimension of the respective cohomologies for the matter curves. We thus have 3 families of quarks and leptons.

even (+) or odd (-) under the Wilson line, L_Y. The massless states which remain after the involution transform as either $(++)$ or $(--)$ under the combined $\mathbb{Z}_2$ involution and Wilson line.[1] The dimension of the respective cohomologies, h^0, h^1, gives the number of sections in the 10 and $\bar{5}$ representations on the respective matter curves. Table 1.

Note, the quark and lepton doublets are contained in the $(--)$ sectors, while the SU(2) singlet states are in the $(++)$ sector, i.e. the doublets are in a Pati-Salam $(4, 2, 1)$, while the SU(2) singlets are in a $(\bar{4}, 1, 2)$. This means that the SU(5) gauge bosons cannot mediate proton decay at the tree level since the resulting massless states in the 10 and $\bar{5}$ come from different 10s and $\bar{5}$s. Only the Pati-Salam gauge bosons in $\text{SU}(4) \times \text{SU}(2)_L \times \text{SU}(2)_R$ act on these states. But these cannot mediate proton decay at the tree level either. Therefore there are no tree level dimension 6 operators mediating proton decay.

What about dimension 4 or 5 baryon and lepton number violating operators? The dimension 4 operators are absent due to R-parity in the model. And the dimension 5 operators are either absent or severely suppressed due the $\mathbb{Z}_4^R$ symmetry [31]. The bottom line is that proton decay is not observable in this model.

[1]The massless states which transform as $(+-)$ and $(-+)$ are projected out of the theory.

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3 Conclusions

In this brief letter we have argued that the global SU(5) F-theory model presented in [28] does not produce any observable proton decay with either dimension 4, 5 or 6 operators. Dimension 4 operators are forbidden by R-parity, dimension 5 are forbidden by a $\mathbb{Z}_4^R$ symmetry and dimension 6 are forbidden at tree level due to the Wilson line breaking of SU(5). Apparently only leptogenesis can be used as a mechanism in the early universe to produce the net matter-anti-matter asymmetry.

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