Accommodating Proton Stability and Light Neutrino Masses in String Inspired Z' Models

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29th September 2010
7th UK Neutrino Network Meeting

Proton Stability and Light Neutrino Masses

- Standard Model experimentally tested
- Low energy effective theory below cutoff
- In SM, Baryon & Lepton # 'accidental' symmetries $\rightarrow$ prevent proton decay operators & no $m^2_{\nu_L}$ terms
- Natural extensions to SM are SUSY SMs
- BUT Dimension 4 and 5 B and L number violating operators
- Global symmetries cannot survive quantum gravity effects
- Require specific L violating operators for seesaw mechanism

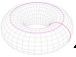
Free Fermionic Construction

Left-Movers : $\psi^{\mu}_{1,2}, \quad \chi_i, \quad y_i, \quad \omega_i \quad (i = 1, \cdots, 6)$

Right-Movers:

$$\bar{\phi}_{A=1,\cdots,44} = \begin{cases} \bar{y}_i \ , \ \bar{\omega}_i & i = 1, \cdots, 6 \\ \bar{\eta}_i & i = 1, 2, 3 \\ \bar{\psi}_{1,\cdots,5} & \\ \bar{\phi}_{1,\cdots,8} & \end{cases}$$

$$f \longrightarrow -e^{i\pi\alpha(f)} f$$



$$Z = \sum_{\substack{all \ spin \\ structures}} c\binom{\vec{\alpha}}{\vec{\beta}} Z\binom{\vec{\alpha}}{\vec{\beta}}$$

Model Construction

- NAHE set of basis vectors $\{1, S, b_1, b_2, b_3\}$
  - Gauge Group : $SO(10) \;\times\; SO(6)^{1,2,3} \;\times\; E_8$
- Choice of α, β, γ
  - Gauge Group : subgroup $\times$ $U(1)_{1,2,3}$ $\times$ subgroup
- 4D models with $N = 1$ SUSY
- 3 chiral generations, from b_1, b_2, b_3

$SO(10)$ breaking

- SM fits in 16-rep of $SO(10)$
- $SO(10) \rightarrow$ subgroup : $b(\bar{\psi}^{1\cdots5})$
- Different symmetry breaking patterns, different boundary conditions on $\bar{\psi}^{1\cdots5}$

$SO(10)$ breaking patterns

1. $b\left\{\bar{\psi}^{1\cdots5}\right\} = \left\{\frac{1}{2}\frac{1}{2}\frac{1}{2}\frac{1}{2}\frac{1}{2}\right\} \implies SU(5)\times U(1)$
2. $b\left\{\bar{\psi}^{1\cdots5}\right\} = \{11100\} \implies SO(6)\times SO(4)$
   - Combination of 1 & 2 $\implies SU(3)\times SU(2)\times U(1)^2$
3. $b\left\{\bar{\psi}^{1\cdots5}\right\} = \left\{\frac{1}{2}\frac{1}{2}\frac{1}{2}00\right\}$
   - But combination of 2 & 3 $\implies SU(3)\times SU(2)^2\times U(1)$

Left-Right Symmetric

- Model presented here is left-right symmetric
- $SU(3) \times SU(2)_L \times SU(2)_R \times U(1)$
- Left-right symmetry assigns opposite charges to left/right doublets
- Allows $U(1)_E$ to be anomaly free
- Forbids baryon number violating operators e.g. $QQQL$
- Permits seesaw mechanism

Extra $U(1)$ Conditions

- Dimension four, five and six proton decay mediating operators forbidden
- Allow seesaw mechanism for suppression of left-handed neutrino masses
- Allow fermion Yukawa couplings to electroweak scale Higgs doublets
- Family Universal
- Anomaly Free

$U(1)_E$

- Combination of $3U(1)$ symmetries generated by WS fermions, $\bar{\eta}_{1,\ldots,3}$
- $U(1)_E = U_1(1) + U_2(1) + U_3(1)$
- Satisfies above conditions
- Anomaly free?

Anomalies

- Find anomalies in $SU(2)_L$
- Adding Higgs-like bidoublet cancels anomaly
- Anomalies appear in $U(1)_E^3$ and Gravitons diagrams
- 4 singlets per generation required to cancel these anomalies
- Also need to add 2 triplets $D \& \bar{D}$
- These do not contribute to anomalies but nullify the change in gauge coupling

Spectrum

$$SU(3)_C \times SU(2)_L \times SU(2)_R \times U(1)_C \times U(1)_E$$

$$Q_L = \begin{pmatrix} u \\ d \end{pmatrix}_L = \left(3, 2, 1, +\frac{1}{2}\right)_{+\frac{1}{2}} ; \quad Q_R = \begin{pmatrix} U \\ D \end{pmatrix}_R = \left(3, 1, 2, -\frac{1}{2}\right)_{-\frac{1}{2}}$$

$$L_L = \begin{pmatrix} e \\ \nu \end{pmatrix}_L = \left(1, 2, 1, -\frac{3}{2}\right)_{+\frac{1}{2}} ; \quad L_R = \begin{pmatrix} E \\ N \end{pmatrix}_R = \left(1, 1, 2, +\frac{3}{2}\right)_{-\frac{1}{2}}$$

$$D = (3, 1, 1, -1)_{-1} ; \quad \bar{D} = (\bar{3}, 1, 1, +1)_{+1} ; \quad h_0 = (1, 2, 2, 0)_0 ;$$

$$h_1 = (1, 2, 2, 0)_{-1} ; \quad S = (1, 1, 1, 0)_{+1} \times 4$$

$$H_R = \left(1, 1, 2, +\frac{3}{2}\right)_{-\frac{1}{2}} ; \quad \bar{H}_R = \left(1, 1, 2, -\frac{3}{2}\right)_{+\frac{1}{2}}$$

Outlook

- $SU(2)_R$ breaking
- Phenomenological implications