"Higgses Masses in some Supersymmetric 3-3-1 Models"

Marcos C. Rodriguez

Universidade Federal do Rio Grande
Instituto de Matemática, Estatística e Física
Av. Itália km 8, Campus Carreiros
96201-900, Rio Grande, RS, Brazil

IX Latin American Symposium on High Energy Physics
December 11, 2012

models $SU(3)_C \otimes SU(3)_L \otimes U(1)_N$ 3-3-1

$$\frac{Q}{e} = \frac{1}{2}(\lambda_3 - \vartheta\lambda_8) + N \;\; I$$

ϑ two different models (1992-1994)

motivations to study this kind of model

1. The family number must be three

2. It explains why $\sin^2\theta_W < \frac{1}{4}$ is observed at the Z-pole

3. It is the simplest model that includes bileptons of both types: scalar and vectors ones

4. The model has several sources of CP violation

First Model MSUSY331 $\vartheta = \sqrt{3}$

- T. V. Duong and E. Ma, Phys. Lett. **B316**, 307 (1993) (Scalar Sector)

- H. N. Long and P. B. Pal, Mod. Phys. Lett. **A13**, 2355 (1998) (Proton Decay)

- J. C. Montero, V. Pleitez and M. C. Rodriguez, Phys. Rev. **D65**, 035006 (2002)

- M. Capdequi-Peyranère and M.C. Rodriguez, Phys. Rev. **D65**, 035001 (2002)

Second Model SUSY331RN $\vartheta = 1/\sqrt{3}$

- J. C. Montero, V. Pleitez and M. C. Rodriguez, Phys. Rev. **D70**, 075004 (2004)

- D. T. Huong, M. C. Rodriguez and H. N. Long, [arXiv:hep-ph/0508045]

More References on these models will be presented during this seminar

MSUSY331 Particle Content

$$L_{aL} \sim \begin{pmatrix} \nu_a \\ l_a \\ l_a^c \end{pmatrix}_L \sim (\mathbf{1}, \mathbf{3}, 0) \quad a = e, \mu, \tau$$

Higgs

$$\eta = \begin{pmatrix} \eta^0 \\ \eta_1^- \\ \eta_2^+ \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, 0)$$

$$\rho = \begin{pmatrix} \rho^+ \\ \rho^0 \\ \rho^{++} \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, +1)$$

$$\chi = \begin{pmatrix} \chi^- \\ \chi^{--} \\ \chi^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, -1)$$

$$S \sim (\mathbf{1}, \mathbf{6}^*, 0)$$

Supersymmetric Partners:

$$\begin{aligned}
\tilde{\eta} &= \begin{pmatrix} \tilde{\eta}^0 \\ \tilde{\eta}_1^- \\ \tilde{\eta}_2^+ \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, 0) \\
\tilde{\rho} &= \begin{pmatrix} \tilde{\rho}^+ \\ \tilde{\rho}^0 \\ \tilde{\rho}^{++} \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, +1) \\
\tilde{\chi} &= \begin{pmatrix} \tilde{\chi}^- \\ \tilde{\chi}^{--} \\ \tilde{\chi}^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, -1) \\
\tilde{S} &\sim (\mathbf{1}, \mathbf{6}^*, 0)
\end{aligned}$$

Cancel Chiral Anomaly

$$\begin{aligned}
\tilde{\eta}' &= \begin{pmatrix} \tilde{\eta}'^0 \\ \tilde{\eta}_1'^+ \\ \tilde{\eta}_2'^- \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}^*, 0) \\
\tilde{\rho}' &= \begin{pmatrix} \tilde{\rho}'^- \\ \tilde{\rho}'^0 \\ \tilde{\rho}'^{--} \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}^*, -1) \\
\tilde{\chi}' &= \begin{pmatrix} \tilde{\chi}'^+ \\ \tilde{\chi}'^{++} \\ \tilde{\chi}'^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}^*, +1) \\
\tilde{S}' &\sim (\mathbf{1}, \mathbf{6}^*, 0)
\end{aligned}$$

Lagrangian

$$\mathcal{L}_{331S} = \mathcal{L}_{SUSY} + \mathcal{L}_{\text{soft}}$$

$$\begin{aligned}\mathcal{L}_{SUSY} &= \mathcal{L}_{\text{Lepton}} + \mathcal{L}_{\text{Quarks}} + \mathcal{L}_{\text{Gauge}} \\ &+ \mathcal{L}_{\text{Scalar}}\end{aligned}$$

symmetry breaking

$$\begin{aligned}&\text{MSUSY331} \overset{\mathcal{L}_{soft}}{\longmapsto} \text{SU(3)}_C \otimes \text{SU(3)}_L \otimes \text{U(1)}_N \\ &\overset{\langle\chi\rangle\langle\chi'\rangle}{\longmapsto} \text{SU(3)}_C \otimes \text{SU(2)}_L \otimes \text{U(1)}_Y \\ &\overset{\langle\rho,\eta,\rho'\eta'\rangle}{\longmapsto} \text{SU(3)}_C \otimes \text{U(1)}_Q\end{aligned}$$

$$\begin{aligned}\mathcal{L}_{\text{Fermion}} &= \mathcal{L}_{ffV} + \mathcal{L}_{\tilde{f}\tilde{f}V} + \mathcal{L}_{f\tilde{f}\tilde{V}} + \mathcal{L}_{\tilde{f}\tilde{f}VV} \\ &+ \mathcal{L}_{cin}^{Fermion} + \mathcal{L}_{F}^{Fermion} + \mathcal{L}_{D}^{Fermion}\end{aligned}$$

$$\mathcal{L}^{gauge} = \mathcal{L}_{dc} + \mathcal{L}_{D}^{gauge}$$

$$\begin{aligned}\mathcal{L}^{scalar} &= \mathcal{L}_{F}^{scalar} + \mathcal{L}_{D}^{scalar} + \mathcal{L}_{Higgs} + \mathcal{L}_{Higgsinos} \\ &+ \mathcal{L}_{H\tilde{H}\tilde{V}}\end{aligned}$$

W is the superpotential

$$W = \frac{W_2}{2} + \frac{W_3}{3}$$

$$\begin{aligned}W_2 &= \mathcal{L}_{F}^{W2} + \mathcal{L}_{\tilde{H}L} + \mathcal{L}_{HMT}, \\ W_3 &= \mathcal{L}_{F}^{W3} + \mathcal{L}_{llH} + \mathcal{L}_{l\tilde{l}\tilde{H}} + \mathcal{L}_{l\tilde{H}H} + \mathcal{L}_{\tilde{l}\tilde{H}\tilde{H}} + \mathcal{L}_{H\tilde{H}\tilde{H}} \\ &+ \mathcal{L}_{qqH} + \mathcal{L}_{q\tilde{q}\tilde{H}} + \mathcal{L}_{lq\tilde{q}} + \mathcal{L}_{qq\tilde{q}} + \mathcal{L}_{qq\tilde{l}}\end{aligned}$$

J. C. Montero, V. Pleitez and M. C. Rodriguez, Phys. Rev. **D65**, 095008 (2002).

$$W_2 = \mu_{0a}\hat{L}_a\hat{\eta}' + \mu_\eta\hat{\eta}\hat{\eta}' + \mu_\rho\hat{\rho}\hat{\rho}' + \mu_\chi\hat{\chi}\hat{\chi}' + \mu_S\hat{S}\hat{S}'$$

$$\begin{aligned}
y \quad & \hat{L}\hat{L}\hat{S} + \lambda_{1abc}\epsilon\hat{L}_a\hat{L}_b\hat{L}_c + \lambda_{2ab}\epsilon\hat{L}_a\hat{L}_b\hat{\eta} + \lambda_{3a}\hat{L}_a\hat{\rho}\hat{\chi} \\
+ \quad & f_1\epsilon\hat{\eta}\hat{\rho}\hat{\chi} + f_1'\epsilon\hat{\eta}'\hat{\rho}'\hat{\chi}' + \lambda'_{\alpha ai}\hat{Q}_\alpha\hat{L}_a\hat{d^c}_i \\
+ \quad & \kappa_{1i}\hat{Q}_1\hat{\eta}'\hat{u}_i^c + \kappa_{2i}\hat{Q}_1\hat{\rho}'\hat{d}_i^c + \kappa_3\hat{Q}_1\hat{\chi}'\hat{J}^c \\
+ \quad & \kappa_{4\alpha i}\hat{Q}_\alpha\hat{\eta}\hat{d}_i^c + \kappa_{5\alpha i}\hat{Q}_\alpha\hat{\rho}\hat{u}_i^c + \kappa_{6\alpha\beta}\hat{Q}_\alpha\hat{\chi}\hat{j}_\beta^c
\end{aligned}$$

$\mu_0, \lambda_2, \lambda_3$ interactions give masses to charged leptons and neutrinos complex generate Leptogenesis $\rho^0 \to \tilde{\chi}^0 l$

M. C. Rodriguez, *Journ. Mod. Phys.* **2**, 1193 (2011)

1. The proton is stable at tree level (No $\widehat{u}\widehat{u}\widehat{d}$) $p \to e^{+}\pi^{0}$;

2. Allow Double Beta Decay without Neutrinos $dd \to uuee$;

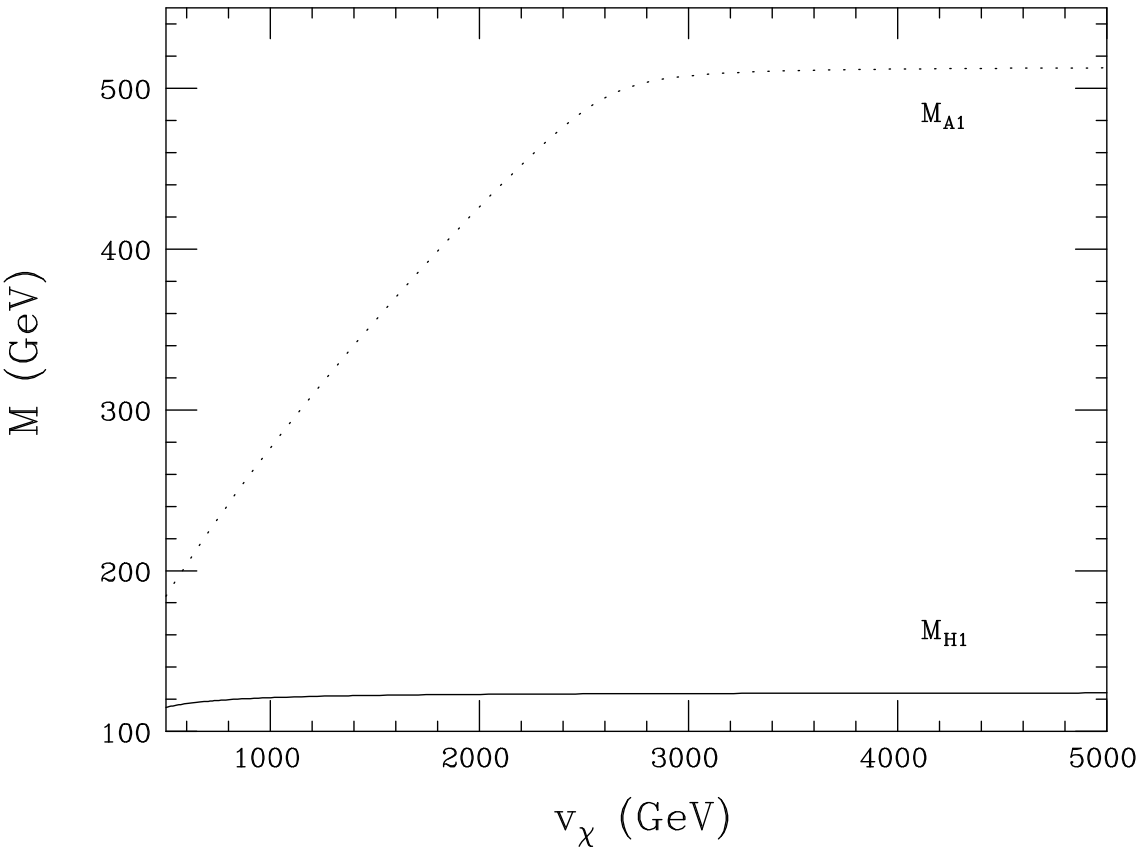
3. New contributions to the muon decay;

4. $D^{+} \to \overline{K^{0}} l_{i}^{+} \nu_{i}$; $K^{+} \to \pi^{+} \nu \bar{\nu}$;

5. New contributions to the Neutrals $K\bar{K}$ and also $B\bar{B}$ Systems (SUPER CKM matrix);

6. Hadronic B Meson Decay.

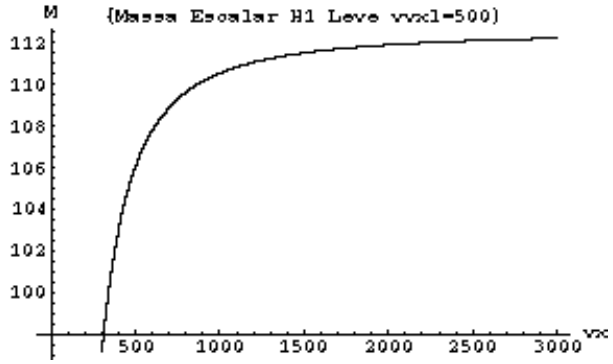
scalar sector with anti-sextet

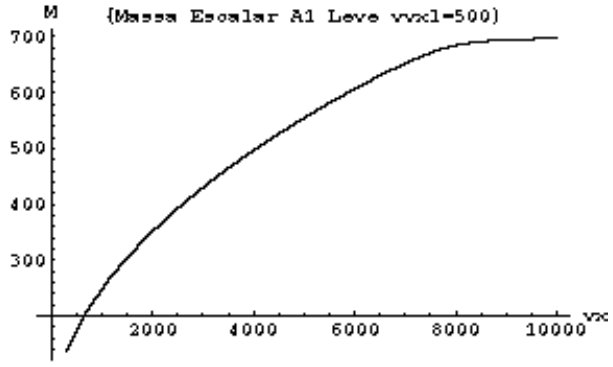


$$M_{H_1}^2 \leq (124.5 + \epsilon)^2 \text{ GeV}^2$$

124.5 GeV tree value ($\epsilon = 0$).

M. C. Rodriguez, Int. J. Mod. Phys. **A21**, 4303 (200€`





$$M_{H_1}^2 \leq (114+\epsilon)^2 \text{ GeV}^2$$
$$M_{A_1} > M_Z$$

SUSY331RN Particle Content

$$L_{aL} = \begin{pmatrix} \nu_a \\ l_a \\ \nu_a^c \end{pmatrix}_L \sim (\mathbf{1}, \mathbf{3}, -1/3)$$

$a = 1, 2, 3$

$$l_{aL}^c \sim (\mathbf{1}, \mathbf{1}, 1)$$

$$\eta = \begin{pmatrix} \eta_1^0 \\ \eta^- \\ \eta_2^0 \end{pmatrix}$$

$$\chi = \begin{pmatrix} \chi_1^0 \\ \chi^- \\ \chi_2^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, -1/3)$$

$$\rho = \begin{pmatrix} \rho_1^+ \\ \rho^0 \\ \rho_2^+ \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, 2/3)$$

Supersymmetric Partners:

$$\tilde{\eta} = \begin{pmatrix} \tilde{\eta}_1^0 \\ \tilde{\eta}^- \\ \tilde{\eta}_2^0 \end{pmatrix}$$

$$\tilde{\chi} = \begin{pmatrix} \tilde{\chi}_1^0 \\ \tilde{\chi}^- \\ \tilde{\chi}_2^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, -1/3)$$

$$\tilde{\rho} = \begin{pmatrix} \tilde{\rho}_1^+ \\ \tilde{\rho}^0 \\ \tilde{\rho}_2^+ \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}, 2/3)$$

Cancel Chiral Anomaly

$$\tilde{\eta}' = \begin{pmatrix} \tilde{\eta}_1'^0 \\ \tilde{\eta}'^+ \\ \tilde{\eta}_2'^0 \end{pmatrix}$$

$$\tilde{\chi}' = \begin{pmatrix} \tilde{\chi}_1'^0 \\ \tilde{\chi}'^+ \\ \tilde{\chi}_2'^0 \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}^*, 1/3)$$

$$\tilde{\rho}' = \begin{pmatrix} \tilde{\rho}_1'^- \\ \tilde{\rho}'^0 \\ \tilde{\rho}_2'^- \end{pmatrix} \sim (\mathbf{1}, \mathbf{3}^*, -2/3)$$

Lagrangian

$$\mathcal{L}_{SUSY331RN} = \mathcal{L}_{SUSY} + \mathcal{L}_{\text{soft}}$$

$$\mathcal{L}_{SUSY} = \mathcal{L}_{\text{Lepton}} + \mathcal{L}_{\text{Quark}} + \mathcal{L}_{\text{Gauge}} + \mathcal{L}_{\text{Scalar}}$$

$\mathcal{L}_{\text{Gauge}}$ equal as MSUSYS331 P8

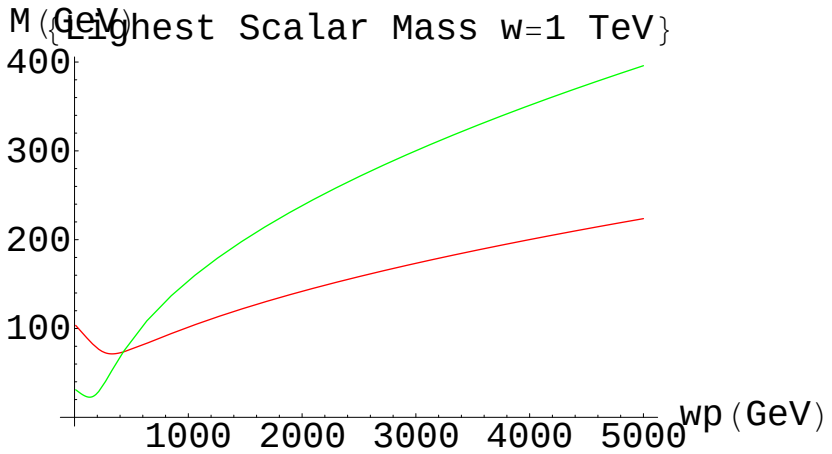
symmetry breaking

$$\begin{array}{l} \text{SUSY331RN} \\ \xrightarrow{\langle\chi\rangle\langle\chi'\rangle} \\ \xrightarrow{\langle\rho,\eta,\rho'\eta'\rangle} \end{array} \begin{array}{l} \overset{\mathcal{L}_{soft}}{\longmapsto} \text{SU(3)}_C \otimes \text{SU(3)}_L \otimes \text{U(1)}_N \\ \text{SU(3)}_C \otimes \text{SU(2)}_L \otimes \text{U(1)}_Y \\ \text{SU(3)}_C \otimes \text{U(1)}_Q \end{array}$$

P. V. Dong, D. T. Huong, M. C. Rodriguez and H. N. Long, Eur. Phys. J. **C48**, 229 (2006)

$$
\begin{aligned}
W_{2RC} &= \mu_0 \hat{L}\hat{\eta}' + \mu_1 \hat{L}\hat{\chi}' + \mu_\eta \hat{\eta}\hat{\eta}' + \mu_\chi \hat{\chi}\hat{\chi}' \\
&+ \mu_2 \hat{\eta}\hat{\chi}' + \mu_3 \hat{\chi}\hat{\eta}' + \mu_\rho \hat{\rho}\hat{\rho}' \\
W_{3RC} &= \lambda_{1ab} \hat{L}_a \hat{\rho}' \hat{l}^c_b + \lambda_{2a} \hat{L}_a \hat{\chi}\hat{\rho} + \lambda_{3a} \hat{L}_a \hat{\eta}\hat{\rho} \\
&+ \lambda_{4ab} \epsilon \hat{L}_a \hat{L}_b \hat{\rho} + f_1 \epsilon \hat{\rho}\hat{\chi}\hat{\eta} + f'_1 \epsilon \hat{\rho}'\hat{\chi}'\hat{\eta}' \\
&+ \kappa_{1i} \hat{Q}_3 \hat{\eta}' \hat{u}^c_i + \kappa'_1 \hat{Q}_3 \hat{\eta}' \hat{T}^c + \kappa_{2i} \hat{Q}_3 \hat{\chi}' \hat{u}^c_i \\
&+ \kappa'_2 \hat{Q}_3 \hat{\chi}' \hat{T}^c + \kappa_{3\alpha i} \hat{Q}_\alpha \hat{\eta} \hat{d}^c_i + \kappa'_{3\alpha\beta} \hat{Q}_\alpha \hat{\eta} \hat{D}^c_\beta \\
&+ \kappa_{4\alpha i} \hat{Q}_\alpha \hat{\rho} \hat{u}^c_i + \kappa'_{4\alpha} \hat{Q}_\alpha \hat{\rho} \hat{T}^c + \kappa_{5i} \hat{Q}_3 \hat{\rho}' \hat{d}^c_i \\
&+ \kappa'_{5\beta} \hat{Q}_3 \hat{\rho}' \hat{D}^c_\beta + \kappa_{6\alpha i} \hat{Q}_\alpha \hat{\chi} \hat{d}^c_i + \kappa'_{6\alpha\beta} \hat{Q}_\alpha \hat{\chi} \hat{d}'^c_\beta \\
&+ \lambda'_{\alpha a i} \hat{Q}_\alpha \hat{L}_a \hat{d}^c_i + \xi_{2\alpha a\beta} \hat{Q}_\alpha \hat{L}_a \hat{d}'^c_\beta
\end{aligned}
$$

Same nice phenomenological aspect as in MSUSY331
Pags(9,10)
P.V.Dong, D.T.Huong, M.C.Rodriguez and H.N.Long,*Journ. of Modern Physics* **2**, 792, (2011)



$$M_{A_1} \approx 5\text{GeV}^2$$

A_1 does not couple to the Z^0