QLC Relation AND neutrino mass hierarchy

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J.F., SANDIP PAKVASA PRD71 (2005) ph/0409060
PLB603 (2004) ph/0412038

$\sin\theta_{12} = 0.53 \pm 0.04$

$\sin\theta_{23} = 0.70 \pm 0.11$

$\sin\theta_{13} < 0.15$

$\Delta m^2_{sun} = \Delta m^2_{21} = (8.2 \pm 0.6) \times 10^{-5}\,eV^2$

$|\Delta m^2_{atm}| = |\Delta m^2_{32}| = (2.45 \pm 0.55) \times 10^{-3}\,eV^2$

$$s_{23} = \frac{1}{\sqrt{2}} + \epsilon_A \lambda_\nu^2$$

$$s_{12} = \frac{1}{\sqrt{2}}(1 - \lambda_\nu + \epsilon_S \lambda_\nu^2)$$

$$s_{13} = \epsilon_{CP} \lambda_\nu^2$$

Rodejohann PRD 69

$$V_{MNSP} = \begin{bmatrix} \frac{1}{\sqrt{2}}(1+\lambda_\nu) & -\frac{1}{\sqrt{2}}(1-\lambda_\nu) & 0 \\ \frac{1}{2}(1-\lambda_\nu) & \frac{1}{2}(1+\lambda_\nu) & -1/\sqrt{2} \\ \frac{1}{2}(1-\lambda_\nu) & \frac{1}{2}(1+\lambda_\nu) & 1/\sqrt{2} \end{bmatrix} + O(\lambda_\nu^2)$$

$$\boxed{\theta_{12} + \theta_C = 45.1 \pm 2.4^\circ (1\sigma)}$$

Pakvasa
Rodejohann PRD69
Smirnov ph/0402

$$s_{\theta_C} \simeq \theta_C = \lambda \simeq |V_{us}| = 0'220 \pm 0'0026$$

$$V_{CKM} = \begin{bmatrix} 1-\lambda^2/2 & \lambda & s a \lambda e^{-i\gamma} \\ \lambda & 1-\lambda^2/2-a^2/2 & a \\ (1-s e^{i\gamma}) a\lambda & a & 1-a^2/2 \end{bmatrix}$$

$$a = |V_{cb}| = 0'0413 \pm 0'0015$$

$$s = \frac{|V_{ub}|}{|V_{us}||V_{cb}|} = 0'40 \pm 0'07$$

$$|V_{ub}| = 0'00367 \pm 0'00047$$

$$A = a/\lambda^2$$

$$f = (\rho^2 + \eta^2)^{1/2}$$

$$\gamma = \tan^{-1}(\eta/\rho)$$

Ferrandis ph/0504

$$V_{MNSP} = (V_L^\ell)^\dagger V_\nu \quad < \quad \begin{cases} M_\ell^{Diag} = (V_L^\ell)^\dagger M_\ell V_R^\ell \\ M_\nu^{Diag} = V_\nu^\dagger M_\nu V_\nu \end{cases}$$

$V_L^\ell = V_{CKM}$; $V_\nu \equiv U_{BiMax}$ Bimaximal from neutrinos Raidal PRL92 ph/0404

$V_L^\ell = U_{BiMax}^\dagger$; $V_\nu = V_{CKM}^\dagger$ Bimaximal from charged leptons

$V_L^\ell = R_{23}^\dagger(\frac{\pi}{4})$; $V_\nu = V_{CKM}^\dagger R_{12}(\frac{\pi}{4})$ Hybrid Minakata-Smirnov PRD 70, ph/0

$V_L^\ell = V_{CKM}$; $M_R = \begin{bmatrix} 0 & M' & 0 \\ M' & 0 & 0 \\ 0 & 0 & M \end{bmatrix}$; $Y_0 = Y_\nu^D \equiv Diag$ Large (23) mixing from neutrinos

$V_L^\ell = R_{23}^\dagger$; $V_\nu = R_{12}(\frac{\pi}{4}) V_{CKM}^\dagger$ Large (23) mixing from charged leptons

SU(5)

$$\frac{1}{4} Y_U \Psi_{10} \Psi_{10} H_5 + \sqrt{2}\, Y_{D,L} \Psi_{10} \Psi_{\bar{5}} H_{\bar{5}}$$

Georgi
Glashow
PRL 32 (74)

$$Y_D = Y_L \Rightarrow Y_u \propto \mathrm{Diag}(h_u, h_c, h_t) \rightarrow V_d^L = V_{CKM} = V_e^L$$

IF $Y_D = Y_L \rightarrow \dfrac{m_e}{m_\mu} = \dfrac{m_d}{m_s}$ and $\dfrac{m_\mu}{m_\tau} = \dfrac{m_s}{m_b}$

$$Y_D = h_b \begin{bmatrix} a & b & d \\ b & c & e \\ d & e & 1 \end{bmatrix} \rightarrow Y_L = h_b \begin{bmatrix} a & b & d \\ b & 3c & e \\ d & e & 1 \end{bmatrix}$$

$$\downarrow$$

$$V_d^L = V_{CKM}$$

Georgi
Jarlskog
PLB 86 (79)

$$H_{\bar{5}} \rightarrow H_{\overline{45}}$$

$$V_e^L \equiv \begin{bmatrix} 1 & \lambda/3 & 0 \\ -\lambda/3 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \mathcal{O}(\lambda^2)$$

Gatto-Sartori-Tonin PLB28(68)

$$\lambda = |V_{us}| \approx \left(\frac{m_d}{m_s}\right)^{1/2} \approx 3\left(\frac{m_e}{m_\mu}\right)^{1/2}$$

Georgi-Jarlskog

$$|V_{us}| = 0.220 \pm 0.0026$$

$$\left(\frac{m_d}{m_s}\right)^{1/2} = 0.211 \pm 0.033$$

M. Jamin, Oller, Pich EPJC24(02)
Gamiz et al JHEP0301(03)

$$3 \cdot \left(\frac{m_e}{m_\mu}\right)^{1/2} = 0.20648 \pm 0.00002$$

$$\frac{(m_d/m_s)^{1/2}}{(m_e/m_\mu)^{1/2}} = 3.06 \pm 0.48$$

Fernandez
EPJC(04)
ph/0406004

$$|V_{us}| \approx \left(\frac{m_d}{m_s}\right)^{1/2}$$

S. Weinberg (77)

$$\text{IF } Y_u \equiv \text{Diag} \Rightarrow \quad Y_d = \begin{bmatrix} 0 & a\lambda & b \\ a\lambda & a & c \\ b & c & 1 \end{bmatrix} h_b$$

$$\left(\frac{m_d}{m_s}\right) = \frac{\frac{(a\lambda)^2}{a}}{a} = \lambda^2 \longleftarrow \quad b \lesssim a\lambda$$

$$b \approx |V_{ub}| \simeq 0.0036$$

In this basis $\quad V_d^L = V_{CKM}$

$$|V_{us}| \simeq 3\left(\frac{m_e}{m_\mu}\right)^{1/2}$$

$\underline{b' \lesssim a'\lambda}$

THERE MUST BE A LEPTONIC BASIS WHERE

$$Y_L = \begin{bmatrix} 0 & a'\lambda & b' \\ a'\lambda & 3a' & c' \\ b' & c' & 1 \end{bmatrix} h_\tau$$

In this basis

$$V_e^L = \begin{bmatrix} 1 & \lambda/3 & 0 \\ -\lambda/3 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} + \mathcal{O}(\lambda^2)$$

$$\frac{m_e}{m_\mu} = \frac{(a'\lambda)^2/3a'}{3a'} = \frac{\lambda^2}{9}$$

In some GUTs

$a' = a$, $b' = b$, $c' = c$

$c = -1$ SM
$c = \frac{2}{3}$ MSSM

$$\frac{d|V_{us}|}{d\mu} = \frac{-3c}{32\pi^2}|V_{us}|\left(h_c^2 + h_s^2 + h_t^2\frac{(|V_{ub}|^2 - |V_{td}|^2)}{|V_{cd}|^2}\right)$$

$$|V_{us}| \lesssim |V_{us}^0| \underbrace{\left(\frac{\Lambda}{m_W}\right)^{\frac{9c}{32\pi^2}\frac{m_s^2}{m_b^2}}}_{\sim 0.1\%}$$

$$\frac{d}{d\ln\Lambda}\left(\frac{m_d}{m_s}\right) = -\frac{3}{32\pi^2}\left(\frac{m_d}{m_s}\right)\left[b h_s^2 + c h_c^2 + c h_t^2 V_{ts}^2\right]$$

$$\left(\frac{m_d}{m_s}\right)_\Lambda = \left(\frac{m_d}{m_s}\right)_{\Lambda_0}$$

Analogously $$\left(\frac{m_e}{m_\mu}\right)_\Lambda = \left(\frac{m_e}{m_\mu}\right)_{\Lambda_0}$$

A FROGATT-NIELSEN / PATI-SALAM MODEL

Antusch - King - Mohapatra hep-ph/0504007

$$SU(4)_c \times SU(2)_L \times SU(2)_R \times U(1)_F$$

	F_1	F_2	F_3	F_1^c	F_2^c	F_3^c	h	H	$\bar{H}$	θ	$\bar{\theta}$
$SU(4)_c$	4	4	4	$\bar{4}$	$\bar{4}$	$\bar{4}$	1	4	$\bar{4}$	1	1
$SU(2)_L$	2	2	2	1	1	1	2	1	1	1	1
$SU(2)_R$	1	1	1	$\bar{2}$	$\bar{2}$	$\bar{2}$	2	2	$\bar{2}$	1	1
$U(1)_F$	-2	1	1	0	1	-1	0	0	0	1	-1

Flavons are gauge singlets

$$F_i = \begin{pmatrix} u_i & u_i & u_i & \nu_i \\ d_i & d_i & d_i & e_i \end{pmatrix}$$

$$Y_d \sim \begin{pmatrix} 0 & \lambda^4 & \lambda^4 \\ * & \lambda^3 & \lambda^2 \\ * & * & 1 \end{pmatrix}$$

$$F_i F_j^c h \left(\frac{H\bar{H}}{M_V^2}\right)^n \left(\frac{\theta}{M_V}\right)^{p_{ij}} \left(\frac{\bar{\theta}}{M_V}\right)^{p_{ij}}$$

$$Y_L \sim \begin{pmatrix} 0 & -3\lambda^4 & \lambda^4 \\ * & 2\lambda^3 & \lambda^2 \\ * & * & 1 \end{pmatrix}$$

$$(m_{RR})_{ij} \quad F_i^c F_j^c \frac{HH}{M} \left(\frac{H\bar{H}}{M_V^2}\right)^m \left(\frac{\theta}{M_V}\right)^{q_{ij}} \left(\frac{\bar{\theta}}{M_V}\right)^{\bar{q}_{ij}}$$

$$(Y_e^L)_{12} = -\frac{3}{2}\lambda \rightarrow \theta_{12} = \frac{\pi}{4} - \frac{3\lambda}{2\sqrt{2}} \qquad \frac{m_d}{m_s} = \lambda^2 \neq \frac{m_e}{m_\mu} = \frac{9}{4}\lambda^2 \qquad m_{LL} = \begin{pmatrix} 0 & m & m' \\ m & 0 & 0 \\ m' & 0 & 0 \end{pmatrix}$$

$$V_{MNS} = \underbrace{\begin{bmatrix} 1 & -\lambda/3 & 0 \\ \lambda/3 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}}_{(V_L^e)^\dagger} \underbrace{\begin{bmatrix} \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \\ \frac{1}{2} & \frac{1}{2} & -\frac{1}{\sqrt{2}} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \end{bmatrix}}_{V_\nu} + \mathcal{O}(\lambda^2)$$

$$\theta_{12} - \frac{\pi}{4} = \frac{\lambda}{6} \ll \lambda$$

$$\theta_{13} = \frac{\lambda}{3\sqrt{2}} = \left(\frac{m_e}{2m_\mu}\right)^{1/2} = 0.052 \pm 0.001$$

Benchmark value for θ_{13} barring cancellations

CHOOZ II will reach ≈ 0.08

DAYA BAY and other reactor experiments ≈ 0.05

J.F. Pakvasa PRD71

RECONSTRUCTING THE NEUTRINO MASS MATRIX

$$M_\nu = V_{MNSP}\, M_\nu^{Diag}\, V_{MNSP}^{\dagger} \quad ; \quad M_\nu^{Diag} = (m_1\ m_2\ m_3)$$

$$M_\nu = M_\nu^{BiMax} + M_\nu^{QLC}$$

$$M_\nu^{BiMax} = \begin{bmatrix} \frac{1}{2}m_{12} & \frac{1}{\sqrt{2}}\Delta_{12} & \frac{1}{\sqrt{2}}\Delta_{12} \\ \frac{1}{\sqrt{2}}\Delta_{12} & \frac{1}{2}(m_{12}+m_3) & \frac{1}{2}(m_{12}-m_3) \\ \frac{1}{\sqrt{2}}\Delta_{12} & \frac{1}{2}(m_{12}-m_3) & \frac{1}{2}(m_{12}+m_3) \end{bmatrix}$$

Barger, Pakvasa, Weiler, Whisnant PLB 437 (98)

$$M_\nu^{QLC} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & -1 & -1 \\ 0 & -1 & -1 \end{bmatrix} \lambda \Delta_{12}$$

J.F, Pakvasa PRD71

$$M_\nu^{BiMax} = M_\nu^{atm} + M_\nu^{sol}$$

$$\Delta_{12} = \frac{1}{2}(m_1 - m_2)$$

$$m_{12} = \frac{1}{2}(m_1 + m_2)$$

NORMAL HIERARCHY

$$M_\nu^{atm} = \frac{m_3}{2}\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & -1 \\ 0 & -1 & 1 \end{bmatrix}$$

$$m_1 = m_2 = 0$$

$$m_3 = \sqrt{\Delta m^2_{atm}} = (4.9 \pm 0.6)\,10^{-2}\,eV$$

$$M_\nu^{sol} = \gamma \frac{m_3}{2}\begin{bmatrix} 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ -1/\sqrt{2} & 1/2 & 1/2 \\ -1/\sqrt{2} & 1/2 & 1/2 \end{bmatrix}$$

$$\frac{m_2^2 - m_1^2}{m_3^2 - m_2^2} = \frac{\gamma^2}{1-\gamma^2} \simeq \gamma^2$$

$$\gamma = \left(\frac{\Delta m^2_{sol}}{\Delta m^2_{atm}}\right)^{1/2} = 0.18 \pm 0.03$$

$$M_\nu^{QLC} = \gamma \frac{m_3}{2}\lambda \begin{bmatrix} -4 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

$$M_\nu^{QLC} \approx M_\nu^{sol} < M_\nu^{atm}$$

INVERTED HIERARCHY WITH SAME CP-PARITIES

$$M_\nu^{atm} = m_1 \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1/2 & 1/2 \\ 0 & 1/2 & 1/2 \end{bmatrix}$$

$m_3 = 0$

$m_1 = m_2 = \sqrt{\Delta m^2_{atm}}$

$$M_\nu^{sol} = \frac{\gamma}{2} m_1 \begin{bmatrix} 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ -1/\sqrt{2} & 1/2 & 1/2 \\ -1/\sqrt{2} & 1/2 & 1/2 \end{bmatrix}$$

$\Delta m^2_{sol} = (m_2^2 - m_1^2) =$
$= m_1^2 \gamma (2 + \gamma)$

$\gamma \simeq \frac{1}{2} \frac{\Delta m^2_{sol}}{\Delta m^2_{atm}} \simeq 0.024$

$$M_\nu^{QLC} = \gamma m_1 \lambda \begin{bmatrix} -1 & 0 & 0 \\ 0 & 1/2 & 1/2 \\ 0 & 1/2 & 1/2 \end{bmatrix}$$

$$M_\nu^{QLC} \lesssim M_\nu^{sol} \ll M_\nu^{atm}$$

INVERTED HIERARCHY WITH OPPOSITE CP PARITIES

$$M_\nu^{atm} = \frac{m_1}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

$m_2 = -m_1$

$m_3 = 0$

$$M_\nu^{sol} = \gamma \frac{m_1}{\sqrt{2}} \begin{bmatrix} -1/\sqrt{2} & 1/2 & 1/2 \\ 1/2 & -1/2\sqrt{2} & -1/2\sqrt{2} \\ 1/2 & -1/2\sqrt{2} & -1/2\sqrt{2} \end{bmatrix}$$

$$\Delta m^2_{sol} = m_1^2 \gamma (2+\gamma)$$

$$\gamma \approx \frac{1}{2} \frac{\Delta m^2_{sol}}{\Delta m^2_{atm}} \sim \frac{\lambda^2}{2}$$

$$M_\nu^{QLC} = \frac{m_1 \lambda}{\sqrt{2}} \begin{bmatrix} 2\sqrt{2} & 0 & 0 \\ 0 & -\sqrt{2} & -\sqrt{2} \\ 0 & -\sqrt{2} & -\sqrt{2} \end{bmatrix}$$

30 to 50% of M_ν^{atm}

$$M_\nu^{sol} \ll M_\nu^{QLC} \lesssim M_\nu^{atm}$$

RADIATIVE STABILITY OF THE QLC RELATION

NORMAL HIERARCHY

$$\frac{d\theta_{12}}{d\ln\Lambda} \simeq 0 \longrightarrow$$

INVERTED HIERARCHY

$$\frac{d\theta_{12}}{d\ln\Lambda} = \frac{c h_\tau^2}{8\pi^2} s_{12} c_{12} s_{23}^2 \frac{\Delta m^2_{atm}}{\Delta m^2_{sol}} \left[1 + \cos(\phi_1 - \phi_2)\right] + \mathcal{O}(\theta_{13})$$

IF V_{MNSP} is approx. bimaximal

$$\Delta\theta_{12} \simeq \frac{c h_\tau^2}{32\pi^2} \frac{1}{\lambda^2} \left[1 + \cos(\phi_1 - \phi_2)\right] \ln\left(\frac{\Lambda}{m_Z}\right) \qquad c = \begin{cases} 3/2 \\ -1 \end{cases}$$

$$\Delta\theta_{12} = \begin{cases} \simeq 3\times 10^{-4}\left[1 + \cos(\phi_1 - \phi_2)\right] & \text{SM} \\ \simeq -\frac{1}{2}\left[1 + \cos(\phi_1 - \phi_2)\right] & \text{MSSM with Large } \tan\beta \end{cases}$$

NORMAL HIERARCHY	$M_\nu^{QLC} \approx M_\nu^{sol} < M_\nu^{atm}$ (10%)	RGE stable
INVERTED HIERARCHY SAME CP	$M_\nu^{QLC} \lesssim M_\nu^{sol} \ll M_\nu^{atm}$ (1%)	RGE unstable for MSSM with large t_β
INVERTED HIERARCHY OPPOSITE CP	$M_\nu^{sol} \ll M_\nu^{QLC} \lesssim M_\nu^{atm}$ (1%)	RGE stable

CAN THE QLC RELATION TRIGGER Δm^2_{sol} ?

At scale Λ $\quad \theta_{12} = \frac{\pi}{4} - \lambda \; ; \quad m_1 = -m_2 = \sqrt{|\Delta m^2_{atm}|} \; , \quad \Delta m^2_{sol} = 0$

$$8\pi^2 \frac{d\Delta m^2_{sol}}{d\ln\Lambda} = \alpha \Delta m^2_{sol} - C h_\tau^2 2 s^2_{23} (m_2^2 c^2_{12} - m_1^2 s^2_{12}) + \mathcal{O}(\theta_{13})$$

Antusch, Kersten, Lindner, Ratz NPB674

IF $\theta_{23} = \pi/4 \longrightarrow$ $$8\pi^2 \frac{d\Delta m^2_{sol}}{d\ln\Lambda} = \alpha \Delta m^2_{sol} - 2 C \lambda h_\tau \Delta m^2_{atm}$$

SM $$\Delta m^2_{sol}(\mu)\Big|_{SM} = \frac{3 m_\tau^2 \lambda}{\alpha m_t^2} \Delta m^2_{atm} \left(1 - e^{\alpha/8\pi^2 \ln\left(\frac{\Lambda}{\Lambda}\right)}\right)$$
$$\approx 3 \times 10^{-5} \Delta m^2_{atm}$$

MSSM $$\Delta m^2_{sol}(\mu)\Big|_{MSSM} = (-) \frac{2 b^2 m_\tau^2 \lambda}{\alpha m_t^2} \Delta m^2_{atm} \left(1 - e^{\frac{\alpha}{8\pi^2} \ln \frac{\Lambda}{\Lambda}}\right)$$
$$\approx -2 \Delta m^2_{atm} \lambda^2$$

For large $\tan\beta$

$$\Delta m^2_{atm} = m_3^2 - m_2^2 < 0$$

SUSY PATI-SALAM MODEL FOR THE QLC

$G_{422} \times U(1)$

ph/0407139
Frampton-Mohapatra

$$F_i, F_i^c \quad + \quad \begin{matrix} S_i \\ S_i^c \end{matrix} \quad + \quad \begin{matrix} \phi \equiv (2\,2\,0) \\ \chi \equiv (2\,1\,4) \\ \chi^c = (1\,2\,4^*) \\ \bar{\chi} = (2\,1\,4^*) \\ \bar{\chi}^c = (1\,2\,4) \end{matrix}$$

$$W = h_{ij} F_i \phi F_j^c + f_{ij}(F_i \bar{\chi} S_j^c + F_i^c \bar{\chi}^c S_j) + \mu_{ij} S_i S_j$$

$$M = \begin{bmatrix} 0 & M_u^0 & 0 \\ M_u^0 & 0 & f v_R \\ 0 & f^T v_R & \mu \end{bmatrix} \quad ; \quad \mu = \begin{pmatrix} 0 & \mu_1 & \mu_2 \\ \mu_1 & 0 & 0 \\ \mu_2 & 0 & 0 \end{pmatrix}$$

$M_u^0 = \tan\beta\, M_d^0 = \tan\beta\, M_L^0$ → Fix m_3 and m_b using susy threshold

Higher dimensional operators → $M_L = \begin{bmatrix} m_0 & -3\delta' \\ -3\delta' & m_\mu^0 - \delta_3 \end{bmatrix}$

SCREENING OF DIRAC FLAVOR STRUCTURE

Lindner, Schmidt, Smirnov
ph/0508067

$$-\mathcal{L} = L^T Y_\nu N \phi + S^T Y_N N \sigma + \frac{1}{2} S^T M_S S + L^T Y_e l^c \phi_d + h.c.$$

$$M = \begin{bmatrix} 0 & Y_\nu \langle\phi\rangle & 0 \\ Y_\nu^T \langle\phi\rangle & 0 & Y_N^T \langle\sigma\rangle \\ 0 & Y_N \langle\sigma\rangle & M_S \end{bmatrix}$$

σ Higgs boson singlet

S_i 3 singlets

$\langle\phi\rangle \ll \langle\sigma\rangle \ll M_S \Rightarrow$ IF $Y_\nu = c Y_N$

$$m_\nu = c^2 \left[\frac{\langle\phi\rangle}{\langle\sigma\rangle}\right]^2 M_S$$

$\langle\phi\rangle \sim m_Z$

$\langle\sigma\rangle \sim m_{GUT}$

$M_S \sim M_{Pl}$

SUSY SO(10) BIMAXIMAL MODEL

Raby, Dermisek ph/0507045

$SO(10) \times D_3 \times U(1) \times Z_2 \times Z_3$

16_i	Matter fields
$10, 45$	Higgs
$\chi\ \bar{\chi}$	SO(10) breaking vevs
$\phi_a\ \bar{\phi}_a$	D_3 flavon doublets
A	Flavon singlet of SO(10)
N_i	3 SO(10) singlets for the ν sector

χ^2 Analysis

14 parameters
20 observables } 6 predictions

COINCIDENTAL ORIGIN OF QLC

SUSY PATI-SALAM TRIBIMAXIMAL MODEL

S.F. King gh/0506297

	$SU(4)_c$	$SU(2)_L$	$SU(2)_R$	$SO(3)$	R	$U(1)$	Z_4^{I}	Z_4^{II}	Z_3^{I}	Z_3^{II}
F_i	4	2	1	3	1	0	0	0	0	0
F_1^c	$\bar{4}$	1	2	1	1	-3	α	0	0	0
F_2^c	$\bar{4}$	1	2	1	1	-3	0	β	0	0
F_3^c	$\bar{4}$	1	2	1	0	0	0	0	0	0
h	1	2	2	1	0	0	0	0	0	0
H	4	1	2	1	0	0	0	0	0	0
$\bar{H}$	4	1	2	1	0	0	0	0	0	0
Z	15	1	3	1	0	2	α^3	β^3	0	0
ϕ_1	1	1	1	3	0	0	0	0	γ	0
ϕ_2	1	1	1	3	0	0	0	0	0	δ
ϕ_3	1	1	3 or 1	3	0	0	0	0	0	0
ϕ_{23}	1	1	1	3	0	1	α	0	0	0
ϕ_{123}	1	1	1	3	0	1	0	β	0	0

SUMMARY

We studied a model independent reconstruction of the neutrino mass matrix

We studied the relative size of the solar, atmospheric and QLC component of the neutrino mass matrix

We propose that Δm^2_{sol} may be generated radiatively in SUSY theories from a high energy QLC

We review a few models proposed.

THERE IS NO CONVINCING AND REALISTIC MODEL OF THE QLC. THE PROBLEM REMAINS OPEN