Model of leptons from $SO(3) \to A_4$

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The Neutrino Mixing Story

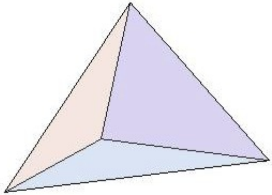
- The latest: three light neutrinos
- From neutrino experiment measurements

$$|U| = \begin{pmatrix} 0.823 & 0.554 & 0.126 \\ 0.480 & 0.558 & 0.677 \\ 0.305 & 0.618 & 0.725 \end{pmatrix}.$$

- Harrison, Perkins and Scott pointed out that

$$U \approx U_{\mathrm{HPS}} = \begin{pmatrix} \sqrt{\frac{2}{3}} & \frac{1}{\sqrt{3}} & 0 \\ -\frac{1}{\sqrt{6}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{2}} \end{pmatrix}$$

How A_4 Helps



$$\psi_e \sim \mathbf{1}, \quad \psi_\mu \sim \mathbf{1}', \quad \psi_\tau \sim \mathbf{1}''$$

$$\langle \phi \rangle = (v, v, v)$$

$$\langle \phi' \rangle = (v', 0, 0)$$

$$m_\ell = \begin{pmatrix} y_e & y_\mu & y_\tau \\ y_e & y_\mu \omega & y_\tau \omega^2 \\ y_e & y_\mu \omega^2 & y_\tau \omega \end{pmatrix}, \qquad m_\nu = \begin{pmatrix} a & 0 & 0 \\ 0 & b & d \\ 0 & d & b \end{pmatrix}$$

Getting A_4 from SSB

- Potential for a **7** of $SO(3)$:

$$V = -\frac{\mu^2}{2} T^{abc} T^{abc} + \frac{\lambda}{4} (T^{abc} T^{abc})^2 + c\, T^{abc} T^{bcd} T^{def} T^{efa}$$

- SSB to A_4 when:

$$\mu^2 > 0, \qquad \lambda > 0, \qquad c > 0$$

Spectrum and Mixing Matrix

Field	$SU(2)_L$	$U(1)_Y$	$SO(3)_F$	Z_2
ψ_ℓ	**2**	$-1/2$	**3**	$-$
ψ_f	**1**	-1	**3**	$-$
ψ_e	**1**	-1	**1**	$+$
ψ_m	**1**	-1	**5**	$+$
ψ_n	**1**	0	**3**	$-$
H	**2**	$1/2$	**1**	$+$
ϕ	**1**	0	**3**	$-$
ϕ'	**1**	0	**3**	$+$
ϕ_5	**1**	0	**5**	$-$
T	**1**	0	**7**	$-$

Field	$SO(3)$ SB
H	None
ϕ	Z_3
ϕ'	Z_2
ϕ_5	Z_3
T	A_4

Conclusions

- A_4 discrete symmetry can explain pattern of ν mixing
- Can get A_4 from SSB of $SO(3)$
- Issues with the model:
  - Many scales: $\Lambda \gg v_T \gg v \sim v' \sim v_5 \gg M \gg v_H$
  - Vacuum alignment
  - Fine-tuning
  - Anomalies