An Asymptotic Freedom Inspired Extension Of The Standard Model.

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- **The standard model is incomplete in many ways.**
  - **Peculiar multiplet structure.**
  - **Too many free parameters.**
  - **No explanation for the families.**
  - **The smallness of the Strong CP-violation.**
  - **Nonvanishing neutrino mass.**
  - **Gravity is not included.**
  - **We still do not know whether the pattern of spontaneous symmetry breaking actually takes place or not.**

- This is a nonperturbative issue and as such is a very difficult problem.

- The pure-Higgs part is a trivial theory when cutoff is removed though it appears to be nontrivial perturbatively.

- Perturbative symptoms are lack of asymptotic freedom, Landau singularities...

- Lattice studies have shown that it is unlikely that inclusion of gauge fields will improve this situation(failure to find non-gaussian fixed points).

- As yet there is no way to investigate nonperturbatively the effect of fermions.

- **The problem of defining Chiral gauge theories on the lattice.**

- **Recent progress in defining Abelian chiral gauge theories on the lattice.**

- **There is need to understand possible extensions of the standard model in its fullest generality.**

- **In this talk we present one such extension based on Asymptotic Freedom.**

- **The Model:**

$$\mathcal{L} = -\frac{1}{2}(\partial_\mu\sigma)^2 - \frac{1}{2}(\partial_\mu\vec{\pi})^2 - \lambda^2(\sigma^2+\vec{\pi}^2-f^2)^2 \\ - \overline{\Psi}_q\left[\mathcal{D}_\mu + g_y(\sigma + i\gamma_5\vec{\tau}\cdot\vec{\pi})\right]\Psi_q - \frac{1}{4}G^a_{\mu\nu}G^{\mu\nu a} \tag{1}$$

• $\mathcal{D}_\mu = \partial_\mu - i g_3 A^a_\mu T^a$
• $G^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + g_3 f_{abc} A^b_\mu A^c_\nu$.

• g_y, g_3 **and** λ **are the Yukawa, QCD, and scalar self- couplings respectively.**

• **The** $\sigma, \vec{\pi}$ **in eqn (1) should not be confused with the chiral multiplet occurring in the low lying spectrum of strongly interacting particles containing the pion(**$m_\pi \simeq 140MeV$**).**

• **The important property of eqn (1) is that it is invariant under the Global** $SU(2)_L \otimes SU(2)_R$ **transformations that affect the quark fields and chiral multiplet.**

$$U = \sigma + i\gamma_5 \vec{\tau} \cdot \vec{\pi} \tag{2}$$

these transformations are given by

$$\psi_L^{'} = g_L \psi_L$$

$$\begin{aligned} \psi_R^{'} &= g_R \psi_L \\ U^{'} &= g_L U g_R^{\dagger} \end{aligned} \tag{3}$$

• **The scalars are colour neutral.**

• **No spontaneous breaking of** $SU(2)_L \otimes SU(2)_R$ **in the** $\sigma, \vec{\pi}$ **sector.**

The RNG Flows

• **The one-loop** β **function for the QCD coupling** α **is unchanged.**

$$\frac{\partial \alpha}{\partial t} = -\left(\frac{33 - 2N_F}{3}\right) \frac{\alpha^2}{8\pi^2} \qquad (g_3^2 = \alpha) \tag{4}$$

• **The** $U(1)$**-coupling** g' **induces radiative corrections that spoil the** $SU(2)_L \times SU(2)_R$ **structure.**

- **One has two Yukawa couplings.**

- **Ignore both the electroweak gauge couplings.**

- $\rho = \frac{g_y^2}{\alpha}$

$$\frac{\partial\rho}{\partial\alpha} = -\frac{\rho}{A\alpha}[12N_g'\rho - 8 + A)] \qquad (5)$$

- **This is analytically soluble.** $\tilde{\rho} = N_g'\rho$

$$\frac{\partial\tilde{\rho}}{\partial\alpha} = -\frac{\tilde{\rho}}{A\alpha}[12\tilde{\rho} - 8 + A)] \qquad (6)$$

- $A = 11 - \frac{2N_F}{3}$

- $\tilde{\rho}_c = \frac{8-A}{12}$

- **The Region** $0 < \tilde{\rho} < \tilde{\rho}_c$

- $\partial\tilde{\rho}/\partial\alpha > 0$

•

• $\tilde{\rho}$ **decreases as** α **decreases, that is,** $\tilde{\rho}$ **will decrease with increasing momentum scale.**

$$\tilde{\rho} = \frac{\alpha^{1/7}K}{(1+12\alpha^{1/7}K)} \tag{7}$$

$$K = \frac{\tilde{\rho}_0\alpha_0^{-1/7}}{1-12\tilde{\rho}_0} \tag{8}$$

• **There is a whole family of solutions corresponding to different K's.**

• **Deep in the ultraviolet** $N_g^{`}g_y^2 \sim K\alpha^{8/7}$

• g_y^2 **is asymptotically free and vanishes faster than** α**. Therefore, the leading behaviour of this theory in the ultraviolet is given by that of standard QCD.**

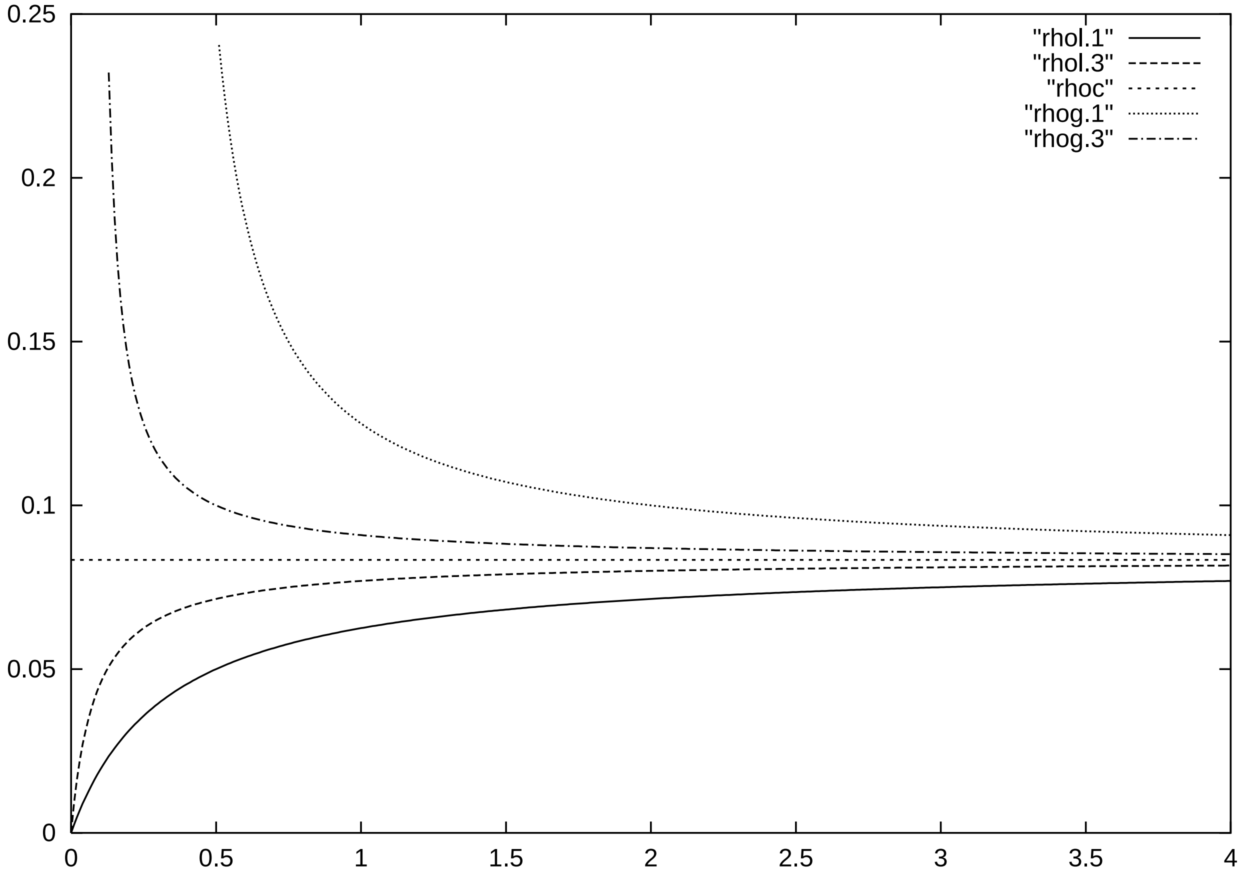

Figure 1: The renormalisation group flows for rho vs alpha.

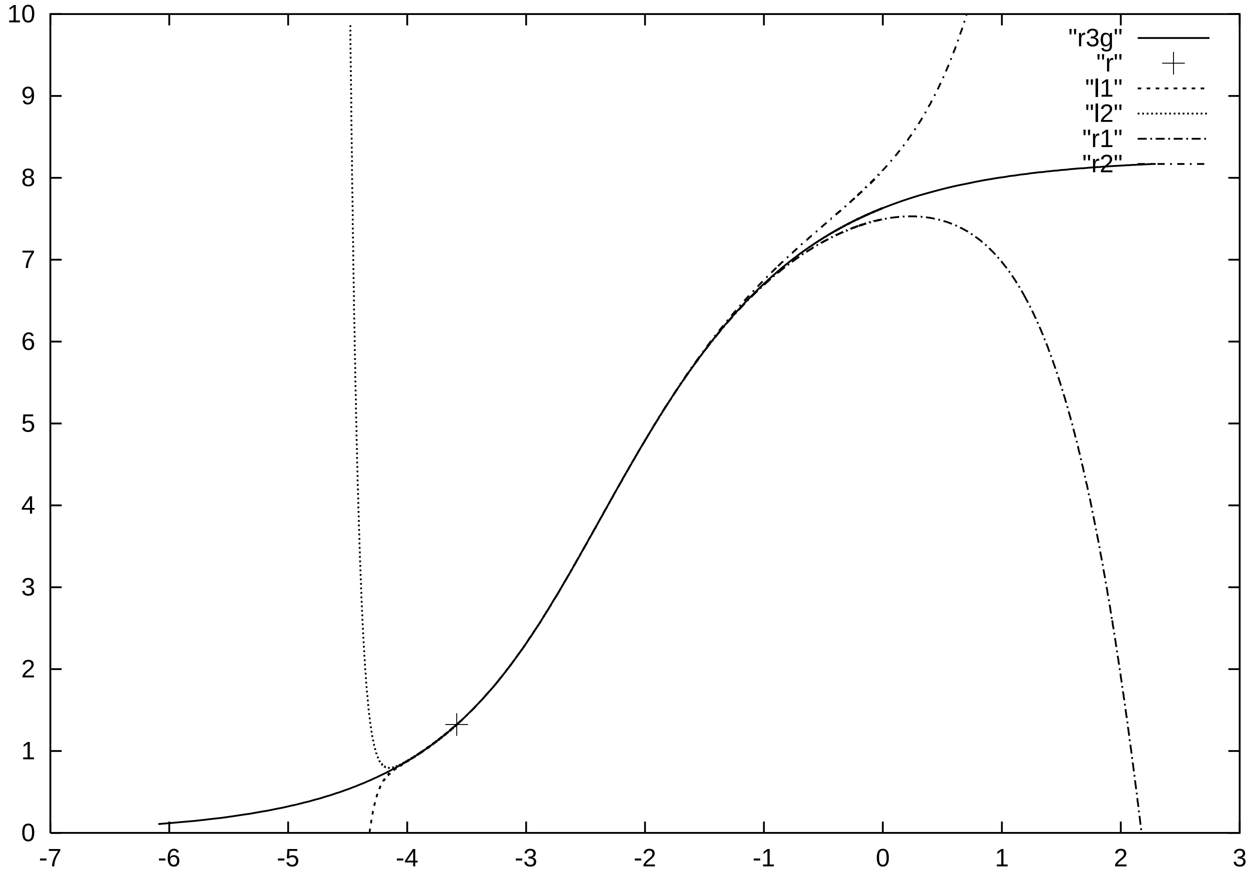

Figure 2: The renormalisation group flows for rho vs alpha.

• **For $N_F \leq 4$ this approximate eqn does not admit any AF regime.**

• **The scalar self coupling λ: $R = \frac{\lambda}{g_y^2}$.**

$$[12N_g'\rho - 8 + A]\frac{dR}{d\rho} = 2R^2 + 12N_g'R + \frac{8R}{\rho} - 144N_g' \tag{9}$$

• **Three quasi-fixed points: $i)\rho = 0, R = 0; \quad ii)\rho = \rho_c, R(\rho_c); \quad iii)\rho = \infty, R = 2$.**

• **The invariant line goes through all these.**

• **The AF phase : $\rho < \rho_c$. IL is the only trajectory on which the theory is AF in all couplings.**

• **There is a reduction in coupling constants.**

• **Near the origin, R is proportional to** ρ **on the IL.**

• λ **goes to 0 even faster than** g_y^2 **in the UV.**

The Phenomenology of the model

• Γ_Z **data rules out** $M_\chi < M_Z/2$.

• **For** $M_\chi > M_Z/2$ **precision tests like muon g-2 do not constrain the model.**

• **FCNC constraints solved in a natural manner by equal coupling of scalars to all generations.**

• **Horizontal symmetry?**

• Electroweak precision parameters S,T,U do not rule out this extension.

• The model predicts excess 4 jet events which look remarkably like what was claimed by ALEPH.

• Equal couplings to all flavours distinguishes these from four jet events of other models.

• Elementary at all scales!

• In QED electrons and photons appear elementary in the IR but the theory being non-AF,no meaning in UV.

• QCD is AF so elementarity at UV but in IR quarks and gluons are confined.