

THE LAST TREASURE - GUTENBERG - WILHELM MULLER - HILLY KERR

I. ASSUME SCALE-INVARIANT MULTI-HILL POTENTIALS + YUKAWA COUPLINGS:

$-V_0(\phi) = \frac{1}{24} f_{ijkl} \phi_i \phi_j \phi_k \phi_l$ (many symmetric tensors)
many Higgs bosons e.g.

$\mathcal{L}_Y = -Y_{ijb} \psi_i \psi_j \phi_b + \text{h.c.}$ (with ψ_i complex SU(2) doublets e.g.)

II. A SIMPLEST EXAMPLE - TWO-HIGGS BOSON MODE (2 HDM)

$\phi_i = \frac{1}{\sqrt{2}} \begin{pmatrix} \rho_i + i a_i \\ \sigma_i + i \tau_i \end{pmatrix}$

$V_0 = \lambda_1 (\phi_1^\dagger \phi_1)^2 + \lambda_2 (\phi_2^\dagger \phi_2)^2 + \lambda_3 (\phi_1^\dagger \phi_1)(\phi_2^\dagger \phi_2) + \text{etc.}$

with Z_2 symmetry on $\phi_{1c} \rightarrow \phi_{1c}; \phi_{2c} \rightarrow -\phi_{2c}$

1. WHEN S.I. IS EXPLICITLY BROKEN, CP = ±1, KEV'S APPEAR:
 $\langle \phi_i \rangle = v_i \ (i=1,2); \ v = \sqrt{v_1^2 + v_2^2}$
 $v_1 = v \cos \beta, \ v_2 = v \sin \beta$

2. CONSIDER $H = \rho_1 \cos \beta + \rho_2 \sin \beta$ (JUST LIKE THE EW GOLDSTONE BOSONS!) THIS LINEAR COMBINATION WILL HAVE SM COUPLINGS TO W, Z AND QUARKS AND LEPTONS.
 CONSIDER THIS AT THE RAY $\rho_1, \rho_2 \rightarrow +\infty$

ie., "H IS (PERFECTLY) ALIGNED!!"
 - IT HAS SM COUPLINGS.

3. ON THE RAY $\rho_1, \rho_2 = \rho \rightarrow \infty$, H IS AN EIGENSTATE AND IT IS MASSLESS - JUST LIKE THE GOLDSTONE BOSONS $W^\pm = H_1^\pm \cos\beta + H_2^\pm \sin\beta$. AND $Z = A_1^\pm \cos\beta + A_2^\pm \sin\beta$ - EATEN BY W^\pm AND Z , RESPECTIVELY.

i.e. H IS THE MASSLESS DILATON OF SPONTANEOUSLY BROKEN SCALE-INVARIANCE.

4. IN THE ONE-LOOP APPROX'N OF S. COLEMAN AND E. WEINBERG, SCALE-INVARIANCE IS EXPLICITLY BROKEN $\rightarrow \rho_i \rightarrow \rho_i + v_i$ ($v_1 = v \cos\beta$, $v_2 = v \sin\beta$; $0 < \beta \leq \pi$). NOW, H GETS A MASS (IT'S A PSEUDO-DILATON). - AS DO ALL THE OTHER

AND THERE RESULTS THE SUM RULE

$$M_H^2 = \frac{8\pi^2}{v^2} (M_{H^+}^4 + 2M_{H^\pm}^4 - 3M_W^4 + M_Z^4)$$

\uparrow MASSIVE HIGGS NOT
EATEN BY Z AND W^\pm !

5. THE SAME SORT OF SUM RULE HOLDS IN ANY GW MODEL OF ELECTROWEAK INTERACTIONS ($SU(2) \otimes U(1)$) WITH COMPLEX-ROBUST HIGGS:

$$\Rightarrow \left(\sum M_{BSM}^4 \right)^{1/4} = \left[\frac{v^2}{8\pi^2} M_H^2 - 3M_W^4 - M_Z^4 \right]^{1/4} = 540 \text{ GeV}$$

i.e. BSM HIGGS MASSES ARE CONSTRAINED BY $M_H = 125 \text{ GeV}$

AGAIN: IN GUT MODELS OF THE EW INTERACTIONS,
BSM Higgs masses are LIGHT BECAUSE $H(125)$ IS LIGHT!
