DUARKS

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VENEZIA

Simplest Extensions of Std. Model

0 - More Families of F.F.

1. Right-handed ν's
   (seesaw masses)

2. Second Higgs Boson (w. a discrete sym.)
   (fun for LHC)

3. Leptoquarks
   (why not?)

4. A second Z^0 OR Axigluons
   (there's room for it)

5. Triplet Majorons
   (too bad!)

6. Axions
   (are they or ain't they?)

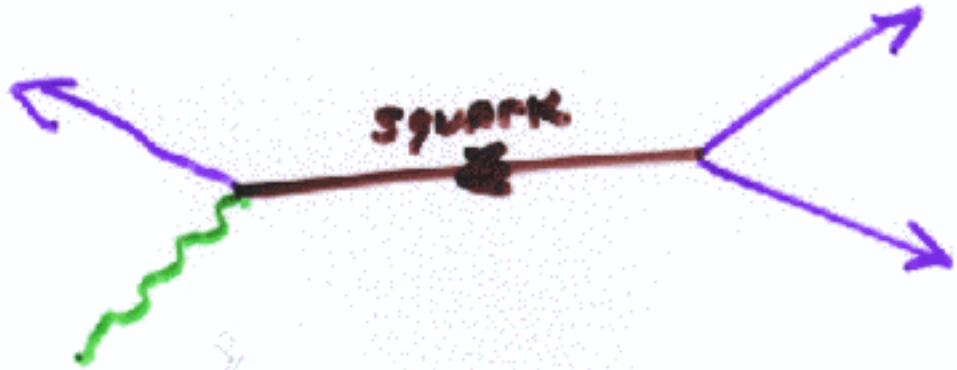
7. **Mesons with Quark No. Two**

Neither Diquarks
Nor Biquarks,
But DUARKS

CAN THE DARK MATTER BE A SQUARK?

i.e., CAN SQUARKS HAVE SMALL COUPLINGS TO QUARKS?

R-odd $\Delta B = 1$



∴ GOODBYE LSP, BUT HELLO

$\Delta B = 2$, R-EVEN

→ NEUTRON-ANTINEUTRON OSCILLATIONS, BUT NO PROTON DECAY.

AND SOMEWHAT LESS SPECULATIVELY:

A QUARK MODEL of SOFT CP VIOLATION

WORK w/ P.F. FRAMPTON + T. YOSHIKAWA

BACKGROUND

THE STRONG CP PROBLEM

- IN the SM, YUKAWA couplings of HIGGS ARE COMPLEX.
- THERE ARE 2 CP VIOLATING PARAMETERS $\bar{\theta}$ AND δ
- BOTH SHOULD BE COMPARABLE, YET $|\bar{\theta}| < 1.5 \times 10^{-10}$, $|\delta| \sim 1$
- SOLUTIONS:
  - MASSLESS UP QUARK, BUT...
  - INVISIBLE AXIONS, BUT...
  - SUPERSYMMETRY (SCHMALTZ VIA HOLOGRAM)
  - SPONTANEOUS CP VIOLATION, BUT...
  - SOFT CP VIOLATION

MANY EARLIER SUGGESTIONS FOUNDERED.

THE GIST OF SOFT CP VIOLATION

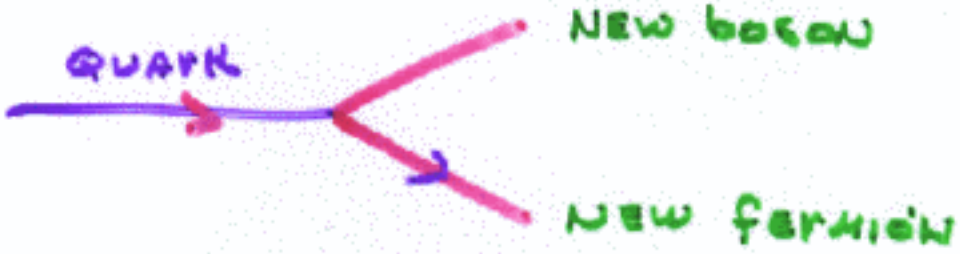
1. CP CONSERVED AT dim 4

⇒ REAL K.M. MATRIX IN TREE.

⇒ NO CHERN-SIMONS TERM Θ

⇒ $\bar{\Theta}$ = 0 IN TREE

2. ADJOIN NEW HEAVY FERMIONS AND BOSONS, SO

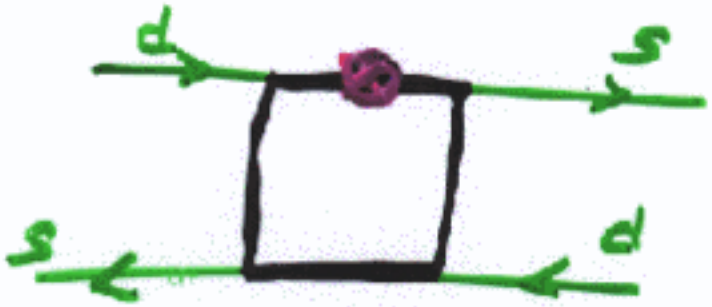


3. CP-VIOLATION HIDDEN IN DIM-2 or 3 MASS TERMS of NEW HEAVY SECTOR

χ_c^+ M_{ij} χ_j $\qquad M \neq M^*$

{AS DISCUSSED, for example in Georgi+Glashow PL B451, 372 (1999)}

So where does the observed CP violation come from?



$= \epsilon_K$

So long as $\frac{\alpha_s}{M} \lesssim 2 \times 10^{-3} / \text{GeV}$

So what about $\bar{\theta}$? Radiative corrections do yield a finite and calculable $\arg \det M$. GG display a class of models for which:

$$\alpha_s < 0.03 \Rightarrow |\bar{\theta}| < 10^{-10}$$

i.e. No strong CP problem.

WHAT ABOUT δ OR $\sin 2\beta$?

YES, THE KM MATRIX DEVELOPS AN IMAGINARY PART, BUT IT IS SMALL

$$\frac{\text{AREA of UNITARITY } \Delta}{\text{STD. VALUE}} \approx \frac{\eta_f}{4\pi}$$

So Soft CP VIOLATION GENERALLY PREDICTS

$$\sin 2\beta \cong 0$$

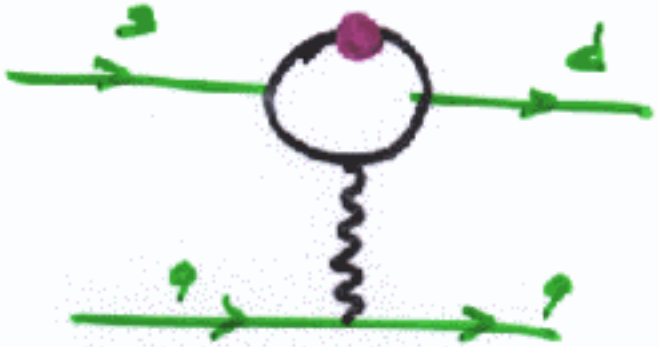
BUT DAVE HITLIN (SLAC SEMINAR 2/01) CLAIMS

$$\sin 2\beta = 0.49 \pm 0.16$$

from AVERAGING All DATA.

WE SHALL SEE !

WHAT ABOUT ε ?



THIS IS THE DOMINANT SOURCE OF DIRECT CP VIOLATION IN KAON SECTOR

$$\frac{\alpha_s}{4\pi}\,\frac{\alpha_F}{M^2}$$

AND IT'S JUST TOO SMALL TO FIT OBSERVATION.

THESE THEORIES ARE SUPERWEAK MIMICS AND CANNOT GIVE

$$\varepsilon'/\varepsilon = 2\times 10^{-3}$$

BUT QUARKS DO BETTER!

Our Doubles:

- Spinless Mesons, Quark #2
- Color Antitriplets
- Weak Isospin Singlets

(i)
- Coupled to Left-handed Quarks and Not to R.H. Quarks
- $Q = 1/3$

(ii)
- Symmetric flavor couplings

(i) Two Higgs Model H^u H^d

$\mathcal{D}$: $H^u \to -H^u$ $u_R \to -u_R$

Down quarks even, along w. everything else.

(ii) Flavor matrix democratic, with all entries comparable

f = coupling goes to $u_{NL}\, d_{ML}$

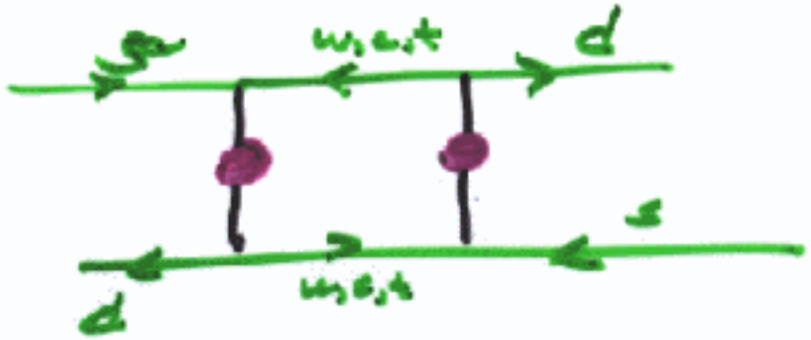
- CP Violation at dim 2

$$\phi^{(a)\dagger} M^2_{(ab)} \phi^{(b)}$$

$$M \neq M^*$$

THE KAON SECTOR

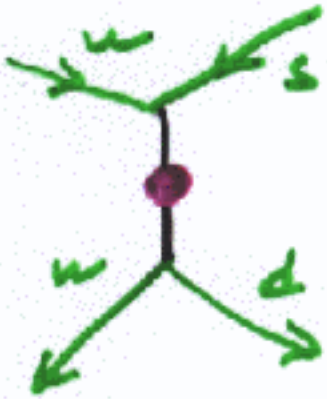
$\Delta M_K \in =$



$\Rightarrow \frac{\alpha_f}{M} \approx 10^{-8}\ \text{GeV}^{-1}$

AS BEFORE

ϵ' ARISES FROM



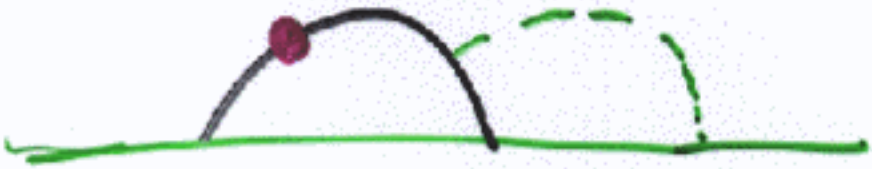
$\Rightarrow \frac{\alpha_f}{M^2} \approx 10^{-10}\ \text{GeV}^{-2}$

$M_N \sim 200\ \text{GeV}$, $\alpha_f \sim 4 \times 10^{-6}$

Cont. to ANOMALY VANISHES IN 2 LIMITS : QUARK MASS → 0 and K.M. = 1.

$$\Rightarrow \Delta\bar{\theta} \simeq \frac{\alpha_s \lambda^2}{(4\pi)^3} \left\{ \frac{m_t^2 m_b^2}{M^2 \langle H^u \rangle^2} \text{ or, } \frac{m_b^2}{\langle H^d \rangle^2} \right\}$$

$$\sim 10^{-12}$$



$$\Rightarrow \Delta\bar{\theta} \simeq \left(\frac{\alpha_s}{4\pi}\right)^2 \sim 10^{-13}$$

NO STRONG CP PROBLEM

PREDICTIONS!

1. FLAT UNITARITY △

2. QUARKS AT A few HUNDRED GEV

* EASILY FALSIFIABLE !

3. POSSIBLE ANOMALY IN $K^+ \to \pi^+ \nu\bar{\nu}$

* UNLIKE CERTAIN other THEORIES.