Nearly conformal electroweak sector
with chiral fermions

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in collaboration with

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Outline and motivation

- BSM Higgs sector
  - Heavy Higgs?
  - Strongly interacting EW symmetry breaking?

- Technicolor idea
  - Walking - nearly conformal
  - Conformal

- Phase diagram of gauge theories \((N_c, N_f, R)\)
  - QCD
  - SUSY YM
  - Other representations?

- Unparticles - conformal hidden sector
Phase diagram \((N_c, N_f, \mathcal{R})\)

- **QCD-like**
  - \(g^* = 0\)
  - UV fixed-point

- **Conformal window**
  - \(g^* > 0\)
  - IR fixed-point
  - \(g^*(N_f) > g^*(N_f)\)

- **Trivial theory**
  - \(g^* = 0\)

\((\mathcal{N} = 1\) YM is a special case)
Phase diagram $(N_c, N_f, R)$ in perturbation theory

Fundamental: gray
(Pallante, Neil, Jin, Deuzeman today, Holland Friday 3:50, Fleming Saturday 9:15)

2 antisym: blue
2 sym: red
adjoint: green

(Sannino)
Technicolor paradigm

Need to know $N_f(\chi)$ for fixed $N_c, R$

A constraint from phenomenology: S-parameter $\sim \text{dim}(R)N_f$ should be small

$SU(3)$ fundamental representation is ruled out

(JLQCD: non-perturbative $\sim$ perturbative)

$SU(3)$ 2S representation produces right number of Goldstones from symmetry breaking

$$
N_f(BZ) = 1.2 \quad \quad N_f(\chi) = 2.5 \quad \quad N_f(AS) = 3.3
$$

$N_f = 2$ just below conformal window - could be walking

If really in conformal window: good for conformal technicolor

(Luty)
Our model

\[ SU(3) \quad N_f = 2 \quad R = 2S \]

Simplest model with small S-parameter, 3 Goldstone-bosons (get eaten by W, Z), EW symmetry breaking works out

Chiral symmetry is important: use dynamical overlap fermions

Previous study: wilson fermions + Schrodinger functional: maybe conformal

Svetitsky ( Friday 2:30 ) DeGrand ( Friday 2:50 )
Problems everyone in this business has to deal with

Small bare coupling (small volume): always free

Large bare coupling: always $\chi_{SB}$

Staggered: taste breaking, effective $N_f < \text{naive } N_f$

Wilson: explicit $\chi_{SB}$

Overlap: strong coupling phase diagram complicated, little is known very expensive

Most important question: how to distinguish $\chi_{SB}$ from conformal?
$\chi_{SB}$ vs. conformal

Possible methods

- $\beta$-function from Schrodinger functional (Appelquist et al.)

- Locating finite $T$ transition (Pallante et al.)

- $\epsilon$-regime $\rho(\lambda)$ characteristics (Fodor/Holland/Kuti/DN/Schroeder)
If $\chi_{SB}$ and $1/f_\pi < L < 1/m_\pi$  

**Can use chiral Lagrangian without kinetic term**

Detailed prediction for microscopic Dirac spectral density $\zeta = \lambda \Sigma V$ and eigenvalue distributions in each $Q$ topological sector, calculable with RMT

$$
\rho_S(\zeta) = \frac{1}{\Sigma V} \rho \left( \frac{\zeta}{\Sigma V} \right) = \sum_{k=0}^{\infty} p_k(\zeta)
$$

For macroscopic $\rho(\lambda)$: Banks-Casher: $\rho(0) = V \Sigma / \pi$
$\varepsilon$-regime and Dirac spectrum

In conformal case: no $\varepsilon$-regime or microscopic spectral density

$$\rho(\lambda) \sim \lambda^{3+\gamma}$$

$\gamma$ anomalous dimension of $\bar{\psi}\psi$

Unfortunately $p_k(\lambda)$ not known, in principle calculable (work in progress)

Effect of finite $m$ and finite $V$ also not known (work in progress)
ε-regime and Dirac spectrum

Strategy: simulate in real or would-be ε-regime and see if $\rho_S(\zeta)$ and/or $\rho(\lambda)$ is or is not consistent with RMT and/or conformal predictions

Algorithms for dynamical overlap

- Hungarian (reflection/refraction)
- Japanese (topology conserving with extra wilson fermion)

We need fix $Q$, Japanese algorithm cheaper: use that for initial study
Preliminary results, $6^4$ volume, $m = 0.05$, $O(100)$ configurations

What $\beta$? Nothing so far in literature, need to start from scratch.

Scan strong coupling $\sim 4.5 < \beta < 5.5 \sim$ free

For RMT one needs $m < \lambda_1$ to see dynamical fermions
Macroscopic spectral density

\[ \beta = 4.85 \]

\[ \beta = 4.975 \]

\[ \beta = 5.10 \]
Microscopic spectral density

\[ \Sigma(4.850) = 0.083(4) \]
\[ \Sigma(4.975) = 0.084(4) \]
\[ \Sigma(5.100) = 0.080(4) \]
Microscopic spectral density from RMT

$\beta = 4.85$

$\beta = 4.975$

$\beta = 5.10$
All our results are preliminary

2S representation seems not consistent with $\chi_{SB}$

Reason can be too small volume, not really $\varepsilon$-regime

Caution! Have not measured any quantity $f_\pi, m_\pi, \ldots$

Conformal? More work needed!
Conclusion

First dynamical overlap simulation of 2S repr of SU(3)

If below conformal window: can predict narrow heavy Higgs particle without free parameters consistent with EW precision (S-parameter)

Measuring $\beta$-function will help, $\gamma(g)$. 