The Sextet Model
An overview of the phase structure with Wilson fermions

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Motivation

- Minimal Walking Technicolor model
  - SU(3) with two flavors of two-index symmetric fermions
- Near the conformal window
- Possible walking behavior
- Might have a light scalar
  - This would be the Higgs particle
- Small $S$ parameter

Dietrich, Sannino 2006
Old phase diagram

- Bulk phase identified from peak in plaquette susceptibility
- Chiral line identified from PCAC relation

Wilson fermions
+ Plaquette gauge
New simulations

- Large number of new simulations (around 150)
New phase diagram

- Phase diagram with 4 regions of interest

Region I, II, III
\[ \frac{d m_q}{d m_0} > 0 \]

Region IV
\[ \frac{d m_q}{d m_0} < 0 \]
1st order transition
Hysteresis

$\beta = 4.00$

Diagram showing a plot with $m_0$ on the x-axis and $\langle P \rangle$ on the y-axis. The plot includes two lines, one for Random and one for Unit.
Hysteresis

\[ \beta = 4.40 \]
Hysteresis

\[ \beta = 4.60 \]
Hysteresis

\[ \beta = 4.80 \]
Hysteresis

\[ \beta = 5.00 \]
Hysteresis

\[ \beta = 5.10 \]

\[ \langle P \rangle \]
Hysteresis

\[ \beta = 5.20 \]
Hysteresis

\[ \beta = 5.30 \]
Spectrum

- Spectrum across transition at $\beta = 4.8$
● Spectrum across transition at $\beta = 5.5$
Spectrum

- Spectrum across transition at $\beta = 6.0$
Region I $\rightarrow$ II
Ratio

- Ratio between $M_V$ and $M_{PS}$ for $\beta = \{3.0, 4.0, 4.6, 4.8, 5.0\}$
- This is in the strong coupling phase (Region I)
Ratio

- Ratio between $M_V$ and $M_{PS}$ for $\beta = \{5.1, 5.2, 5.3\}$
- This is in the weak coupling region (Region II)
Gradient flow

- Use gradient flow to measure change in lattice spacing

\[ E(t) = \langle t^2 E(t) \rangle \]

\[ W(t) = t \frac{dE(t)}{dt} \]

\[ E(t_0) = E_{\text{ref}} \]

\[ W(w_0^2) = W_{\text{ref}} \]

Lüscher 2010
BMW Collaboration 2012
Gradient flow

- Chiral limit with $t_0$ observable.
Gradient flow

- Chiral limit with $w_0$ observable.

$$w_0^2 \sim \frac{1}{m^2_{\pi}}$$
Large Volume Runs
Meson and baryon spectrum for $\beta = 5.4$
Meson and baryon spectrum for $\beta = 5.5$
Ratio

- Ratio between $M_V$ and $M_{PS}$ for $\beta = \{5.4, 5.5\}$
Chiral behavior

- Conformal fits

\[ M_x = A_x m^{\frac{1}{1+\gamma}} + \tilde{A}_x m^{\frac{1}{1+\alpha_x}} \]
\[ F_x = B_x m^{\frac{1}{1+\gamma}} + \tilde{B}_x m^{\frac{1}{1+\beta_x}} \]

- Chiral fits

\[ M_\pi^2 = M^2 + \frac{M^4}{F^2} (a_M L + b_M) + \cdots \]
\[ F_\pi = F + \frac{M^2}{F} (a_F L + b_F) + \cdots \]

- Leading order pion mass and log term

\[ M^2 = 2Bm, \quad L = \frac{1}{16\pi^2} \log \left( \frac{M^2}{\mu^2} \right) \]
Conformal fits

- Combined fit to 6 channels for $\beta = 5.4$

$\chi^2$/dof = $\{7.04, 2.62\}$
Chiral fits

- Combined fit to $f_{PS}$ and $m_{PS}$ for $\beta = 5.4$  \[ \chi^2/dof = \{7.85, 1.01\} \]
Conclusions

- The phase structure is non-trivial
- Different behavior in different regions of the parameter space
- The model looks conformal in the weak coupling phase

Things to consider includes:
- Open boundary conditions
- Finite volume effects