Gauge theories with fermions in two-index representations

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with

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Outline

- Near-conformal theories are not QCD!

- Beta functions: methodology and results

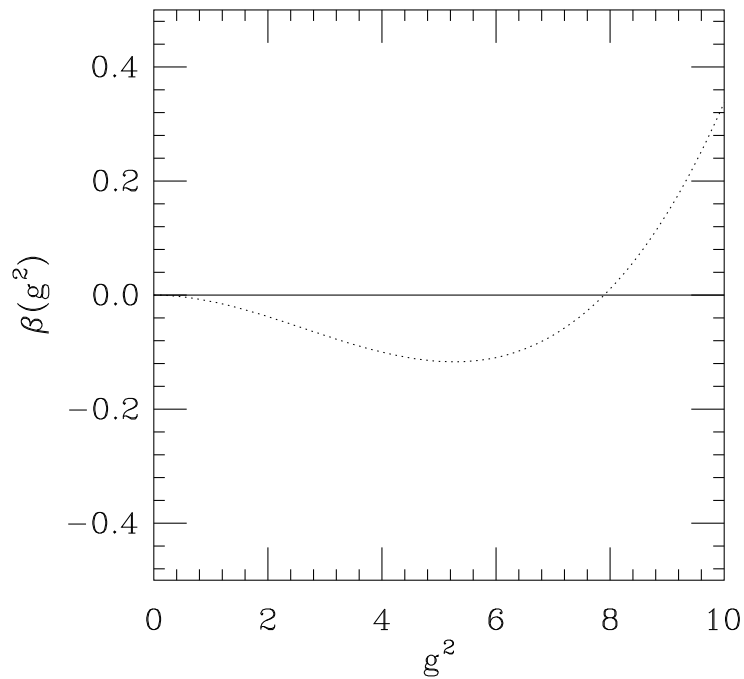- Mass anomalous dimension: results

in this talk

- SU(4) with $N_f = 6$ Dirac fermions in 2-index antisymmetric rep

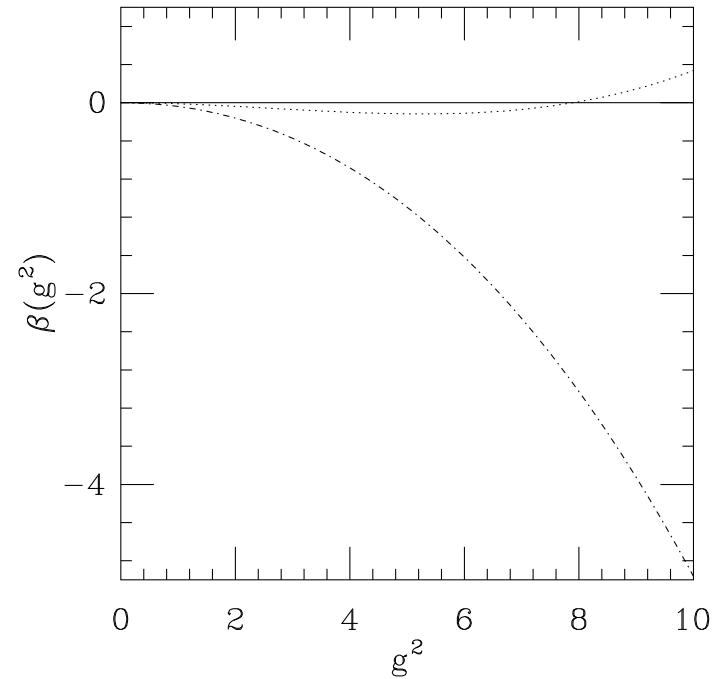- SU(3) with $N_f = 2$ Dirac fermions in adjoint rep

Both theories lie near the bottom of the respective conformal window as predicted by the two-loop beta function

Near-conformal theories are not QCD!

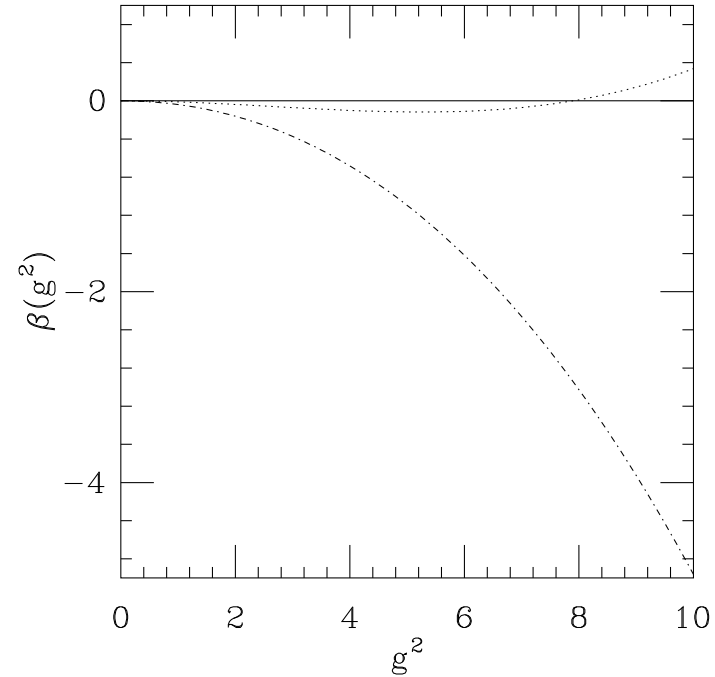Two-loop beta function $\beta(g^2) = -b_1\, g^4 - b_2\, g^6$ for 2-flavor SU(2) with
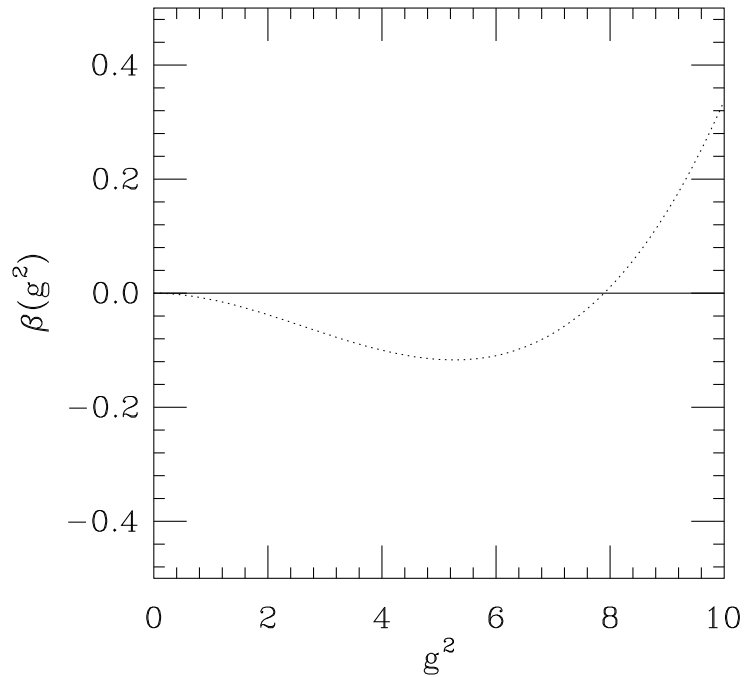

adjoint: $b_1 > 0,\ b_2 < 0$

fundamental: $b_1, b_2 > 0$

Near-conformal theories are not QCD!

- **QCD:** Perturbation theory valid at lattice scale, while volume big enough to accommodate even the lightest of the hadrons

- **Slow running:** Whether the IR physics is conformal of confining, must have strong bare coupling to probe it

⇒ Need different set of analysis tools

Lattice simulations

- Wilson-clover fermions with nHYP smearing

- Tune to $\kappa_c(\beta)$ using unimproved axial WI

- Schrödinger functional boundary conditions

- Mass anomalous dimension from pseudoscalar renormalization constant Z_P on the same lattices

- Work at strong bare coupling $\Rightarrow$ short trajectories, low acceptance

- Long auto-correlations; demand consistency between 4 streams

- Volumes L^4, where $L = 6, 8, 10, 12, 16$

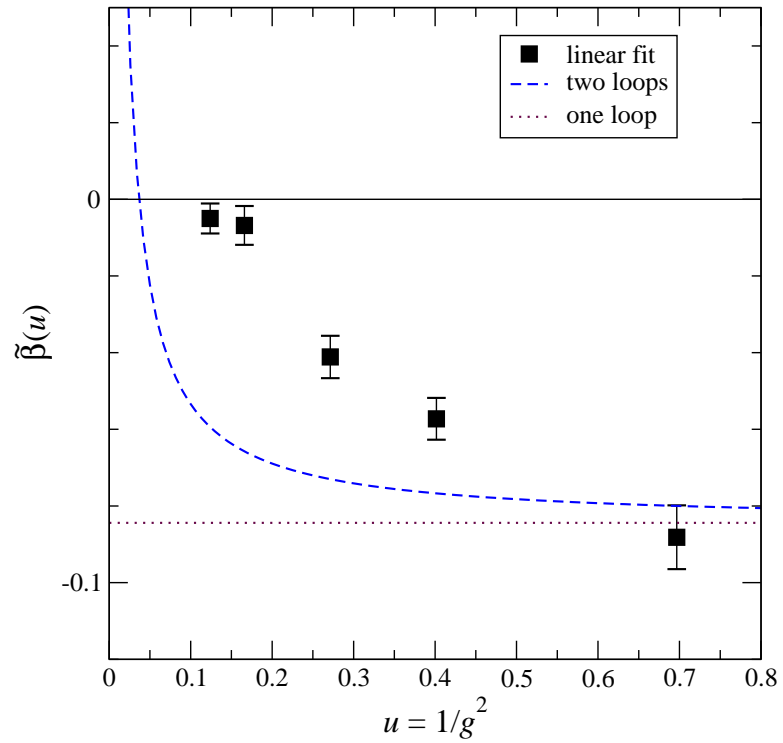# First look* at beta function: SU(4) with 6 as
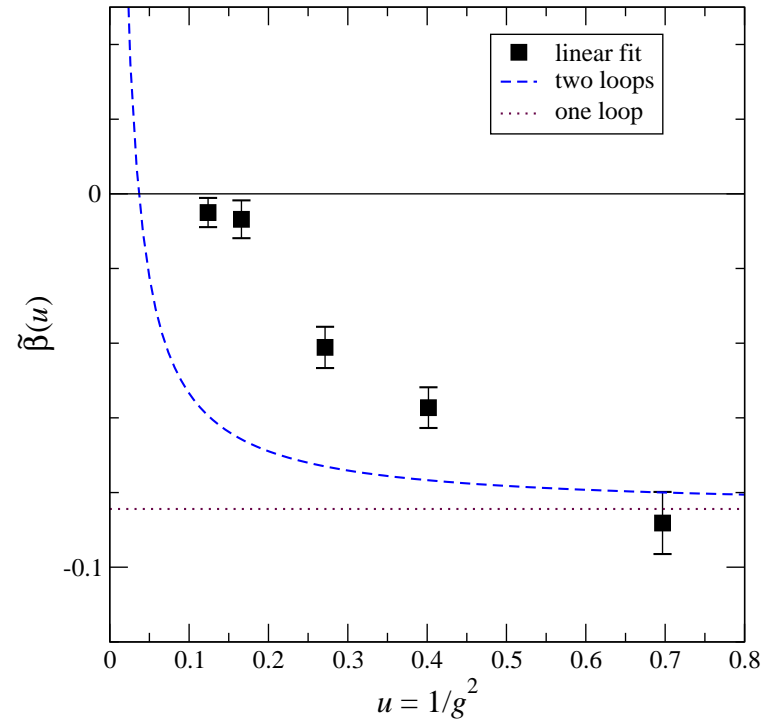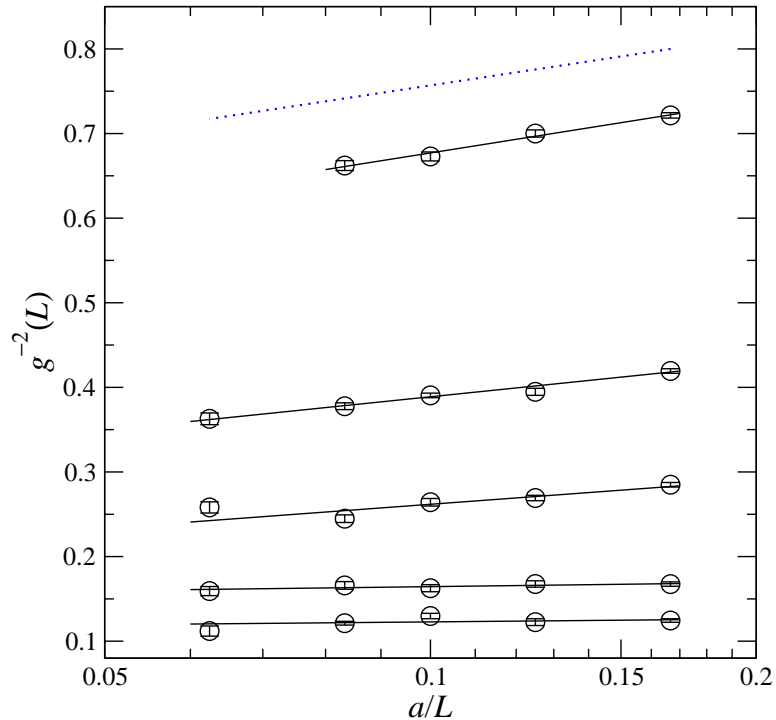
Top to bottom:
$\beta = 10.0,\ 8.0,\ 7.0,\ 6.0,\ 5.5$

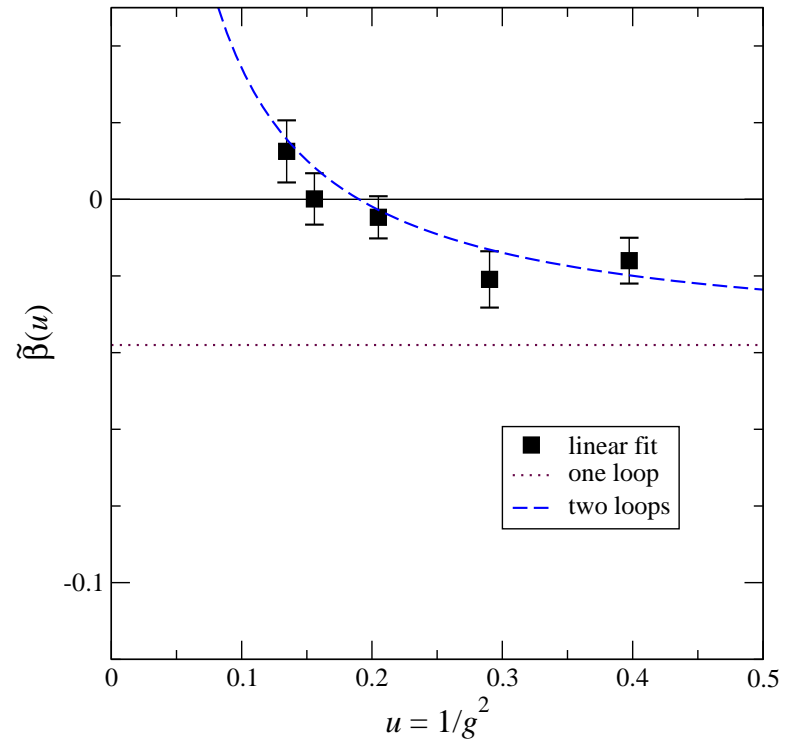* ignoring discretization error

$$\frac{1}{g^2(L)} = c_0 + \tilde{\beta} \log \frac{L}{8a}$$

$$\tilde{\beta}(1/g^2) = \frac{\partial(1/g^2)}{\log L} = 2\beta(g^2)/g^4$$
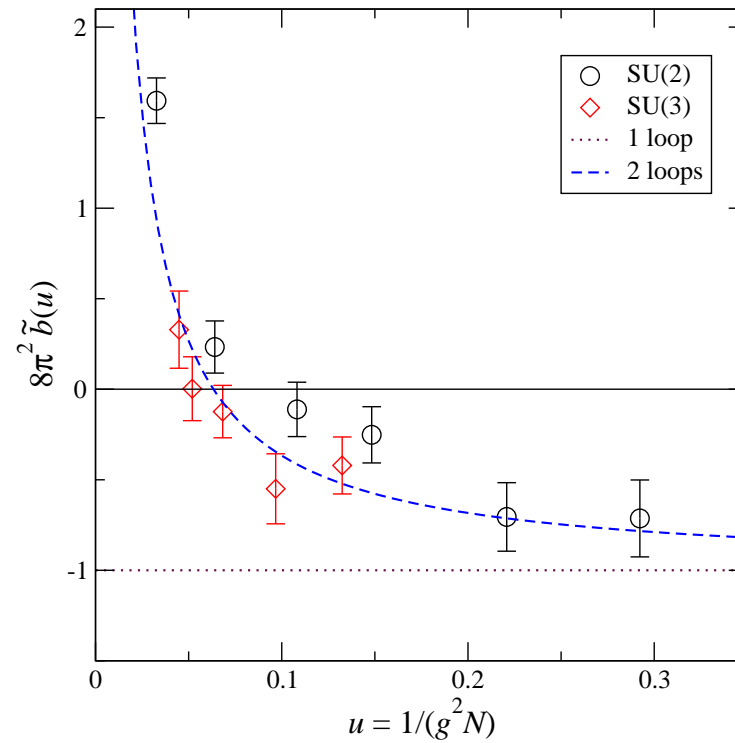
First look at beta functions

SU(4) with 6 as

SU(3) with 2 adj

N_c scaling: two Dirac fermions in adjoint rep

- Two-loop beta function depends only on $1/(g^2 N_c)$

- SU2 and SU3 fall on the same curve

Continuum extrapolation

- Work at strong bare coupling $\Rightarrow$ perturbation theory can't guide us!

- (near) conformality: results depend on a/L

- successive fits $(L_1 < L_2 < L_3 < \cdots)$:

$$
\begin{aligned}
1/g^2(L) &= c_0^{(1)} + c_1^{(1)} \log(L/8a), & L/a = 6, 8, 10, 12, 16, & \qquad a/L_1 = 1/6 \\
1/g^2(L) &= c_0^{(2)} + c_1^{(2)} \log(L/8a), & L/a = 8, 10, 12, 16, & \qquad a/L_2 = 1/8
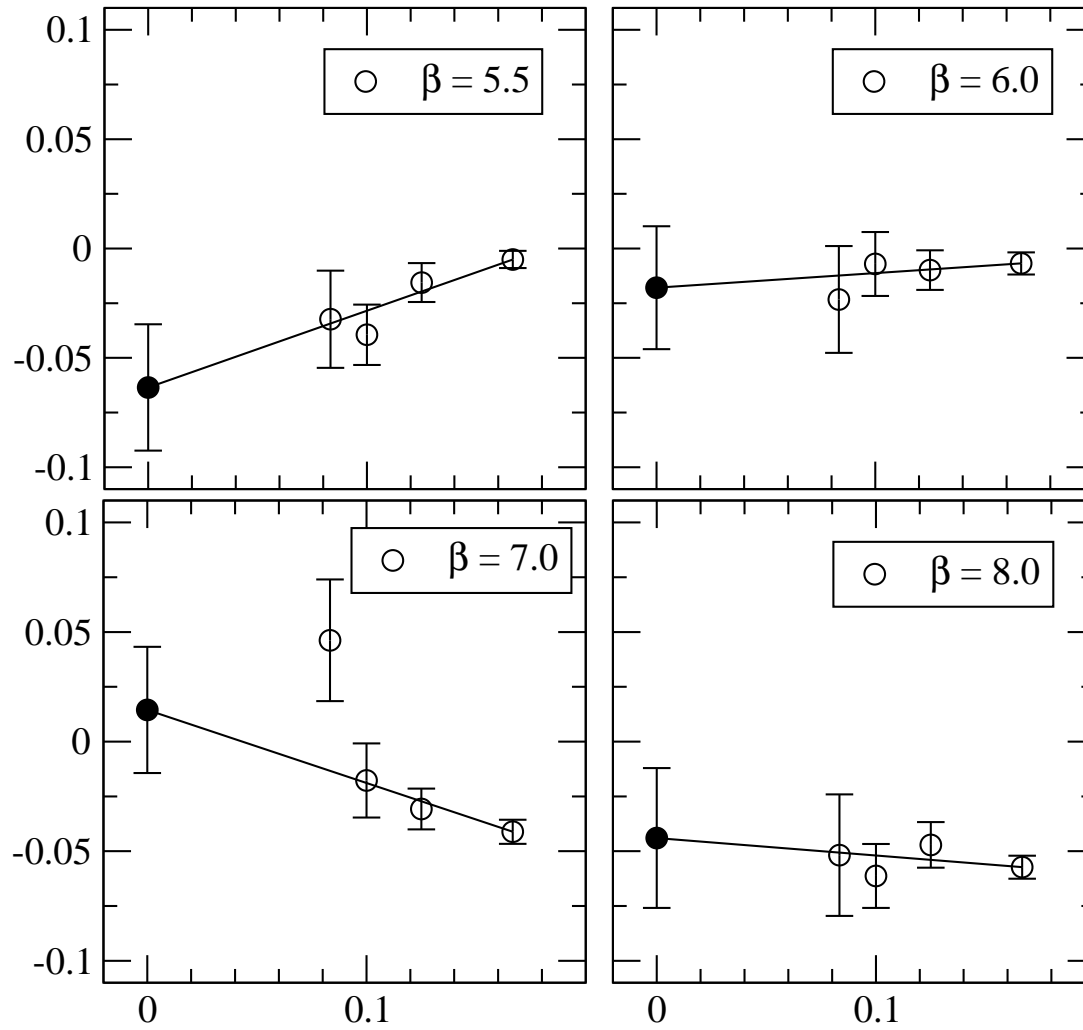\end{aligned}
$$

....

- continuum extrapolations – different models:

linear: $c_1^{(n)} = \tilde{\beta} + C \, a/L_n$

quad: $c_1^{(n)} = \tilde{\beta} + C(a/L_n)^2$
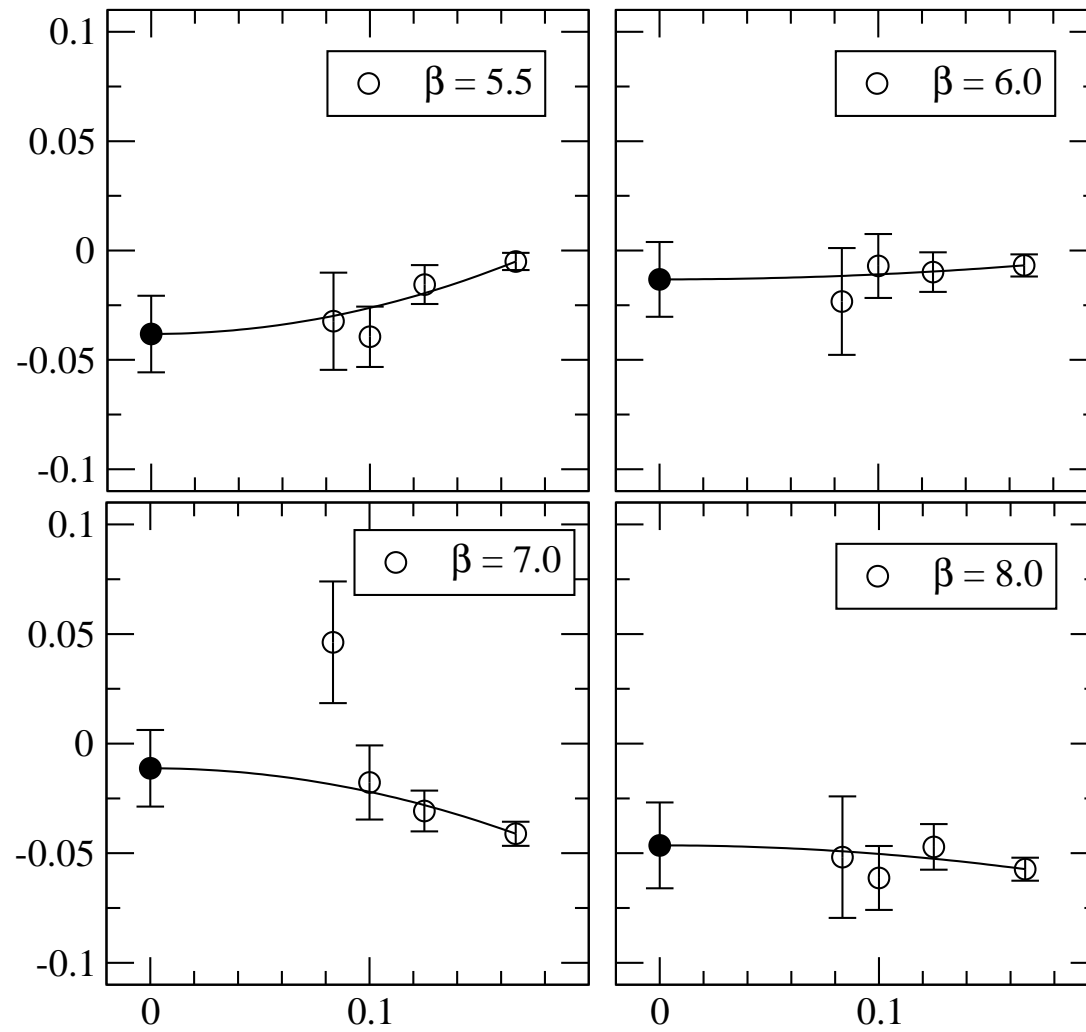
$\tilde{\beta} = $ estimate for beta function

- Correlations: for $n \leq m$, $cov(c_1^{(n)}, c_1^{(m)})$ is the variance $\sigma^2(c_1^{(n)})$
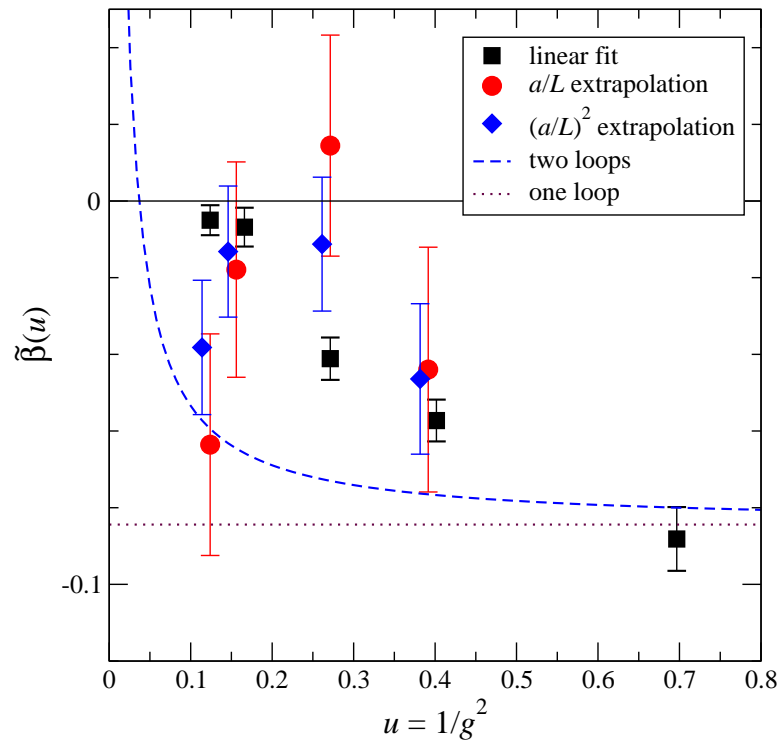
SU(4) beta function – linear extrapolation

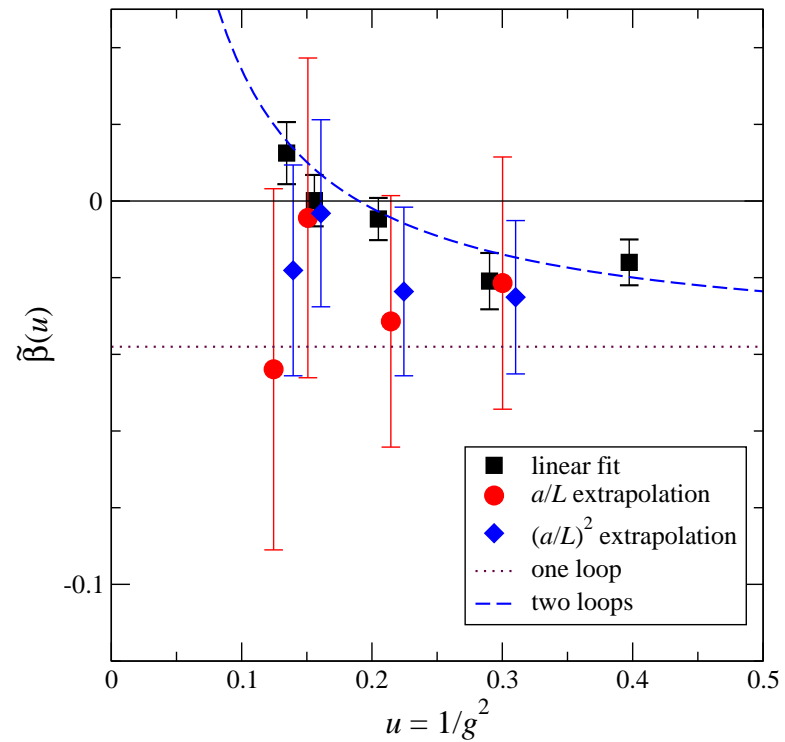# SU(4) beta function – quadratic extrapolation

Beta functions – continuum extrapolations
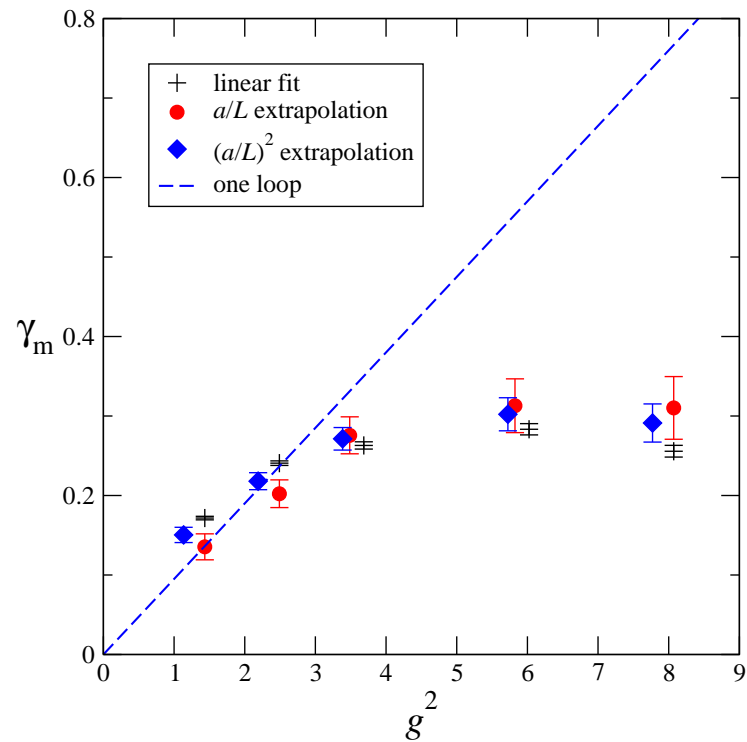

SU(4) with 6 as

hint of walking?
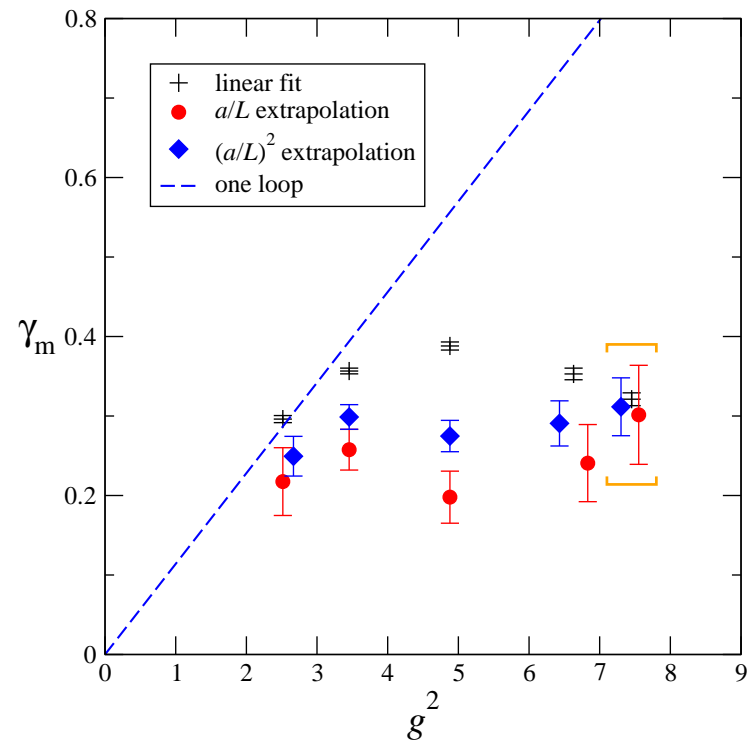
SU(3) with 2 adj

Mass anomalous dimensions

Basic fit: $\log Z_P = c_0 + \gamma \log(8a/L)$

followed by continuum extrapolation as before

SU(4) with 6 as

SU(3) with 2 adj

Summary

- Long-term project of studying marginally-conformal theories with fermions in two-index representations:

SU(2) with 2 adj $= 2$ sym
SU(3) with 2 sym
SU(3) with 2 adj   this talk
SU(4) with 2 sym
SU(4) with 6 antisym   this talk

- Mass anomalous dimensions:
  - Grow perturbatively, then level off
  - All plateaus satisfy $\gamma < 0.5$

- Beta functions:
  - In all cases studied, beta functions "touch" zero
  - Strong evidence for IRFP in SU(2) with 2 sym
  - Inconclusive for the other theories

- Nice N_c scaling

N_c scaling: two Dirac fermions in symmetric rep