Conformal vs confining scenario in SU(2) with adjoint fermions. Gluonic observables

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Phys. Rev. D **80**, 074507 (2009), arXiv:0907.3896
arXiv:1004.3206
arXiv:1004.3197

Lattice, Villasimius, 15 June 2010

Outline

Some simulation details

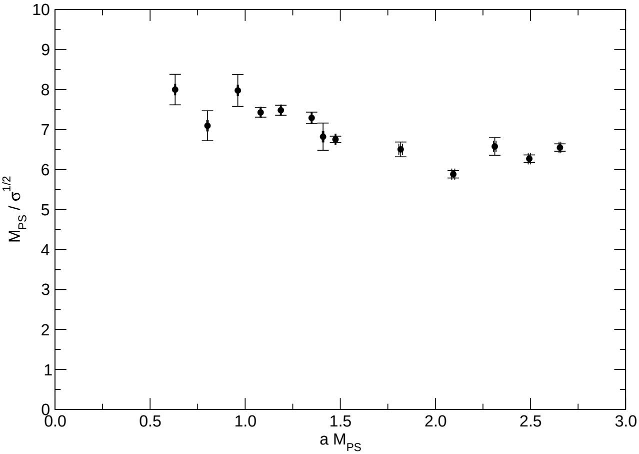
- SU(2) 1x1 plaquette action in the fundamental representation
  + 2 Wilson fermions in the adjoint representation
- RHMC algorithm implemented in HiRep code
  (for generic number of colors, and generic representation of the fermions)
  L. Del Debbio, AP and C. Pica, PhysRevD81:094503 (2010)
- fixed lattice spacing: $\beta = 2.25$
  4 volumes: $16\text{x}8^3$, $24\text{x}12^3$, $32\text{x}16^3$, $64\text{x}24^3$
  list of masses: $0.25, 0, -0.25, -0.5, -0.75, -0.9, -0.95, -0.975, -1, -1.025, -1.05,$ $-1.075, -1.1, -1.125, -1.15$, $-1.175, -1.18, -1.185, -1.19$
  $\mathcal{O}(5000)$ configurations
- measured observables:
  - quark mass from axial Ward identity (PCAC mass)
  - isotriplet PS and V meson masses and decay constants
  - distribution of temporal and spatial Polyakov loops
  - 0^{++} and 2^{++} glueball masses
  - fundamental string tension

Outline

1. Introduction
2. **Results**
3. Technicalities
4. Conclusions

Signals for conformality

PS mass over $\sigma^{1/2}$ ratio



Large mass:

$$M_{PS} \simeq 2M_q$$

$$\sigma \simeq \sigma_{YM}$$

Small mass, χSB:

$$M_{PS}^2 \simeq -\frac{\langle\bar{\psi}\psi\rangle}{F_{PS}^2} m_q$$

$$\sigma \neq 0$$

Small mass, IR-conf:

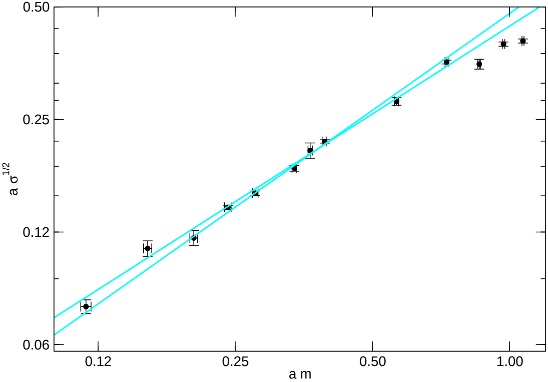
$$M_{PS} \propto m_q^{\frac{1}{1+\gamma}}$$

$$\sigma^{1/2} \propto m_q^{\frac{1}{1+\gamma}}$$

$$M_{PS} \simeq 8\sigma^{1/2}$$

Signals for conformality

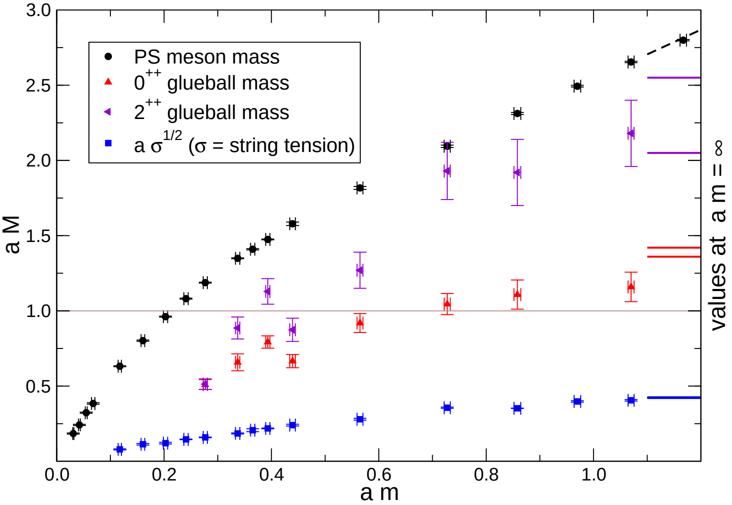
Scaling of the string tension



$$a\sigma^{1/2} = A_\sigma (am_q)^{\frac{1}{1+\gamma}}$$

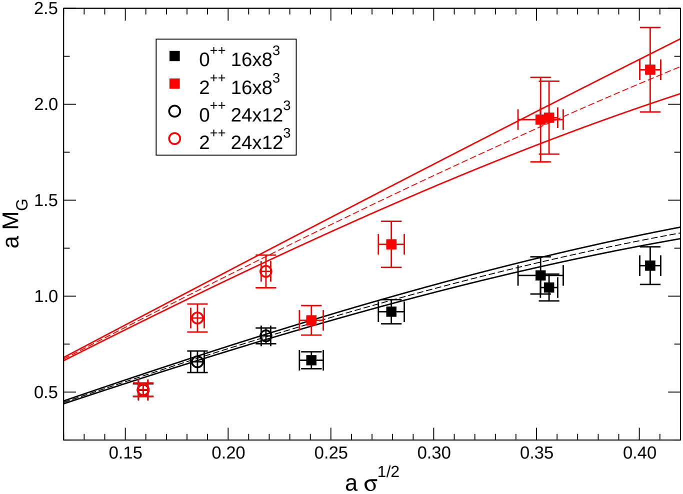
$$\gamma \simeq 0.19 \ \ldots \ 0.30$$

Spectrum hierarchy



IR dynamics

Comparison with pure YM



IR dynamics

Interpretation

The physics below the fermion mass is effectively described by:

$$\mathcal{L}_{\mathit{eff}} = -\frac{1}{2g_{\mathit{eff}}^2} \mathrm{tr}\, F_{\mu\nu}F^{\mu\nu} + \sum_i \frac{a_i}{M_q^2} \mathcal{O}_i^{(6)}$$

which is a pure Yang-Mills with a energy-scale $\sigma^{1/2}$ and corrections of order σ/M_q^2.

This is true both in the large-mass and chiral regimes ($M_{PS}/\sigma^{1/2} \simeq 8$).
Again, in the two regimes the string tension has a very different behaviour as a function of the mass.

- In the large-mass regime, σ does not depend on the fermion mass.
- In the chiral/scaling region, σ slides with the fermionic mass to zero:

$$\sigma^{1/2} \propto M_q \propto m_q^{\frac{1}{1+\gamma}}$$

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String tension

Temporal string tension.

$$\langle \sum_{y,z} P^\dagger(0,y,z) \sum_{y,z} P(X,y,z) \rangle = \sum_n |c(T)|^2 e^{-XE_n(T)}$$

The ground state is extracted using a variational method over a set of fuzzy operators. (*B. Lucini, M. Teper, U. Wenger, JHEP0406:012 (2004)*).

$$E_0(T) = \sigma T \sqrt{1 - \frac{2\pi}{3\sigma T^2}} \simeq \sigma T - \frac{\pi}{3T} - \frac{\pi^2}{18\sigma T^3} + \dots$$

The string tension is extracted assuming the Nambu-Goto action. No difference is found if we use the truncated formula that includes only the universal terms (*O. Aharony, E. Karzbrun, JHEP0906:012 (2009)*).

Spatial string tension.
As above, using Polyakov loops wrapping around a spatial direction and separated along the temporal direction.

Static potential

$$\langle W(T,R)\rangle = \sum_n |a_n(R)|^2 e^{-TV_n(R)}$$

HYP smeared Wilson loops (*A. Hasenfratz, F. Knechtli, PhysRevD64:034504 (2001)*).

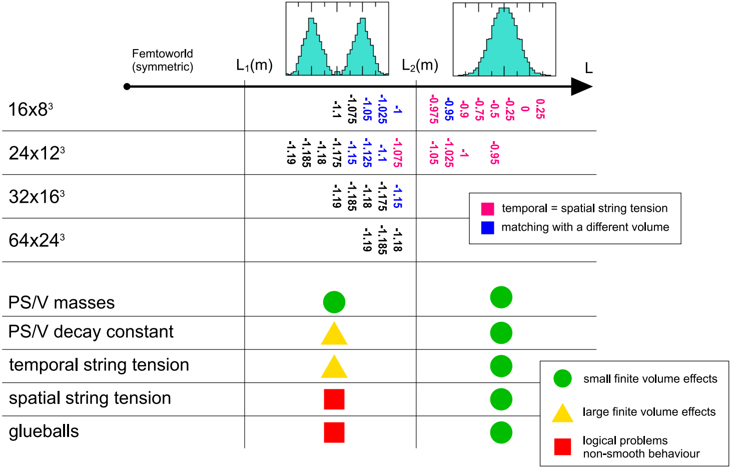
The ground state is extracted by adapting the Prony's method for extracting masses from correlators (*G. T. Fleming, S. D. Cohen, H. W. Lin, V. Pereyra, PhysRevD80:074506 (2009)*).

At large distance the static potential gives the string tension:

$$V(R) \simeq \sigma R + \dots$$

The universal corrections are spoiled by the HYP smearing.

Polyakov loops and finite volume effects



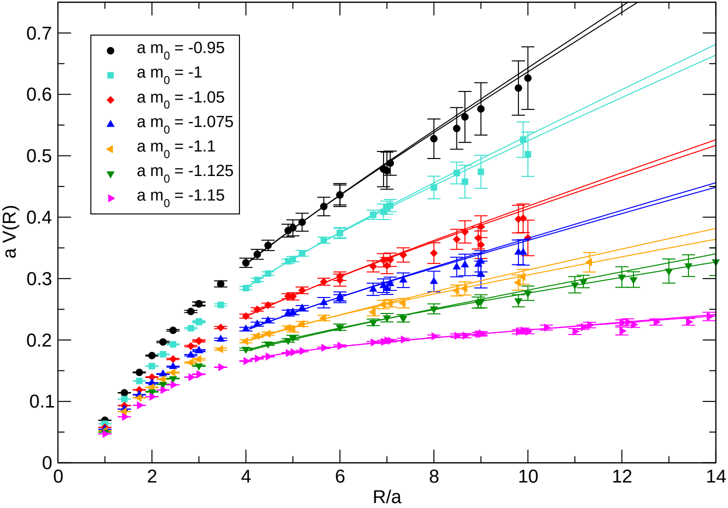
	Femtoworld (symmetric)	$L_1(m)$	$L_2(m)$
16×8^3		-1.1, -1.075, -1.05, -1.025, -1	-0.975, -0.95, -0.9, -0.75, -0.5, -0.25, 0, 0.25
24×12^3		-1.19, -1.185, -1.18, -1.175, -1.15, -1.125, -1.1, -1.075	-1.05, -1.025, -1, -0.95
32×16^3		-1.19, -1.185, -1.18, -1.175, -1.15	
64×24^3		-1.19, -1.185, -1.18	
PS/V masses		●	●
PS/V decay constant		▲	●
temporal string tension		▲	●
spatial string tension		■	●
glueballs		■	●

🟥 temporal = spatial string tension
🟦 matching with a different volume

● small finite volume effects
▲ large finite volume effects
■ logical problems
non-smooth behaviour

J. C. Myers, M. C. Ogilvie, NuclPhysA820:187C (2009). T. J. Hollowood, J. C. Myers, JHEP0911:008 (2009). G. Cossu, M. D'Elia, JHEP0907:048 (2009). T. Azeyanagi, M. Hanada, M. Unsal, R. Yacoby, arXiv:1006.0717.

String tensions and static potentials – results



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Conclusions

Hints for conformality:

- Plateaux at small masses in the M_V/M_{PS}, $M_{PS}/\sigma^{1/2}$.
- Power-law behaviour of the string tension.
- Finite size scaling of F_{PS} and $\sigma^{1/2}$.

This theory shows some qualitative features of the Banks-Zaks fixed point:
– What happens in other theories in the conformal window?

- The spectrum shows a well-defined hierarchy: the PS meson is heavier than the two lightest glueballs. In particular $M_{PS}/\sigma^{1/2} \simeq 8$.
- The IR spectrum is reproduced by the quenched theory (with renormalized parameters).
- The PS/V mass ratio is close to 1.
- The anomalous dimension of the mass is small ($\gamma \simeq 0.2$). Maybe not useful for phenomenology.

Outlook:

- Simulate at different β.
- Better determination of gluonic observables at the lowest masses (larger volumes).
- Finite temperature.
- More accurate finite size scaling.