Exploring the phases of $N_f = 8$ and 12 QCD on the lattice

Xiao-Yong Jin

RIKEN Advanced Institute for Computational Science

SCGT12Mini

with Robert Mawhinney (Columbia University)

- More details in:
 - My dissertation: http://academiccommons.columbia.edu/catalog/ac:137844
 - Lattice conference proceedings (2008-).

- Goal: Identify the phase (walking or conformal or ...)
 - Hadronic observables from zero temperature simulations, including meson propagators and masses, π decay constant, Quark potential and string tension...
 - Zero temperature and finite temperature
 - DBW2 gauge with naïve staggered fermion action

- Lattice theory represents the continuum theory only when correlation lengths diverge.
- Only then, the lattice system forgets about the underlying lattice.
- It only happens near some ultraviolet fixed points.
- $\beta \to \infty \ (g \to 0)$ for standard model QCD.
- No direct relation between the lattice input gauge coupling to the continuum gauge coupling.
- The behavior of a continuum theory is only realized in the limit of UV fixed point on the lattice.



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Zero temperature simulations



$\langle \bar{\psi}\psi angle$ in linear extrapolation



• Nonzero in the chiral limit with linear extrapolation.

Continuum ChiPT on the strongest couplings



Continuum next-to-leading order fits fine at strong coupling.

• $\langle \bar{\psi} \psi \rangle$ has a factor of 3/4 because of different normalization.



- Circles are $m_{\rho}^{m_q}$, boxes represents m_{a_1}
- No visible degeneracy exists between ρ and a_1 for both 8 and 12 flavors
- Finite volume effects are small
- Chiral symmetry is broken



• If we keep m_{π}/f_{π} fixed, m_q increases with β for both 8 and 12 flavors, if m_q is large.



• Need much smaller quark mass to see m_{π}/f_{π} going to zero with decreasing quark mass with 12 flavors.

Scaling of m_{π}/f_{π} versus quark mass



Consequences of a much larger change in lattice scale



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Finite temperature



Polyakov loop (Real and imaginary part)



Finite T, 8 flavors, $\beta = 0.54$ Strong coupling



 $\langle \bar{\psi} \psi \rangle$



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The bulk transition



8 flavors:

- Bulk transition appears (strengthens) when simple plaquette action is used instead of DBW2.
- 12 flavors:
 - ► Volume independent → finite temperature effect less likely.
 - Most of the mass gaps on the line of the bulk transition become smaller and vanish when quark mass is increased.
 - The scalar singlet is found to be special.

Scalar singlet meson



- Weaker the transition is, lighter the scalar singlet meson becomes.
- Critical exponent is consistent with Ginzburg-Landau theory.
- Continuum limit of the lattice theory at second order critical point is a free field scalar theory.



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