Strong coupling limit of lattice QCD with many staggered quarks

Seyong Kim

Sejong University

Ph. de Forcrand and W. Unger

based on JHEP1302 (2013) 051 + work in progress

Outline

1. Motivation
2. LQCD at $\beta = 0$
3. Conclusion

Conformal theory and LGT

- how can we see a interacting conformal theory on lattices (with moderate resources)?

- Ising model at criticality: power-law correlation functions

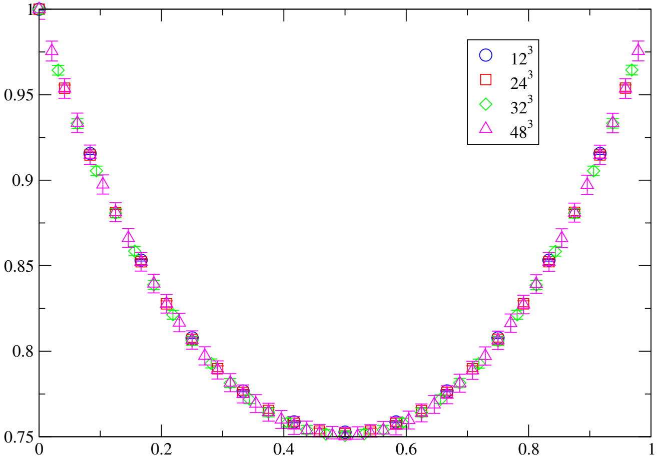
$$H = -K \sum_{\vec{x},i} \sigma(\vec{x})\sigma(\vec{x}+i) - h \sum_{\vec{x}} \sigma(\vec{x}) \quad (1)$$

$$\langle \sigma(0)\sigma(r) \rangle \sim \frac{1}{r^{d-2+\eta}} \quad (2)$$

- massless limit in finite lattice volume?

Conformal theory and LGT

- 3-dimensional Ising model at critical coupling ($K_c = 0.2216544$)



Strong coupling limit of LQCD ($\beta = 0$)

$$S = -\frac{N_f}{4}\mathrm{Tr}\log(\not{D} + m) + \beta \sum_{\mu \neq \nu} [1 - P_{\mu\nu}] \quad (1)$$

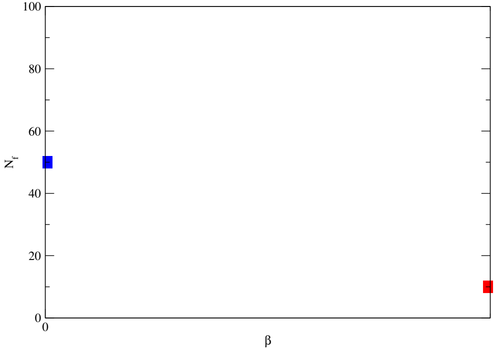
with $\beta = \frac{6}{g^2}$

- Hybrid Monte Carlo (HMC) or Rational Hybrid Monte Carlo (RHMC)

- staggered quarks (exact $U(1) \times U(1)$ chiral symmetry with $m = 0$)

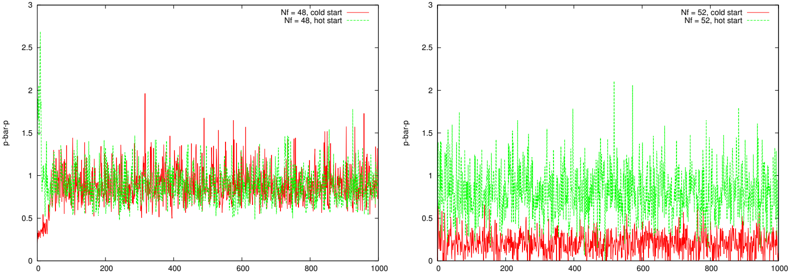
- analytic studies (e.g., A.S. Christensen et al, arXiv:1410.0541, E.T. Tomboulis, arXiv:1403.0664 and many earlier works)

Strong coupling limit of LQCD ($\beta = 0$)



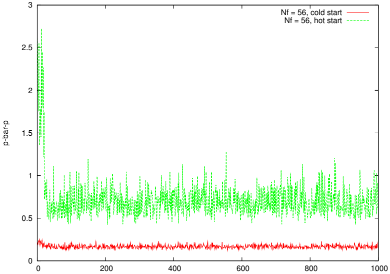
Strong coupling limit of LQCD ($\beta = 0$)

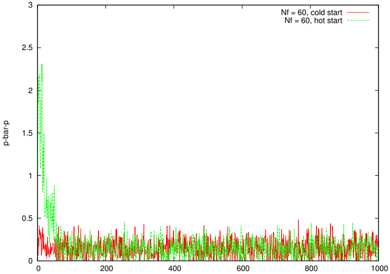
- monte carlo evolution of chiral condensate ($\hat{N}_f = 12, 13$)



Strong coupling limit of LQCD ($\beta = 0$)

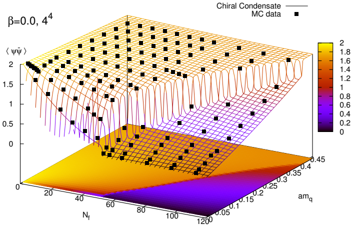
- monte carlo evolution of chiral condensate ($\hat{N}_f = 14, 15$)

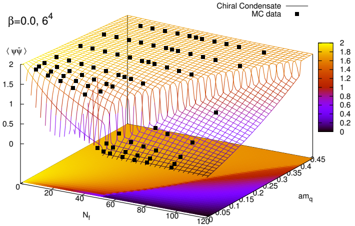




Strong coupling limit of LQCD ($\beta = 0$)

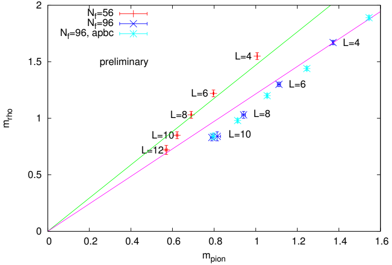
- chiral condensate at $\beta = 0$

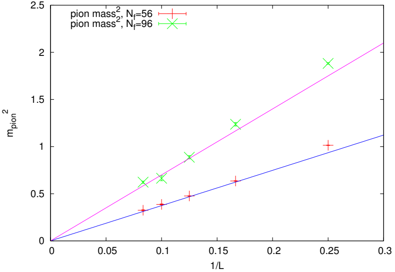




Strong coupling limit of LQCD ($\beta = 0$)

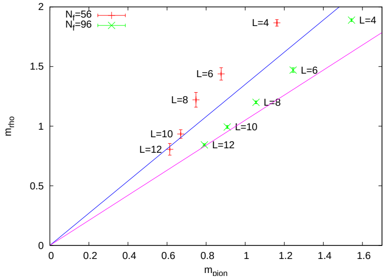
- hadron spectrum

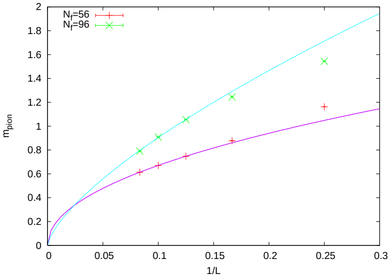




Strong coupling limit of LQCD ($\beta = 0$)

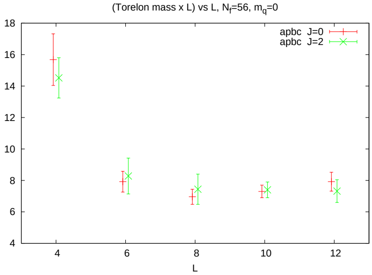
- hadron spectrum ($1/L^{1/(1+\gamma^*)}, \gamma^* \sim 1.0$ for $\hat{N}_f = 14$ and ~ 0.4 for $\hat{N}_f = 24$)

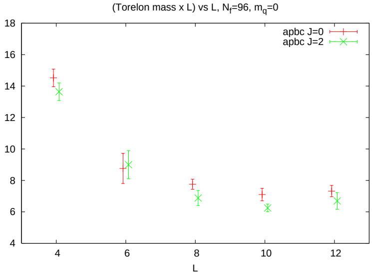




Strong coupling limit of LQCD ($\beta = 0$)

- torelon spectrum

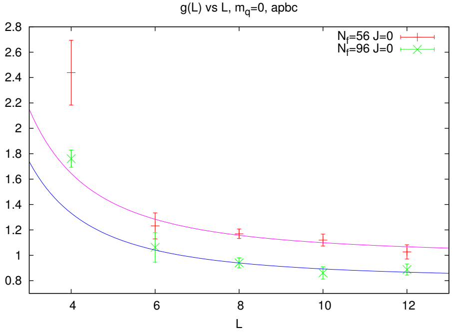




Strong coupling limit of LQCD ($\beta = 0$)

- running of coupling constant defined as

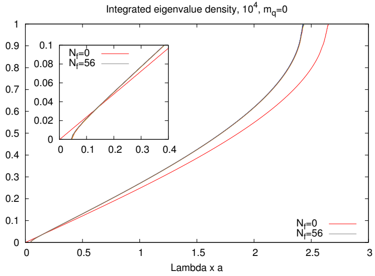
$$g(L) = \frac{m_{\text{torelon}}(L)L}{2\sqrt{\frac{N_c}{3} + \frac{N_f}{6}}} \quad (1)$$

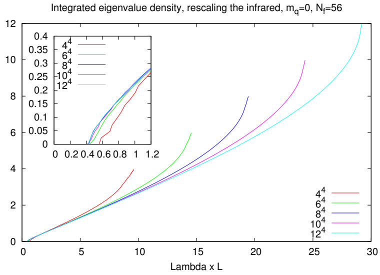


(line is for $1/L^2$)

Strong coupling limit of LQCD ($\beta = 0$)

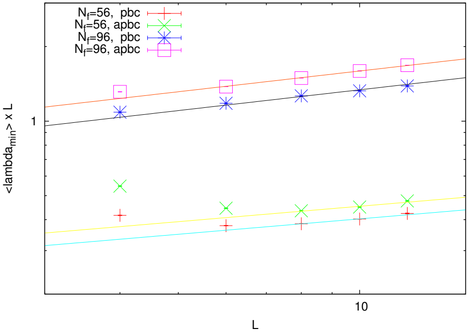
- Dirac eigenvalue spectrum





Strong coupling limit of LQCD ($\beta = 0$)

- Dirac eigenvalue vs. lattice size



$$\gamma^* \sim 0.26(\hat{N}_f = 14), \quad \gamma^* \sim 0.38(\hat{N}_f = 24)$$

Conclusion

- at $\beta = 0$ with $\hat{N}_f = 14$, we found a phase which is connected to $\beta \sim \infty$, large N_f

- this phase is chirally symmetric and a zero mass limit can be studied as L is changed

- our study suggests an interacting conformal limit

- but it is still difficult to get a consistent scaling picture for various dimensional quantities (hadron mass, torelon, Dirac eigen-value spectrum vs. L) with moderate $L(= 12)$ we studied

- strong coupling limit of QCD is an interesting test grounds for various ideas