One flavour adjoint QCD with overlap fermions

Georg Bergner
FSU Jena
with J. C. Lopez, S. Piemonte, I. Soler Calero
arXiv:2205.00792 (2022)

Heisenberg-Programm DFG Deutsche Forschungsgemeinschaft

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

DFG Deutsche Forschungsgemeinschaft
German Research Foundation

Lattice 2022: Aug 10, 2022

Yang-Mills theory coupled to one adjoint Dirac flavor

- confining theory with fermions and no explicit center symmetry breaking
- closely related to $\mathcal{N} = 1$ supersymmetric Yang-Mills theory (SYM) (one Majorana flavor) and $\mathcal{N} = 2$ supersymmetric Yang-Mills theory (additional scalar fields)
- closely related to $N_f^{(A)} = 2$ Dirac flavors: minimal walking technicolor and composite Higgs theories
- recent interest: non-standard conjectures of IR scenario based 't Hooft anomaly matching conditions
- to investigate chiral symmetry breaking and relations between chiral and deconfinement transition: overlap fermions

[A. Athenodorou, E. Bennett, GB, B. Lucini, arXiv:1412.5994]

[Z. Bi, A. Grebe, G. Kanwar, P. Ledwith, D. Murphy, M. L. Wagman, arXiv:1912.11723]

[A. Athenodorou, E. Bennett, GB, B. Lucini, arXiv:2103.10485], Talk by E. Bennet (Mon)

General theory space

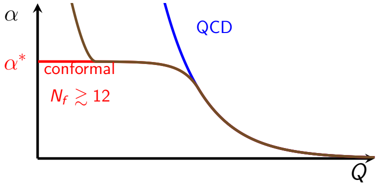
$$\mathcal{S}_L = S_G + \sum_{x,y} \sum_{n_f=1}^{N_f^{(F)}} \bar{\psi}_x^{n_f} (D_w^{(F)})_{xy} \psi_y^{n_f} + \sum_{x,y} \sum_{n_f=1}^{N_f^{(A)}} \bar{\psi}_x^{n_f} (D_w^{(A)})_{xy} \psi_y^{n_f} + S_{\text{Scalar}} + S_{\text{Yukawa}}$$

- $N_f^{(F)}$ fundamental and $N_f^{(A)}$ adjoint Dirac fermions, scalars and Yukawa interactions
- supersymmetric QCD correspond to specific point in theory space
- number of tuning parameters reduced, if chiral symmetry is present

[GB, S. Piemonte, arXiv:2008.02855]

Possible IR scenarios for one adjoint Dirac flavor

- confining + chiral symmetry breaking, chiral perturbation theory (QCD like):
  SYM ($N_f^{(A)} = 1/2$)
- conformal scaling, IR conformal fixed point:
  MWT ($N_f^{(A)} = 2$)
- alternative scenario: light fermion bound state



Overlap fermions and polynomial approximation

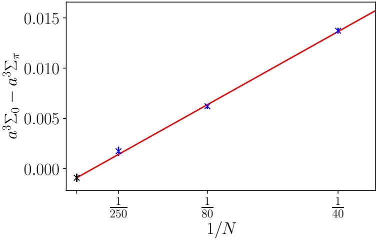
- chiral symmetry crucial to measure fermion condensate
- Ginsparg-Wilson fermions allow to define condensate that represents order parameter of chiral symmetry breaking
- Overlap operator with Dirac-Wilson kernel D_w ($D_\mathrm{H} = \gamma_5 D_w$)

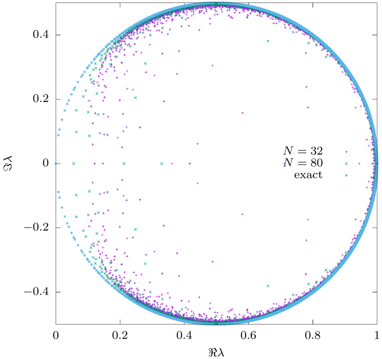
$$D_{ov} = \frac{1}{2} + \frac{1}{2}\,\gamma_5\,\mathrm{sign}(D_\mathrm{H}(\kappa))\,, \quad \mathrm{sign}(D_\mathrm{H}) = \frac{D_\mathrm{H}(\kappa)}{\sqrt{D_\mathrm{H}(\kappa)\;D_\mathrm{H}(\kappa)}}$$

- RHMC force ill-defined around origin of spectrum: choose polynomial approximation of sign function, order N
- chiral limit corresponds to $N \to \infty$

Representation of chiral symmetry

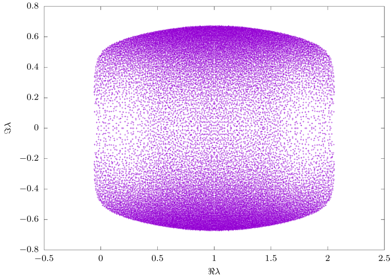
Ginsparg-Wilson relation defines chiral rotation. Difference between condensate before and after rotation by π measures violation of GW relation.



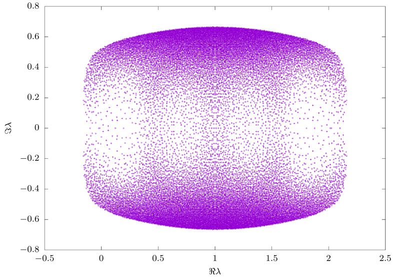


Simulation parameters

- $\beta = 1.6 - 1.8$, tree level Symanzik improved gauge action
- additional stout smearing in D_w
- so far coarse lattices: $8^4 - 18^4$
- $\kappa = 0.2$ tuned according to D_w eigenvalue spectrum
- $m_{res} \propto 1/N + O((1/N)^2)$ to extrapolate chiral limit



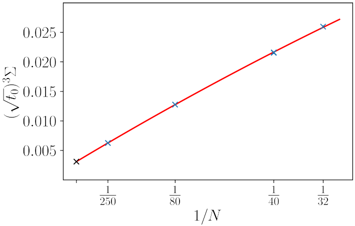
$\beta = 1.6$



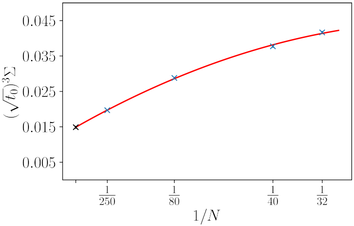
$\beta = 1.75$

Chiral condensate

- finite chiral condensate extrapolated to large N limit
- assuming linear + quadratic extrapolation
- indicates chiral symmetry breaking and not conformal scenario



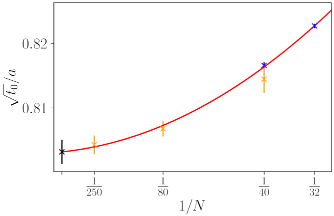
$\beta = 1.6$



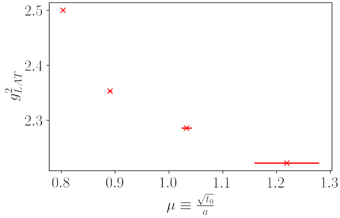
$\beta = 1.7$

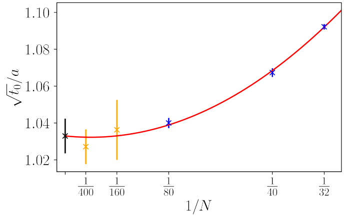
Scale setting

- infinite N extrapolation of t_0 to obtain chiral limit
- larger t_0 at larger β: scaling as expected for QCD like theory
- indicates non-conformal scenario



$\beta = 1.6$





$\beta = 1.75$

Running coupling from gradient flow

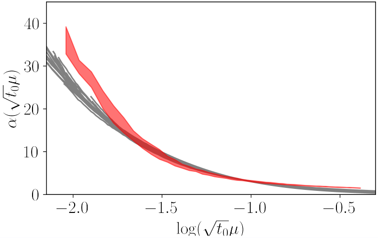
Definition of gradient flow coupling:

$$g^2_{\mathrm{GF}}(\mu) = \frac{16\pi^2}{3(N^2-1)}\tau^2 \left.\langle E(\tau)\rangle\right|_{\tau^2=1/8\mu} \,.$$

Extrapolations:

$$g(\mu)^2 = g_0 + c_0 t_0^{-1} + c_1 t_0^{-\frac{3}{2}} + d_1 \frac{\sqrt{t_0}}{N} + d_2 \frac{1}{N} + d_3 \left(\frac{\sqrt{t_0}}{N}\right)^2$$

running indicates non-conformal scenario



Summary/Conclusions

- infrared scenario of one flavor adjoint QCD still controversial
- Ginsparg-Wilson fermions ideal too to study chiral symmetry breaking in the theory
- first simulations with Overlap fermions
- simple polynomial approximation provides reasonable extrapolations to chiral limit ($N \to \infty$)
- non-zero fermion condensate
- QCD like running of strong coupling
- indications for non-conformal scenario
- further studies required to extend parameter range and complete picture