Finite-temperature study of eight-flavor SU(3) gauge theory
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Abstract: Lattice explorations of the phase structure of strongly coupled gauge theories can provide important insight into the chiral dynamics of these systems. With the Lattice Strong Dynamics Collaboration we have investigated finite-temperature transitions of SU(3) gauge theory with \( N_F = 8 \) light flavors on lattice volumes up to \( 48^3 \times 24 \). In stark contrast to QCD, we find that these transitions run into a lattice phase before reaching the chiral limit. This indicates an absence of spontaneous chiral symmetry breaking even at fairly strong renormalized couplings \( g^2 \sim 20 \).

Properties and uses of the finite-temperature phase transitions

Knowledge of phase diagram needed to choose appropriate parameters for spectral studies

In the chiral limit may also distinguish between IR conformality and spontaneous chiral symmetry breaking (S\( \chi \)SB)

\( S\chi\)SB: Thermal transitions move to weaker couplings, 
\[ \beta_c \to \infty \text{ as } N_T = 1/(aT) \to \infty \]

Conformal: Thermal transitions accumulate at bulk transition

Our prior work for \( N_F = 8 \) studied \( 8 \leq N_T \leq 20 \) and \( m \geq 0.005 \)


—Observed thermal transitions moving with \( N_T \) for sufficiently large \( m \)

—Transitions ran into \( S^4 \) phase: Could not establish \( S\chi\)SB in chiral limit

New results for \( 20 \leq N_T \leq 24 \), \( m \geq 0.0025 \)

40\( ^3 \times 20 \) and 48\( ^3 \times 24 \) volumes are very large but insufficient to probe \( S\chi\)SB in chiral limit

\( N_T = 24 \) transitions still run into \( S^4 \) phase, with \( mN_T \) almost constant for \( 20 \leq N_T \leq 24 \)

Extrapolating \( m \to 0 \) at fixed \( \beta_F = 4.7 \) suggests \( N_T \gtrsim 48 \) needed to test \( S\chi\)SB

Consistent with running coupling results:

arXiv:1410.5886 sees no \( S\chi\)SB for \( g^2 \lesssim 18 \)

Methods to identify transitions

Polyakov loop measured after gradient flow shows clear confinement transitions for large \( N_T \)

—Gap \( \rho(\lambda > 0) = 0 \) in chirally symmetric phase

—Condensate \( \rho(0) > 0 \) in chirally broken phase

—Soft edge \( \rho(\lambda) \propto \sqrt{\lambda - \lambda_c} \) in \( S^4 \) phase

For \( m = 0.005 \) and \( N_T = 16 \), \( \rho(0) = 0 \) for all \( \beta_F \)

Need \( N_T = 20 \) to observe chirally broken phase

Smaller \( m \leq 0.0025 \) require larger \( N_T > 20 \) to observe chirally broken phase

\( S\chi\)SB in \( m \to 0 \) chiral limit not yet established

Extremely different from QCD!

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