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 $g^2 \sim 20$.

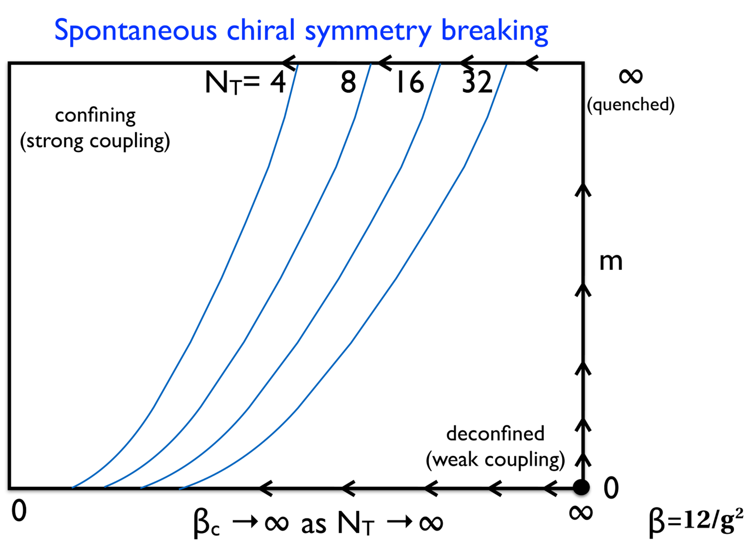
Properties and uses of the finite-temperature phase transitions

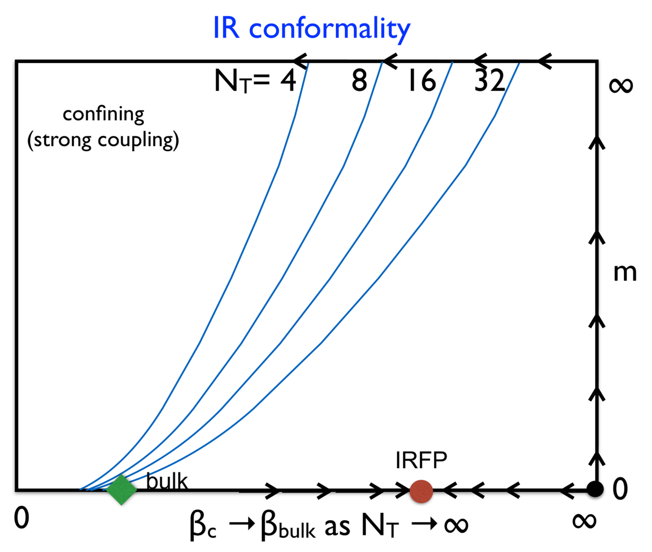
Knowledge of phase diagram needed to choose appropriate parameters for spectral studies

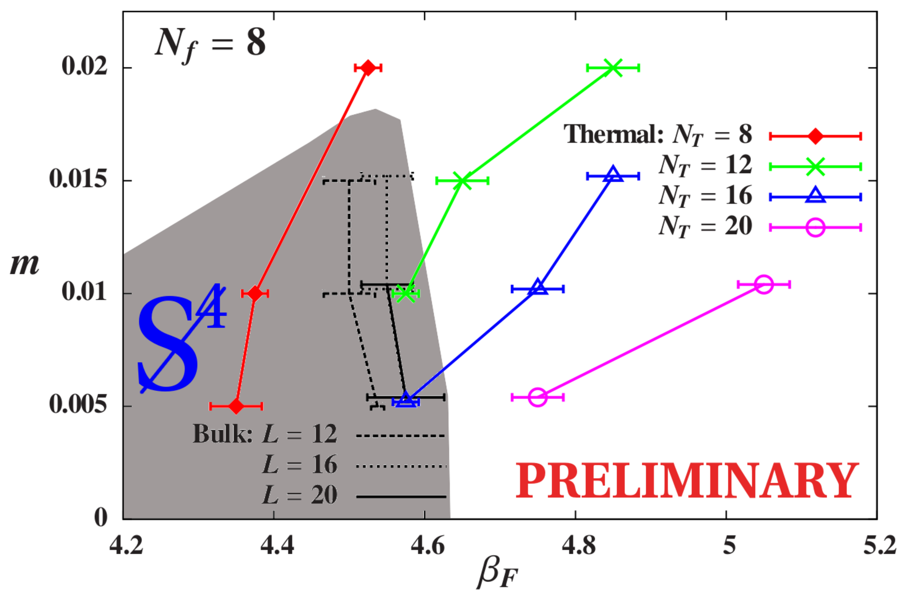
In the chiral limit may also distinguish between IR conformality and spontaneous chiral symmetry breaking (SχSB)

SχSB: Thermal transitions move to weaker couplings, $\beta_c \to \infty$ as $N_T = 1/(aT) \to \infty$

Conformal: Thermal transitions accumulate at bulk transition







Our prior work for $N_F = 8$ studied $8 \le N_T \le 20$ and $m \ge 0.005$

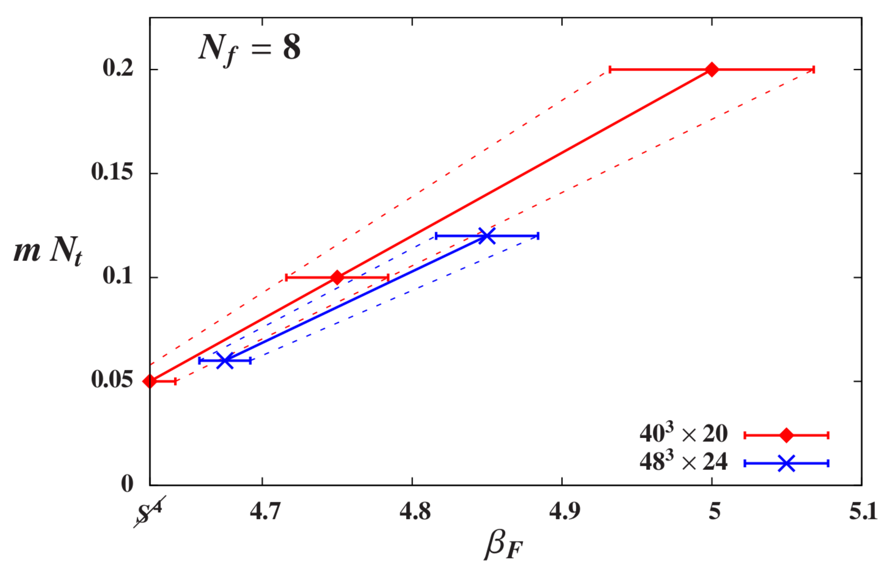
—Characterized novel "S^4" lattice phase (arXiv:1207.7164, arXiv:1303.7129)

—Observed thermal transitions moving with N_T for sufficiently large m

—Transitions ran into S^4 phase: Could not establish SχSB in chiral limit

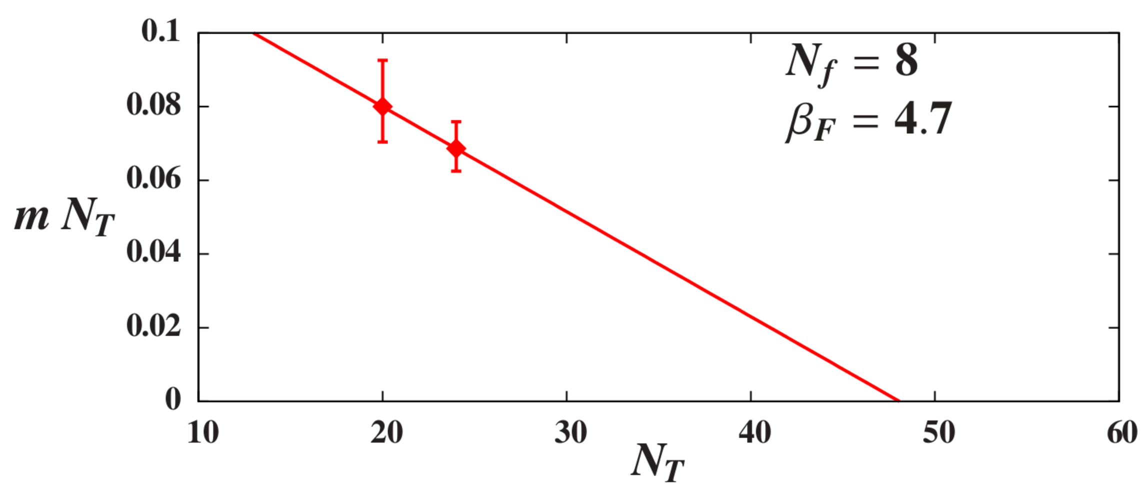
New results for $20 \le N_T \le 24$, $m \ge 0.0025$

$40^3 \times 20$ and $48^3 \times 24$ volumes are very large but insufficient to probe SχSB in chiral limit

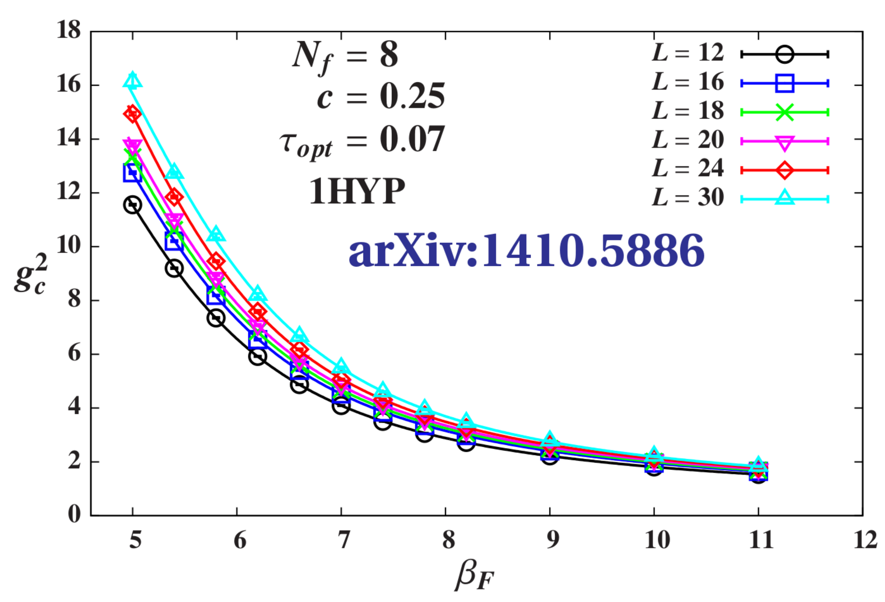


$N_T = 24$ transitions still run into S^4 phase, with mN_T almost constant for $20 \le N_T \le 24$

Extrapolating $m \to 0$ at fixed $\beta_F = 4.7$ suggests $N_T \gtrsim 48$ needed to test SχSB

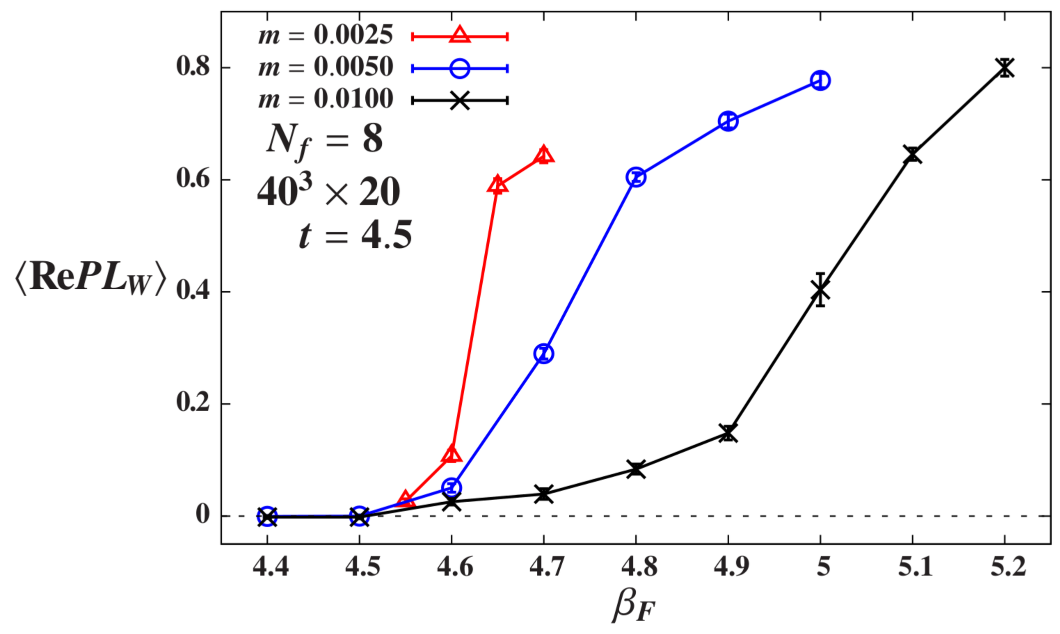


Consistent with running coupling results: arXiv:1410.5886 sees no SχSB for $g_c^2 \lesssim 18$



Methods to identify transitions

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

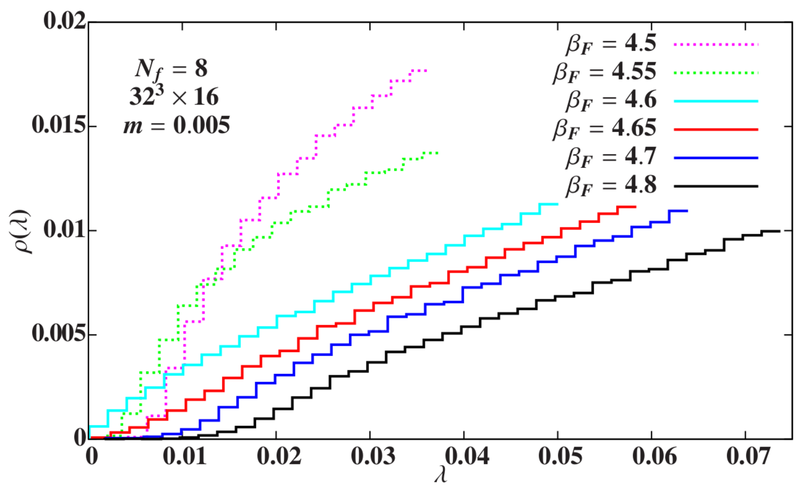


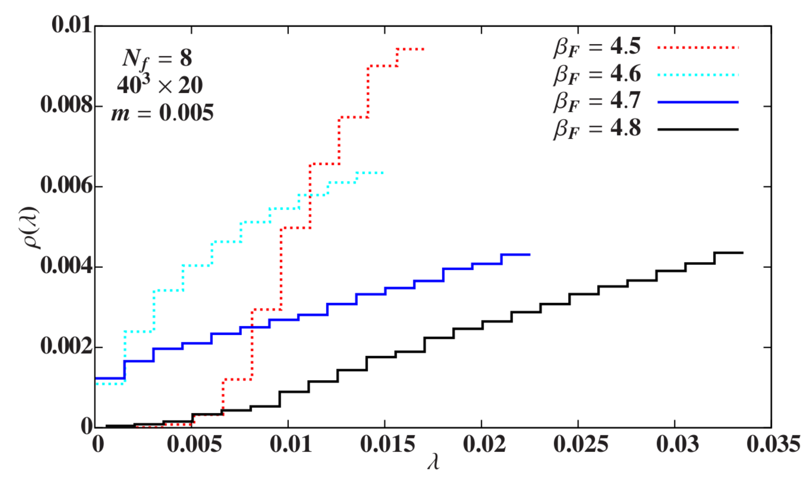
Dirac eigenspectra probe chiral transitions

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

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

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





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

Need $N_T = 20$ to observe chirally broken phase

Smaller $m \le 0.0025$ require larger $N_T > 20$ to observe chirally broken phase

SχSB in $m \to 0$ chiral limit not yet established

Extremely different from QCD!

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