Maximally supersymmetric Yang–Mills in three dimensions

David Schaich and Angel Sherletov (University of Liverpool)

Phase diagram from lattice calculations

System: Naive dimensional reduction of maximal super-Yang–Mills (4d $\mathcal{N} = 4$ SYM) [arXiv:2010.00026]
Richer dynamics than 2d [arXiv:2312.04980], computationally cheaper than 4d [arXiv:2304.04655]

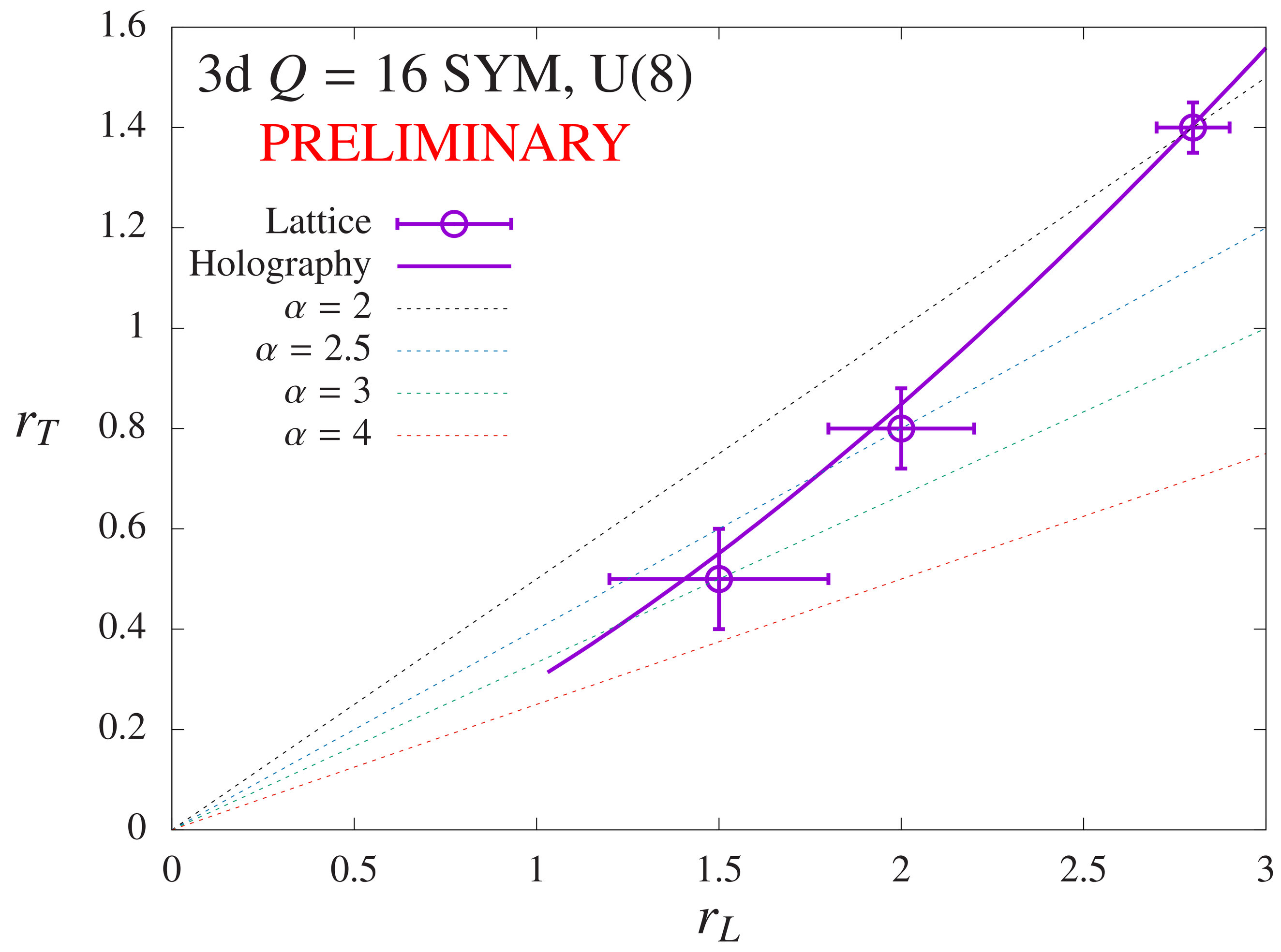
Goal: Map 'spatial deconfinement' transition [dual to black brane / black hole]
from high-temperature 2d bosonic theory to low-temperature holographic regime

Dim'less torus size $r_L \times r_L \times r_T$ $\longrightarrow$ **aspect ratio** $\alpha = r_L / r_T$

Dim'less temperature $T = 4/(r_T\sqrt{3})$ [skewed 3-torus]

Fix gauge group U(8) and $N_T = 8$
$\longrightarrow \alpha = 2, 2.5, 3, 4$ from $N_L = 16, 20, 24, 32$

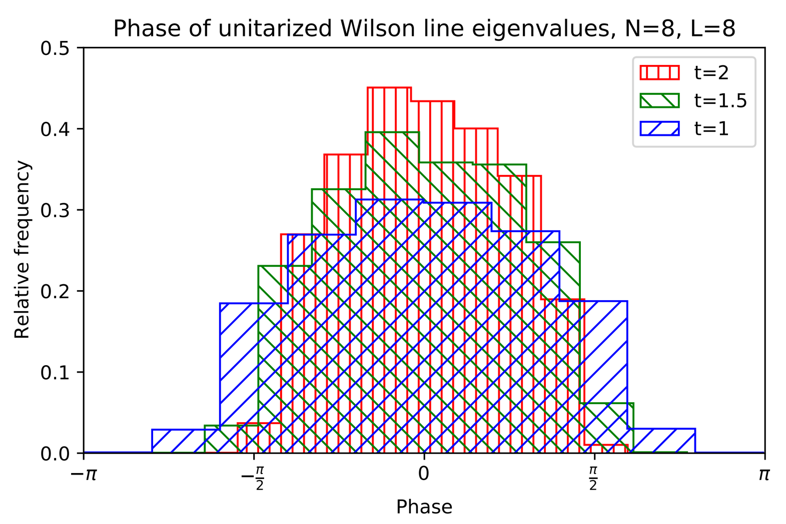
Preliminary results consistent with holographic expectation
$$r_L^{3/2} \propto r_T \quad \longrightarrow \quad T_c \propto \alpha^3$$

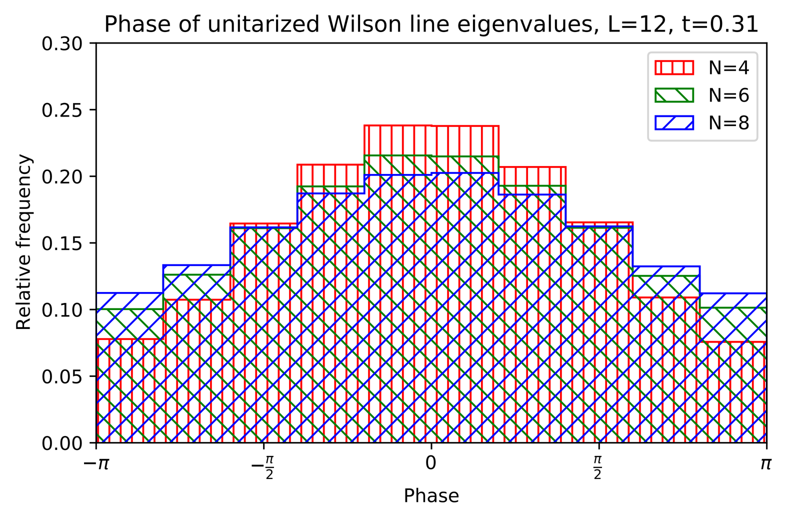


Transition observables

Magnitude of spatial Wilson line (WL)
Large for high-T deconfined phase
Vanishes for low-T confined (in large-N limit)

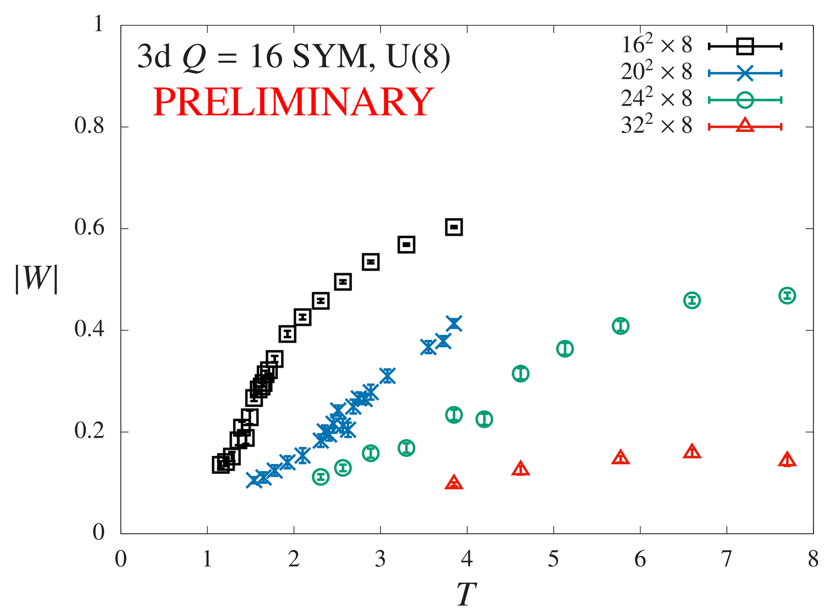
WL eigenvalue distribution
Localized for high-T deconfined phase
Homogeneous for low-T confined (large-N)

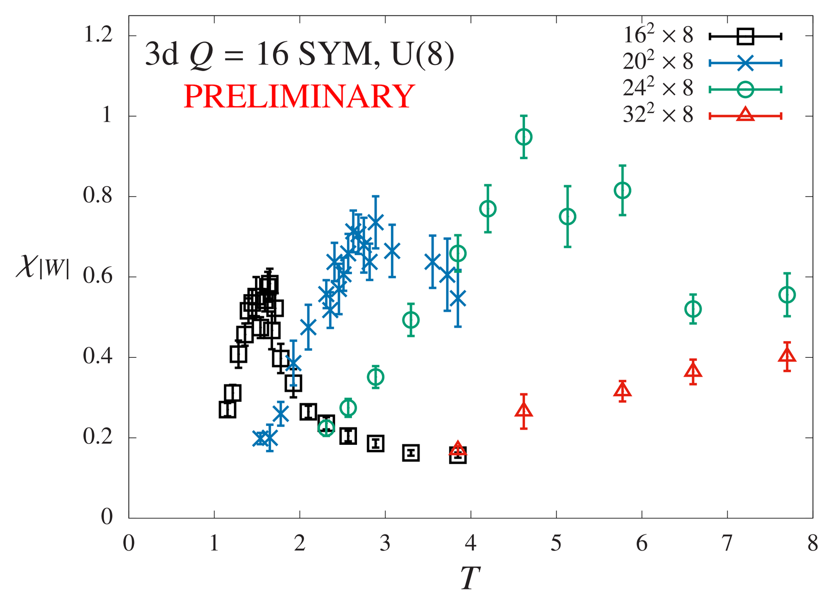




Transition signals

T_c from peaks in WL magnitude **susceptibility**





Larger aspect ratio (larger spatial volume)
$\longrightarrow$ higher T_c
$\longrightarrow$ harder to stabilize lattice system

Critical scaling needs U(N) with larger $N > 8$

More technical details of the lattice system

Twisted formulation preserves two (of 16) supersymmetries at non-zero lattice spacing
Requires A_3^* (body-centered cubic) lattice $\longrightarrow$ skewed 3-torus [arXiv:2010.00026]

16 fermions $\longrightarrow$ 2 site $\{\eta, \psi_5\}$ + 8 link $\{\psi_a, \chi_{5a}\}$ + 6 plaquette $\{\chi_{ab}\}$

Gauge field A_μ + 7 scalars $\longrightarrow$ complexified $\{\mathcal{U}_5, \overline{\mathcal{U}}_5\}$ + $\{\mathcal{U}_a, \overline{\mathcal{U}}_a\}$ $\longrightarrow$ U(N) gauge invariance

Use 't Hooft coupling λ to define dim'less $r_T = \beta\lambda$ and $r_L = \alpha\beta\lambda$
Fixed torus size $\longrightarrow$ larger lattice volumes produce smaller lattice spacing a and smaller $\lambda_{\text{lat}} = a\lambda$

Soft-supersymmetry-breaking scalar potential $\propto \lambda_{\text{lat}}$ needed to stabilize RHMC lattice calculations

Future work to adapt gradient flow to naive dimensional reduction [$1 \times N_L \times N_L \times N_T$ lattices]