Exploring the gluoN_c plasma

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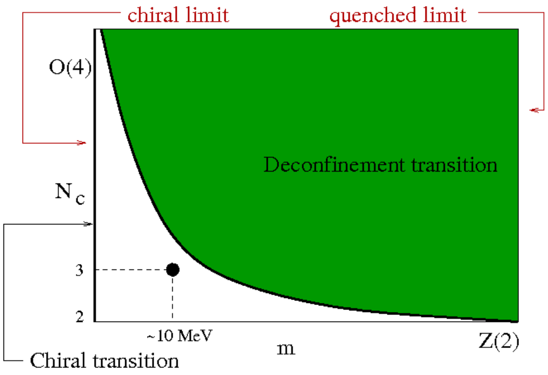
TIFR

Quark Matter 2009
April 3, 2009

1. Introduction
2. The temperature scale
3. The equation of state
4. Conclusions

Outline

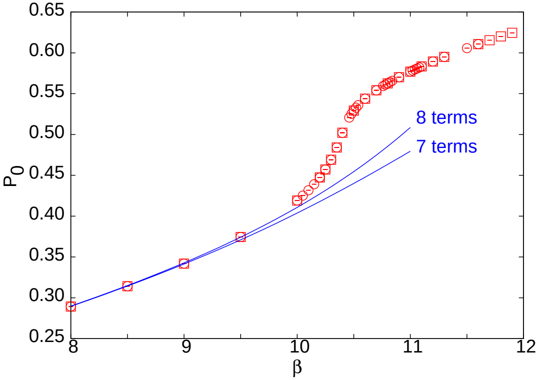
Deconfinement and chiral phase transition



$$Z(T, m, N_c) = \int \mathcal{D}U \det M_f(T, m, N_c) \exp[-S_g(T, N_c)].$$

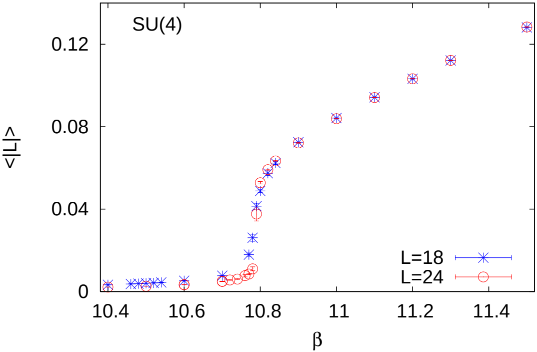
Outline

SU(4): crossover to weak coupling



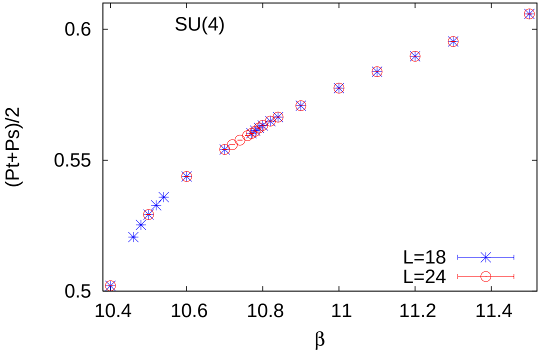
Strong coupling series fails: weak coupling should be understood in RG.
Coincidence: finite-T transition for $N_t = 4$ interferes with this transition.
(Gocksch Okawa, Batrouni Svetitsky, Wingate Ohta, Gavai, Teper et al)
Our solution: go to larger N_t.

SU(4) with $N_t = 6$



Thermal phase transition signalled by $\langle |L| \rangle$. No associated bulk transition seen in average plaquette. Similar for larger N_c.

SU(4) with $N_t = 6$



Thermal phase transition signalled by $\langle|L|\rangle$. No associated bulk transition seen in average plaquette. Similar for larger N_c.

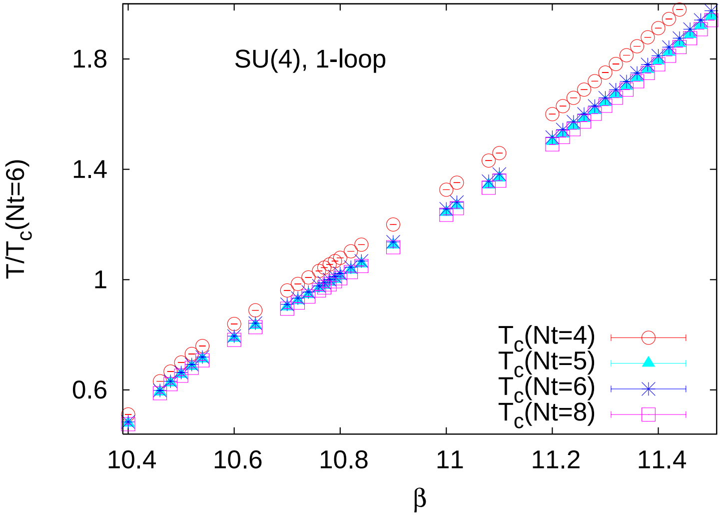
Determining the temperature scale

1. Trade the bare coupling (β) for the renormalized coupling (α_s). The zero-temperature plaquette (P) is used to determine α_s using the weak coupling expansion of carried out to second order: V-scheme.
2. Use the beta-function to find the lattice spacing for a given α_s:

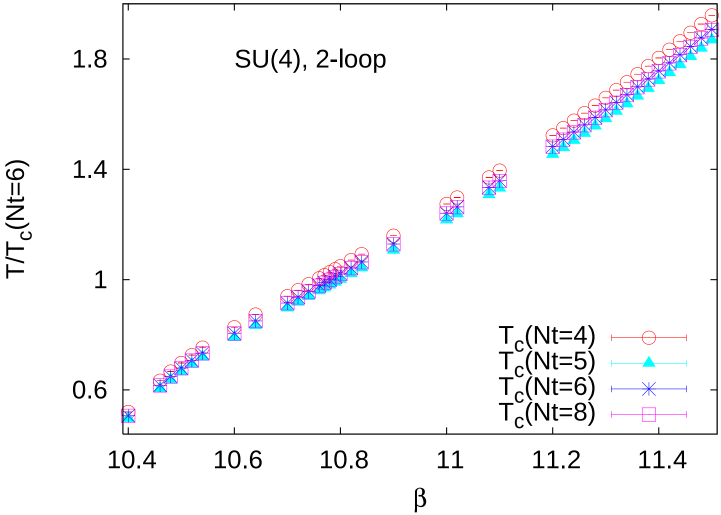
$$a\Lambda_{\overline{MS}} = kR(1/4\pi\beta_0\alpha_s) \qquad R^2(x) = \exp(-x)x^{\beta_0/\beta_1}.$$

3. When β is tuned so that there is a finite temperature transition on an $N_t \times N_s^3$ lattice ($N_s \gg N_t$) then $a = 1/(N_t T_c)$. This allows us to determine $T_c/\Lambda_{\overline{MS}}$. Also, using the RGE, allows us to find T/T_c corresponding to any other β.
4. Consistency check on the approach to the continuum limit: the lattice spacings extracted from the RGE at fixed T with different N_t should be in the ratios of N_t.

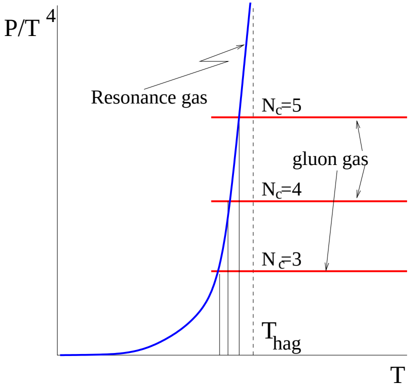
SU(4) scaling with 1-loop RGE



SU(4) scaling with 2-loop RGE

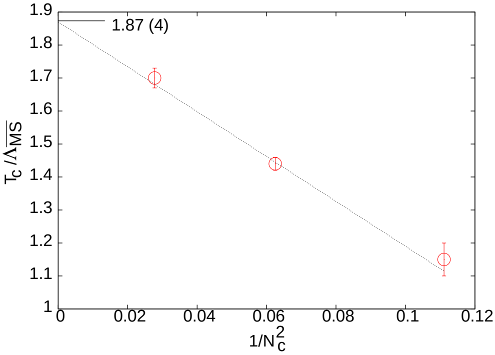


A resonance gas?



A simple possibility at large N_c: pressure of a glueball resonance gas equals the pressure of a gluon gas at a first order deconfining transition. Correction should be regular in N_c and starts at order $1/N_c^2$.

The Hagedorn temperature?



$N_c = 3$ from SG 2001. Fit gives the limiting temperature: $T_c/\Lambda_{\overline{MS}} = 1.87(4)$. Is this the Hagedorn temperature?

Summary (1)

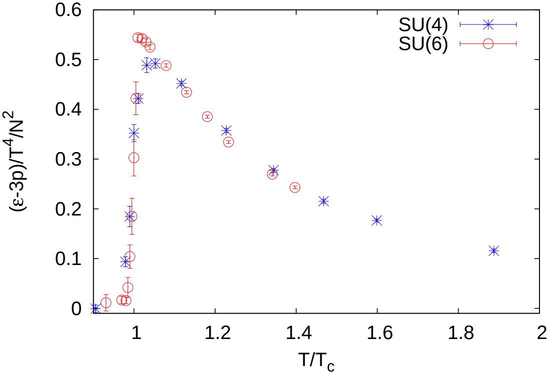
- Temperature scale determined for $N_c = 4$ and 6 using lattice simulations at finite cutoff. Extrapolated to continuum limit using two-loop β-function of QCD. The result is $T_c/\Lambda_{\overline{MS}}$ for each N_c.
- A model of the first order transitions seen is that on the low temperature side one has a resonance gas of glueballs, and on the plasma side one has a gas of gluons. If this picture becomes exact at $N_c = \infty$, then one should be able extrapolate smoothly to the limit.
- We find

$$\frac{T_{\rm c}}{\Lambda_{\overline{MS}}} = 1.87 \pm 0.04. \text{ (stat only)}.$$

Systematic errors involved in the choice of RG scheme remain to be evaluated.

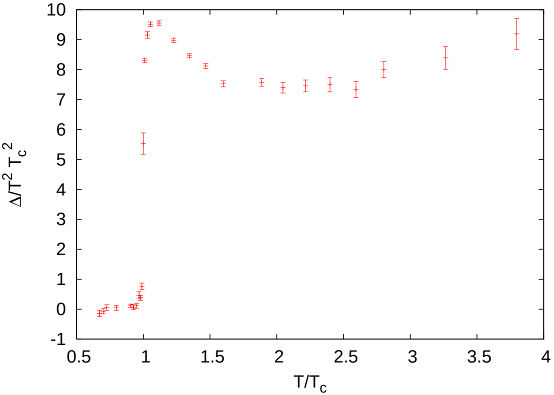
Outline

The conformal anomaly: $\Delta = E - 3P$

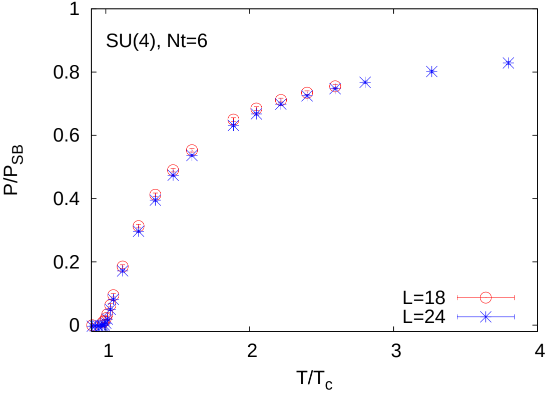


Peak of Δ/T^4 shifted from T_c: evidence of change with N_c? Perhaps peak shifts to T_H as $N_c \to \infty$? (Pisarski)

Pisarski plot



Pressure in SU(4)



Evaluated using the integral method. Negligible volume dependence when $N_s/N_t > T/T_c$. Cutoff dependence within control: continuum limit within reach.

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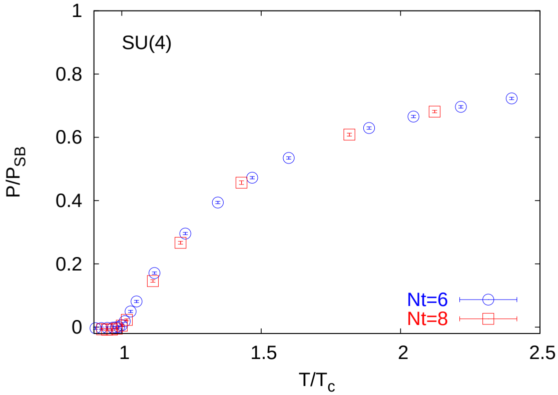

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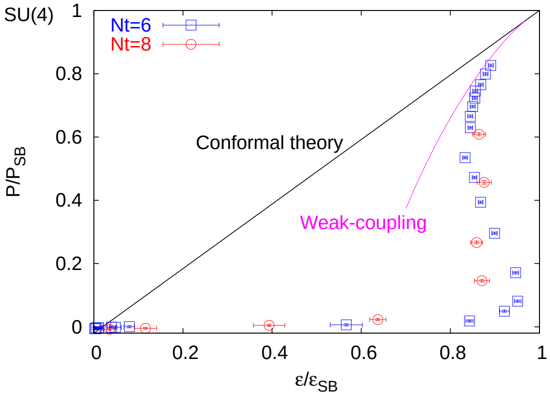
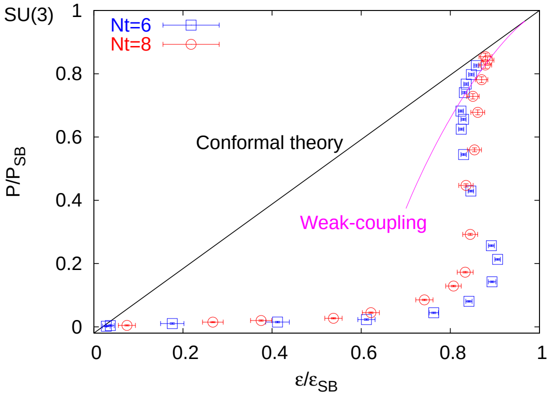
Equation of state for SU(4)



Weak coupling theory treated in DR (Hietanen et al, hep-ph/0603048).
EOS closer to weak-coupling QCD than conformal theory.

Equation of state for SU(3)



Weak coupling theory treated in DR (Hietanen et al, hep-ph/0603048).
EOS closer to weak-coupling QCD than conformal theory.

Summary (2)

- P/T^4 in SU(4) pure gauge theory scales for $T \geq 3T_c/2$ already for $N_t = 6$. For $T \simeq 1.1T_c$ there is scaling violation between $N_t = 6$ and $N_t = 8$. The EOS curve becomes smoother with increasing N_t. Similar effects were also seen for SU(3).
- EOS comes close to the conformal symmetric limit only for $T > 2T_c$. Even at high temperature the results are closer to weak-coupling QCD (evaluated to order $g^6 \ln g$) than to the conformal symmetric limit.
- The complete EQCD results in smaller Δ/T^4 than the weak-coupling results: this leaves out terms that could be important for the hard modes which dominate the EOS. However, the lattice results would still be closer to such a computation than to a conformal symmetric model.
- Qualitatively accurate intuition for the plasma may perhaps be obtained from conformally symmetric models only for temperatures higher than $2T_c$.

Outline

Summary

Simple theory at large N_c

In the limit $N_c \to \infty$ we find that $T_c/\Lambda_{\overline{MS}} = 1.87(4)$ Consistent with a simple model of phase transition: resonance gas on one side, gluon gas on the other.

Weak-coupling better than conformal field theory for EOS

There seems to be no window for non-trivial (almost) conformal scaling in the data for the equation of state. The EOS is either strongly non-conformal or compatible with a weak-coupling expansion.

An advertisement

TIFR is planning to expand research directions: one of the new directions under consideration is experimental and theoretical heavy-ion physics and allied topics in extreme QCD.