Summary of the discussion on QCD with many flavors N_f

Edward Shuryak

Department of Physics and Astronomy,
Stony Brook University,
Stony Brook, NY 11794, USA
(Dated: January 20, 2012)

I. TOPICS

Why is it interesting? It opens a window into stronger coupling domain, and is just became accessible to lattice

As a preliminary list of issue to discuss, I suggested the following

(i) Emerging conformal window, physics of anomalous dimensions
(ii) Differences between large/small N_f: chiral symmetry/confinement etc
(iii) "Large" N_f region for $\mathcal{N}$=2 theories and Seiberg-Witten predictions for those
(iv) Electric-magnetic duality in the large N_f region

II. THE MAPS

Let us start by reviewing current lattice data. Our version of the phase diagram uses the "critical lattice coupling"

$$\beta_c(T_c) = \frac{2N_c}{g^2(T_c)} \tag{1}$$

as a function of N_f or N_a. The "bare" coupling values in lattice works are defined at the lattice UV scale a. In order to make it lattice-independent we have evolved the scale from a by a factor N_t (the number of points in the time direction) to the physical scale $N_t a = 1/T_c$ using the two-loop beta function. The near overlapping points in Fig.1(a) are from different N_t simulations: their spread is a measure of the inaccuracy of the two-loop beta function used.

Fig.1(a) is based on the current lattice data [1] (the diamond points) for various number of the fundamental fermions. Moving downward on this figure means increasing the gauge coupling constant. The chiral symmetry is broken below the solid curve. There are many other simulations reported in lattice literature, of course: we decided not to put those on this plot because of the rather different actions used produce rather random spread of the couplings confusing the picture. The deconfinement line is not very well defined, at least by current Polyakov susceptibility criterion, but it is believed to be coincident or close to the chiral one, at least till $N_f < 4$ and perhaps even further.

The box point in Fig.1(a). corresponds to the 12 quark flavors point studied in [2] . These authors concluded that this theory is only partly "QCD-like", it is confining but chirally symmetric. If so, the two phase transition lines must get separated somewhere below $N_f = 12$. On the other hand, a number of recent lattice works contradicted this and put the $N_f = 12$ theory inside the the so called "conformal window" . This issue remains unresolved and we tenatively put the vertical dashed line separating it (to the right) through the $N_f = 12$ point. The two-loop zero of the beta function line and excluded region it suggests (red line and shaded region) plotted on this figure are for orientation only, since at rather strong coupling involved its perturbative location may be different from the exact nonperturbative one.

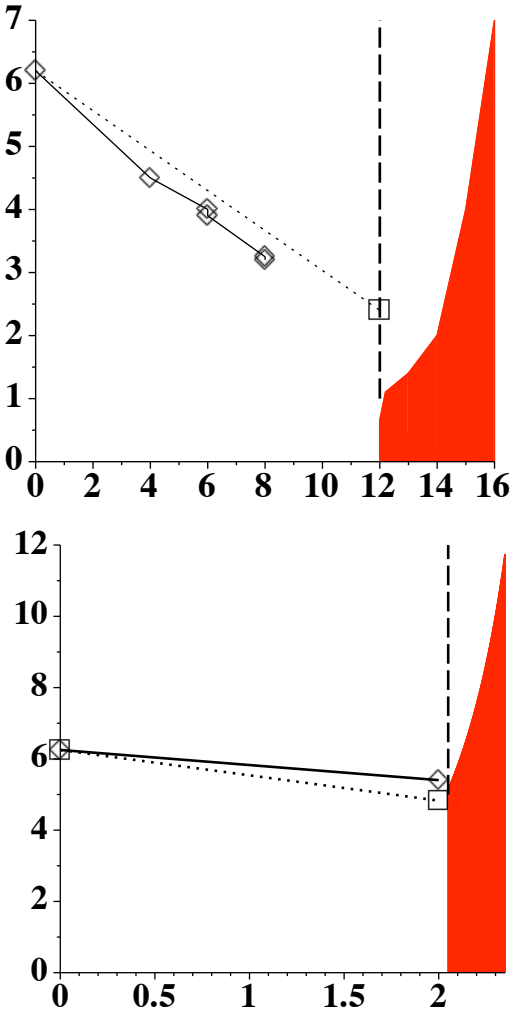

FIG. 1: (Color online) The critical lines for chiral restoration (solid line and diamonds) and deconfinement (dotted line a box) of the $N_c = 3$ gauge theory. Left figure shows the critical lattice coupling $\beta_c(T_c) = 6/g_c^2(T_c)$ versus the number of fundamental quarks N_f, the right one shows it as a function of number of adjoint quarks N_a. In both the path of the infrared fixed point , calculated in the 2-loop approximation, separate from the shaded (red) region on the right, which cannot be reached from the weak coupling regime. To the right of the vertical dashed line is the so called conformal window, in which UV to IR evolution ends on the fixed point line.

III. ANOMALOUS DIMENSIONS

Romuald Janik briefly described how anomalous dimensions depend on the coupling, as follows from exact solution of the $\mathcal{N}$=4 SYM. He emphasize the existence of a gap between "protected" modes with zero anomalous dimensions and the rest which have them of the order of $\lambda^{1/4}$. The spectrum of the excitations are basically angular harmonics of the space S^5 complementing AdS_5. The operators may have spin S and R-charge (analog of flavor in QCD)

Daniel Nogradi described the lattice data obtained in the cases listed in the following table

N_c	N_f	repr.
2	2,4,6	F
2	$\bar{2}$	adj
3	2,4,6,8,10,12, $\bar{16}$	F
3	2	adj
3	2,$\bar{3}$	sym
4	2	sym

where the cases with the bar over the number are shown to be inside the conformal window. So far the anomalous dimension are only for the mass operator (or, equivaliently for the σ channel $\bar{q}q$: and the values are not large, the largest about 1/2.

[1] K. Miura, M. P. Lombardo, E. Pallante, [arXiv:1110.3152 [hep-lat]].

[2] A. Deuzeman, M. P. Lombardo, E. Pallante,

[arXiv:1012.6023 [hep-lat]]