# holography with a landau pole

javier tarrío
université libre de bruxelles

arXiv:1611.05808
w/ A. Faedo, D. Mateos and C. Pantelidou

iberian strings, january 19th 2017

# motivation

study gravity duals of UV-incomplete theories, in particular $\mathcal{N} = 4$ SYM with $N_f$ quark flavors

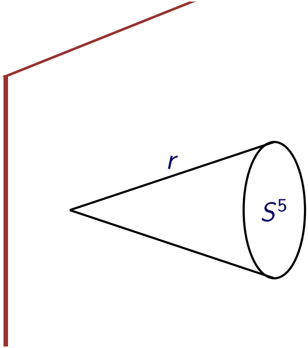
arXiv:1611.05808

# intro

* $\mathcal{N} = 4$ SYM is a conformal theory; in particular the coupling constant does not run: $\beta = 0$
* couple it to quark (fundamental) matter: then $\beta \simeq N_f$
* positive beta function implies a Landau pole and the theory needs UV completion
* my aim is to study what are the implications of the LP at face value, not to study the UV completion

# table of contents

# SYM theories from type IIB SUGRA

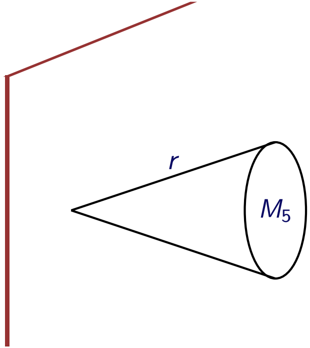



$U(N)$ SYM with 16 supercharges

$$\mathrm{d}s^2 = h^{-1/2}\,\mathrm{d}x_{1,3}^2 + h^{1/2}\,\left(\mathrm{d}r^2 + r^2\mathrm{d}\Omega_5^2\right)$$

$$\int_{S^5} *F_5 \sim N_c$$

# SYM theories from type IIB SUGRA




SYM with other gauge group
and less supercharges

$$\mathrm{d}s^2 = h^{-1/2}\,\mathrm{d}x_{1,3}^2 + h^{1/2}\,\left(\mathrm{d}r^2 + r^2\mathrm{d}\Sigma_{SE}^2\right)$$

$$\int_{M_5} *F_5 \sim N_c$$

# fundamental matter

* add D7-branes as flavor sources [Karch and Katz '03]
* to observe the Landau pole backreaction must be included
* we consider the $N_c \to \infty$ limit with $N_f/N_c$ kept fixed (a la Veneziano)
* a continuous distribution of D7-branes helps to simplify the equations [Kiritsis et al. '05]
* actually everything is $\mathcal{N} = 1$ and one solves BPS eqs. (except at finite temperature later)

# a taste of the smeared solution (D3/D7) [Benini et al '06]

* one can consider just the simple ansatz

$$\mathrm{d}s^2 = f_1(\rho)\,\mathrm{d}x_{1,3}^2 + f_2(\rho)\,\mathrm{d}\rho^2 + f_3(\rho)\,\mathrm{d}s_{KE}^2 + f_4(\rho)\,\eta^2 \ ,$$

with dilaton and RR forms

$$F_5 \sim N_c\,(1+*)J \wedge J \wedge \eta \ , \qquad F_1 \sim N_f\,\eta \ ,$$

* a SUSY solution exists, for example

$$\phi' = -N_f\,e^{\phi} \quad \Rightarrow \quad e^{\phi} = \frac{1}{N_f\,\rho}$$

# asymptotic geometry

- asymptotically near the boundary one has

$$\mathrm{d}s^2 \simeq r^{-2\theta/3}\left(r^2\mathrm{d}x_{1,3}^2 + \frac{\mathrm{d}r^2}{r^2}\right) + \text{corrections in } \frac{1}{r}$$

  with $\theta = 7/2$, and $e^{\phi} \simeq r^{1/2}/N_f$ and two more scalars

- this form of the metric is the ultimate responsible of all the UV behaviors of physical quantities

- actually, one can perform holographic renormalization by relating this geometry via analytic continuation in the dimension to an asymptotically-AdS one

# table of contents

# minimum length in the field theory

$$|g_{tt}| = g_{xx} \simeq \left(\frac{r}{L}\right)^{-1/3}$$

* near UV an object with fixed proper size in the bulk increases in field theory size

* near IR this behavior is reversed, as customary in ads/cft

* maximum of $g_{xx}$ implies a minimum size as we increase the radius (energy scale)

* this also provides a maximum density of degrees of freedom

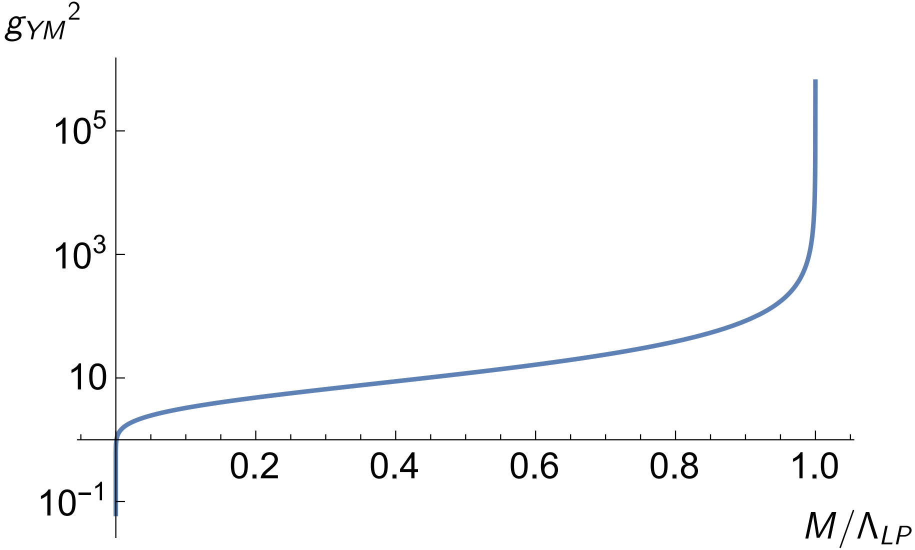
$$n \sim \ell_P^{-3} \sqrt{g_{xx}^3}$$

# mass of a string

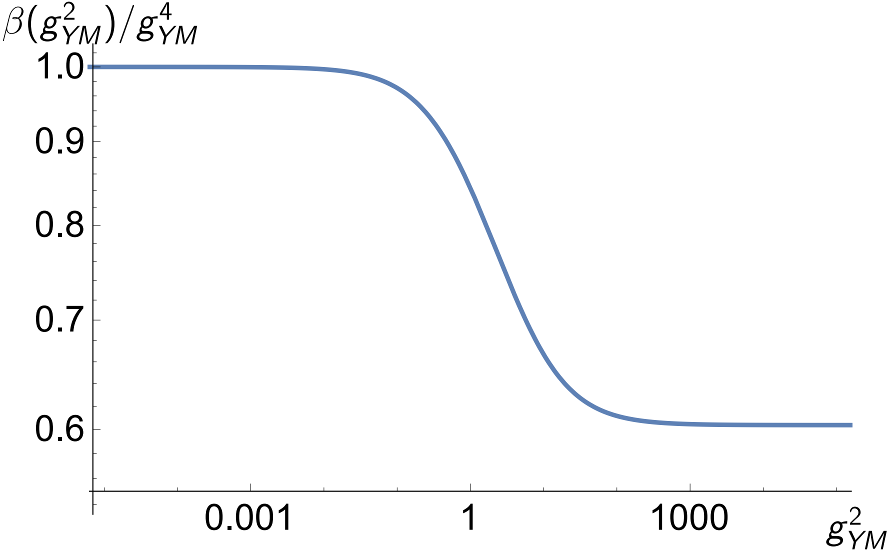
$$M(r) = \frac{1}{2\pi\ell_s^2}\int_0^r \sqrt{-G_{tt}\,G_{rr}}\,\mathrm{d}r$$

* at $r \to \infty$ this is the self-energy of a charged particle and in our setup it is finite
* maximum mass for an external charge to which the theory can couple

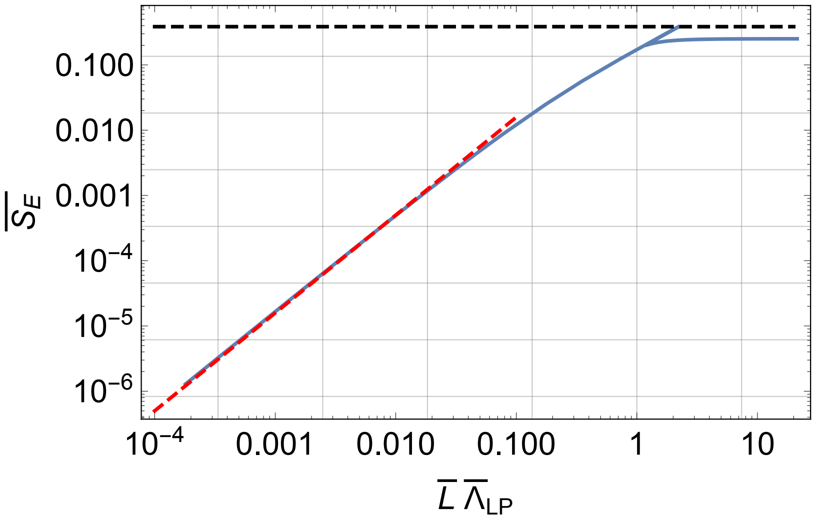
## beta function



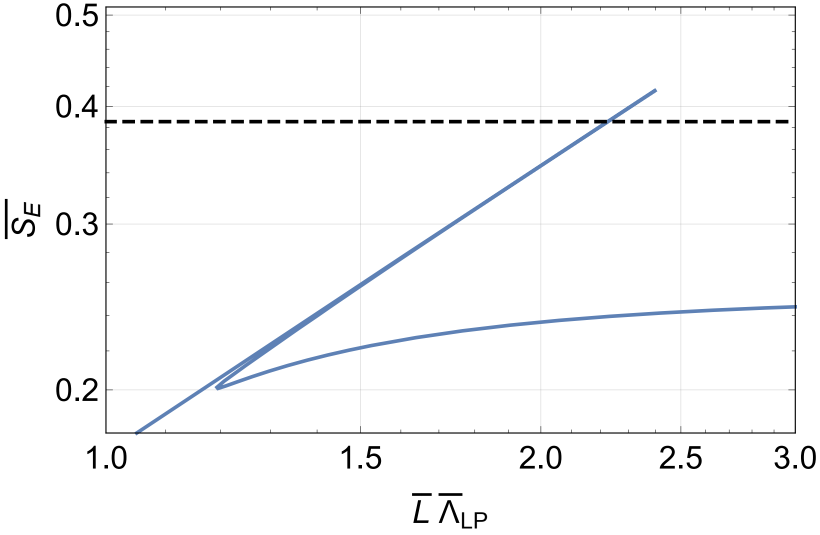
# beta function



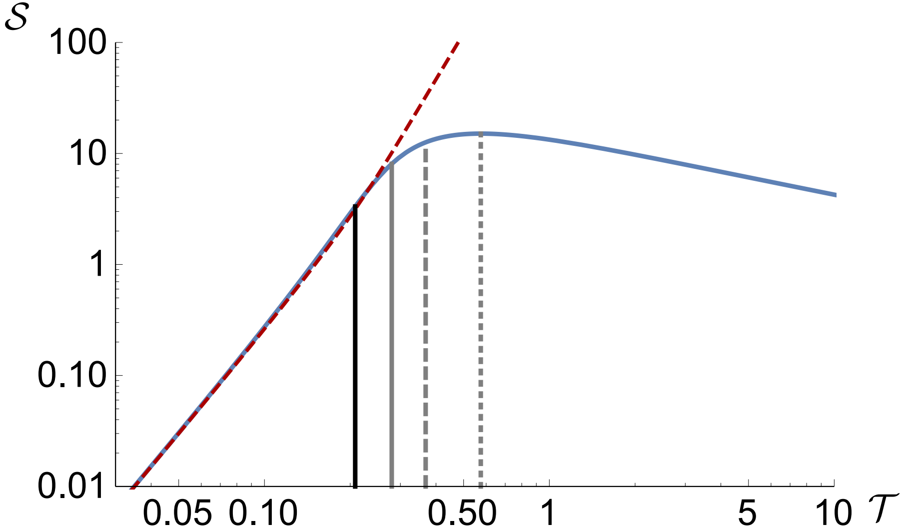
# entanglement entropy



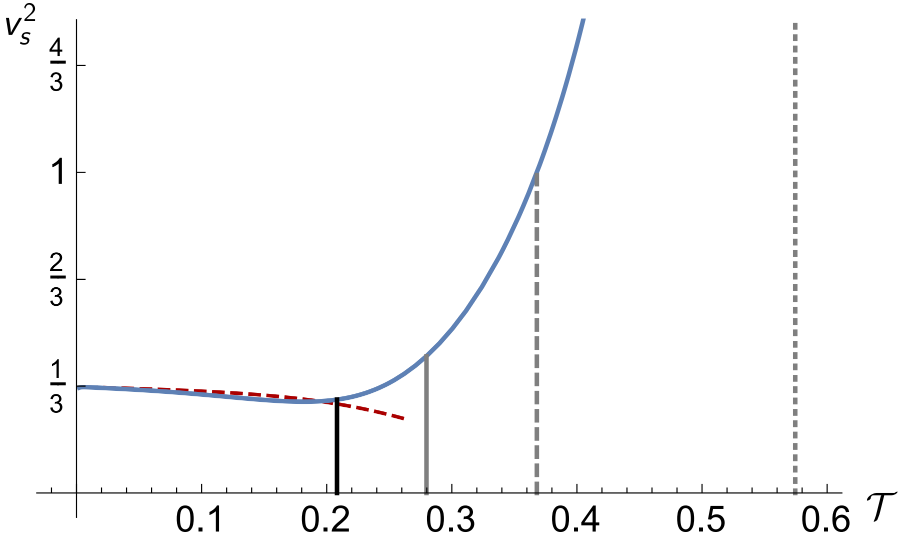
# entanglement entropy



thermodynamics



# thermodynamics



# table of contents

# why was I interested

* helps in a bigger program that studies the phase diagram of holographic SYM theories coupled to flavor at finite temperature and chemical potential

* shows that the holographic implementation of the UV behavior is not ill-defined after all

* surprises appeared: what is that phase transition in the entanglement entropy?

thank you