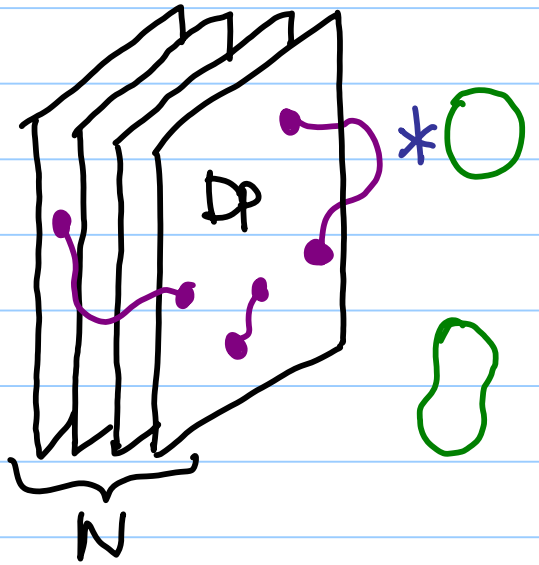
AdS/CFT : a holographic duality

VI MX QG School

Note Title 23/11/2004

Decoupling limit :-
$E\ell_s \to 0$ such that
$(g_{YM}^2 N) E^{p-3}$ is fixed;
$\equiv \lambda(E) = (2\pi)^{p-2} (g_s N) (\ell_s E)^{p-3}$.



Turns off interactions between open & closed strings

Taking the limit simplifies life for open & closed strings:

OPEN	CLOSED
Large-N gauge theory. Use 't Hooft scaling $\Rightarrow$ $\left(\lambda = g_{YM}^2 N \; ; \; \frac{1}{N}\right)$	Lose asymptotically flat part of SUGRA spacetime; get metric $ds^2 = H^{-1/2}\left(-dt^2 K + d\vec{x}_{//}^2\right) + H^{1/2}\left(\frac{dr^2}{K} + r^2 d\Omega_{8-p}^2\right)$
Dimensionless 't Hooft coupling is finite; $\lambda E^{p-3} = (2\pi)^{p-2} (g_s N) (\ell_s E)^{p-3}$	with $H = c_p g_s N \left(\frac{\ell_s}{r}\right)^{7-p}$; $K = 1 - \left(\frac{r_H}{r}\right)^{7-p}$
SU(N) SYM theory	Double perturbation series in $(\alpha' \mathcal{R}, g_s e^{\Phi})$

IMSY : phase diagrams

- For D3, geometry of BPS stack of N D-branes is

$$ds^2 = +\frac{r^2}{R^2}(-dt^2 + d\vec{x}_3^2) + R^2\left(\frac{dr^2}{r^2} + d\Omega_{8-p}^2\right) \qquad R^4 = 4\pi g_s l_s^4$$

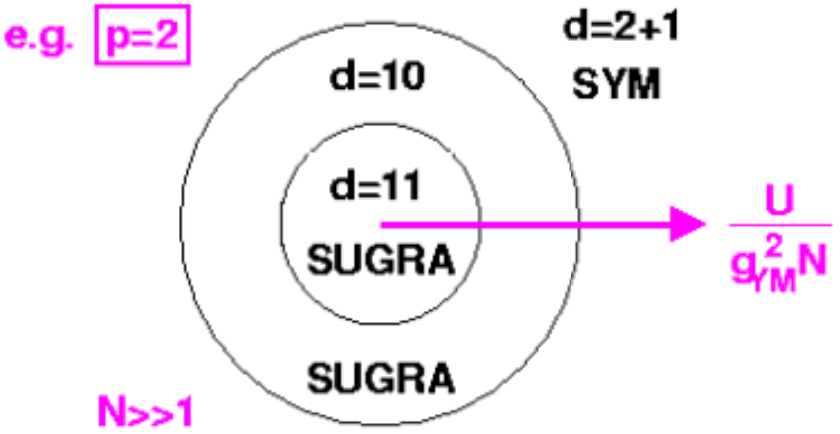
{Poincaré patch of AdS_5} x {S^5}.

Ads/CFT : same system, exactly equivalent degrees of freedom.

DUALITY

- Different situation ensues for Dp, $p \neq 3$. First, SYM theory either super-renormalizable or non-renormalizable. For $p>3$, string theory unambiguously completes theory in UV. For $p<3$, theory strongly coupled in IR (rather than UV)

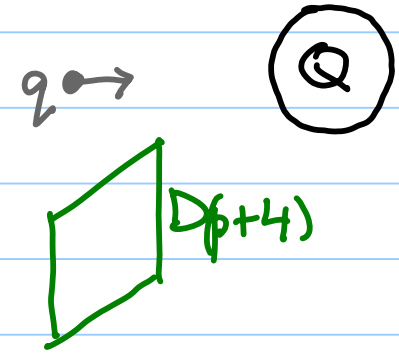
- SYM not valid $\forall E = U \equiv r/l_s^2$;
SUGRA complementary.
$e^{\Phi} \to$ large near $r=0$
$\alpha' R \to$ large as $r \to \infty$
(monotonicity ex decoupling limit)
Resolution of null singularity ☺



Gauge Theory Duals of Gravity Phenomena

- Phenomena where gravity & gauge theory inform <u>each other</u>.

e.g. ① No-hair/CMW duality
Take $D_p \to D(p+4)$:
- Find baldness for $p=0,1$ (power-law; log) but localization possible for $p \geq 2$.



no pimples on horizon

e.g. ② Gregory-Laflamme transition of black brane wrapped on S^1.
- Numerical relativity informs (but not yet settles) endpt debate.
- See phase transition via eigenvalue distribution in large-N field theory in d=1+1 relevant to D-branes.

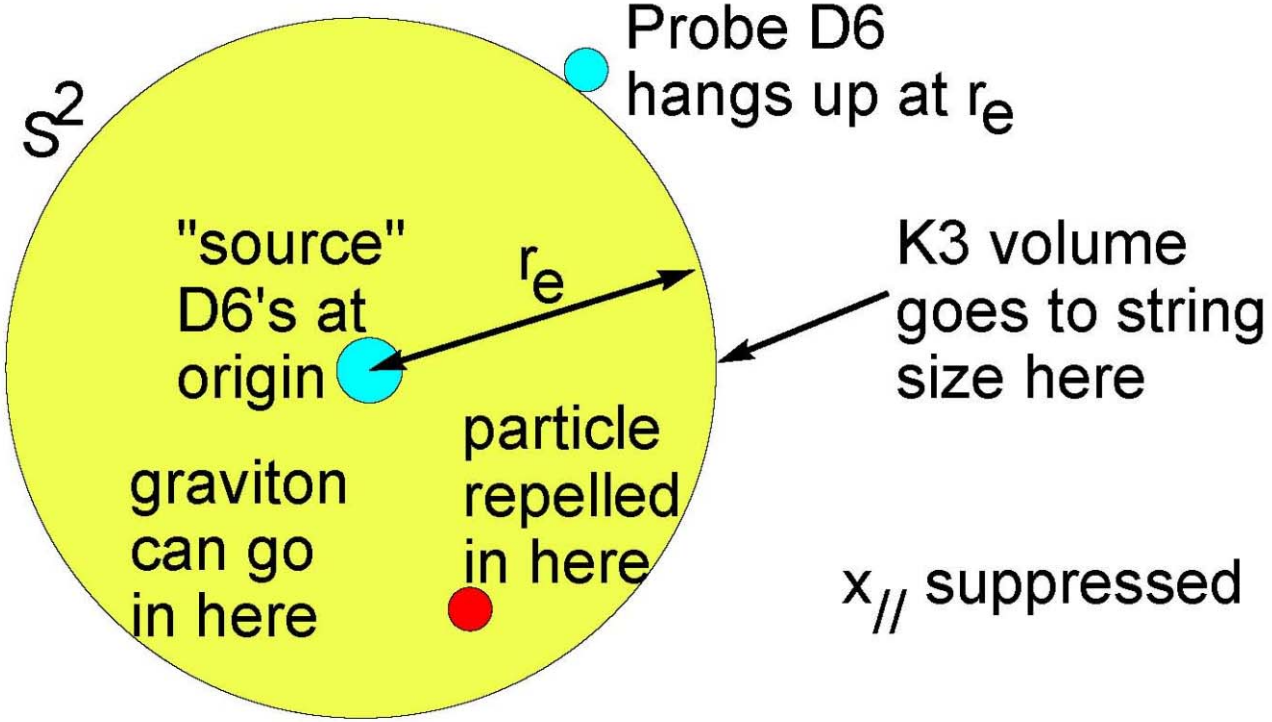
e.g. ③ - Many large-N field theories have (!) a Hagedorn transition even at zero coupling!

e.g. ④ - In-principle resolution of BH information problem.
- Maldacena proposal: eternal BH = $CFT_1 \otimes CFT_2$.

e.g. trying for pure $\mathcal{N}=2$ duality

- Various people tried but failed to take decoupling limit for brane systems with 8 supercharges ($\mathcal{N}=2$ in $d=4$) but no matter/hypermultiplets. Not all SUGRA geometries have weakly coupled dual in region where $\alpha' R \gtrsim 1$, $g_s e^{\Phi} \gtrsim 1$!
- Two dual realizations: D(p+4) on K3; fractional Dp.

- Enhançon mechanism: resolution of timelike naked singularity ("repulson")



- People also turned to deforming AdS/CFT (lots of great work!)

Spacetime Singularity Resolution

- Two ways classical spacetimes break down: curvature singularities and regions of bad chronology (i.e. with CTCs). String theory resolves these in one of two ways:
  - rules them out ab initio: some spacetimes do not <u>have</u> a quantum continuation - figments of classical imagination!;
  - resolves them by fuzzing out pointlike singularity <u>or</u> preventing even strongly curved regions altogether.

- Classical GR singularity theorems inform (note that SUGRA matter fields do not violate WEC) but only classically, and do not apply (as originally derived) with brane action sources $S_{Dp} = -T_p \int d^{p+1}\sigma\, e^{-\Phi}\sqrt{-\det\left(2\pi F_{\alpha\beta} + P(g_{\alpha\beta}+B_{\alpha\beta})\right)} - T_p \int_M e^{2\pi F + B} \wedge \bigoplus_n C_{[n]}$.

- Are sources needed, or are fluxes enough - for AF brane spacetimes?

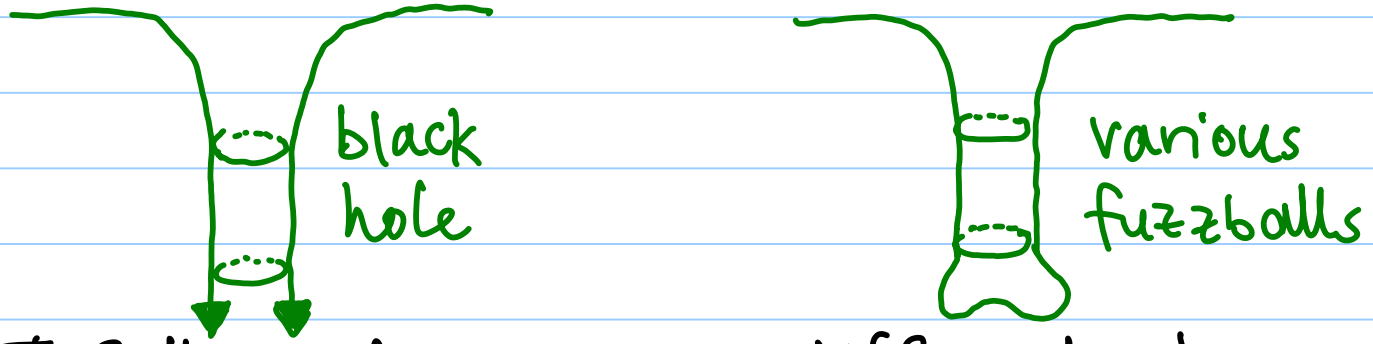
- String theory problems always have <u>precisely</u> specified, unique field content (at least, in $d=10$!) $\Rightarrow$ "S-branes" are for us string theory SDp-branes which are understood in CFT.

Mathur's fuzzball program

- Central proposal: S_{BH} arises because of coarse-graining over microstates — and microstates are geometries with no horizon or singularity or entropy!

- So far, limited class of examples, but intriguing to most string theorists. Doubts regarding generalizability: potential stumbling block is insistence that microstates are valid SUGRA spacetimes. * Toronto group: pert. non-extr.

- All examples so far BPS. Horizon at end of ∞ throat; fuzzballs are effectively capped throats [2-charges; 3-]



- Infalling observer sees different physics than for BH but several aspects (e.g. delay time) work out great.

Unstable D-branes

- Obvious reason why finding these spacetimes is both important -and hard: (several bogus claims/papers in this area exist...)
  - time dependence
  - brane has codimension & $\perp$ directions have r, Ω
  - $\Rightarrow$ at best, trying for solution of PDE's in (t,r)

- Spacetimes with right asymptotics seem to be (generically) singular. Looked at possible resolution via source action, but still singular, apparently.

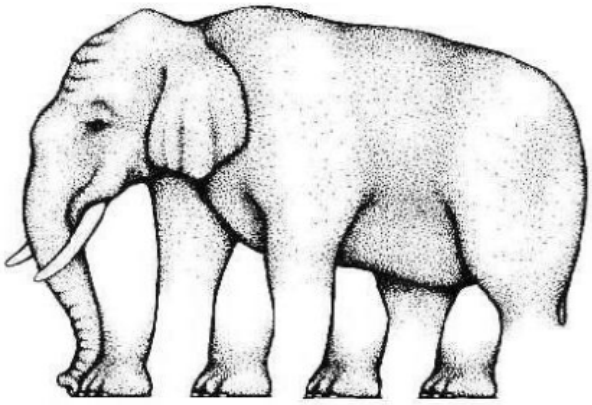
- Sen (et al.) have CFT description (t-dependent) for decay of unstable Dp-branes. Strong indications arising that open string [field] theory has necessary degrees of freedom to describe closed string physics - collective modes...

- If want string theory connection for your "S-brane" spacetime, need
  - precise string theoretic massless fields
  - quantum continuation of spacetime

Take-home messages; & Many Frontiers

- Solid, exciting accounting for BPS BH microstates, beyond leading order. Exact agreement of entropy and greybody factors for near-BPS d=5,4 cases. Qualitative agreement even for far-from-BPS cases – as in Guijosa's work & presentation here. New calculations for BPS black rings also exciting successes.

- Gravity/gauge correspondences = explicit realizations of holography. Closed string theory (SUGRA with corrections) and SYM QFT usefully inform each other. Other stringy examples abound, e.g. BPS black hole entropy ↔ topological string theory ↔ matrix models



←Nonperturbative string theory

String theorists→ (us ☺)

Let's seek more joint triumphs ♥ ♥