Do we live in a hologram ?

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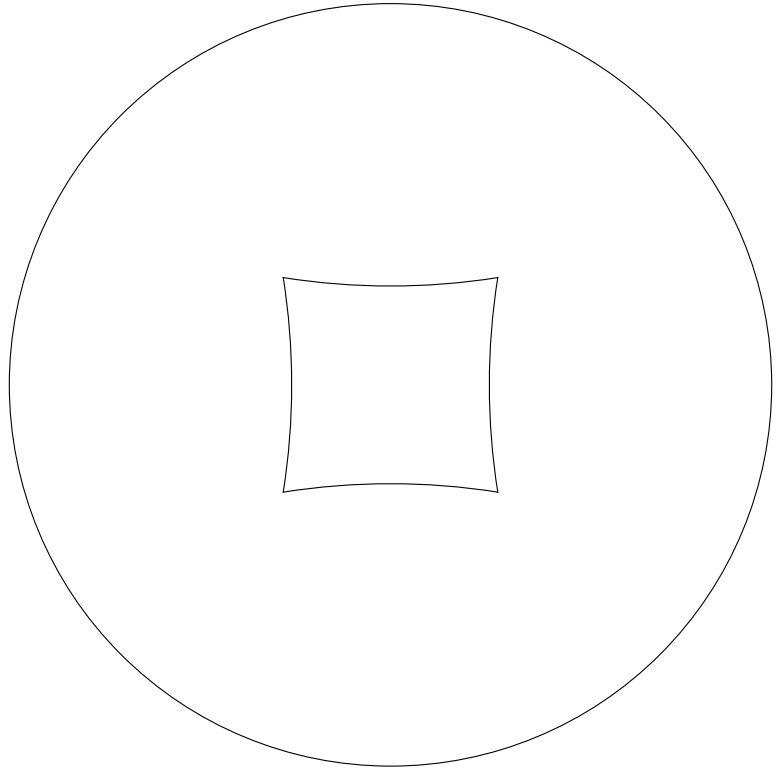
Hyperbolic geometry : the Poincaré Disk



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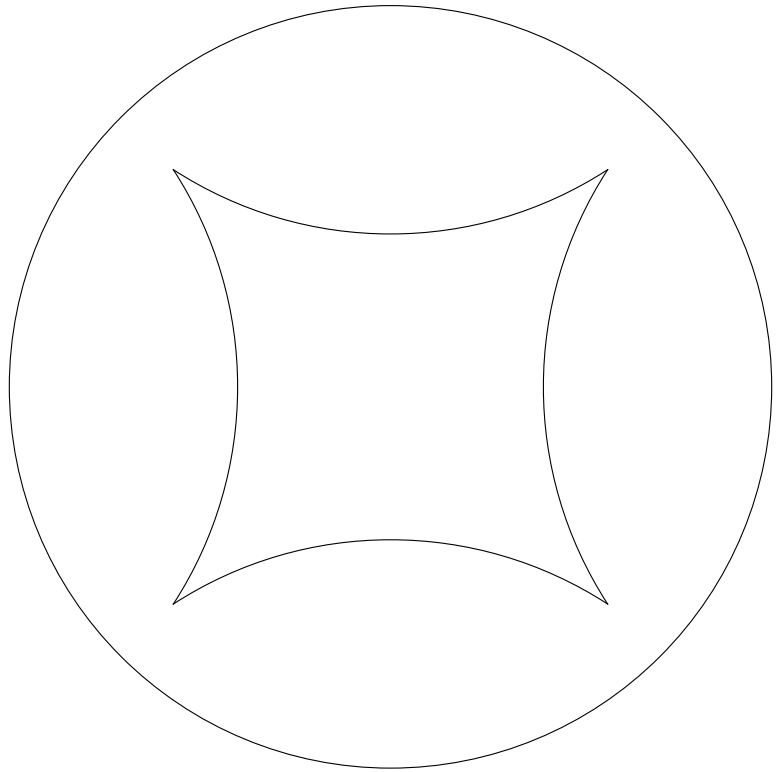

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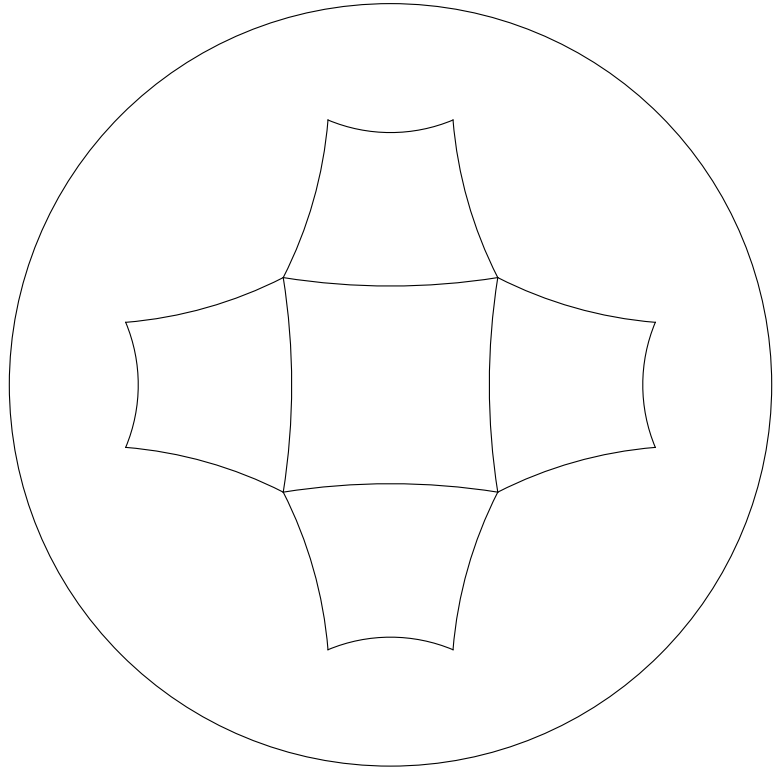

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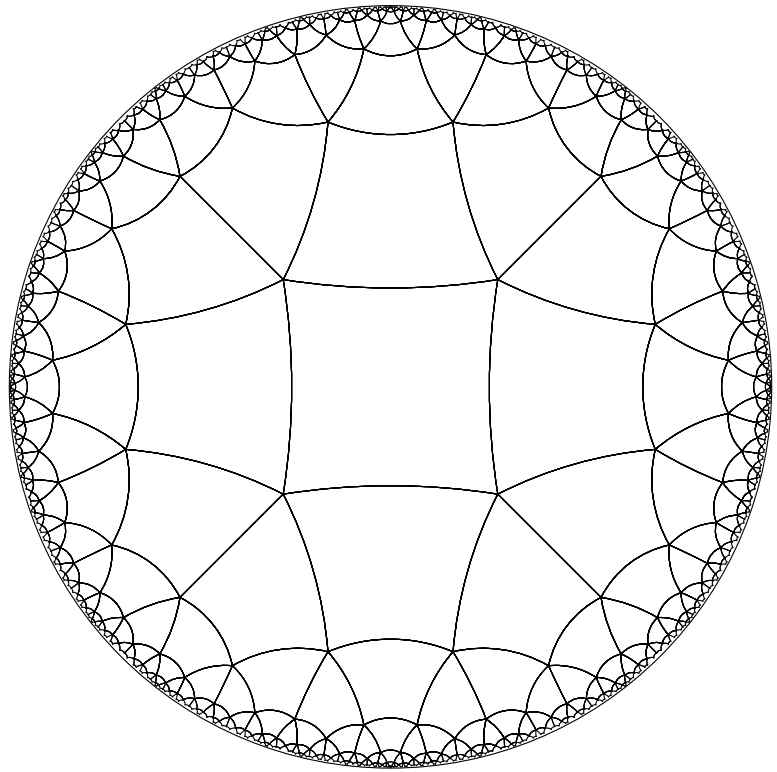

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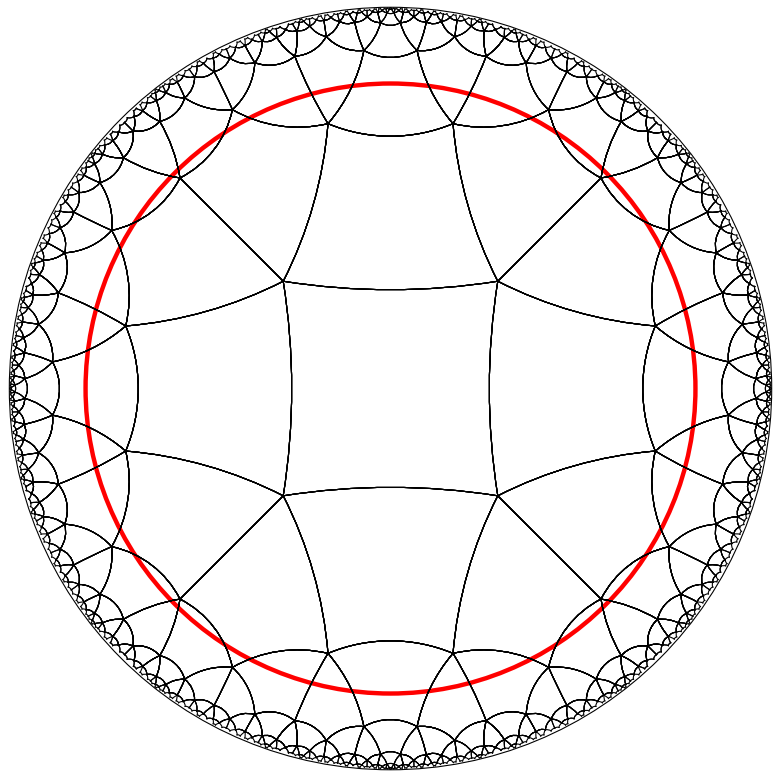
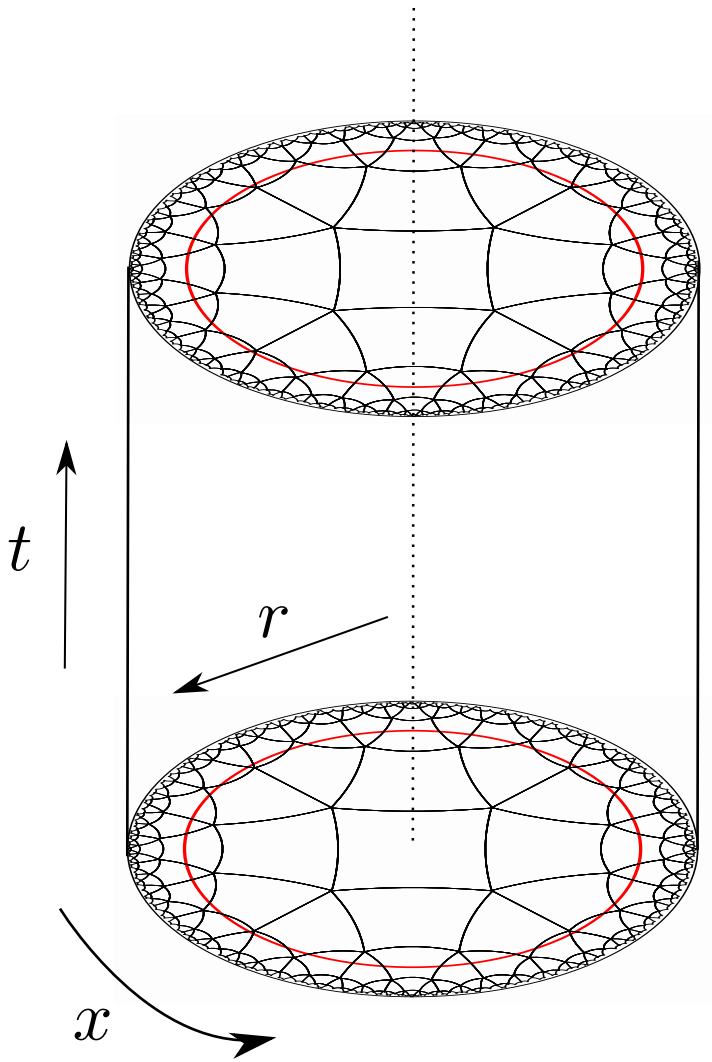


$$\text{Radius} = R = 2\,\mathsf{argth}\,r \tag{1}$$

$$\text{Perimeter} = 2\pi\,\mathsf{sinh}\,R \qquad \text{Area} = 2\pi(\mathsf{cosh}\,R - 1) \tag{2}$$

The Holographic Principle



In hyperbolic space-times (Anti-de Sitter), we could choose to describe reality with two different sets of laws :

- 3 space dimensions with gravity
- 2 space dimensions without gravity

This would give a complete and logically consistent quantum description of gravity.

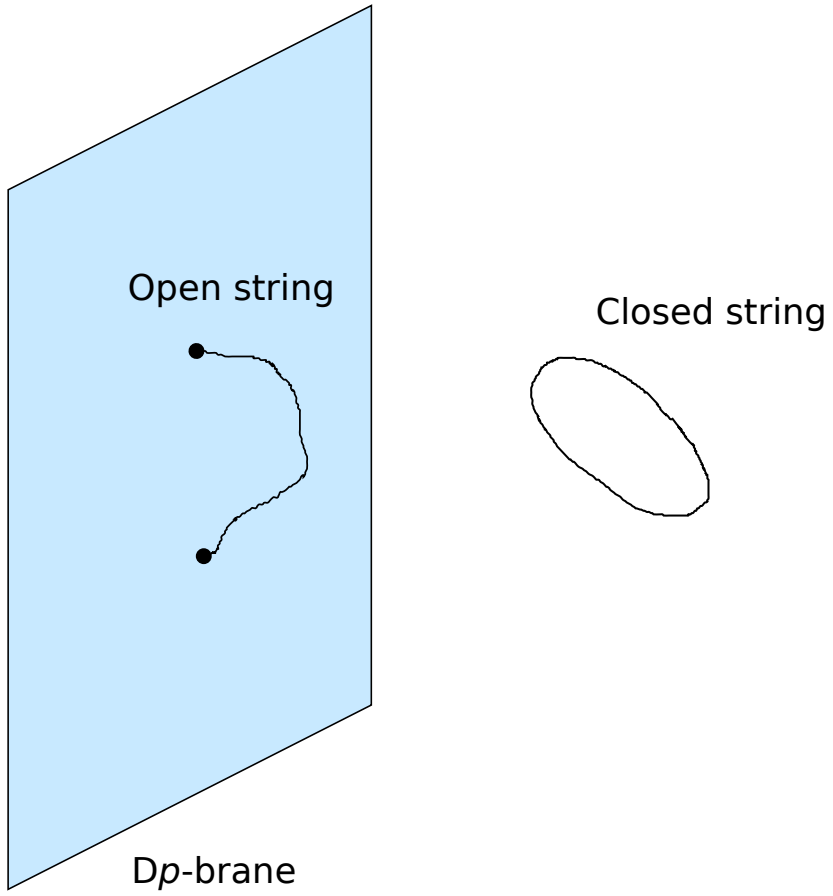
Do we live in a hologram ?

- A crucial aspect of AdS spacetime is that it has a boundary where time is well defined. In an expanding universe which started with a Big Bang, where can we put the boundary theory ?
- What is the spacial curvature of our universe ?
- Mathematical difficulties

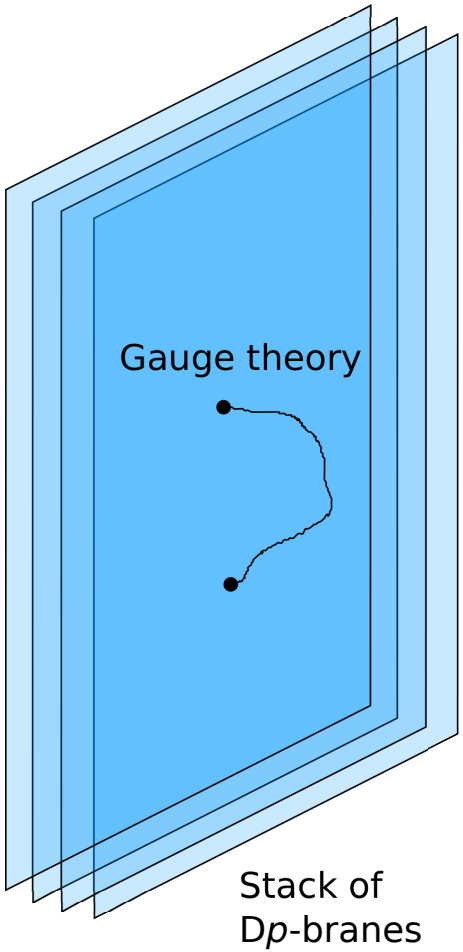
But many other applications !

- Understand better the general properties of gravity
- Shed new light on the physics of strongly coupled systems, for instance in Condensed Matter Theory
- Description of quark-gluon plasma at high energy

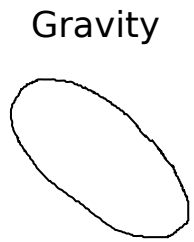
D-branes in string theory



D-branes and gauge theories



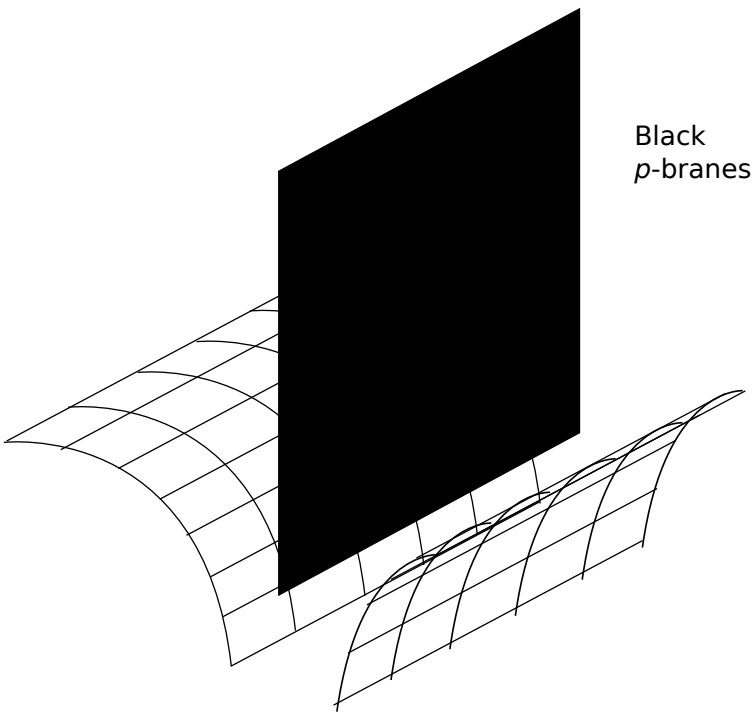
On the worldvolume of a stack of N D3-branes lives a 4-dimensional $SU(N)$ gauge theory at low energy.



The coupling between closed and open strings is controlled by $\lambda = g_s N \ll 1$.
An observer sees two decoupled theories :

- A $SU(N)$ gauge theory from the open strings;
- A (super)gravity theory in flat spacetime from closed strings.

Black branes



Black
p-branes

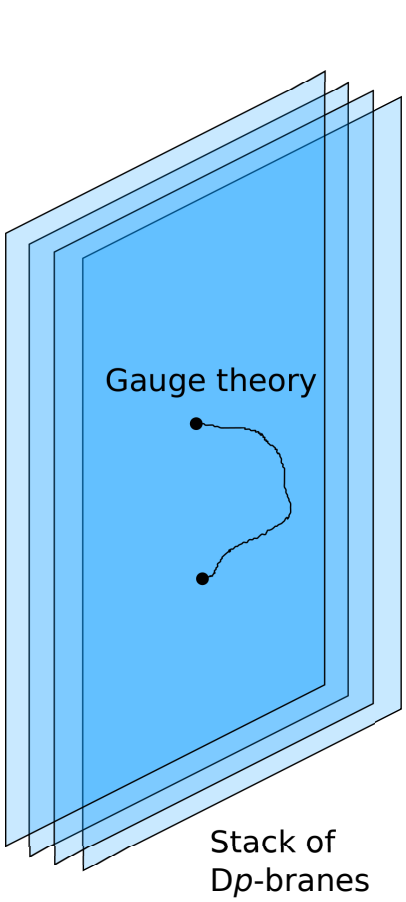
The brane is now very massive and curves spacetime:

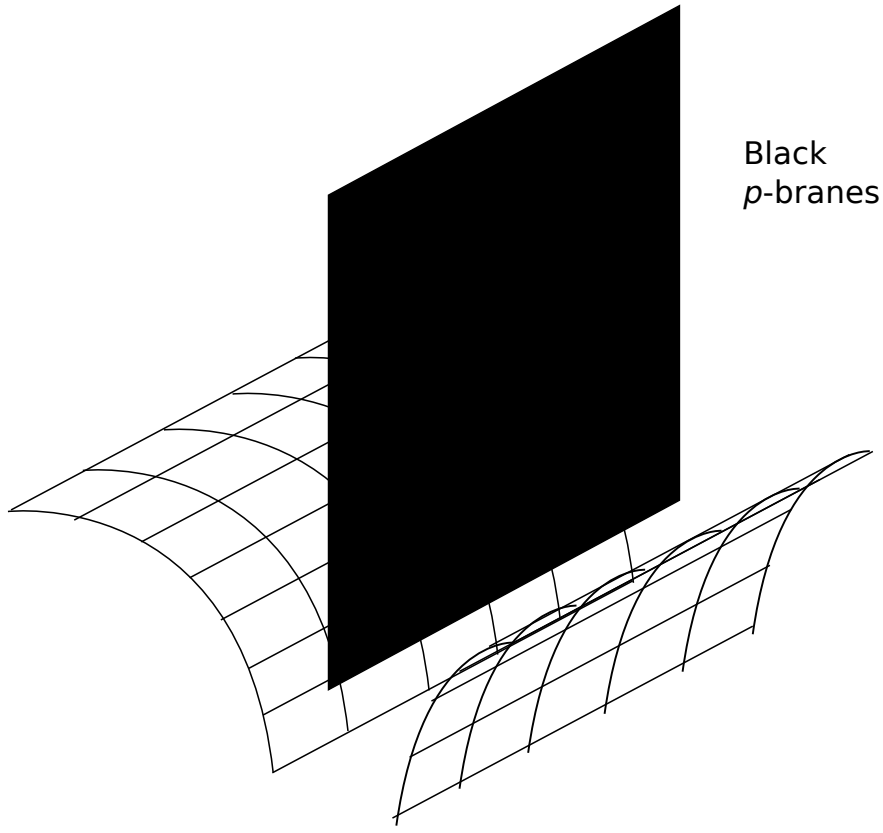
$$\mathrm{d}s^2 = \frac{\eta_{\mu\nu}\mathrm{d}x^\mu \mathrm{d}x^\nu}{\sqrt{1+(L/r)^4}} + \sqrt{1+(L/r)^4}\,\delta_{ij}\mathrm{d}x^i\mathrm{d}x^j$$

An observer at infinity sees two different low-energy modes :

- supergravity modes in flat spacetime;
- string excitations in the throat region which is curved.

AdS/CFT correspondence





$$\begin{bmatrix}\text{Gauge}\\ \text{Theory}\end{bmatrix} \times \begin{bmatrix}\text{Gravity in}\\ \text{Flat space}\end{bmatrix} = \begin{bmatrix}\text{String Theory}\\ \text{on } AdS_5 \times S^5\end{bmatrix} \times \begin{bmatrix}\text{Gravity in}\\ \text{Flat space}\end{bmatrix}$$

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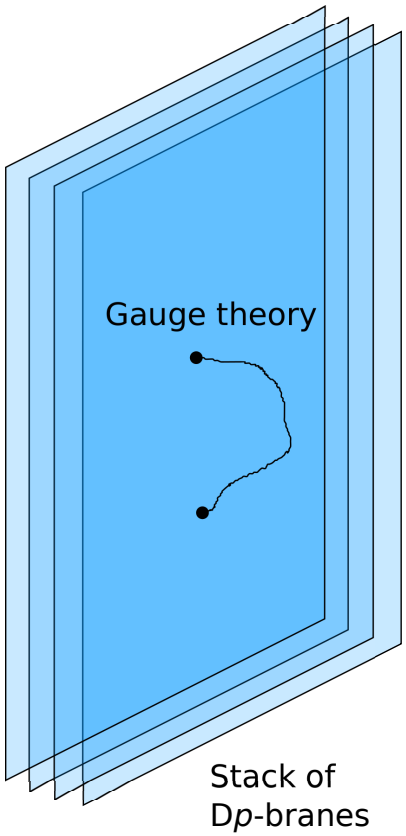

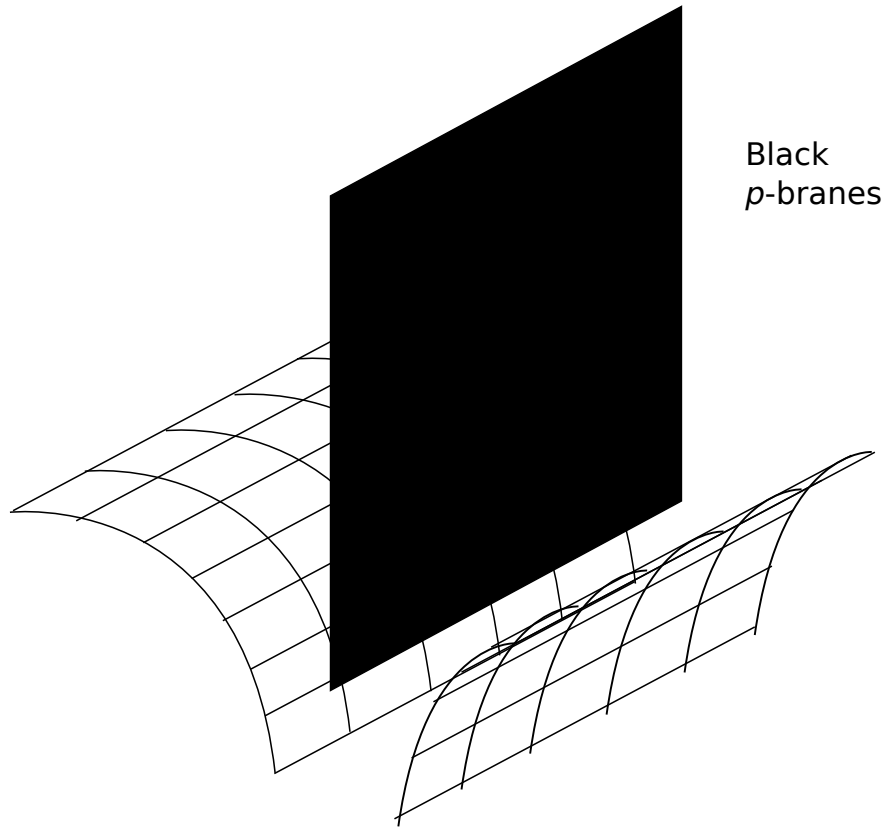

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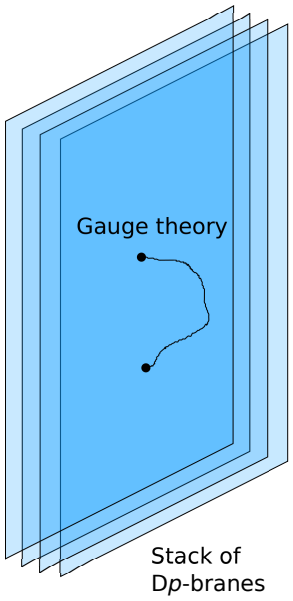
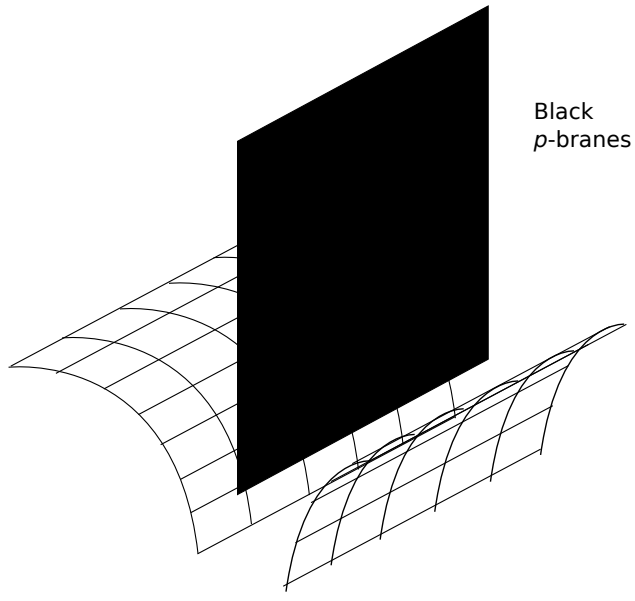


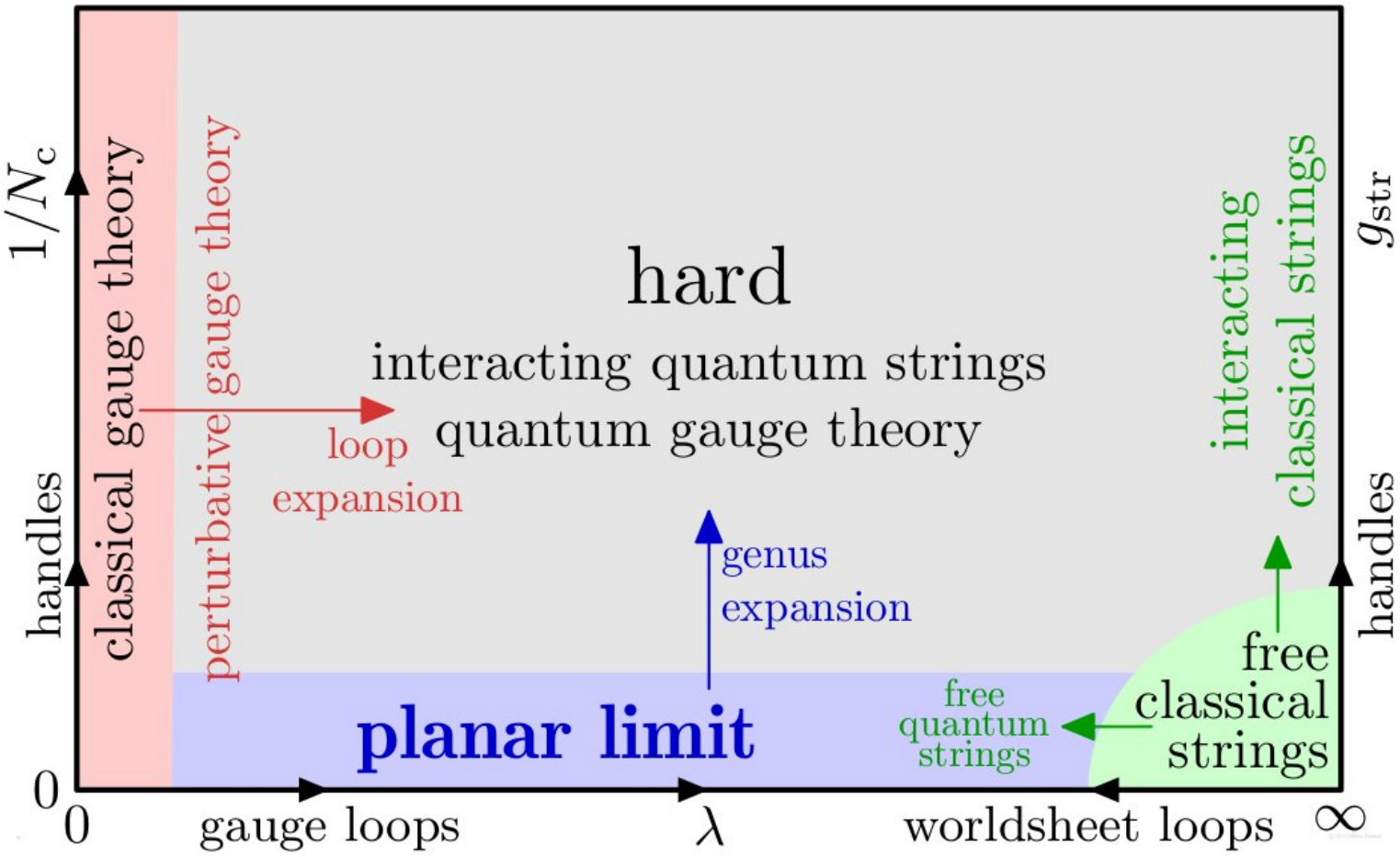


$\mathcal{N} = 4$ Super Yang-Mills theory in 4 dimensions with gauge group $SU(N)$ and coupling constant g_{YM}

Type IIB string theory with string length l_s and coupling constant g_s on $AdS_5 \times S^5$ with radius of curvature L and N units of $F_{(5)}$ flux on S^5

provided we identify the parameters as $g_{YM}^2 = 2\pi g_s$ and $2g_{YM}^2 N = (L/l_s)^4$

AdS/CFT correspondence



(Beisert et al. [1012.3982])

Thank you for your attention !

Questions ?