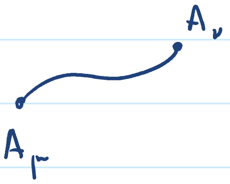
# Gauge theory from open strings, gravity from closed strings

sábado, 26 de noviembre de 2022 16:08

This last lecture will be more descriptive and qualitative, and less detailed.

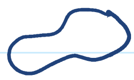
Fundamental strings are one-dimensional objects which can be quantized, and their quantized oscillation modes can be regarded as an infinite set of particles, with a spectrum of masses $\propto$ Tension $\sim \frac{1}{l_s} \sim m_s \sim \sqrt{\alpha'}$.
The properties of these states (eg spin, charges etc) depend on the kind of string.
Of particular interest are the lightest states, which will be massless for susy strings.

Open strings 

have spin-1, gauge vector massless oscillation states

We take the string endpoints to be free, and we impose Neumann bdy conditions.

The endpoints of the string can be assigned a charge, in principle a quantum number of a global symmetry $SU(n)$.
But these charged-endpoints couple to gauge fields $A_\mu$

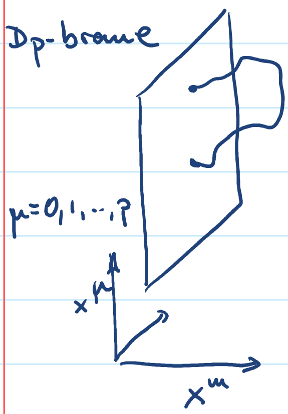
Closed strings 

have a massless spin-2, graviton oscillation state (also a scalar and a 2-form field)

Perturbatively, we describe these as a field $h_{\mu\nu}$

Open and closed strings can also coexist with extended objects called D-branes.

D-branes appear first as hyper-planes at which one imposes Dirichlet bdry conds for open strings ie their endpoints are fixed on them

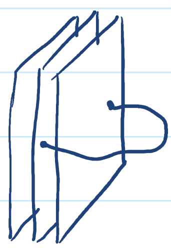



Along the directions of the D-brane we have worldvolume fields $A_\mu$ $\mu=0,1,\dots,p$

In transverse directions we have worldvolume scalars $X_m$ $m=p+1,\dots,D-1$

Conventional open strings in 10D can be viewed as ending on a D9-brane that fills all of spacetime

If there are several Dp-branes stacked on top of each other, then $A_\mu^{ij}$ indicates which branes the string ends on:




$A^{ij} \in SU(N)$

So for N Dp-branes, we have a SU(N) Yang-Mills theory in p+1 dimensions.

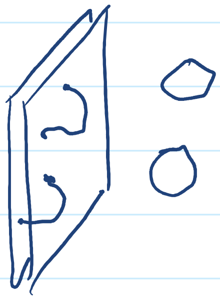
We also have worldvolume scalars $X_m^{ij}$ and fermions $\psi^{ij}$ (ie adjoint-rep)

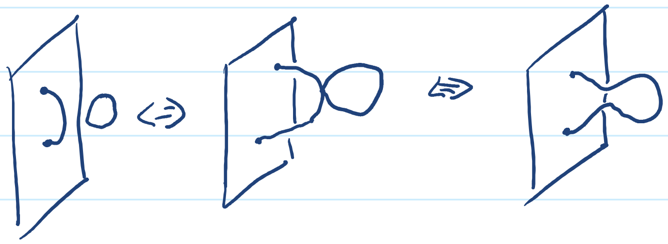
For susy-preserving D-branes, they form a vector supermultiplet and are

described by SU(N) SYM (maximally susy)
+ stringy corrections

There are also closed strings propagating away from the D-branes

In general they interact, joining/recombining





At low enough energies, the two systems decouple and we can isolate the dynamics of the SU(N) SYM gauge theory from that of closed strings (gravitons) propagating away from it.

All of this is a description that is valid for weakly interacting, perturbative strings.

Consider now increasing the string coupling constant, and therefore also the gravitational coupling constant

$$\sqrt{G_N} = g_s \, l_s \qquad \text{(in 4D with string-size extra dims)}$$

Non-linear effects of the gravitons will be more important.

We don't know how to describe full string theory in this case, but if we only consider its massless excitations, it must be a field theory of gravity coupled to other massless fields: dilaton $\phi$, $B_{\mu\nu}$, and other p-form fields $F_{(p)}$ that couple to charges of the same type that susy D-branes can carry.

There aren't the $A_\mu^{ij}$ fields in the worldvolume of Dp-branes: those correspond to open-string modes, while here we're concerned with closed-string modes.

Susy strongly restricts the field content, and requires that these "Ramond-Ramond" p-form fields $F_{(p)}$ are present.

For instance, for Type IIB strings, the effective action is of the form

$$I = \frac{1}{16\pi G} \int d^{10}x \sqrt{-g} \Big[ e^{-2\Phi} \big( \underset{\text{graviton}}{\underset{\downarrow}{R}} + \underset{\text{dilaton}}{\underset{\downarrow}{4(\nabla\Phi)^2}} - \frac{1}{2\cdot 3!} \underset{H_{(3)} = dB_{(2)}}{\underset{\downarrow}{H_{(3)}^2}} \big) \qquad \text{NS-NS (same for all closed strings)}$$

$$- \frac{1}{2\cdot 5!} F_{(5)}^2 + \text{other RR fields} \Big] \qquad \text{R-R}$$

$$+ \text{Chern-Simons terms}$$

$$+ \text{fermions}$$

with $F_{(5)} = * F_{(5)}$

$16\pi G = (2\pi)^7 g_s^2 \ell_s^8$

ie $\ell_p^8 \sim g_s^2 \ell_s^8 \qquad \ell_p^4 \sim g_s \ell_s^4$

This is a "supergravity action" that describes the non-linear dynamics of closed strings at energies $\ll m_{string}$