Standard compactification

$$ds^2 = dx_4^2 + \overset{\text{CY CFT}\ldots}{g_{mn}(y)}\, dy^m dy^n$$

Warped

~~Standard~~ compactification

$$ds^2 = e^{2A(y)} dx_4^2 + g_{mn}(y)\, dy^m dy^n$$

~~CY, CFT...~~

"Warp factor"

Motivations

- Most general Poincaré invariant possibility
- Branes/brane worlds $\longrightarrow$ warping
- Fluxes $\longrightarrow$ warping

  moduli fixing
- Richer phenomenology - more scales

  e.g. TeVG
- New approaches to ~~SUSY~~

Outline

1. W.C. Ingredients
2. Phenomenology 101: geometric scales

   M_P, M_4, M_{scalar}, M_{BH}, M_{KK} ...

3. Phenomenology 102: dynamical scales

   $M_{\cancel{SUSY}}$, M_{moduli}, ...

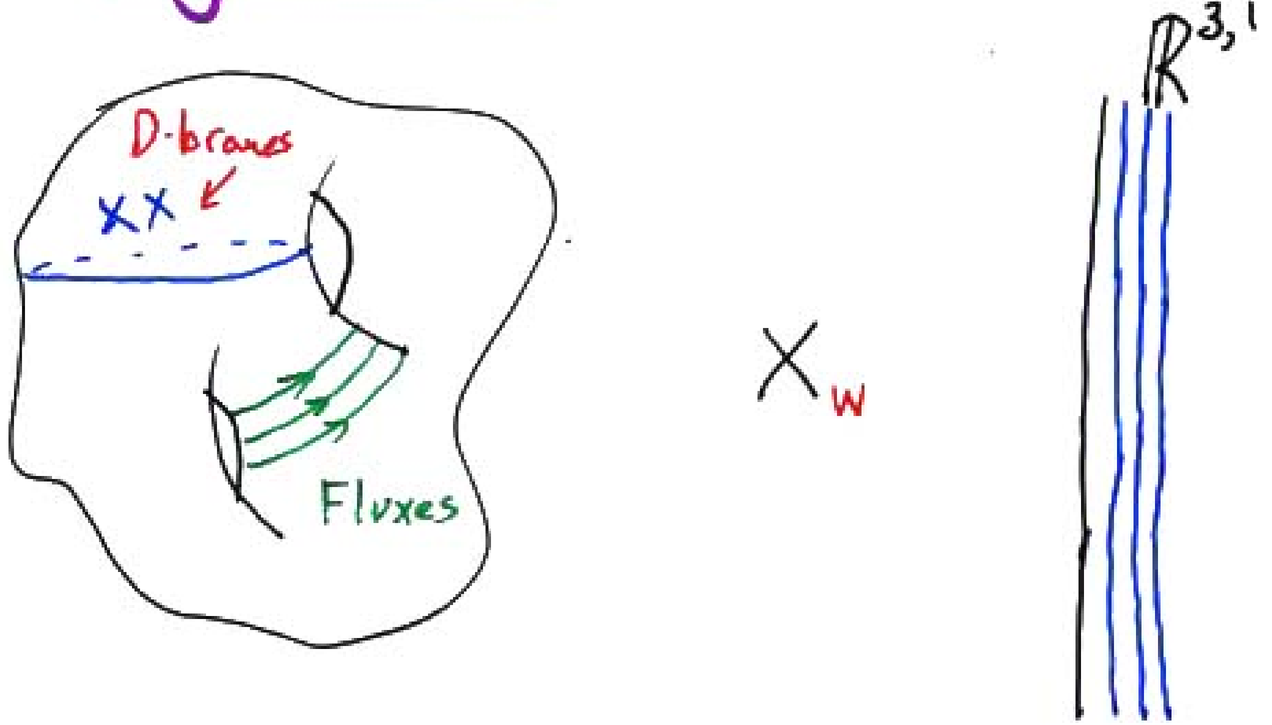
4. Example: IIB solutions (SG, Kachru, Polchinski)

   A. Structure
   B. Kahler & superpotentials
   C. Hierarchy
   D. ~~SUSY~~

w/ O. DeWolfe (to appear)

also see S. Kachru's talk

Ingredients



$$ds^2 = e^{2A} dx_4^2 + g_{mn}(y)\, dy^m dy^n$$

- Spacefilling branes

IIB : D3, D7, D9 ; (p,q)5

IIA : D4, D6, D8, NS5

M : M5

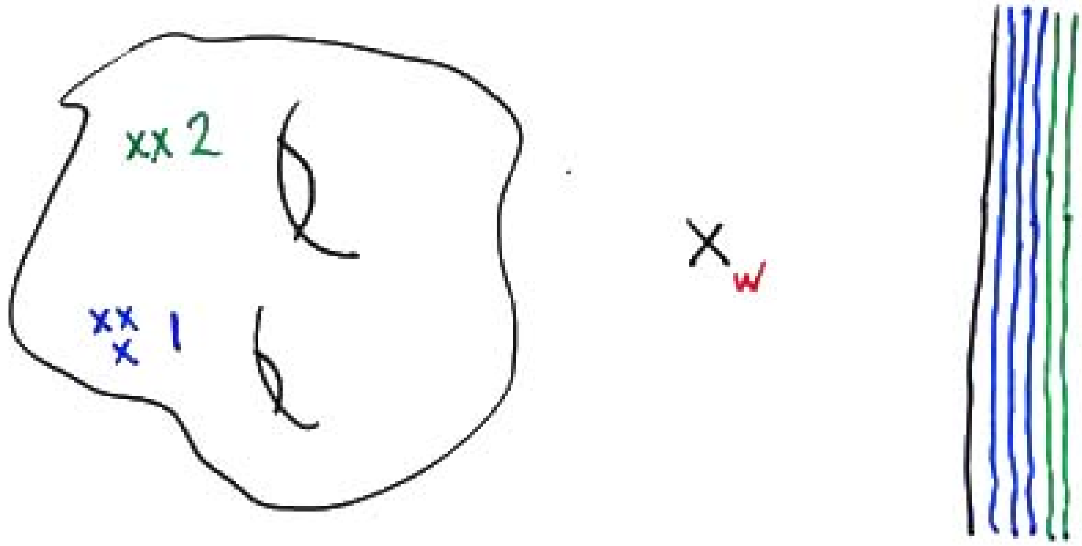
- Fluxes

IIB : $F^1_m(y)$, $F^3_{mnp}(y)$, $F^5_{mnpqr}(y)$; $H_{mnp}(y)$, $\phi(y)$

IIA : $F^2_{mn}(y)$, $H_{mnp}(y)$, ...

M : $G_{mnpq}(y)$

Phenomenology 101: Geometric scales/thresholds



$$ds^2 = e^{2A} dx_4^2 + g_{mn} dy^m dy^n$$

<u>Fundamental Planck; String</u> $\quad M_p \sim g_s^{-1/4}/\sqrt{\alpha'}$

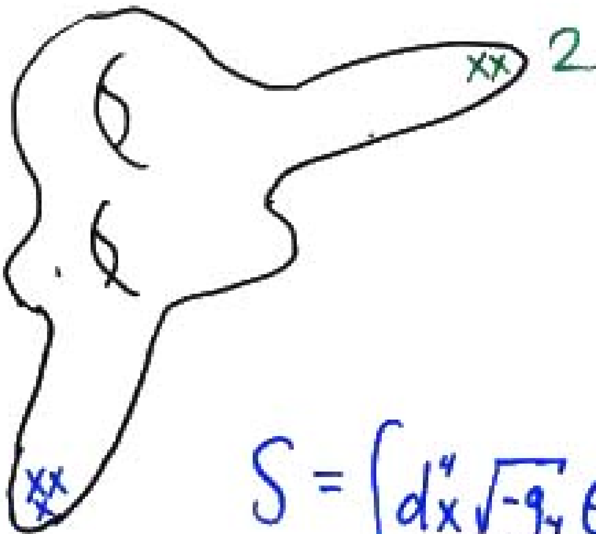
<u>4d Planck</u>

$$S = M_p^8 \int d^{10}x \sqrt{-g}\, R \sim M_p^8 \int d^6y \sqrt{g_6}\, e^{2A} \int d^4x \sqrt{-g_4}\, R_4$$

$$\Rightarrow \quad \boxed{\frac{M_4^2}{M_p^2} = M_p^6 \int d^6y \sqrt{g_6}\, e^{2A} \equiv M_p^6 V_w}$$

~ 1 ? "Warped volume"

Brane matter: masses



$$S = \int d^4x \sqrt{-g_4}\, e^{4A_1} \left[e^{-2A_1} (\nabla\phi)^2 + M_p^2 \phi^2 \right]$$

natural scale (loops ...)

$\Rightarrow$

$$M_1 \sim e^{A_1} M_p$$

$$M_2 \sim e^{A_2} M_p$$

... **different scales;**

if $e^{A_1} \ll 1 \Rightarrow$ **hierarchy** ($\sim$ RS)

Complementary viewpoint:

$$M_1 \sim e^{A_1} M_p$$

Weyl symmetry:

$$g \to \lambda^2 g \; ; \; \phi \to \frac{\phi}{\lambda} \; ; \; M \to \frac{M}{\lambda} \; ; \; \ldots$$

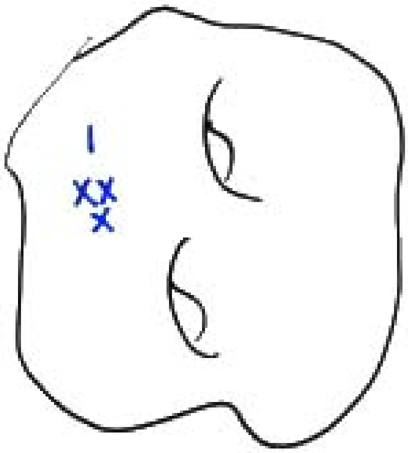
$\rightsquigarrow$ choose $\underline{A_1 = 0}$; e.g. $M_p \sim 1\,\mathrm{TeV}$;

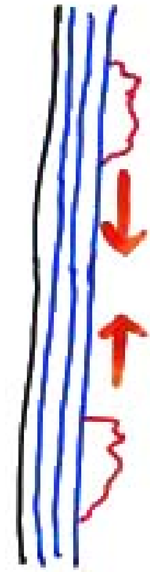
then:

$$\frac{M_4^2}{M_p^2} \sim M_p^6 \int d^6y \sqrt{g_6}\, e^{2A} \gg 1$$

~ large extra dimensions

Black holes; strings





$$E \sim M_p \sim 1\,\text{TeV?}$$

... black hole threshold

(cf S.G. & E. Katz ; S.G. & S. Thomas ; Dimopoulos & Landsberg ...)

$E \sim g_s^{1/4} M_p$ ... string threshold

KK Modes

L ... proper geometrical scale < curvature, radii

$$M_{KK} \sim \frac{1}{L}\, e^{A}$$

e.g. AdS region @ 1 : $M_{KK} \sim \frac{1}{R} \cdot 1$

$$1 = e^{A},$$

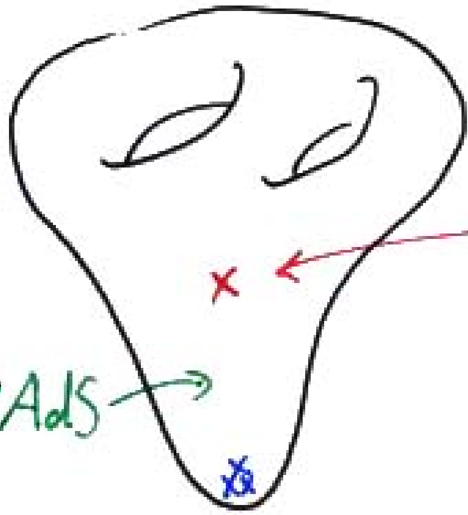
Phenomenology 102: Dynamical Scales

- SUSY breaking
- Moduli masses

⋮

~~SUSY~~ : if hidden sector, generically

$$m_{3/2} \sim \frac{\Lambda^2_{susy}}{M_4}$$



$$\Lambda_{susy} \sim e^{A_{susy}} \Lambda^{proper}_{susy}$$

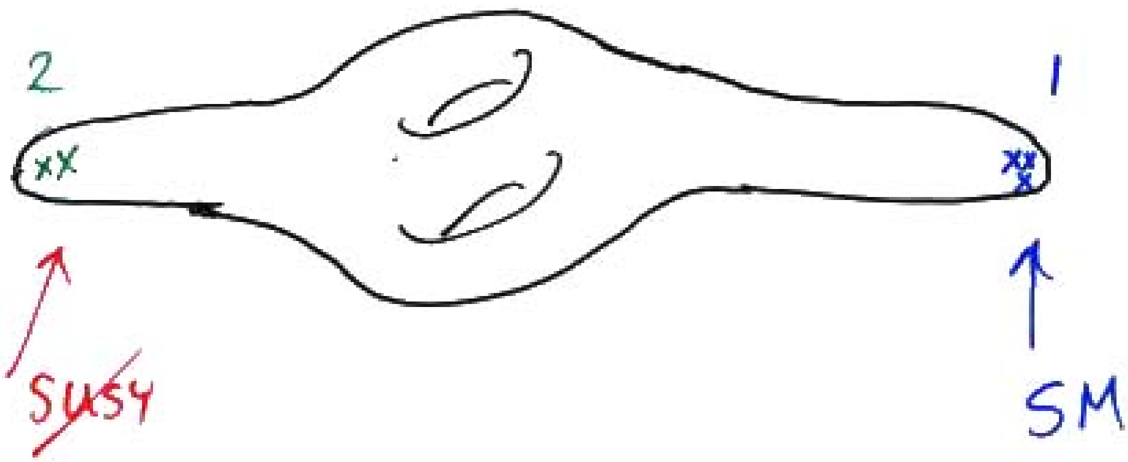
expect $\Lambda^{proper}_{susy} \lesssim M_p$

... Wide range of possible scales

but, note:

- if $A_{susy} = 0$, $m_{3/2} \sim \frac{M_p^2}{M_4} \sim 10^{-4}\,eV$
- gauge mediated scenarios don't work ?

Alternately,



$$m_{3/2} \sim \frac{e^{2A_2} M_p^2}{M_4}$$

(Stabilization ? ...)

But, also sometimes

$$m_{\text{spartner}} \neq m_{3/2}$$

Example (SG, Kachru, Polchinski)

• IIB: general Poincaré invt. solution:

$$ds^2 = e^{2A(y)} dx_4^2 + g_{mn}(y)\, dy^m dy^n \qquad m,n = 1,\dots,6$$

$$\tau = C_0 + i\, e^{-\phi} = \tau(y)$$

$$G_3 = F_3 - \tau H_3 = G_{mnp}(y)\, dy^m dy^n dy^p$$

$$\tilde{F}_5 = (1+*)\, \partial_m \alpha(y)\, dy^m \wedge dx^0 \wedge dx^1 \wedge dx^2 \wedge dx^3$$

D3   D5   D7   D9   NS5

Assumption 1   ↑ (D3)   ↑ (D7)

Assumption 2: $\quad T_{D3} \geq \rho_{D3}$ (e.g. O3's allowed)

$\Rightarrow$ Special class of ~"BPS" solutions

• $G_3 = i *_6 G_3$

• $e^{4A} = \alpha$

• $g_{mn} = e^{-2A} g_{mn}^{CY}$ ← or F-thy, if D7's

also, • $N_{D3} \propto \int_M F_3 \wedge H_3$

CY: moduli $\quad h_{1,1}$ Kahler

$h_{2,1}$ Complex

$G \rightsquigarrow$ potential

$$V = \frac{1}{2\kappa_4^2} e^{\mathcal{K}} \left(G^{a\bar{b}} D_a W \overline{D_b W} - 3|W|^2 \right)$$

$\mathcal{K} = ?$

$W = ?$

needed for phenomenology

No warping:

CY holo 3 form

$$W = W_{GVW} = \int_{\mathcal{M}_6} \Omega \wedge G_3$$

$$\mathcal{K} = -\ln\left(-i \int_{\mathcal{M}_6} \Omega \wedge \bar{\Omega}\right) - 3\ln\left[-i(\rho - \bar{\rho})\right]$$

Volume modulus (Kahler)