

Title: Warped Heterotic Axions

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Abstract: TBA

WARPED IET AXION.

RHIANNON GWYN.

HASSAN FIRO

WARPED IET AXION.

- RHIANNON GWYN.

- HASSAN FIRDOUZJAH

WARPED HET AXION

- RHIANNON GWYN.
- HASSAN FIRDUZ.

$$0 \int d^4x \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$$

D HET AXION

NNON GWYN.

AN FIROUZJAH

$$\theta \int d^4x \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$$

$$= \theta \int F \wedge F.$$

D HET AXION

$$\theta \int d^4x \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$$

$$= \theta \int F \wedge F$$

$\theta = \text{angular parameter}$

NNON C

AN FIB

h

AXION

$$\theta \int d^4x \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$$

$$= \theta \int F \wedge F$$

$\theta = \text{angular parameter}$

$$\theta \sim 10^{-6}$$

axion: a

$$\int a F \wedge F$$

$$a \rightarrow a + \text{const.}$$

DN

$$\theta \int d^4x \epsilon^{\mu\nu\rho\sigma} F_{\mu\nu} F_{\rho\sigma}$$

$$= \theta \int F \wedge F$$

$\theta = \text{angular parameter}$

$$\theta \sim 10^{-6}$$

axion: a

$$\int a F \wedge F$$

$$a \rightarrow a + \text{const.}$$

axion in string theory
is very natural.

antisym tensor $B_{\mu\nu}$.

$$\int H \wedge *H$$

$$*H = da.$$

$$\int da \wedge *da.$$

antisym tensor $B_{\mu\nu}$.

$$\int H \wedge * H$$

$$* H = da.$$

$$\int da \wedge * da.$$

ishy

antisym tensor $B_{\mu\nu}$.

$$10^9 \text{ GeV} < f_a < 10^{12} \text{ GeV}.$$

$$\int H \wedge *H$$

$$*H = da.$$

$$\int da \wedge *da.$$

antisymmetric tensor $B_{\mu\nu}$.

$$\int H \wedge *H$$

$$*H = da.$$

$$\int da \wedge *da.$$

$$10^9 \text{ GeV} < f_a < 10^{12} \text{ GeV}.$$

Svrcek - Witten.

antisym tensor $B_{\mu\nu}$.

$$\int H \wedge * H$$

$$* H = da.$$

$$\int da \wedge * da.$$

$$10^9 \text{ GeV} < f_a < 10^{12} \text{ GeV}.$$

String - Witten.

Heterotic theory.

$$g_{\mu\nu}, B_{\mu\nu}, \phi.$$

antisym tensor $B_{\mu\nu}$.

$$\int H \wedge * H$$

$$* H = da.$$

$$\int da \wedge * da.$$

$$10^9 \text{ GeV} < f_a < 10^{12} \text{ GeV}.$$

String - Witten.

Heterotic theory.

$$g_{\mu\nu}, B_{\mu\nu}, \phi.$$

$$A_{\mu}^a \quad SO(\infty), E_8 \times E_8$$

$f_a < 10^{12} \text{ GeV}$.

ov - Witten

theory

M, ϕ

$SO(32)$

Γ_8

$$S = \frac{1}{2\kappa^2} \int d^{10}x \sqrt{g} \left[R + \partial_m \phi \partial^m \phi - \frac{1}{12} e^{-\phi} H^2 - \frac{\alpha'}{4} \text{Tr} F^2 \right]$$

$$\text{Tr} F^2 = \kappa F \wedge * F = \sum_{\mu, \nu} F_{\mu\nu}^2$$

10^{12} GeV.

Witten.

$$S = \frac{1}{2k^2} \int d^{10}x \sqrt{g} \left[R + \partial_m \phi \partial^m \phi - \frac{1}{12} e^{-\phi} H^2 - \frac{\alpha'}{4} \text{Tr} F^2 \right]$$

$$\text{Tr} F^2 = \frac{1}{2} F \wedge * F = \sum_{\mu, \nu} F_{\mu\nu}^2 F^{\mu\nu}$$

$$H^2 = H \wedge * H.$$

$F_8 \times E_8$

10^{12} GeV.

Witten.

theory

ϕ

$$S = \frac{1}{2\kappa^2} \int d^{10}x \sqrt{g} \left[R + \partial_m \phi \partial^m \phi - \frac{1}{12} e^{-\phi} H^2 - \frac{\alpha'}{4} \text{Tr} F^2 \right]$$

$$\text{Tr} F^2 = \text{Tr} F \wedge * F = \sum_a F_a^\mu F_a^\nu$$

$$H^2 = H \wedge * H$$

$$H \neq 0 = \left[\frac{1}{2} R R R - \frac{\text{Tr}}{30} F \wedge F \right]$$

12 GeV .

then

only

$(2), E_6 \times E_8$

$$S = \frac{1}{2\kappa^2} \int d^{10}x \sqrt{g} \left[R + \partial_\mu \phi \partial^\mu \phi - \frac{1}{12} e^{\frac{2\phi}{\sqrt{3}}} H^2 - \frac{\alpha'}{4} F^2 \right]$$

$$F^2 = F_{\mu\nu} \wedge F^{\mu\nu} = \sum_{\mu, \nu} F_{\mu\nu}^2$$

$$H^2 = H_{\mu\nu\rho} \wedge H^{\mu\nu\rho}$$

$$dH \neq 0 = \left[\frac{1}{2} R \wedge R - \frac{T_0}{30} F \wedge F \right]$$



$$\int d^10 x \sqrt{-g} R.$$

$$\int d^4x \sqrt{-g} R.$$

BACKGROUND:

$$ds^2 = h_{\mu\nu} g_{\mu\nu} dx^\mu dx^\nu$$

$$+ g_{mn} dy^m dy^n$$

$$\int d^10 x \sqrt{-g} R.$$

BACKGROUND:

$$ds^2 = h_{\mu\nu} dx^\mu dx^\nu + g_{mn} dy^m dy^n$$

$$\frac{1}{2k^2} \int d^{10}x \sqrt{-g} R$$

$$\rightarrow \frac{1}{2k^2} \int d^4x \sqrt{-\bar{g}} \bar{R} \int d^6y \sqrt{g(y)} h^2(y)$$

BACKGROUND:

$$ds^2 = h_w^2 \bar{g}_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{(6)} dy^m dy^n$$

$$k^2 = (2\pi\sqrt{\alpha'})^8 = M_s^{-8}$$

$$\frac{1}{2k^2} \int d^{10}x \sqrt{-g} R$$

BACKGROUND:

$$g_{\mu\nu} dx^\mu dx^\nu$$

$$g_{mn} dy^m dy^n$$

$$\rightarrow \frac{1}{2k^2} \int d^4x \sqrt{-g} \bar{R} \int d^6y \sqrt{g(y)} h^2(y)$$

$$k^2 = (2\pi\sqrt{\alpha'})^8 = M_s^{-8}$$

$$\boxed{\frac{1}{2k^2} \int d^6y \sqrt{g(y)} h^2 \equiv M_p^2}$$

$$\frac{1}{2k^2} \int d^{10}x \sqrt{-g} R$$

$$\rightarrow \frac{1}{2k^2} \int d^4x \sqrt{-g} \bar{R} \int d^6y \sqrt{g_6} h_6^2(y)$$

BACKGROUND:

$$ds^2 = h_6^2 \bar{g}_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{(6)} dy^m dy^n$$

H_6

$$k^2 = (2\pi\alpha')^8 = M_5^{-8}$$

$$\boxed{\frac{1}{2k^2} \int d^6y \sqrt{g_6} h_6^2 = M_P^2}$$

$$M_P^2 \int d^4x \sqrt{-g} \bar{R}$$

$$\rightarrow \frac{1}{2k^2} \int d^4x \sqrt{-g} \bar{R} \int d^4y \sqrt{g(y)} h^2(y)$$

$$k^2 = (2\pi f_{pl})^2 = M_{pl}^{-2}$$

$$\boxed{\frac{1}{2k^2} \int d^4y \sqrt{g(y)} h^2 = M_{pl}^2}$$

$$M_{pl}^2 \int d^4x \sqrt{-g} \bar{R}$$

$$\frac{1}{2k^2} \int d^{10}x \delta^p H \wedge * H$$

$$\propto \sqrt{-g} \bar{R} \int d^6 y \sqrt{g(y)} h^2(y)$$

$$\frac{1}{2k^2} \int d^{10} x \delta^p H \wedge * H$$

$$(2\pi\alpha')^8 = M_5^{-8}$$

$$\int d^6 y \sqrt{g(y)} h^2 =$$

$$M_5 \times \sqrt{g} \bar{R}$$



CAUTION
 DO NOT TOUCH THE BOARD WHEN
 IT IS BEING USED BY OTHERS
 AND PLEASE KEEP IT CLEAN

$$\int_{\mathbb{R}^D} d^D y \sqrt{g(y)} h^2(y)$$

$$g = M_S^{-2}$$

$$h^2 = M$$

\mathbb{R}^D

$$\frac{1}{2\kappa^2} \int d^{10} x \sqrt{-g} H \wedge * H$$

$$= \frac{1}{2\kappa^2} \int d^4 x H \wedge * H$$

$$\bar{R} \int d^6 y \sqrt{g(y)} h_{10}^2(y)$$

$$) = M_s^{-8}$$

$$) h_{10}^2 \equiv M_p^2$$

\bar{R}

$$\frac{1}{2\kappa^2} \int d^{10} x e^{-\phi} H \wedge * H$$

$$= \frac{1}{2\kappa^2} \int d^4 x H \wedge * H \otimes \int$$

$$\int d^6 y \sqrt{g(y)} e^{-\phi} h_{10}^{-2}$$

$$\bar{R} \int d^6 y \sqrt{g_6} h_0^2(y)$$

$$) = M_s^{-8}$$

$$) h_0^2 \equiv M_p^2$$

\bar{R}

$$\frac{1}{2\kappa^2} \int d^{10} x e^{-\phi} H \wedge * H$$

$$= \frac{1}{2\kappa^2} \int d^4 x H \wedge * H \otimes \int$$

$$\int d^6 y \sqrt{g_6} e^{-\phi} h_0^{-2}$$

$$\beta = \frac{\int d^6 y \sqrt{g_6} e^{-\phi} h_0^2}{\int d^6 y \sqrt{g_6} h_0^2}$$

$$\sqrt{g(y)} h_w^2(y)$$

$$\frac{1}{2\kappa^2} \int d^{10}x e^{-\phi} H \wedge * H$$

$$= \frac{1}{2\kappa^2} \int d^4x H \wedge * H \otimes \int$$

$$\int d^6y \sqrt{g(y)} e^{-\phi} h_w^{-2}$$

$$\beta = \frac{\int d^6y \sqrt{g(y)} e^{-\phi} h_w^2}{\int d^6y \sqrt{g(y)} h_w^2}$$

$$\int d^6y \sqrt{g(y)} h_w^2$$

$$M_P^2$$

$$\frac{1}{2k^2} \int d^{10}x \sqrt{-g} R$$

$$\rightarrow \frac{1}{2k^2} \int d^4x \sqrt{-g} \bar{R} \int d^6y \sqrt{g(y)}$$

BACKGROUND:

$$g_{\mu\nu} dx^\mu dx^\nu$$

$$g_{mn} dy^m dy^n$$

$$k^2 = (2\pi\alpha')^8 = M_s^{-8}$$

$$\boxed{\frac{1}{2k^2} \int d^6y \sqrt{g(y)} h^2 = M_p^2}$$

$$S_1 = M_p^2 \int d^4x \sqrt{-g} \bar{R}$$

$$S_2 =$$

BACKGROUND:

$$ds^2 = h_{\mu\nu} \bar{g}^{\mu\nu} dx^\mu dx^\nu + g_{mn}^{(6)} dy^m dy^n$$

H_{10}

$$k^2 = (2\pi\sqrt{\alpha'})^8 = M_s^{-8}$$

$$\frac{1}{2k^2} \int d^6y \sqrt{g_{(6)}} h_{\mu\nu}^2 \equiv M_p^2$$

$$S_1 = M_p^2 \int d^4x \sqrt{|g|} R$$

$$S_2 = \beta M_p^2 \int d^4x H \wedge * H$$

$$R \int dy \sqrt{g(y)} h(y)$$

$$)^8 = M_5^{-8}$$

$$\left(h^2 = M_p^2 \right)$$

* #

$$\frac{1}{2k^2} \int dx \dots$$

$$= \frac{1}{2k^2} \int d^4x \text{ # } \Lambda^* \text{ # } \otimes$$

$$\left(\int d^6y \sqrt{g(y)} e^{-\phi} h^2 \right)$$

$$\beta = \frac{\int d^6y \sqrt{g(y)} e^{-\phi} h^2}{\int d^6y \sqrt{g(y)} h^2}$$

$$\frac{1}{2\kappa^2} \int d^{10}x \sqrt{-g} R$$

BACKGROUND:

$$ds^2 = h_{\mu\nu} dx^\mu dx^\nu$$

$$+ \dots$$

$\frac{1}{h_{\mu\nu}}$

$$\rightarrow \frac{1}{2\kappa^2} \int d^4x \sqrt{-g} \bar{R} \left(\int d^6y \sqrt{g_6} h_{\mu\nu}^2 \right)$$

$$\kappa^2 = (2\pi\alpha')^4 = M_s^{-8}$$

$$\left\{ \frac{1}{2\kappa^2} \int d^6y \sqrt{g_6} h_{\mu\nu}^2 = M_p^2 \right\}$$

$$S_1 = M_p^2 \int d^4x \sqrt{-g} \bar{R}$$

$$S_2 = \beta M_p^2 \int d^4x H \wedge * H$$

$$\frac{1}{2\kappa^2} \int d^{10}x \sigma^{\mu\nu} H \wedge * H$$

$$= \frac{1}{2\kappa^2} \int d^4x H \wedge * H \left(\int d^6y \sqrt{g_6} \right)$$

$$\left(\int d^6y \sqrt{g_6} \right) e^{-\phi} h_{\mu\nu}^{-2}$$

$$\beta = \frac{\int d^4y \sqrt{-g_4} \sigma^{\mu\nu} h_{\mu\nu}^2}{\int d^6y \sqrt{g_6} h_{\mu\nu}^2}$$

$$\bar{R} \left(\int d^6 y \sqrt{g(y)} h^2(y) \right)$$

$$)^\circ = M_s^{-8}$$

$$(c) h^2 \equiv M_p^2$$

\bar{R}

$$\frac{1}{2\kappa^2} \int d^{10} x \, e^{-\phi} H \wedge * H$$

$$= \frac{1}{2\kappa^2} \int d^4 x \, H \wedge * H \quad \otimes$$

$$\int d^6 y \sqrt{g(y)} e^{-\phi} h^2$$

$$\beta = \int d^6 y \sqrt{g(y)} e^{-\phi} h^2$$

$$S_2 = \beta M_P^2 \int d^4x H \wedge * H'$$

$$dH = \left(k R \wedge R - \frac{T_F}{30} F \wedge F \right)$$

$$S_2 = \beta M_P^2 \int d^4x H \wedge * H + \int a \left[dH - \left(k R \wedge R - \frac{T_F}{30} F \wedge F \right) \right]$$

$$S = \frac{1}{2M_P^2}$$

$$T_F F^2 = T_F F$$

$$H^2 = H$$

$$dH \neq 0$$

CAUTION

$$S_2 = \beta M_P^2 \int d^4x H \wedge * H'$$

$$dH = \left(t R \wedge R - \frac{T_F}{30} F \wedge F \right)$$

$$S_2 = \beta M_P^2 \int d^4x H \wedge * H + \int a \left[dH - \left(t R \wedge R - \frac{T_F}{30} F \wedge F \right) \right]$$

$$= \frac{1}{\beta M_P^2} \int da \wedge * da + \int a \left(\frac{T_F}{30} F \wedge F - t R \wedge R \right)$$

$$S = \frac{1}{2k^2}$$

$$T_F F^2 = \frac{T_F}{30} F \wedge F$$

$$H^2 = H \wedge * H$$

$$dH \neq 0$$

$$S_2 = \beta M_P^2 \int d^4x H \wedge * H'$$

$$dH = \left(\frac{1}{2} R \wedge R - \frac{T_F}{30} F \wedge F \right)$$

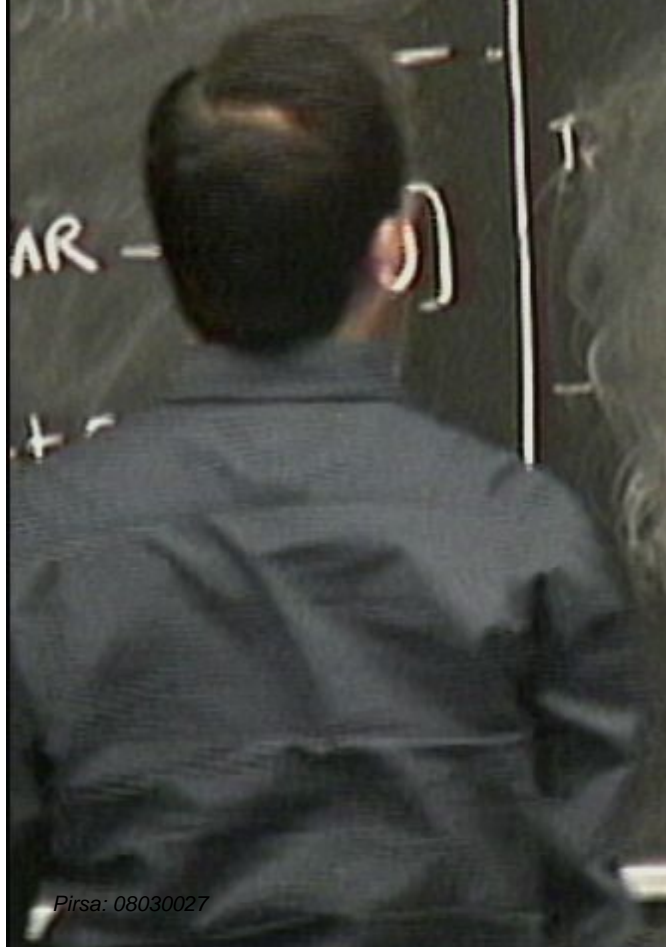
$$S_2 = \beta M_P^2 \int d^4x H \wedge * H + \int a \left[dH - \left(\frac{1}{2} R \wedge R - \frac{T_F}{30} F \wedge F \right) \right]$$

$$= \frac{1}{\beta M_P^2} \int da \wedge * da + \int a \left(\frac{T_F}{30} F \wedge F - \frac{1}{2} R \wedge R \right)$$

$$\tilde{a} = \frac{1}{\sqrt{\beta M_P^2}} a$$

$$S = \int d\tilde{a} \wedge *d\tilde{a}$$

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$$S_2 = \beta M_P^2 \int d^4x \, H \wedge * H.$$

$$dH = \left(t R \wedge R - \frac{T_F}{30} F \wedge F \right)$$

$$S_2 = \beta M_P^2 \int d^4x \, H \wedge * H + \int a \left[dH - \left(t R \wedge R - \frac{T_F}{30} F \wedge F \right) \right]$$

$$= \left(\frac{1}{\beta M_P^2} \right) \int da \wedge * da + \int a \left(\frac{T_F}{30} F \wedge F - t R \wedge R \right)$$

$$\tilde{a} = \left(\frac{1}{\sqrt{\beta M_P^2}} \right) a.$$

CAUTION

$$S = \int d\tilde{a} \wedge *d\tilde{a} + \sqrt{\beta} M_P \int \tilde{a} \left(\frac{T_F}{30} F \wedge F - k R \wedge R \right)$$

$$-\left(k R \wedge R - \frac{T_F}{30} F \wedge F \right)$$

$$F \wedge F - k R \wedge R$$

$$S = - \int d\tilde{a} \wedge * d\tilde{a} + (\beta M\theta) \int \tilde{a} \left(\frac{\text{Tr} F \wedge F}{30} - k R \wedge R \right)$$

$$S = \int d\tilde{a} \wedge * d\tilde{a} + \int \frac{1}{f_m} \tilde{a} (\text{Tr} F \wedge F)$$

$$\left(k RAR - \frac{T_r}{30} FAF \right)$$

$$F - k RAR$$

$$S = \int d\tilde{a} \wedge * d\tilde{a}$$

$$+ \left(\frac{1}{\sqrt{\beta M_p}} \right) \int \tilde{a} \left(\frac{T_r}{30} FAF - k RAR \right)$$

$$S = \int d\tilde{a} \wedge * d\tilde{a} + \int \frac{1}{f_m} a (T_r FAF)$$

$$f_m \sim \frac{1}{\sqrt{\beta M_p}}$$



$$S = \int d\tilde{a} \wedge * d\tilde{a} + \left(\frac{1}{\sqrt{\beta M_p}} \right) \int \tilde{a} \left(\frac{T_F}{30} F \wedge F - k R \wedge R \right)$$

$$S = \int da \wedge da + \int \frac{1}{f_a} a (T_F F \wedge F)$$

$$f_a \sim \frac{M_s^2}{\sqrt{\beta M_p}}$$

$$10^9 \text{ GeV} < \Lambda < 10^{12} \text{ GeV}$$

$$S_2 = \beta M_P^2 \int d^4x \ H \Lambda^* H'$$

$$dH = \left(k RAR - \frac{T_C}{30} FAF \right)$$

$$S_2 = \beta M_P^2 \int d^4x \ H \Lambda^* H' \left(a \left[dH - \left(k RAR - \frac{T_C}{30} FAF \right) \right] \right)$$

$$= \left(\frac{1}{\beta M_P^2} \right) \int d^4x \ \Lambda^* a \left(\frac{T_C}{30} FAF - k RAR \right)$$

$$\tilde{a} = \left(\frac{1}{\beta M_P^2} \right) a$$

$$S = \int d^4x \ \Lambda^* da + \left(\frac{1}{\beta M_P^2} \right)$$

$$S = \int d^4x \ \Lambda^* da + da$$

$$f_a \sim \frac{M_s}{\sqrt{\beta M_P}}$$

eg! heterotic theory on CY3.

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{CY} dy^m dy^n.$$

eg! heterotic theory on CY3.

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{CY} dy^m dy^n.$$

$$\beta \sim 1.$$

$$f_a \sim \frac{m_s^2}{M_p} \sim m_s$$

eg! heliostic theory on Cys.

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn} dy^m dy^n.$$

$$\beta \sim 1.$$

$$f_{\text{ca}} \sim \frac{m_s^2}{M_p} \sim M_s$$

q2:



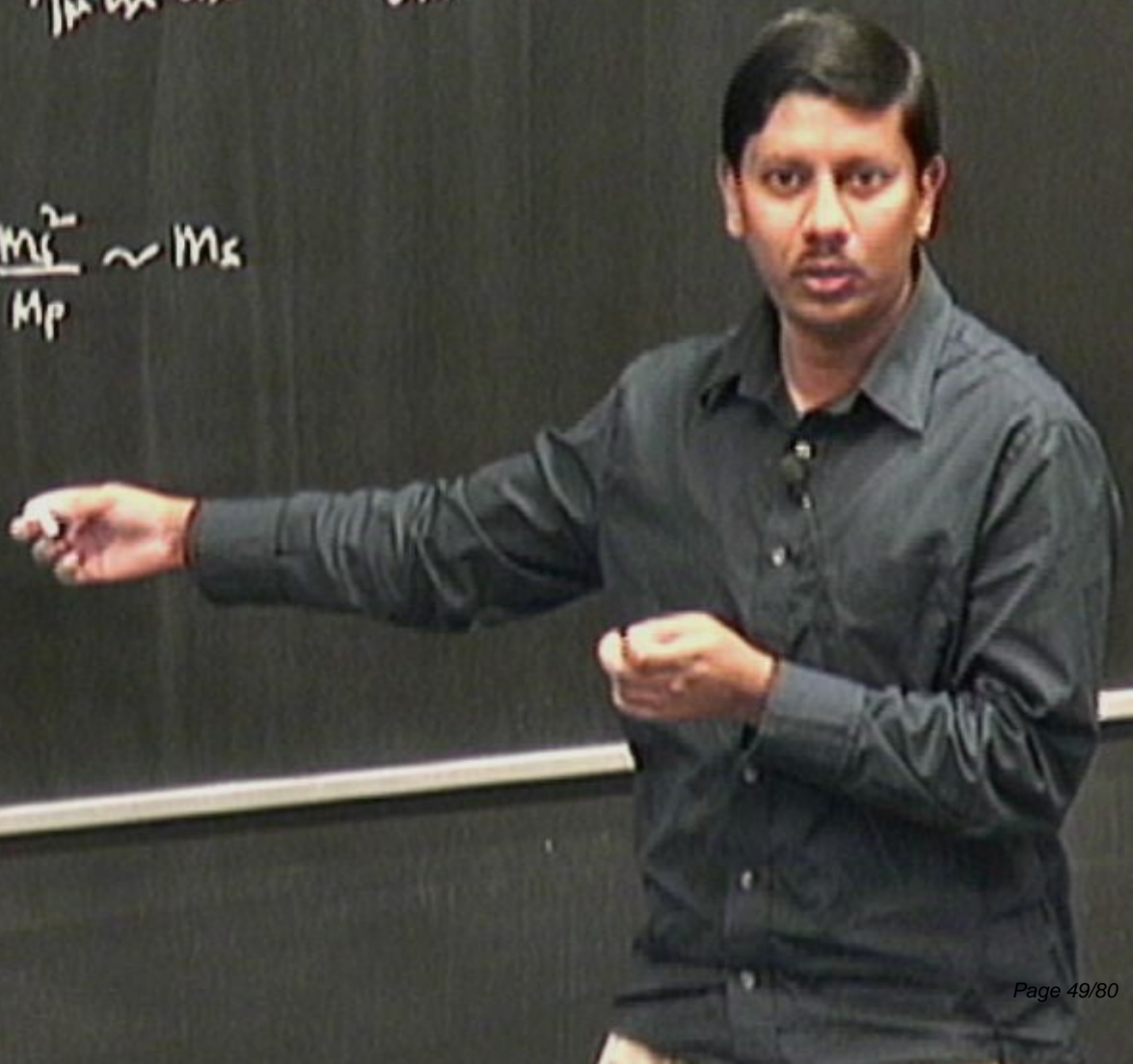
eg! heterotic theory on CY_3 .

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{CY_3} dy^m dy^n.$$

$$\beta \sim 1.$$

$$f_a \sim \frac{M_s^2}{M_p} \sim M_s$$

q2:



eg! heterotic theory on CY3.

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{CY} dy^m dy^n.$$

$$\beta \sim 1.$$

$$f_a \sim \frac{m_s^2}{M_p} \sim m_s$$

q2: heterotic string with
ltts.

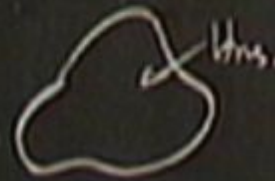
eg! heterotic theory on CYs.

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{CY} dy^m dy^n.$$

$$\beta \sim 1.$$

$$f_a \sim \frac{m_s^2}{M_p} \sim M_s$$

q2: heterotic string with
Hrs.



$$dJ \neq 0.$$

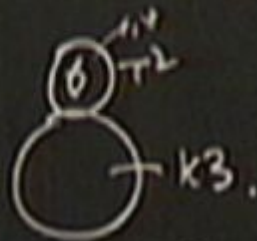
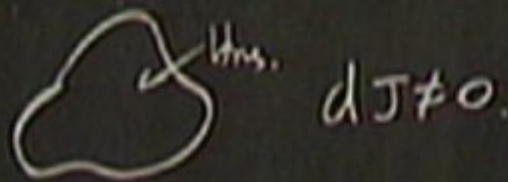
eg! heterotic theory on CY_3 .

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{CY} dy^m dy^n.$$

$$\beta \sim 1.$$

$$f_a \sim \frac{m_s^2}{M_p} \sim m_s$$

q2: heterotic string with
 l_{HNS} .

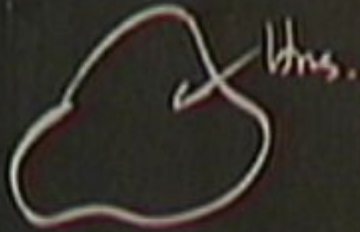


$$ds_{(4)}^2 = e^{-2\phi} \left[(dx + A)^2 + (dy + B)^2 \right] + e^{2\phi} ds_{K3}^2.$$

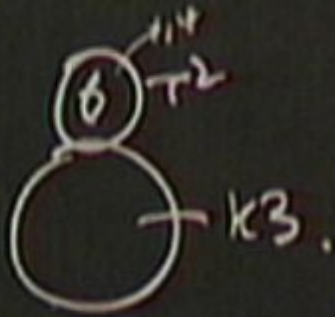
$$(\alpha, \beta) = 1\text{-forms on } K3.$$

CY3.

$dy^m dy^n$.



$$dJ \neq 0.$$



$$ds^2 = e^{-2\phi} \left[(dx + A)^2 + (dy + B)^2 \right] + e^{2\phi} ds^2_{K^3}.$$

$(\alpha, \beta) = 1$ -forms on K^3 .

$$\frac{1}{2\kappa^2} \int d^{10}x \sqrt{-g} R$$

$$ds^2 = e^{-\frac{4}{3}\phi} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}_6^2$$

BACKGROUND:

$$ds^2 = h_{\mu\nu}^2 dx^\mu dx^\nu + g_{mn}^6 dy^m dy^n$$

$$e^{-\phi} = h^{1/4}$$

$$\frac{1}{2\pi^2} \int d^{10}x \sqrt{-g} R$$

BACKGROUND

$$ds^2 = \dots + g_{mn} dy^m dy^n$$

$\frac{1}{H_{10}}$

$$ds^2 = e^{-\frac{\phi}{2}} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}_m^2$$

$$e^{-\phi} = h w^4$$

$$\beta = 1$$

$$\frac{1}{2k^2} \int d^{10}x \sqrt{-g} R.$$

BACKGROUND:

$$ds^2 = h_{\mu\nu} g_{\alpha\beta} dx^\alpha dx^\beta$$

$\frac{1}{h_{\mu\nu}}$

$\int d^m y$

$$ds^2 = e^{-\phi/2} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}_m^2$$

$$\boxed{e^{-\phi} = h^k}$$

$$\beta = 1.$$

$d^{10}x \sqrt{-g} R$

$$ds^2 = e^{-\phi/2} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}_6^2$$

BACKGROUND:

$$ds^2 = h_w^2 \bar{g}_{\mu\nu} dx^\mu dx^\nu + g_{mn}^{(6)} dy^m dy^n$$

H_w

$$e^{-\phi} = h_w^4$$

$$\beta = 1.$$

- manifold is M^6
- dilaton is ϕ

$d^{10}x \sqrt{-g} R$

BACKGROUND:

$$= \int h^2 \bar{g}_{\mu\nu} dx^\mu dx^\nu + \int \bar{g}_{mn} dy^m dy^n$$

$$ds^2 = e^{-\phi/2} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}_6^2$$

$$\boxed{e^{-\phi} = h^2}$$

$$\beta = 1.$$

- manifold is MK
- dilaton is indep of warp

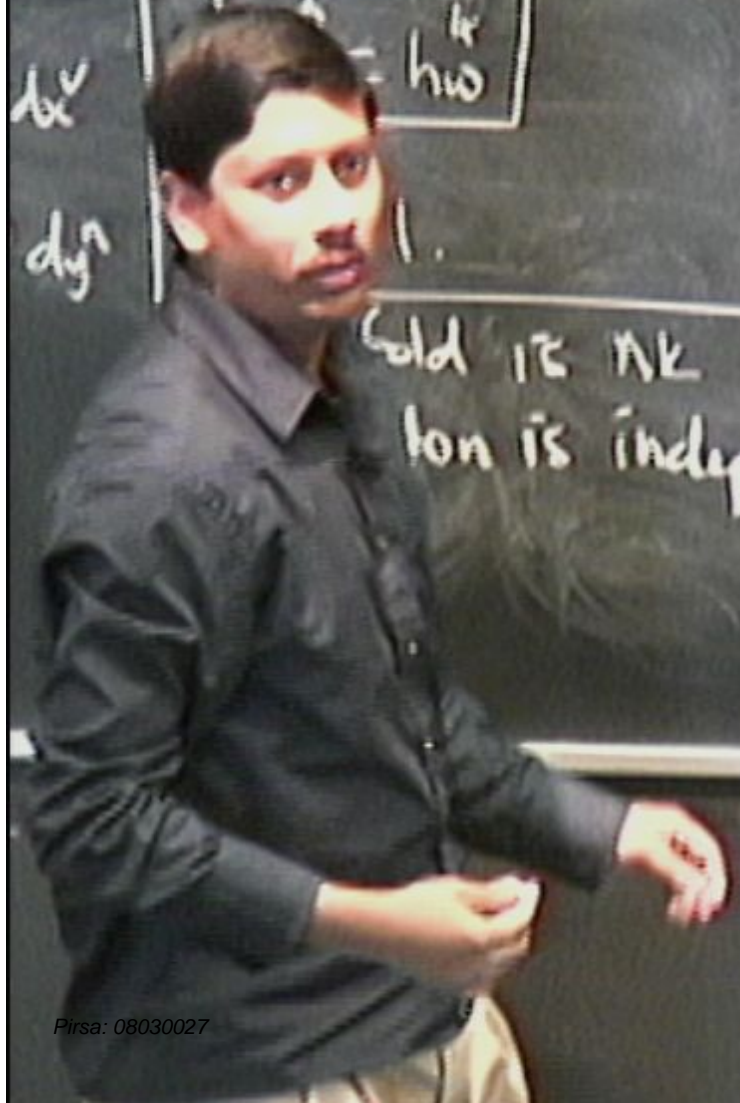
$$dS^2 = e^{-\phi/2} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{S}^2$$

(2,2) σ -model

\longleftrightarrow (0,2) . . .

$$\hbar = h\nu$$

Gold is NK
Ion is indep of warp



$$ds^2 = e^{-\phi/2} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}_5^2$$

(2/2) σ -model

\longleftrightarrow (0/2) . . .

$$ds^2 = e^\phi ds_{AdS_5}^2 + ds_{X^5}^2$$

$$\left[\frac{e^{-\phi}}{\beta} \right]$$

$$\beta =$$

- M/

\approx NK

indep of warp

dx^ν

dy^a

$$\frac{1}{2} \eta_{\mu\nu} dx^\mu dx^\nu + d\tilde{s}^2$$

hw

1.
old is
lon is

warp

(2,2) \rightarrow model

\leftrightarrow (0,2)

$$ds^2 = e^\phi ds_{AdS_5}^2 + ds_{x^5}^2$$

$$e^\phi =$$

+ $d\tilde{\zeta}_6$

(2,2) σ -model

\longleftrightarrow (0,2)

$$ds^2 = e^\phi ds_{\text{AdS}_5}^2 + ds_{X^5}^2$$



$\text{AdS}_5 \times S^5$

$\gamma, \phi_1, \phi_2, \psi, \phi_3$

σ warp

+ $dS^2_{(6)}$

(2,2) σ -model

\longleftrightarrow (0,2)

$$ds^2 = e^\phi ds^2_{AdS_5} + ds^2_{X^5}$$



$AdS_5 \times S^5$

$\gamma, \phi_1, \phi_2, \psi, \phi_3$

σ warp

$$\begin{aligned}
 ds^2 = & \sin^2 \psi \sqrt{\sin \psi \cos \psi} \left[\frac{c^2}{R} dx^2 dx^2 + \sqrt{R^3} \left(\frac{d\psi^2}{r^2} + dr^2 \right) \right. \\
 & \left. + \omega^2 r d\varphi_3^2 + \sin^2 \psi d\psi^2 \right] \\
 & + \frac{\alpha' \sqrt{\sin \psi}}{R \omega^2 r \sin \psi} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos \psi}}{R \omega^2 r \sin \psi} d\varphi_3^2
 \end{aligned}$$

$\delta =$

$S =$

fa

$$\begin{aligned}
 ds^2 \stackrel{L}{=} & \underbrace{\sin\psi \cos\psi}_{\text{circles}} \left[\left(\frac{r^2}{R} dx^2 + dx^2 + \sqrt{R^3} \left(\frac{dr^2}{r^2} + dr^2 \right) \right. \right. \\
 & \left. \left. + \omega^2 r d\varphi_3^2 + \sin^2 r d\psi^2 \right) \right] \\
 & + \frac{\alpha' \sqrt{\sin\psi}}{R \omega^{3/2} \sin r} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos\psi}}{R \omega^{3/2} \sin r} d\varphi_2^2
 \end{aligned}$$

$$\begin{aligned}
 ds^2 = & \underbrace{g_{\mu\nu}}_{\sin\psi \cos\psi} \left[\left(\frac{r^2}{R} dx^\mu dx^\nu + \sqrt{R^3} \left(\frac{dr^2}{r^2} + dr^2 \right) \right. \right. \\
 & \left. \left. + \omega^2 r d\varphi_3^2 + g_{\mu\nu} r^2 d\psi^2 \right) \right] \\
 & + \frac{\alpha' \sqrt{g_{\mu\nu}}}{R \omega^2 r \sin\psi} d\varphi_1^2 + \frac{\alpha' \sqrt{g_{\mu\nu}}}{R \omega^2 r \cos\psi} d\varphi_2^2
 \end{aligned}$$

$$ds^2 = \underbrace{\sin^2 \gamma \sqrt{\sin \psi \cos \psi}}_{\text{circumference}} \left[\left(\frac{r^2}{R} dx^2 + dx^2 + \sqrt{R^3} \left(\frac{dr^2}{r^2} + dr^2 \right) + \omega^2 r d\varphi_3^2 + \sin^2 \gamma d\psi^2 \right) \right]$$

$$+ \frac{\alpha' \sqrt{\sin \psi}}{R \omega^2 \gamma \sin \gamma} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos \psi}}{R \omega^2 \gamma \sin \gamma} d\varphi_2^2$$

$$e\phi = \frac{R}{2} \sin^2 \gamma \sin 2\psi$$

HNS = torsion

$$R = \sqrt{\frac{4\pi \alpha' N}{3}}$$

$$dx^\mu + d\tilde{\zeta}^\mu$$

(2,2) σ -model

\longleftrightarrow (0,2)

$$= e^\phi ds_{AdS_5}^2 + ds_{X^5}^2$$

$AdS_5 \times S^5$
 $\gamma, \phi, \psi, \phi_2$

$$ds^2 = \underbrace{\sin^2 \psi \cos^2 \psi}_{\text{area}} \left[\underbrace{\frac{r^2}{R}}_{\text{circ}} dx^2 dx^2 + \sqrt{R^3} \left(\frac{dr^2}{r^2} + dr^2 \right) \right]$$

$$+ \omega^2 r d\varphi_3^2 + \sin^2 \psi d\psi^2 + \frac{\alpha' \sqrt{\sin \psi}}{R \omega^2 \psi \sin \psi} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos \psi}}{R \sin^{3/2} \psi \sin \psi} d\varphi_2^2$$

$$e^{\phi} = \frac{R}{2} \sin^2 \psi \sin 2\psi$$

$$H_3 = \text{torsion} = dr \wedge d\varphi_3 \wedge d\psi$$

$$R = \sqrt{4\pi \alpha' N}$$

CAUTION

$$ds^2 = \underbrace{\sin^2 \psi \cos^2 \psi}_{\text{area element}} \left[\left(\frac{r^2}{R} dx^2 + dx^2 + \sqrt{R^3} \left(\frac{d\phi^2}{r^2} + dr^2 \right) + \omega^2 r d\phi^2 + \sin^2 r d\psi^2 \right) \right. \\ \left. + \frac{\alpha' \sqrt{\sin \psi}}{R \sin^2 \psi \cos r} d\phi_1^2 + \frac{\alpha' \sqrt{\cos r}}{R \sin^2 \psi \cos r} d\phi_2^2 \right]$$

$$e^{\Phi} = \frac{R}{2} \sin^2 r \sin 2\psi.$$

$H_3 = \text{torsion} \cdot dr \wedge d\phi_1 \wedge d\psi$

$$R = \sqrt{4\pi \alpha' N}$$

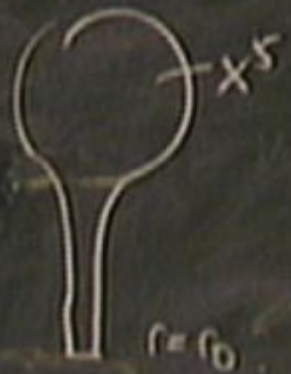
$$ds^2 = \underbrace{\sin^2 \psi \cos^2 \psi}_{\text{angular}} \left[\frac{c^2}{R} dx^2 dx^2 + \int R^3 \left(\frac{dr^2}{r^2} + dr^2 \right) \right. \\ \left. + \omega^2 r d\varphi_3^2 + g_{n^2} r d\psi^2 \right]$$

$$+ \frac{\alpha' \sqrt{g_{n^2}}}{R \omega^2 r \sin \psi} d\varphi_1^2 + \frac{\alpha' \sqrt{g_{n^2}}}{R \omega^2 r \sin \psi} d\varphi_2^2$$

$$d\phi = \frac{R}{2} \sin^2 \psi \sin 2\psi$$

$H_3 = \text{torsion} = dr \wedge d\varphi_3 \wedge d\psi$

$$R = \sqrt{4\pi \alpha' N}$$



near the IR

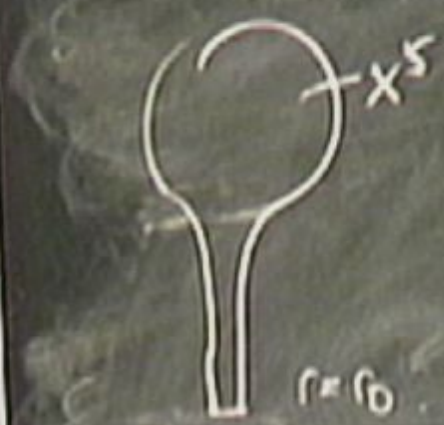
$$h_0 \sim \frac{r_0}{\sqrt{R}}$$

$$\int x^2 dx + \int R^3 \left(\frac{dr^2}{r^2} + dr^2 \right)$$

$$d\varphi_3^2 + \sin^2 r d\varphi^2$$

$$d\varphi_1^2 + \frac{\alpha}{R} d\varphi_3^2$$

ψ
 $R_B \Delta \psi$



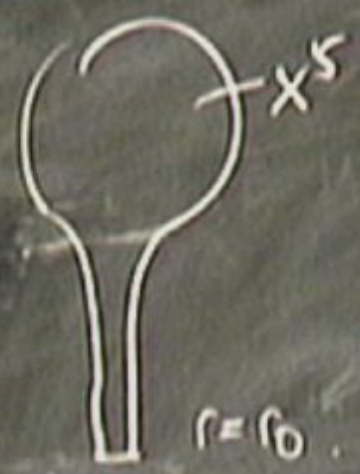
near the IR

$$h_0 \sim \frac{r_0}{\sqrt{R}}$$

$$f_0 \sim m_s h_0$$

$$+ dr^2$$

$$\phi_3^2$$



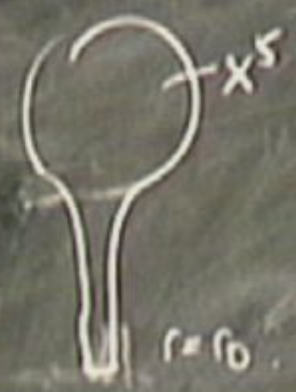
near the IR

$$h_0 \sim \frac{r_0}{\sqrt{R}}$$

$$f_a \sim \underbrace{m_s h_0}_{\text{wavy line}} \otimes \dots$$

$$\left(\frac{dr^2}{r^2} + dr^2 + d\psi^2 \right)$$

$$\frac{\sqrt{6\pi r}}{2\pi} d\psi_3$$



near the IR
 $h_0 \sim \frac{r_0}{\sqrt{R}}$

$$f_a \sim \underbrace{m_s h_0}_\omega$$

eg! hel

$$ds^2 = \dots$$

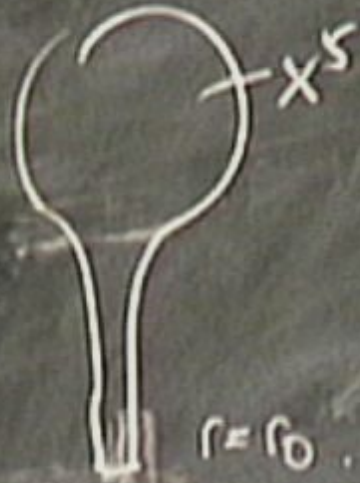
$$\beta \sim 1.$$

$$f_a \sim \frac{m_s^2}{M_p}$$

2: heterot

$$dr^2$$

$$d\varphi_3^2$$



$$f_{\text{an}} \sim \underbrace{m_s h_0}_{\text{...}} \otimes \dots$$

near the IR

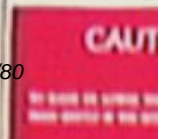
$$h_0 \sim \frac{r_0}{\sqrt{R}}$$

$$ds^2 = e^{\phi} ds_{AdS_5}^2 + ds_{S^5}^2$$

$$AdS_5 \times S^5$$

$r, \phi, \theta_1, \theta_2, \psi, \theta_3$

$$S^5: dr^2 + \omega^2 r^2 d\theta_3^2 + \sinh^2 r (d\psi^2 +$$



$$ds^2 = e^\phi ds_{\text{AdS}_5}^2 + ds_{S^5}^2$$

$$\text{AdS}_5 \times S^5$$

$$r, \phi, \psi, \theta_1, \theta_2, \theta_3$$

$$S^5: dr^2 + \omega^2 r d\theta_3^2 + \sinh^2 r (d\psi^2 + \omega^2 \psi d\theta_1^2 + \sin^2 \psi d\theta_2^2)$$

r warp

$$ds^2 = e^\phi ds_{\text{AdS}_5}^2 + ds_{S^5}^2$$

AdS₅ × S⁵

$r, \phi, \psi, \theta_1, \theta_2, \theta_3$

$$S^5: dr^2 + \omega^2 r d\theta_3^2 + \sin^2 r (d\psi^2 + \omega^2 \psi d\theta_1^2 + \sin^2 \psi d\theta_2^2)$$

$$\begin{aligned}
 & + \omega^2 r d\varphi_3^2 + \delta n^2 r d\psi^2) \\
 & + \frac{\alpha' \sqrt{\delta n^4}}{R \omega^{3/2} \psi \delta n r} d\varphi_1^2 + \frac{\alpha' \sqrt{\cos r}}{R \omega^{3/2} \psi \delta n r} d\varphi_3^2 \\
 e\phi = & \frac{R}{2} \delta n^2 r \sin 2\psi.
 \end{aligned}$$

$$\begin{aligned}
 H_{13} = \text{torsion} & = drnd\varphi_3 nd\psi + \mathcal{O}(\alpha') \\
 R & = \sqrt{\frac{4n^2 N}{\dots}}
 \end{aligned}$$

Ad is NK
tion is indep

$$ds^2 = e^{\phi} ds_{AdS_5}^2 + ds_{S^5}^2$$

AdS₅ × S⁵

r, φ, θ₁, ψ, φ₂

$$S^5: dr^2 + \omega^2 r d\varphi_2^2 + \sinh^2 r (d\psi^2 + \omega^2 \psi d\varphi_1^2 + \sinh^2 \psi d\varphi_3^2)$$